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A preliminary review of scientific data and research relevant to potential management options for marlin and sailfish in the IOTC

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Executive Summary

Background and Purpose

The most recent assessments of marlin and sailfish stocks in the Indian Ocean have identified that striped marlin, black marlin and blue marlin are all subject to overfishing and striped marlin and blue marlin are currently overfished (**Table E1**). The SC has advised that a) reductions in catch, relative to recent levels, are required for each of these stocks, to ensure or return biomass to MSY levels, and; b) Resolution 18/05 should be revised to reflect recommended catch limits and implement strengthened measures to reduce fishing mortality on these stocks.

This paper aims to provide a **preliminary** review of relevant data and scientific research to support the Working Party on Billfish (WPB) develop advice to the Scientific Committee (SC) relating to:

a. the potential effectiveness of a range of different management tools (specifically **catch limits**, **non-retention**, and **gear/method-based options)** for reducing fishing mortality, and;
b. the need to address any gaps and uncertainties in available data and research to assist further consideration of these and other potential management options.

Fishery catch review

Table E2 summarises the recent average proportion of total catch (for 2018-2022) taken by each fishery (gear) type for each stock. On the basis of catch proportions alone, effective measures applied to reduce fishing mortality by gillnet and longline are likely to have the greatest impact on overall fishing mortality on these stocks. For **blue marlin**, the majority of recent (2018-2022) catch has been taken by longline (66.8%), followed by gillnet (22.5%), and handline (6.4%). For **black marlin** and **striped marlin** the majority is taken by gillnet (63.3% and 66% respectively) followed by longline (26.9% and 27.7%) with lesser contributions by purse seine and handline (for black marlin). **Sailfish** catches are predominantly gillnet (70.9%) with lower contributions by longline (14.4%), trolling (8.6%) and handline (5.3%).

Table E1 – Status, current and recommended catch limits, and recent catches, for IOTC marlin and sailfish stocks (see Table 1 within main report for further details)

Species (Assessment Year)	Biomass status (B/BMSY)	Fishing mortality status (F/FMSY)	Stock Depletion	2018/05 adopted limit (mt)	Current SC recommended limit (not adopted)	2023 catch (mt)	Recent av 5 year catch (2019-23)
Striped marlin (2024)	Overfished (B_{2022}/B_{MSY}=0.17*)	Overfishing (F_{2022}/F_{MSY}=3.95*)	3-6%	3260	867(70%) / 1157 (58%)	3553	3024
Blue marlin (2022)	Overfished (B_{2020}/B_{MSY}=0.73)	Overfishing (F_{2020}/F_{MSY}=1.13)	36%	11930	~5700	7888	7049
Black marlin (2024)	Not overfished (B_{2022}/B_{MSY}=1.35)	Overfishing (F_{2022}/F_{MSY}=1.39)	49%	9932	10626	27872	20060
Indo Pacific Sailfish (2022)	Not overfished (B_{2019}/B_{MSY}=1.17)	No overfishing (F_{2019}/F_{MSY}=0.98)	58%	25000	25900*	32158	32386

Table E2 – Percentage (%) of average annual total catch of each species in the IOTC Area, by fishery type, for the period 2018-2022 (Source; IOTC 2024a,b,c,d)

Fishery	Black marlin		Blue marlin		Striped marlin		Sailfish	
Purse seine | Other	4.1		1.5		1.3		0.8	
Longline | Other	0.3	26.9	1.2	66.8	1.3	27.7	0.1	14.4
Longline | Fresh	5.6		21.4		6.4		2.2	
Longline | Deep-freezing	1.2		27.8		12.6		0.9	
Line | Coastal longline	19.9		16.4		7.4		11.2	
Line | Trolling	1.2		2.8		2.0		8.6	
Line | Handline	3.8		6.4		2.7		5.3	
Baitboat	0.2		0		0		0.1	
Gillnet	63.3		22.5		66.0		70.9	
Other	0.4		0.0		0.3		0.1	

Option 1 – Catch limits

The IOTC SC has provided advice to the Commission on stock level catch limits (**Table E1**) for marlins and sailfish, within which the Commission could potentially agree to determine CPC catch limits, similar to the approach adopted for some marlin stocks in other RFMOs (e.g. WCPFC, ICCAT). The most effective type of catch limit is that which accounts for both retained and discarded catch mortality, which requires information on at-haul and post-release mortality (summarised in Option 2 below) or which require retention of all catch (no discarding). However, there are a range of challenges associated with catch limits for bycatch species. These include the creation of a "choke" on target catches (with associated economic consequences), subsequent non-compliance, high levels of unmonitored discarding (unaccounted mortality), and a lack of effective monitoring/enforcement for some fisheries, all which can reduce effectiveness of this type of measure.

Option 2 – Non-retention options

Prohibiting the retention of a species subject to overfishing can be an effective measure to reduce fishing mortality (e.g. ICCAT blue marlin and white marlin) in cases where discarding, at-haul mortality (AHM) and post-release mortality (PRM) rates are low or moderate (and handling/release practices are good). Very preliminary information on each of these factors, from observer data (IOTC Secretariat) and published research and other papers, for each species and fishery type, was reviewed and assessed in the context of the potential effectiveness of non-retention options.

For **longline**, this review notes: 1) that longline accounts for a high proportion of total IOTC catch of blue marlin, and a lower but significant component of black and striped marlin catch (**Table E2**), and; 2) evidence for high retention rates across species (>95%), low to moderate AHM (varying by fleet), and low-moderate PRM (based on limited studies). As such, non-retention approaches in longline fisheries may have potential to contribute to reductions in overall fishing mortality for the three marlin species (especially blue marlin). However, further analyses should aim to gather more information on discard proportions and AHM by fleet and quantify potential mortality reductions, using also information on PRM and other key factors (e.g. hook type). Model based analyses of condition/AHM at a fleet level could identify factors driving AHM/condition and subsequently, additional method/gear mitigation options.

For **gillnet**, despite contributing a high proportion of catches (and retention) of black and striped marlin and sailfish, non-retention options are unlikely to be effective. This is based on information indicating that at haul mortality is very high (near 100%) across all four species. However, confirming this with direct observational data will be important.

Purse seine takes a more minor component of the total catch of these species, has lower retention levels (preliminary data*), and initial information indicates very high AHM. If confirmed by further data from across the IOTC fishery, non-retention appears unlikely to be an effective management option for that fishery type.

For line fisheries such as **troll and handline**, which contribute much lower but not insignificant catches of marlins and sailfish, further information on AHM and PRM is ideally needed. WPB experts could consider if AHM and PRM rates are likely to be similar to those in recreational game fisheries using trolling methods, and from which significant research is summarised in this paper.

Option 3 – Fishing gear/method options

For **longline** fisheries, four fishing gear/measure related options were considered, being hook type, setting depth, leader material and handling practices.

- **Hook type** - Two separate meta-analyses of numerous published research studies concluded that the use of circle hooks (relative to J hooks) results in significantly lower at haulback mortality of blue marlin, and significantly lower catch rates for blue marlin, sailfish and striped marlin*. Further review to identify hook type use by fleets, hook size effects, and more clearly quantify likely changes in fishing mortality from circle hook adoption, as well as target species implications, could assist in assessing this option further.
- **Depth of setting** – Switching longline gear from shallow to deeper sets has been demonstrated to also provide an option by which to reduce catch rates of marlin and sailfish (due to the significant time spent by these species in shallower waters). Fleet specific CPUE analyses using depth proxy indicators (e.g. HPB) could assist in assessing this option further.
- **Leader material** - There is not strong evidence from experimental fishing trials that marlin and sailfish catch rates differ significantly depending on leader material type (e.g. monofilament nylon or wire).
- **Handling practices** – studies of safe handling and release practices in recreational game fisheries (and for other large species in commercial fisheries) has demonstrated a number of principles of safe handling and release that could assist hook based commercial fisheries to improve post release survival.*

For **gillnet** fisheries, the review noted some CPCs are seeking to shift fishing effort from gillnet to line fisheries, but the implications of this for catch and mortality on marlin and sailfish was not examined. Otherwise, the review focussed on gillnet depth of setting-based options, due to firstly, the existing requirement (Resolution 21/01) for all gillnet fisheries to implement subsurface setting (minimum 2m) by 2023, and secondly, research confirming the substantial time spent by marlin and sailfish in surface waters, particularly at night (when gillnets are soaked in some* fisheries). Globally and in

IOTC, subsurface setting of gillnets has been promoted largely on the basis of reducing interactions/mortality of cetaceans, and/or turtles, pinnipeds, and seabirds, but there has been relatively little research on the implications for billfish catches. Noting previously reported reductions in average monthly billfish catch by gillnetters in Pakistan, following adoption of subsurface setting, the potential effectiveness of subsurface setting in reducing billfish mortality in the broader IOTC fishery remains very uncertain. It is recommended that experimental research trials be prioritised to test different depths of setting, times of setting/soaking, and to collect accurate species-specific catch/mortality data across the full range of interacting species, including billfish, target tuna and vulnerable bycatch species (e.g. cetaceans, turtles). This would provide the SC and Commission a more quantified understanding of likely effects and possible trade-offs.

The review did not have time to consider potential gear/method related options for **purse seine** and **troll/handline** fisheries, although it is possible hook type research (covered under longline) and handling practices are relevant to the troll/handline fisheries.

Other management options

The authors are aware of a range of other potential management options (e.g. spatial temporal options) that could be considered by the Commission but there was insufficient time to consider these in detail in this initial preliminary review.

Conclusions

The aim of this paper was to provide a preliminary review of available data, information and research relevant to assessing a number of potential management options for reducing fishing mortality of marlins (and sailfish) in IOTC. Where possible, it makes comment on both the potential effectiveness of each option for each species and fishery type, and/or the key gaps in information and knowledge that create uncertainty in our ability to assess the likely effectiveness of some options in some fisheries.

It does not aim to advocate that the Commission adopt any specific option in any specific fishery.

Recommendations

The authors note that this is a preliminary review, with an intention to update either prior to SC or prior to WPB in 2026. As such the authors are seeking initially that WPB discuss and provide feedback on:

a) New information on stock status relevant to a future updated paper.
b) Any errors or misinterpretations of fishery data/information contained in the preliminary review.
c) Additional sources of relevant fishery data, information and published research that should be included in an updated review paper
d) Additional management tools/options for which relevant data/research should be reviewed and included in an updated paper.
e) Discuss the potential relevance of game fishing (troll) based estimates of AHM and PRM to commercial troll and handline fisheries in IOTC.
f) The papers preliminary recommendations (below).

Noting the preliminary nature of the review, and pending WPB feedback on points a – d above, the authors suggest that the WPB consider:

- firstly, highlighting to the SC some of the key preliminary findings of this review, and
- secondly, where appropriate, incorporating relevant information into the draft species executive summaries
- thirdly, recommending to the IOTC Scientific Committee that the Scientific Committee should request the following:
  - CPCs (and/or IOTC Secretariat) provide summary data (observer and/or logbook derived) and/or information, to WPB (or IOTC Secretariat to compile), pertaining to:
    - **All gear/fishery types** – discarding/retention rates and at-haul mortality (%) for each marlin and sailfish species, by fishery/gear type.
    - **Longline** – proportion of fleet using different hook types and sizes (Japanese tuna, J hook, Circle hook, other)
    - **Longline** – proportion of fleet setting shallow or deep, at night or during day.
    - **Gillnet** – proportion of the gillnet fleet using subsurface setting, and if possible, preferred depths used in fishery.
    - Any other information or data the WPB considers would assist WPB in providing advice to the SC in future
  - CPCs individually or collaboratively conduct gillnet experimental fishing trials to test different setting depths and times of setting/soaking (e.g. day/night), on catch rates and mortality of the full range of interacting species, including billfish bycatch, target tuna and vulnerable species (e.g. cetaceans, turtles), in order to provide the Commission a quantified understanding of likely effects and possible trade-offs of various subsurface setting options, on each species. Collection of accurate data at a species-specific level should be a high priority. The SC should recommend that the Commission give consideration to how such a trial might be supported financially and logistically.
  - CPCS to consider undertaking model-based analyses of condition/AHM at a longline fleet level to identify key factors driving AHM/condition and subsequently, additional potential method/gear mitigation options.

Following the conclusion of WPB the authors will be reaching out to interested WPB scientists to discuss some of these issues further and potentially collaborate on updating of the review in future.

1 Purpose

The Scientific Committee has identified that updated and strengthened management measures are required to stop current and/or prevent future overfishing of IOTC marlin and sailfish stocks and recover those stocks that are currently overfished.

There are a broad range of potential management options that the Commission could consider to address these recommendations, and a systematic review of the available scientific data and research may assist in determining what types of options might be most effective, for different fishing fleets, and/or identify gaps in scientific knowledge that create uncertainty in the understanding of the likely effectiveness of different options.

As such, the purpose of this paper is to:

- Provide a ***preliminary*** review of scientific data and research that is relevant to the consideration of a range of common globally used tools for controlling fishing mortality. These tools include catch limits, non-retention measures, gear and fishing method-based options.
- Promote discussion and engagement among WPB scientists and experts regarding:
    - the available data and research to evaluate these (or additional suggested) options,
    - any additional data and research needed to evaluate these options, and subsequently,
- Obtain advice and recommendations from WPB to assist the further updating and revision of this paper.

2 Introduction

2.1 Background

The IOTC Agreement (FAO, 1993) specifies five billfish species as being under the management of the Indian Ocean Tuna Commission (IOTC), these being black marlin (*Istiompax indica*), blue marlin (*Makaira nigricans*), striped marlin (*Kajikia audax*), Indo-Pacific sailfish (*Istiophorus platypterus*), and swordfish (*Xiphias gladius)*. IOTC catches of these species are estimated to make up a very significant component (43%) of total global billfish catches (IOTC-2024-WPB22-07). Indo-Pacific sailfish represent the highest proportion of IOTC billfish catch in recent years, followed by swordfish, then black, blue and striped marlins (Fig 1).

Swordfish is a target species for which the IOTC has recently adopted a Management Procedure to guide total allowable catch decisions (Resolution 25/07). However, the other four billfish species (blue, black and striped marlins and sailfish) are considered generally to be "mostly retained" bycatch species taken by IOTC fisheries targeting oceanic or neritic tunas or swordfish (IOTC-2024-WPB22-07)*. IOTC management provisions for these species are contained in Resolution 18/05 (*On management measures for the conservation of the billfishes: striped marlin, black marlin, blue marlin and Indo Pacific sailfish*).

This introductory section outlines the IOTC Scientific Committee's concerns over the current and/or future likely stock status for these four species and the associated need for more effective management by IOTC (including revision of Resolution 18/05) in order to reduce fishing mortality on these stocks.

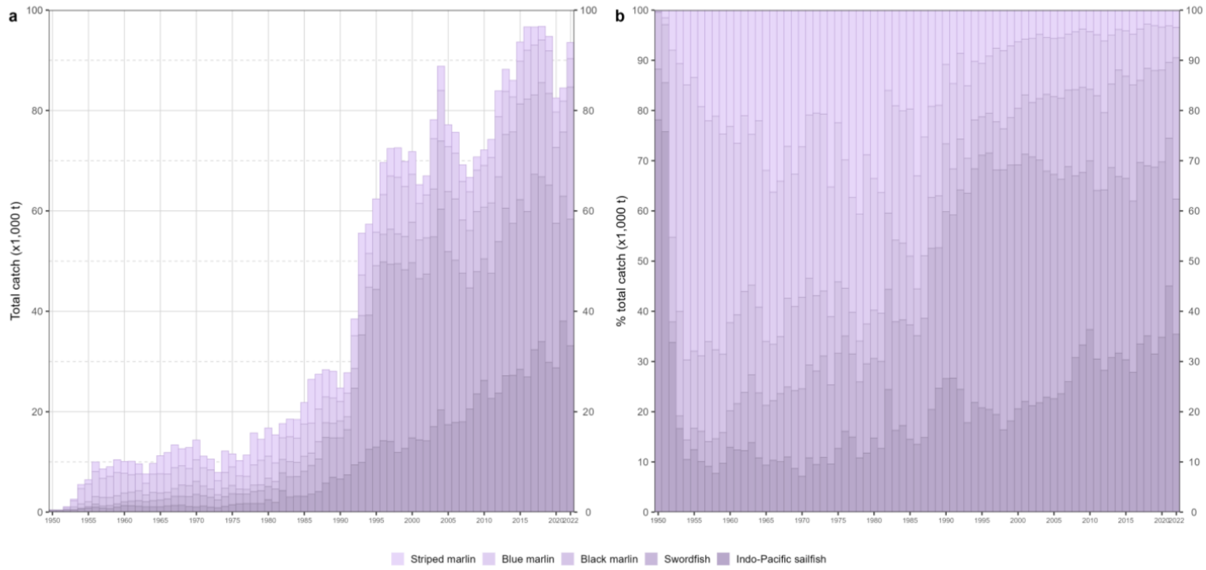


Figure 1: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of IOTC billfish by species for the period 1950-2022. (Source – Fig 5 from IOTC-2024-WPB22-07)

2.1.1 Stock status

The stock status of black marlin, blue marlin, striped marlin and Indo-Pacific sailfish species in the IOTC varies by species. According to the IOTC Scientific Committee, Indo-Pacific sailfish is currently assessed to be not overfished and not subject to overfishing (IOTC–SC27 2024). However, recent catch levels have been well above estimated MSY levels, and there is concern that these levels need to be reduced.

The status of the three marlin species is more pessimistic, with striped marlin, black marlin and blue marlin all subject to overfishing and striped marlin and blue marlin currently overfished (**Table 1**). Blue marlin and sailfish are due to be reassessed in 2025. For all three marlin species, the Scientific Committee has recommended reductions in catches (and fishing mortality) in order to either rebuild these stocks and/or stop overfishing (IOTC–SC27 2024), as follows:

- for **striped marlin**, the Scientific Committee noted with concern that the stock has been overfished for more than a decade and is now in a highly depleted state (*at 3-6% of pre-fished biomass). K2SM projection indicate a 70% reduction from the recent average 2020-22 catch of 2,891 t (i.e. reducing to a catch of 867 t) would recover the stock to the green quadrant by 2032 with a probability of 78%. A 60% reduction in recent average catch (i.e. to a catch of 1,157 t) would achieve this with a probability of 58% (IOTC–SC27 2024).
- for **blue marlin**, the Scientific Committee advised that a reduction of 20% of catches (to 5,700 t) from 2020 catches (7,126 t) would recover the stock to the green quadrant by 2030 with a probability of 79% and if the catches are reduced by 10% (6,413 t) the probability would be 67% (IOTC–SC27 2024).

Table 1 – Summarises the current stock status (including depletion) and Resolution 2018/05 catch limits, for each of four IOTC billfish species, alongside a) revised estimates of SC recommended catch limits and b) both 2023 and 2019-2023 average catch levels.

Species (Assessment Year)	Biomass status (B/BMSY)	Fishing mortality status (F/FMSY)	Stock Depletion	2018/05 limit (mt)	Current SC recommended limit (not adopted)	2023 catch (mt)	Recent av 5 year catch (2019-23)
Striped marlin (2024)	Overfished (B_{2022}/B_{MSY}=0.17*)	Overfishing (F_{2022}/F_{MSY}=3.95*)	3-6%	3260	867(70%) / 1157 (58%)[1]	3553	3024
Blue marlin (2022)	Overfished (B_{2020}/B_{MSY}=0.73)	Overfishing (F_{2020}/F_{MSY}=1.13)	36%	11930	~5700[2]	7888	7049
Black marlin (2024)	Not overfished (B_{2022}/B_{MSY}=1.35)	Overfishing (F_{2022}/F_{MSY}=1.39)	49%	9932	10626[3]	27872	20060
Indo Pacific Sailfish (2022)	Not overfished (B_{2019}/B_{MSY}=1.17)	No overfishing (F_{2019}/F_{MSY}=0.98)	58%	25000	25900[4]	32158	32386

[1] Catch level required recover the stock to the green quadrant of the Kobe plot with a probability ranging from 60% to 90% between 2027 and 2032 (IOTC–SC27 2024)
[2] To recover the stock to the green quadrant of the Kobe Plot by 2027 with at least a 60% chance (IOTC–SC27 2024)
[3] To recover the stock to the green quadrant of the Kobe plot with a probability ranging from 60% to 90% by 2026 (IOTC–SC27 2024)
[4] Provisionally, equivalent to the MSY, but with K2SM projections still to be undertaken.

- for **black marlin**, the Scientific Committee advised that if the Commission wishes to recover the stock to the green quadrant of the Kobe plot with a probability ranging from 60% to 90% by 2026 as per Resolution 18/05, it needs to provide mechanisms to ensure the maximum annual catches remain less than 10 626 t (IOTC–SC27 2024).

For **Indo-Pacific Sailfish**, while the stock is not overfished or subject to overfishing, the Scientific Committee noted that catches have exceeded the estimated MSY since 2013 and the current catches (average of 32,386 t in the last 5 years, 2019-2023) are substantially higher than the current MSY estimate of 25,905 t. This increase in coastal gillnet longline catches and fishing effort in recent years is a substantial cause for concern for the Indian Ocean stock, however there is not sufficient information to evaluate the effect this will have on the resource (IOTC–SC27 2024).

2.1.2 Scientific Committee concerns with current management settings

Currently these four species are subject to IOTC Resolution 18/05 (*On management measures for the conservation of the billfishes: striped marlin, black marlin, blue marlin and Indo Pacific Sailfish*) which includes the following conditions:

1. Overall IOTC catch limits for each species (see **Table 1**) and a requirement for the review of the measure should the average annual total catch of any of the species, in any two consecutive years period from 2020 onward, exceed the species limit.
2. Prohibition of retaining on board, trans-shipping or landing any specimen smaller than 60 cm Lower Jaw Fork Length (LJFL) of any of these species.
3. *Non-mandatory* adoption by CPCs of additional fisheries management measures to limit fishing mortality such as: releasing any specimen brought alive on-board or alongside for taking on board the vessel; modify fishing practices and/or fishing gears to reduce juvenile catches; adopting spatial/temporal management measures to reduce fishing in nursery grounds; limiting days at sea and/or fishing vessels exploiting billfishes.

The Resolution also contains a number of conditions pertaining to improving data collection and reporting for these species as well as requests for the Scientific Committee advice, including on:

a. *Options to reduce fishing mortality with a view to recover and/or maintain the stocks in the Green zone of the Kobe Plot with levels of probability ranging from 60 to 90% by 2026 at latest. The advice shall be provided on the basis of the current exploitation pattern as well as of its likely change to take into account the advice under point c.* below;

b. *Species specific minimum conservation sizes by taking into account the size at maturity and the recruitment size to the fishery by gear as well as its practicability. Where adequate, due to considerations on technical interaction of fisheries, advice shall provide also a minimum conservation size common to the four species*.

Both the Working Party on Billfish and the IOTC Scientific Committee have repeatedly raised significant concerns with the current Resolution, noting that limits are based on old and out of date stock assessments and projections and that since the adoption of Resolution 18/05, the poor stock status for three of these stocks has continued. New assessments and catch projections have been undertaken since 2018 providing new information on stock status and the sustainable catch limits required to avoid overfishing and/or recover those stocks that are overfished (see **Table 1**). Recent catch levels have exceeded the SC's revised recommended limits for each stock, in most cases by significant margins, and catches (fishing mortality) need to be urgently reduced. This is particularly the case for stocks assessed to be overfished and subject to overfishing and most urgently so for striped marlin which estimated to be at 3-6% of its unfished levels.

The 2023 Scientific Committee "*RECOMMENDED that Resolution 18/05 be urgently revised and updated so as to reflect MSY based catch limits for each species based on the most recent stock assessment and projections information available,* ***and to contain provisions to ensure that catches do not exceed such limits****. The SC REQUESTED that for Indo-Pacific sailfish, K2SM projections be provided based on the most recent assessment so as to inform revised limits for that stock*" (IOTC-2023-SC26). The 2024 Scientific Committee advice re-affirmed this, recommending that the Commission reassess the effectiveness of the current measures within this resolution and to revise Resolution 18/05 to update the catch limits based on the latest stock assessments and projections for the billfish species, and provide mechanisms to maintain catches within SC recommended limits (IOTC-2024-SC27).

2.2 Key considerations for assessing potential management options

In undertaking the preliminary review of data and research relevant to assessing the potential efficacy of a range of different management options, the paper takes account of two key consideration "areas":

1. **Catch by fishery type** – it is important to take account of which fisheries/gears contribute the majority of historical and recent fishing mortality on these stocks. This information can assist the WPB, SC and Commission to understand what type of management options (below) and in which fishery types, might be most effective in achieving the required reductions.
2. **Bycatch management options** – in choosing a range of potential management options to consider, the review has given priority to the (currently) non-mandatory options for management approaches outlined in Resolution 18/05, as well management practices taken in other RFMOs for managing non-target billfish catch levels (see **Table 2** below). On this basis, this paper provides a preliminary review of data and research relevant to 3 main categories of management option being:
    a. **Catch/bycatch limit**s
    b. **Non-retention**
    c. **Fishing gear/method** options

There are of course additional options not yet considered under this preliminary review, including **spatial-temporal options** and options that comprise combinations of measures. These were not covered in the initial review (due to time/resources) but should be discussed by WPB and potentially included in future reviews**.**

Ultimately, if the Commission wishes to stop overfishing and recover the overfished stocks, the Commission may need to consider including (and making mandatory) more than one option for managing catch/bycatch of these species (e.g. similar to the Resolution for seabirds) in a revised billfish resolution. This may be required to accommodate the specific gear types and circumstances of each fleet/fishery and where possible to avoid or minimise impacts on target species catches.

Table 2 – A summary of stock status of marlins and sailfish species in non-IOTC RFMOs, highlighting the management approaches used by those RFMOs to control fishing mortality in cases where the stocks are assessed as overfished or subject to overfishing.

Summary	RFMO	Stock status	Management	Reference
Blue marlin	ICCAT	Overfished but not subject to overfishing	TAC limits (1,670 t since 2020) with CPC allocations; Recreational catch limits (250 t US (combined with white marlin) and 10 t other CPCs); Overcatch provisions (payback of quota); No undercatch; Live release requirements and safe handling and release requirements	Resolution 19-05
	IATTC	Not overfished and not subject to overfishing	na	
	WCPFC	Not overfished and not subject to overfishing	na	
Black marlin	ICCAT IATTC WCPFC	na	na	
Striped marlin	ICCAT	na	na	
	IATTC	Not overfished and not subject to overfishing	na	
	WCPFC	Southwest; Overfished and not subject to overfishing; NPO - Overfished and subject to overfishing	NPO - TAC limits (2,400 t between 2024-2027) with CCM allocations; Overcatch and undercatch provisions	CMM 2024-06
Indo-Pacific Sailfish/ Atlantic sailfish	ICCAT	Eastern - Overfished but not subject to overfishing; Western - Overfished but not subject to overfishing	TAC limits (1,271 t East & 1,030 t West since 2016). Set at 67% of average estimated MSY.; Encourage live release, use of circle hooks and other potential mitigation measures to reduce mortality.	Resolution 16-11
	IATTC	Not possible to determine status	na	
	WCPFC	na	na	

3 Methods

This paper has reviewed relevant publicly available data and research literature pertaining to the status, catches and assessment of the potential effectiveness of a range of possible management options for IOTC black marlin, blue marlin, striped marlin and Indo-Pacific sailfish.

The literature review was conducted using a combination of:

- Google scholar
- Review and interrogation of historical IOTC working party and SC meeting papers
- Directly contacting relevant researchers and the IOTC Secretariat data team for copies of relevant research papers and data.

Nearly all of the fishery catch data summaries and plots were sourced directly from the IOTC Secretariat papers provided to past meetings of the WPB and SC.

It is hoped that discussions with WPB in 2025 will identify further data and research for inclusion in a future update of this paper.

4 Summary of catches by fishery type

4.1 Introduction

A brief review of recent and historic IOTC area catches of each of the four species, including commentary on discarding and catch data quality, is provided below. This information is an important consideration, noting that the current status of these stocks are a consequence of not just recent catch levels (which relate closely to recent fishing mortality status), but also historic catch levels (which contribute to the current biomass status of the stocks) by different gears and fleets, which have changed through time. The information summarised below is derived predominantly from the IOTC Secretariats 2024 species data summary papers (provided to the WPB meeting). More detailed (and up to date) information on catches on a species by species basis and by CPC fleets are available in the IOTC Secretariats current WPB data summary papers for each species, as well as the species executive summaries in the 2024 Scientific Committee Report.

4.2 Overview/Summary

The best scientific estimates of catch histories of the four billfish species show some important differences between species, both in terms of overall total catch trends over time and also which fisheries have contributed the most significantly to historic and recent (2018-2022) catches in the IOTC.

For both **blue marlin** and **striped marlin**, the majority of total historic catches (from 1950 - present) have been taken by industrial longline fisheries (**Table 4**). However, the proportion of total catches by fishery type have changed over time. For **blue marlin**, while the majority of recent total catch (2018-2022) is taken by longline (66.8%) (Table 3) the composition of that fishery has changed recently, with historically low levels of catch by industrial deep freeze (27.8%) and fresh storage (21.4%) longline vessels, offset by increases in coastal longline catch (16.4%) (**Table 3 and 4**). The proportion of total catch of blue marlin taken by gillnet has also significantly increased (22.5%) in recent years. For **striped marlin**, the proportion of total catches taken by longline has declined to comprise 27.7% of total recent catch, while gillnet catches have increased to account for 66% of recent catches (Table 3).

Table 3 – Percentage of average annual total catch of each species in the IOTC Area, by fishery type, for the period 2018-2022 (IOTC, 2024a, b, c, d).

<table>
<tr><th>Fishery</th><th colspan="2">Black marlin</th><th colspan="2">Blue marlin</th><th colspan="2">Striped marlin</th><th colspan="2">Sailfish</th></tr>
<tr><td>Purse seine | Other</td><td colspan="2">4.1</td><td colspan="2">1.5</td><td colspan="2">1.3</td><td colspan="2">0.8</td></tr>
<tr><td>Longline | Other</td><td>0.3</td><td rowspan="4">26.9</td><td>1.2</td><td rowspan="4">66.8</td><td>1.3</td><td rowspan="4">27.7</td><td>0.1</td><td rowspan="4">14.4</td></tr>
<tr><td>Longline | Fresh</td><td>5.6</td><td>21.4</td><td>6.4</td><td>2.2</td></tr>
<tr><td>Longline | Deep-freezing</td><td>1.2</td><td>27.8</td><td>12.6</td><td>0.9</td></tr>
<tr><td>Line | Coastal longline</td><td>19.9</td><td>16.4</td><td>7.4</td><td>11.2</td></tr>
<tr><td>Line | Trolling</td><td colspan="2">1.2</td><td colspan="2">2.8</td><td colspan="2">2.0</td><td colspan="2">8.6</td></tr>
<tr><td>Line | Handline</td><td colspan="2">3.8</td><td colspan="2">6.4</td><td colspan="2">2.7</td><td colspan="2">5.3</td></tr>
<tr><td>Baitboat</td><td colspan="2">0.2</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">0.1</td></tr>
<tr><td>Gillnet</td><td colspan="2">63.3</td><td colspan="2">22.5</td><td colspan="2">66.0</td><td colspan="2">70.9</td></tr>
<tr><td>Other</td><td colspan="2">0.4</td><td colspan="2">0.0</td><td colspan="2">0.3</td><td colspan="2">0.1</td></tr>
</table>

In contrast to blue marlin and striped marlin, the historic catches of **black marlin** and **Indo-Pacific sailfish** have been largely dominated by the gillnet sector since the 1970s (for sailfish) and 1980s (for black marlin). This trend continues in recent years (Tables 3-5).

For **black marlin**, gillnet has accounted for 63.3% of total recent catch, with the combined longline fishery accounting for another 26.9% of catch. The majority of this is coastal longline (19.9%). Purse seine (4.1%) and handline (3.8%) make more minor contributions (Tables 3-5).

For **sailfish**, gillnet has accounted for 70.9% of total sailfish catches, while longline (mainly coastal longline) only accounts for 14.4% of recent total catches, with trolling (8.6%) and handline (5.3%) also contributing to catch (Table 3).

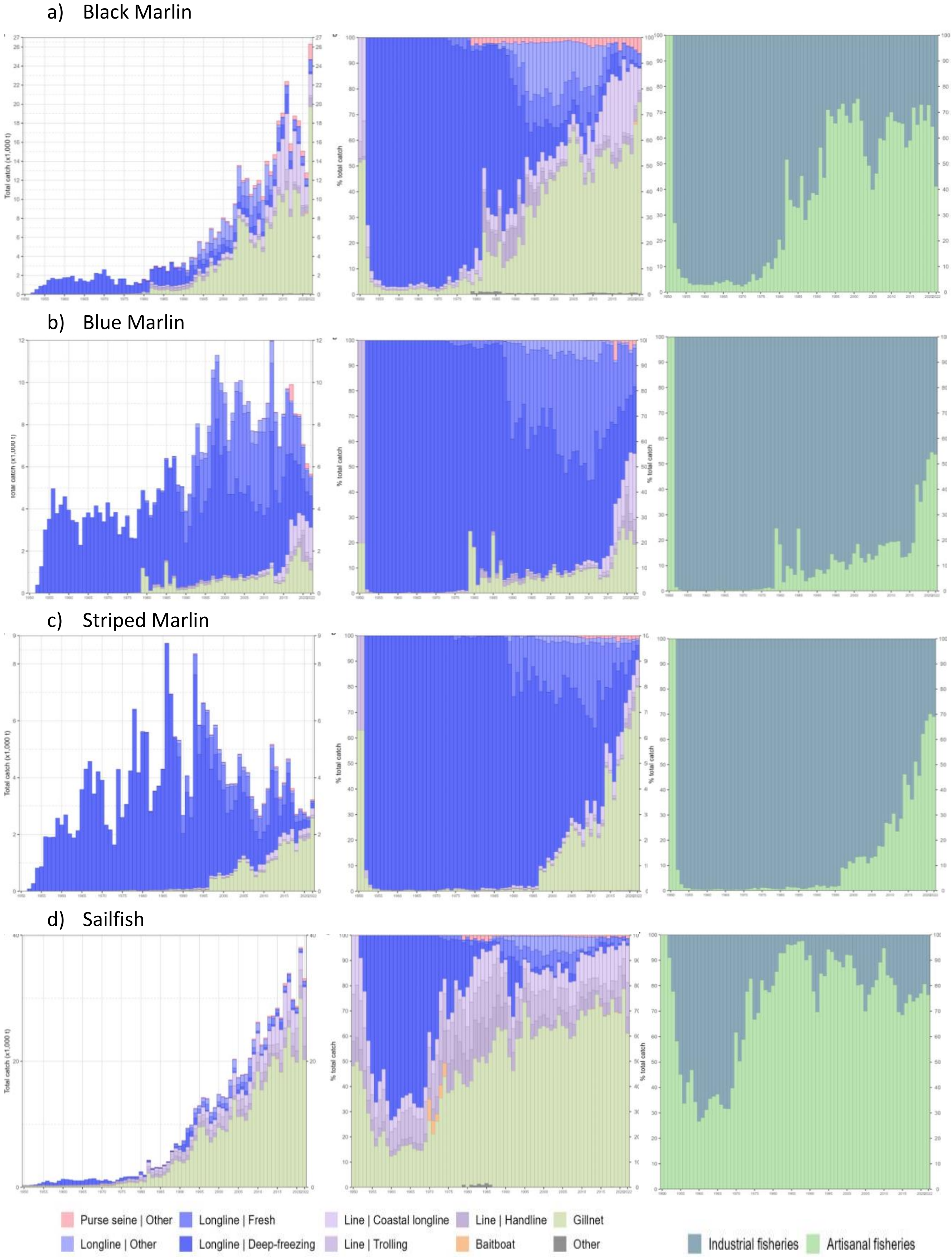


Figure 2: Annual time series of cumulative retained absolute (left column) and relative (right side) catches (metric tonnes; t) of a) black marlin, b) blue marlin, c) striped marlin and d) Indo-Pacific sailfish, by fishery type for the period 1950-2022. Data source: Source – IOTC (2024a, b, c – utilising best scientific estimates of retained catches).

Table 4: Best scientific estimates of average annual retained catches (metric tonnes; t) of black marlin, blue marlin and striped marlin by decade and fishery for the period 1950-2019. The background intensity color of each cell is directly proportional to the catch level. Source – IOTC (2024a, b, c, d – utilising best scientific estimates of retained catches - https://www.iotc.org/WPB/21/Data/03-NC)

Species	Fishery	1950s	1960s	1970s	1980s	1990s	2000s	2010s
Black Marlin	Purse seine | Other	0	0	4	60	95	193	478
	Longline | Other	0	0	0	30	866	1,809	692
	Longline | Fresh	0	0	24	55	596	1,236	1,165
	Longline | Deep-freezing	862	1,661	1,367	1,647	952	724	842
	Line | Coastal longline	16	15	21	163	302	706	3,578
	Line | Trolling	8	11	20	25	56	118	331
	Line | Handline	1	1	1	259	362	199	540
	Baitboat	0	0	0	0	0	0	1
	Gillnet	26	31	44	368	1,655	5,416	8,742
	Other	0	0	1	19	17	33	73
	Total (Black marlin)	912	1,719	1,482	2,626	4,902	10,434	16,442
Blue Marlin	Purse seine | Other	0	0	0	2	4	7	108
	Longline | Other	0	0	0	10	237	511	341
	Longline | Fresh	0	0	38	230	2,293	3,310	2,985
	Longline | Deep-freezing	2,567	3,535	3,370	4,328	4,545	4,038	3,652
	Line | Coastal longline	0	0	0	10	33	62	575
	Line | Trolling	5	9	17	12	27	50	138
	Line | Handline	0	0	0	83	103	36	121
	Gillnet	1	2	124	454	395	690	1,076
	Other	0	0	0	0	0	0	1
	Total (Blue marlin)	2,574	3,546	3,550	5,129	7,635	8,704	8,997
Striped Marlin	Purse seine | Other	0	0	0	5	8	17	41
	Longline | Other	0	0	0	12	51	89	79
	Longline | Fresh	0	0	18	63	832	745	635
	Longline | Deep-freezing	1,028	3,104	3,441	5,069	4,232	2,103	1,272
	Line | Coastal longline	0	0	1	23	46	94	236
	Line | Trolling	3	5	9	6	14	23	48
	Line | Handline	0	0	0	2	10	20	31
	Gillnet	5	8	16	20	170	721	1,384
	Other	0	0	0	1	2	3	7
	Total (Striped marlin)	1,036	3,117	3,485	5,202	5,365	3,814	3,734
Indo-Pacific Sailfish	Purse seine | Other	0	0	3	44	40	81	202
	Longline | Other	0	0	0	19	488	1,127	517
	Longline | Fresh	0	0	17	69	711	991	636
	Longline | Deep-freezing	297	804	368	189	616	345	382
	Line | Coastal longline	62	62	68	374	689	1,523	3,473
	Line | Trolling	79	121	217	560	1,104	1,655	1,552
	Line | Handline	30	30	142	494	710	776	1,299
	Baitboat	0	0	29	0	0	0	34
	Gillnet	165	181	504	2,081	6,809	11,307	19,745
	Other	0	0	2	20	2	4	14
	Total (Sailfish)	633	1,197	1,350	3,850	11,169	17,809	27,853

Table 5: Best scientific estimates of annual retained catches (metric tonnes; t) of black marlin (top), blue marlin (middle) and striped marlin (bottom) by fishery for the period 2013-2022. The background intensity color of each cell is directly proportional to the catch level. Data source: IOTC 2024a, b, c - [best scientific estimates of retained catches](https://www.iotc.org/WPB/21/Data/03-NC)

Species	Fishery	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	% 2018-22
Black Marlin	Purse seine | Other	486	428	429	407	807	393	589	555	611	1,625	4.1
	Longline | Other	661	304	60	73	55	48	54	50	57	55	0.3
	Longline | Fresh	1,510	1,572	770	874	932	932	1,566	730	627	1,244	5.6
	Longline | Deep-freezing	653	866	1,461	2,038	858	216	218	215	160	241	1.2
	Line | Coastal longline	2,310	3,830	5,809	5,857	4,191	5,347	4,406	4,201	1,946	2,251	19.9
	Line | Trolling	349	263	203	1,275	138	261	224	194	174	277	1.2
	Line | Handline	472	535	615	872	673	537	551	887	597	915	3.8
	Baitboat	0	0	6	5	0	1	0	1	140	1	0.2
	Gillnet	8,180	10,355	9,640	10,917	8,081	10,959	10,578	8,149	8,394	19,635	63.3
	Other	84	74	73	69	94	55	64	94	75	77	0.4
	Total (Black marlin)	14,704	18,228	19,066	22,387	15,828	18,750	18,251	15,076	12,779	26,320	
Blue Marlin	Purse seine | Other	18	16	23	52	785	47	95	65	234	99	1.5
	Longline | Other	443	43	125	156	95	74	86	79	93	81	1.2
	Longline | Fresh	3,247	2,624	2,847	2,934	2,409	2,122	2,202	1,502	1,006	858	21.4
	Longline | Deep-freezing	4,054	3,300	4,259	4,744	3,112	3,073	2,287	1,725	1,392	1,497	27.8
	Line | Coastal longline	208	393	505	457	1,540	983	1,233	716	1,485	1,466	16.4
	Line | Trolling	105	106	132	216	235	158	154	232	199	252	2.8
	Line | Handline	40	23	74	218	211	266	237	1,250	229	317	6.4
	Gillnet	473	449	542	929	1,517	1,793	2,187	1,503	1,511	1,087	22.5
	Other	0	0	0	11	1	1	0	0	0	0	0.0
	Total (Blue marlin)	8,588	6,954	8,507	9,717	9,905	8,518	8,482	7,072	6,148	5,658	
Striped Marlin	Purse seine | Other	42	37	36	37	87	30	32	47	37	41	1.3
	Longline | Other	137	56	82	103	88	53	54	36	27	22	1.3
	Longline | Fresh	935	577	672	366	326	206	360	190	95	61	6.4
	Longline | Deep-freezing	1,817	729	967	2,161	926	733	318	320	247	183	12.6
	Line | Coastal longline	240	246	255	254	333	247	183	204	181	237	7.4
	Line | Trolling	55	47	46	49	62	37	48	60	49	91	2.0
	Line | Handline	48	25	0	29	26	6	55	163	142	19	2.7
	Gillnet	1,107	1,594	1,761	1,659	1,764	1,396	1,852	1,763	1,852	2,564	66.0
	Other	9	8	8	7	9	6	7	10	8	8	0.3
	Total (Striped marlin)	4,390	3,318	3,827	4,665	3,620	2,714	2,909	2,792	2,638	3,225	
Indo-Pacific Sailfish	Purse seine | Other	202	183	178	170	419	170	184	273	229	412	0.8
	Longline | Other	1,061	236	67	110	69	56	58	30	29	46	0.1
	Longline | Fresh	944	1,010	545	504	714	822	1,194	625	355	617	2.2
	Longline | Deep-freezing	122	283	510	1,160	297	377	289	235	226	288	0.9
	Line | Coastal longline	2,270	2,924	4,380	3,215	5,587	4,694	3,705	2,369	2,688	4,847	11.2
	Line | Trolling	1,327	1,373	1,480	2,114	1,619	1,383	2,019	3,559	2,510	4,532	8.6
	Line | Handline	1,947	389	778	1,346	1,455	1,054	1,613	1,769	2,068	2,158	5.3
	Baitboat	81	0	130	48	26	11	40	32	0	0	0.1
	Gillnet	19,191	20,837	20,358	18,254	22,157	25,360	20,739	19,820	29,930	20,225	70.9
	Other	10	8	8	8	20	46	13	28	11	9	0.1
	Total	27,155	27,244	28,434	26,928	32,364	33,974	29,854	28,740	38,046	33,135	

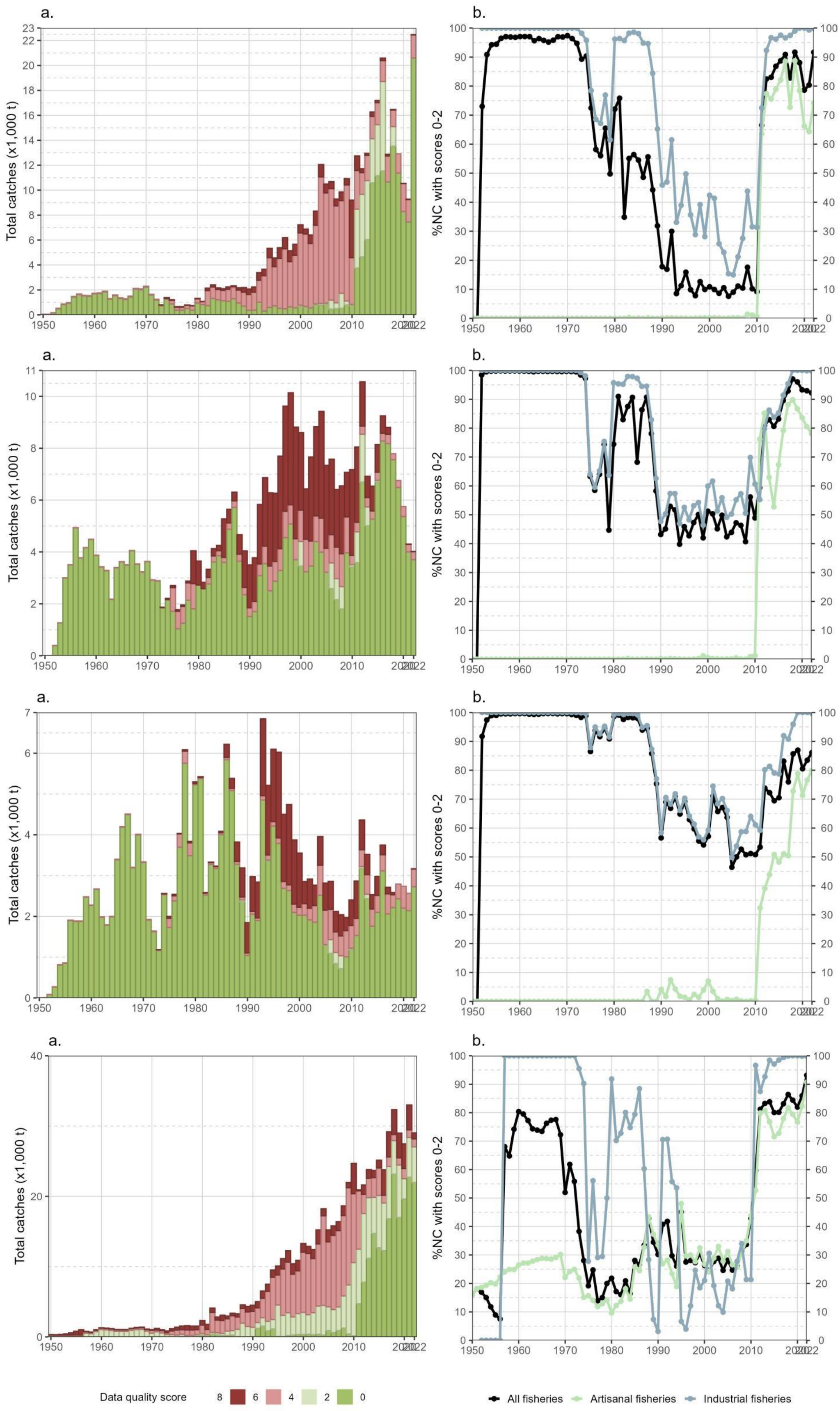


Figure 3: (a) Annual retained catches (metric tonnes; t) of black marlin, blue marlin, striped marlin estimated by quality score and (b) percentage of total retained catches fully/partially reported to the IOTC Secretariat for all fisheries and by type of fishery, in the period 1950-2022.

5 Review of data and research relevant to potential management options

5.1 Introduction

This section reviews existing and potential management options to reduce fishing mortality of marlin (and if necessary, sailfish) in the Indian Ocean. Cross-fishery tools such as catch limits and retention bans are addressed first, followed by gear/method specific approaches. Spatial temporal and other management options are not yet included in the review (due to lack of time).

Unless stated otherwise we use the term “marlins” to refer to black marlin, blue marlin and striped marlin. Indo-Pacific Sailfish are referred to simply as “sailfish”. The term Billfish refers to the broader group Xiphioidea which includes Swordfish (*Xiphias gladius*).

An important issue to be aware of when considering the various potential management options is the mixed status of these marlin and sailfish species as either target or bycatch species. It is often the case that specific management measures for specific fleets are chosen dependent on whether the species is considered a target or bycatch species. Target species are more often subject to catch limits while bycatch species are often subject to retention based or fishing gear/method mitigation. A review of the IOTC literature indicates that:

- For industrial and coastal tuna/swordfish **longline fisheries** these species are predominantly a bycatch, albeit commercially valuable and very commonly retained (e.g. Bandaranayake et al 2024; Wang et al 2021; Surya et al 2021).

- For tuna **purse seine fisheries** they are also predominantly a bycatch (e.g. Thitipongtrakul et al 2024), but also often retained.

- For **gillnet fisheries**, while they are often considered a commercially valuable bycatch of fleets targeting mainly tropical and neritic tuna (e.g. Bandaranayake et al 2024; Dafrazi 2023; Surya et al 2021), for some gillnet fleets they are also sometimes considered a target (e.g. Moazzam, 2024).

- For **line fisheries**, in particular, handline and troll fisheries, the review was uncertain whether these species are targeted or taken as bycatch (or both).

5.2 Fleet specific catch limits

5.2.1 Introduction

Fleet specific annual catch limits act to impose a limit on the total number or weight of a nominated species/stock that is retained by a CPC fleet each year, with the aim of managing fishing mortality of the species by each fleet, to remain at or under a fishery wide total annual catch limit.

Such catch limits tend to be more commonly applied to target species. For example, currently, the IOTC already implements CPC fleet specific catch limits for tuna target species (e.g. for bigeye and yellowfin tuna). However, globally, such limits are also sometimes used for “retained” bycatch species including billfish taken as bycatch (see examples below). Occasionally, they are also imposed at a finer scale (below fleet level), for example, trip catch limits.

Examples of implemented billfish bycatch limits include:

- WCPFC imposes fleet (member country) catch limits, associated with a total allowable catch (TAC), for North Pacific Striped marlin (predominantly a bycatch of tuna/swordfish targeting vessels)(CMM 2024-06).
- ICCAT implements CPC catch limits for both blue marlin and white marlin, associated with species-specific TACs (Resolution 19-05).
- WCPFC imposes swordfish TACs on fleets (target and bycatch fleets) operating south of 20°S (WCPFC, 2009).
- ICCAT imposes bycatch limits for Atlantic swordfish fleets via the swordfish recovery plan.

5.2.2 Key data and research considerations

There are a range of factors that will impact the likely effectiveness of fleet specific catch limits for marlin and sailfish in the IOTC, including:

a. Whether the limits are based on retained catch only (including whether they contain a requirement to retain any dead fish or are based on total catch (retained and discarded).
    i. If the limit is applied to retained catch only, operators would be forced to discard fish (or high grade) once the limit is reached, reducing the measures effectiveness if fishing mortality increased above agreed limits.
    ii. If the limit was applied to total catch, it could act as a choke on catches of the target species and come at a very high economic cost.
b. Appropriate reporting and monitoring (port and on-board) in place to ensure catches are accurately estimated, limits are adhered to, high-grading and discarding practices aren’t occurring.
c. Vessel operator’s ability to adjust fishing practices/gear to avoid capture or improve post release survival if the limit is reached.

As such, consideration of the potential effectiveness of, and how to best apply, catch limits will require data and information pertaining to:

- The quality of catch data for different CPCs and fleets. This is already assessed by the IOTC Secretariat and considered annually by the WPDCS (e.g. see Figure 3 above).
- Information on at-haul mortality, discarding trends, and post-release mortality - to assess the effect of such limits if imposed on retained catch only, or if calculated to take into account likely discarding. These factors are discussed further under non-retention option below.

5.3 Non-retention

5.3.1 Introduction

Prohibiting the retention of species subject to overfishing can be an effective measure to reduce fishing mortality by deterring targeting and increasing the number of incidentally caught individuals being released alive. For commercially valuable bycatch species like marlin and sailfish, such a measure is often considered in cases of very poor stock status and can be implemented in several ways, including prohibiting retention:

- Of all individuals caught (of that species), or
- Of individuals that are alive at haul-back, or
- Of individual of specific sizes or maturity stages (e.g. releasing all juveniles or known spawners)
- In association with trip catch limits (e.g. a maximum allowable bycatch per trip)

Typically, from a monitoring and compliance perspective, prohibiting retention of all individuals caught, or of specific size classes, is the most easily monitored approach (via in port or at sea inspections). Live release options require on board observers or electronic monitoring (EM) (i.e. cameras) to ensure compliance.

In the IOTC, there is already currently a prohibition on retention of marlin or sailfish smaller than 60 cm Lower Jaw Fork Length (LJFL) (Resolution 18/05). Other global examples of non-retention of billfish or other bycatch, being implemented include:

- ICCAT prohibition of retention of live (at haul-back) blue marlin and white marlin (Resolution 19-05).
- Black and blue marlin retention ban in Australian Commonwealth fisheries (AFMA, 2022)
- Oceanic whitetip shark retention bans in all RFMOs, with silky, thresher, and hammerhead sharks banned in some RFMOs (Hall et al., 2017; Tolotti et al., 2015).
- Recent IOTC retention bans on shortfin and longfin mako that are alive at-haulback and only allowed to be retained when dead if there is a functioning EM system or at-sea observer on board (Resolution 25/09)

5.3.2 Key data and research considerations

There are a range of factors that will impact the likely effectiveness of non-retention measures for marlin and sailfish in the IOTC, and these are likely to vary between species and fisheries/fishing methods depending on:

a. **Proportion of overall marlin fishing mortality by that fishery:** If a particular gear contributes a large share of total marlin or sailfish catch/mortality, a retention ban in that fishery has greater potential impact on reducing overall fishing mortality (depending on points b and c below). The proportion of retained catch by fishery types and species is summarised in **Section 4 (above).**
b. **Proportion of hauled catch that is retained –** if a fishery already discards/releases most of its catch of a species, then non-retention measures will be less effective (but can act to prevent

future retention). In these cases, improvements in safe handling and release (to improve post release survival likelihood) may be more effective options. Preliminary IOTC observer data (Table 6 below) indicates very high retention in longline fisheries (consistent with longline fisheries globally – Table 7) but significant discarding in purse seine fisheries, for each of the marlin and sailfish species. Further review of available observer data by fleet is needed to understanding retention/discard trends at the fleet level.

c. **At-haul mortality (AHM) rate**: The fraction of marlin or sailfish found dead upon hauling to vessel (before any chance of release). The lower the AHM, the greater the potential effectiveness of non-retention measures, providing that post release mortality is also low. May vary by size. Examples of AHM rates reported in IOTC fisheries are provided in Table 6.
d. **Post-release mortality rate**: The fraction of marlin or sailfish released alive, that subsequently die after being released, due to injury, stress and/or greater vulnerability to predation. May vary by size of fish.
e. **Practicality of improved handling or gear adjustments:** The ease of modifying handling practices or gear to improve survival at release (e.g. using techniques to minimize injury during capture).
f. **Size-selectivity of the gear**: Different fishing gears catch different size ranges of marlin or sailfish. AHM and PRM are likely to vary by size.
g. **Reliability of monitoring and reporting:** Effective enforcement requires timely and reliable data on catch and discards.

Where at-haul and/or post-release mortality rates are very high, non-retention measures will be ineffective for reducing bycatch mortality. In such fisheries, meaningful mortality reductions can only be achieved by either, modifying fishing methods and handling practices to reduce AHM/PRM, or, adopting measures that *reduce the number of interactions/captures* in the first place (i.e. reducing the catchability or selectivity of the gear, or ceasing fishing at a given catch limit, etc).

The following sections provide a preliminary review of current knowledge of at haul mortality (AHM) and post release mortality (PRM) for marlin and sailfish species, using IOTC relevant data/research where possible but drawing on broader global research also.

5.3.3 At-haul mortality

For the purposes of this review, the most relevant at-haul mortality (AHM) data will be IOTC fleet specific estimates of AHM derived from CPC/regional observer data, which may be reflective of each fleets fishing gear, fishing strategy, area/environmental factors, handling and other fleet specific factors. Preliminary summaries of observer data, detailing discarding and at-haul mortality rates, for a limited number of IOTC CPC longline and purse seine fleets, were provided by the IOTC Secretariat (Table 6 below).

Longline fisheries

Table 6 summarises AHM rates for a limited number of IOTC CPC longline fleets (derived from recent observer data) for marlin and sailfish species, alongside discarding rate data for these fleets. The data indicate retention rates for longline of above 95% for all species for both fleets. However, AHM rates varied between fleet, with EU(France) longline AHM significantly lower for blue marlin (50%), striped marlin (23%) and sailfish (56%) than reported for Japan longline (71%, 52% and 82% respectively).

Table 6 – Percentage at-haul mortality for marlins and sailfish as reported by at-sea observers deployed on longline and purse seine vessels in the IOTC (pre 2021?*). "Total Classified" means the number of observed fish which were classified as either dead or alive (not unknown). AHM – at-haul mortality; DAHM = at haul mortality for fish then discarded; RAHM = at-haul mortality for fish then retained. (Source – IOTC Secretariat, Regional Observer Program Data, 2025).

Species	Fishery Type	Fleet	Total observed	Total Retained	% Retained	Total Classified	Dead	Alive	AHM (%)	DAHM (%)	RAHM (%)
Black Marlin	Longline	EU (France)	293	288	98.3	29	21	8	72.4	100.0	66.7
		Japan	164	157	95.7	164	104	60	63.4	100.0	61.8
	Purse seine	EU (France)	397	192	48.4	189	179	10	94.7	94.7	U
		EU (Spain)	348	300	86.2	48	48	0	100.0	100.0	U
		Seychelles	691	611	88.4	80	76	4	95.0	95.0	U
Blue Marlin	Longline	EU (France)	890	852	95.7	291	146	145	50.2	84.2	45.1
		Japan	247	235	95.1	247	177	70	71.7	100.0	70.2
	Purse seine	EU (France)	907	582	64.2	175	172	3	98.3	98.3	U
		EU (Spain)	445	308	69.2	137	137	0	100.0	100.0	U
		Seychelles	462	396	85.7	66	53	13	80.3	80.3	U
Striped Marlin	Longline	EU (France)	178	178	100.0	55	13	42	23.6	NA	23.6
		Japan	172	167	97.1	172	90	82	52.3	100.0	50.9
	Purse seine	EU (France)	68	33	48.5	35	35	0	100.0	100.0	U
		EU (Spain)	16	8	50.0	8	8	0	100.0	100.0	U
		Seychelles	28	26	92.9	2	2	0	100.0	100.0	U
Sailfish	Longline	EU (France)	500	480	96.0	189	106	83	56.1	90.0	52.1
		Japan	186	180	96.8	186	154	32	82.8	100.0	82.2
	Purse seine	EU (France)	41	23	56.1	10	10	0	100.0	100.0	U
		EU (Spain)	35	17	48.6	18	18	0	100.0	100.0	U
		Seychelles	10	9	90.0	1	1	0	100.0	100.0	U

Table 7 Reported at-haul mortality (AHM) rates for marlin and sailfish caught by longline from published observer program and experimental studies. Data include study reference, location, species, sample size (N), and the percentage of individuals found dead at haul.

Species	Study	Location	Number observed	At-Haul-Mortality (% dead at haul)	Weighted Mean AHM (%)
Black Marlin	Gilman et al., 2016	Palau (Western Pacific)	39	44%	63%
	Sharples et al., n.d.	Western and central Pacific	625	64%	
Blue Marlin	Jackson & Farber, 1998	Atlantic	863	51%	48%
	Pacheco et al., 2011	Equatorial South Atlantic Ocean	13	69%	
	Curran & Bigelow, 2011	Hawaii	288	58%	
	Beerkircher et al., 2002	Northwest Atlantic	1322	35%	
	Gilman et al., 2016	Palau (Western Pacific)	213	40%	
	Sharples et al., n.d.	Western and central Pacific	1985	54%	
Sailfish	Pacheco et al., 2011	Equatorial South Atlantic Ocean	6	75%	66%
	Beerkircher et al., 2002	Northwest Atlantic	1674	59%	
	Gilman et al., 2016	Palau (Western Pacific)	214	70%	
	Sharples et al., n.d.	Western and central Pacific	1108	75%	
Striped Marlin	Curran & Bigelow, 2011	Hawaii	1131	59%	54%
	Gilman et al., 2016	Palau (Western Pacific)	56	41%	
	Sharples et al., n.d.	Western and central Pacific	859	51%	
	Li et al., 2024	Western Indian Ocean	774	52%	
White Marlin	Jackson & Farber, 1998	Atlantic	1799	56%	51%
	Pacheco et al., 2011	Equatorial South Atlantic Ocean	34	65%	
	Beerkircher et al., 2002	Northwest Atlantic	2188	47%	

Across fleets striped marlin had the lowest AHM. It is worth noting that while retention rates are high, of the small proportion discarded, the vast majority were already dead (possibly discarded due to depredation or capture injuries) (Table 6).

The review also summarized AHM figures from other global studies of AHM in longline fisheries (**Table 7)**, including a pooled mean across species, weighted by study sample size. Mortality rates vary among species, and then within species, between studies. Sailfish exhibited the highest “pooled mean” mortality (66%) while study specific estimates varied for sailfish from 59%-75% (Table 7), followed by black marlin (mean 63%; 44%-64%). Striped marlin (mean 54%; 41-59%), white marlin (mean 51%; 47-65%) and blue marlin (mean 48%; 40%-58%) had lower AHM.

The inter-specific differences likely reflect a combination of species-specific biological traits, vulnerability to capture stress, and differences in gear configuration or handling practices, amongst other factors. Both interspecific and inter-fleet differences in AHM may have important implications for tailoring management measures by fishery, gear type and region.

Factors influencing AHM are complex and interrelated. Environmental variables (sea surface temperature, season, oxygen levels, etc.) as well as gear characteristics (set depth, soak time, hook type) may all play a role. A recent study on striped marlin condition at haul in the western Indian Ocean longline fishery (Li et al., 2024) assessed various covariates including season, SST, hook type, fish size, chlorophyll concentration, and location. It found that chlorophyll levels and longitude had only minor effects on survival, whereas gear configuration, the fish’s condition upon capture, and specific operational practices strongly influenced the probability of survival at haul back. This suggests that operational changes (such as gear adjustments or handling improvements) could meaningfully reduce at-haul mortality. Similar studies could usefully be conducted across other CPC fleets.

Conclusions/Recommendations

The key take-away from review of limited IOTC observer data (Table 6) and the global longline based studies (Table 7) is that, while AHM will vary between individual species, studies and fisheries, in many fisheries there is consistently a significant proportion of individuals (of each species) that are alive at haul. This raises the possibility of non-retention options having some effect in reducing fishing mortality by longline on these species, depending on post release mortality rates. However, noting the above observations are based on limited data from IOTC fisheries, it is ***recommended*** that:

- Fleet/CPC specific data or information on both discarding/retention rates and AHM are obtained and summarised/reviewed as a priority by WPB in order better assess the degree to which non-retention options could reduce fishing mortality on these species.
- CPCs are encouraged to independently undertake model-based analyses of factors that effect AHM for each fleet (similar to Li et al 2024) utilising observer data, for example, factors such as targeting depth, soak time, hook type, fish size, hooking position. An alternative is for an independent consultant to analyse across CPC observer data. This type of analysis can potentially identify ways to reduce AHM (i.e. management options) for species subject to overfishing.

Gillnet fisheries

The review did not find published research or data on discarding/retention or AHM rates in IOTC **gillnet fisheries**. Communications with the IOTC Secretariat (and their follow-up with CPC counterparts in countries with gillnet fisheries) indicates anecdotally that a very high proportion (near 100%) of billfish caught in IOTC gillnet fisheries are dead at haul (IOTC Secretariat pers comm, 2025), most likely due to entanglement and subsequent lack of oxygenation. This is consistent with published data from other pelagic tuna/billfish gillnet fisheries globally. For example, from 1990–2006, observer records from the California Drift Gillnet Fishery, that targets swordfish and thresher shark, reported at-haul mortality rates of 95% for striped marlin (n=324) and 98% for blue marlin (n=49) (Larese & Coan, 2008). While it will be important to confirm from observational/research data in IOTC, on current understanding it appears that due to high AHM, non-retention options applied to gillnet fisheries would have very little impact on reducing fishing mortality for marlin and sailfish.

Purse seine fisheries

Similarly, for IOTC **purse seine** fisheries, IOTC observer data from three CPC fleets (Table 6) indicate that firstly, retention rates were generally lower (than longline), varying between 48-90% by fleet and species, and secondly, a very high proportion (generally 95-100%) of marlin and sailfish are dead at haul. Similar to longline, it would be useful to get summaries of AHM from observer data from additional IOTC CPC fleets, to confirm these trends. However, based on current available data, and noting the generally small proportion of total IOTC marlin/sailfish catches taken by purse seine[5], it seems non-retention measures in purse seine fishery would be likely to have little impact on total fishing mortality rates in IOTC.

Other fisheries

This study did not have time to review data and literature pertaining to AHM in other fisheries taking IOTC marlin and sailfish, in particular handline and trolling fisheries, which do account for smaller but not insignificant proportions (5-8% in some cases) of total catches of these species. It is likely that as a result of the shorter capture/fight times associated with these methods, AHM may be lower for these methods, however, further data and research review is needed to confirm this.

5.3.4 Post release mortality

There have been relatively few studies, globally, of post-release mortality (PRM) of marlin and sailfish caught by commercial tuna/billfish fisheries. Of the studies that have been conducted from commercial fisheries, all have been conducted from tuna/swordfish longline fisheries (Kerstetter et al., 2003, 2007; Brill et al 1993; Lam et al., 2022). This is likely due, in part, to the high AHM apparent in other commercial tuna fisheries (e.g. gillnet and purse seine).

The vast majority of studies yielding PRM estimates for marlin and sailfish have been conducted using fish captured by recreational (game fishing) line methods (e.g. Logan et al 2022; Sippel et al 2011; Domeier et al 2006, 2003; Holdsworth et al 2009; Graves and Horodysky 2010; Graves et al

[5] albeit black marlin = 4.1%

2002; Gunn et al 2003; Hoolihan 2005; Hoolihan and Luo 2007; Neiblas et al 2023). It's possible that these studies have findings relevant to similar commercial line fishing methods (troll, handline) that occur in the IOTC, and as such these studies are also briefly summarised below.

Longline based studies

There is relatively limited information on PRM in longline fisheries (compared to recreational fisheries) with four such studies identified (Kerstetter et al., 2003, 2007; Brill et al 1993; Lam et al., 2022), relating to blue marlin, striped marlin and sailfish.

Blue marlin

Kerstetter et al. (2003) used data from nine popup satellite tags (seven 5-day and two 30-day duration tags) attached to blue marlin caught by commercial pelagic longline vessels in the western Atlantic. Seven fish survived, giving a maximum PRM of 22% (this assumes the two non-reporting tags were mortalities). The study aimed to determine PRM for fish taken by standard commercial longline fishing operations (same gear setup, soak times - ranged 6-35hrs av ~14hr, hook types - 8/9 J and 16 circle hooks, etc) with live fish tagged regardless of condition at haul (the exception being one fish that had been half eaten already). As per normal longline operations, hooks were left in, with fish tagged in the water (not brought on deck). A broad range of different sized fish were tagged. The study concluded that combined at-haul and post-release mortality would likely lie in the range 53-65%. The authors noted the limitations to conclusions associated with the relatively small number of tagged fish, and the size of fish all being greater than 100 pounds.

Matsumoto et al. (2002) attached pop up satellite tags to two blue marlin caught by longline (research cruise, not commercial fishing) but only one tag successfully reported, with the fish surviving and tag eventually popping off. The longline gear was configured to fish deeper and set at night or early morning and was in the water for at least 12 hours (including setting and hauling). Other gear details were not reported. Three additional tags were deployed on blue marlin by observers operating on Japanese longline vessels around the same period (Matsumoto et al 2003, 2004 in Musyl et al. 2015) but copies of these papers were not obtained. Musyl et al. (2015) reported all blue marlin survived.

Striped marlin

Two published studies of PRM for longline caught striped marlin were identified (Brill et al., 1993; Lam et al., 2022).

Brill et al. (1993) tracked 6 striped marlin caught off Hawaii using commercial longline gear, using ultrasonic depth sensitive transmitters. One marlin died within 4 hours of release, while the other five fish survived the duration of the study, leading to a PRM of 16.7%. However, while the study used standard commercial monofilament longline gear, the sets were significantly shortened (3-6nm, 120 hooks, 4-8hr soak only) compared to normal operations, and only fish that "appeared healthy" were tagged. As such it's possible that these conditions might underestimate the PRM compared to normal commercial longline operations that have longer soak time and where fish selected for tagging were not selected based on good condition.

Lam et al. (2022) reported ~14% PRM (19 survivors out 22) for striped marlin tagged after capture in the Hawaiian commercial longline fishery. The study did not provide details on the nature of the operations (gear set up, hook types, soak times etc). Tags deployed off commercial longline vessels, only tagged individual assessed to be in good condition were tagged, some had hooks removed (some kept in), some tagged in water, some on deck. Otherwise very little detail about the nature of the longline operations in terms of gear setup, soak times etc.

Musyl et al., 2015 also cite some additional unpublished ("in prep") research on PRM for marlin taken by longline but these studies did not appear to have been subsequently published.

Sailfish

Kerstetter and Graves (2008) used data from 17 satellite archival tagged sailfish incidentally caught by commercial pelagic longlines in the Gulf of Mexico (Atlantic Ocean). Fifteen of the fish survived at least 10 days, resulting in a PRM of 11.7%. In this study, all sailfish evaluated as alive were tagged opportunistically during normal longline operations, regardless of physical condition (i.e., there was no "highgrading" of animals). An additional nine fish were dead at haul (and so were not tagged). Tagged fish showed a range of hooking positions including corner of mouth, eye orbit, foul hooked and jaw hooked. The longline sets utilised size 16 non-offset and 18 offset circle hooks. The authors concluded that live-releasing sailfish currently retained by pelagic longline fisheries in the Atlantic would have positive benefits to the Atlantic stocks.

Purse seine and gillnet fisheries

No PRM studies were identified that had been conducted in either purse seine or gillnet fisheries, likely due to the very high at-haul mortality of these species for these gear types (see section 5.3.3). Based on current information it appears unlikely that non-retention measures in these fisheries would provide any conservation benefit to marlin and sailfish stocks, however, this could be confirmed through further review of at haul mortality data for these fisheries.

Troll and handline fisheries

The authors were not able to identify any PRM studies done from commercial troll or handline fisheries. However, there have been many studies conducted in recreational gamefish fisheries globally (e.g. Logan et al 2022; Sippel et al 2011; Domeier et al 2006, 2003; Holdsworth et al 2009; Graves and Horodysky 2010; Graves et al 2002; Gunn et al 2003; Hoolihan 2005; Hoolihan and Luo 2007; Neiblas et al 2023) and these utilise a somewhat similar class of fishing gear and method (i.e. trolling) (Musyl et al 2015). It's possible that game fishery based PRM studies may provide a proxy for expected PRM rates in commercial troll and, possibly, handline fisheries (particularly if mechanised). This should be discussed by the WPB experts.

Musyl et al., (2015) used an inverse-variance weighted random-effects meta-analysis model to combine data from 46 studies on six billfish species, incorporating results from over 460 pop-up satellite archival tags and 64 acoustic tags. The study included around 40 recreational fishery-based studies (using troll and rod/reel gear types) and a small number of longline based studies. The study found that, despite wide variation in capture conditions, locations, and gear types, estimated post-release mortality rates were relatively homogeneous among species, with most variability attributable to random sampling error within studies. The results indicated overall PRM across species was relatively low, ranging from 10% (for blue marlin and sailfish) to 14-15% (for black marlin and striped marlin) (Table 8). Results were supported by exact nonparametric tests and sensitivity analyses. Species specific results are summarised in Table 8. When data are taken only from the studies using troll gear, or from troll and rod-and-reel combined (excluding longline and other gear types) the raw PRMs remain relatively low (Table 9), with blue marlin having the lowest PRM (2% and 5%). The authors concluded from the study that their "*results support earlier findings in the Atlantic and substantiate the majority of istiophorid billfish survive when released from recreational and longline fishing gear, clearly implying catch-and-release as a viable management option that permits fishing activity while protecting parental biomass and the fishery*".

Table 8 – Post release mortality rate estimates (mean and 95% CI) from Musyl et al 2015.

Species	Studies	N individuals	PRM	95% CI
Blue marlin	16	144	10%	5.6%-18.3%
Black Marlin	4	27	14%	4.5%-36.5%
Sailfish	7	85	10%	5.3%-18.8%
Striped Marlin	10	111	15%	8.9%-22.6%

Table 9 – Raw post release mortality rate estimates from troll and troll+rod and reel recreational fishing method based studies included in the Musyl et al 2015 meta-analysis.

	Troll method only				All Recreational methods			
Species	Studies	N individuals	Mortalities	PRM	Studies	N individuals	Mortalities	PRM
Blue marlin	4	93	2	2%	10	124	6	5%
Black Marlin	2	4	1	25%	3	10	2	20%
Sailfish	0	0	0	na	6	68	5	7%
Striped Marlin	2	6	0	0%	7	125	23	18%
White marlin	1	6	0	0%	4	68	2	3%

Additional data pertaining to rod and reel caught marlin and sailfish PRM in the Indian Ocean may soon become available as a result of the analyses of the FLOPPED project (Neiblas et al 2023) in which 111 billfish covering the four species (and swordfish) were tagged over 4 years in IOTC area. Preliminary results presented to WPB in 2023 did not contain detailed information on PRM.

Conclusions

The above review of PRM studies may not yet be comprehensive but represent the best available information. None of the longline based studies were conducted in the IOTC area or fisheries and it's possible that PRM in IOTC longline and coastal line fisheries is likely to vary across fisheries and species, based on many different factors including fishing gear setup, practices (e.g. soak times), environmental factors and handling practices. Discussions in WPB may identify further relevant studies. Noting the recommendations for gathering further data on AHM (section 5.3.3) it is also recommended that:

- WPB discuss the relevance of recreational fishing gear-based studies of PRM to assessing likely PRM in commercial troll and handline fisheries in IOTC.
- WPB consider the combined implications of available (or future summarised) IOTC fleet estimates of AHM in the context of longline based PRM studies. While it seems likely based on available AHM and PRM data/studies that non-retention measures in longline fisheries would provide some reduction in fishing mortality on marlin and sailfish stocks, it is currently unclear what degree of reduction might be possible, without further research. Thus, WPB should look to consolidate AHM and PRM estimates across fisheries to determine potential changes in fishing mortality by longline fisheries that might occur under non-retention measures. Such estimates could also potentially take account of additional measures to improve AHM, such as the use of circle hooks.

5.4 Gear based mitigation options

5.4.1 Introduction

Research efforts to identify ways to mitigate or reduce catches (and increase survivability) of marlin and sailfish species in tuna fisheries have historically tended to be focussed on commercial longline fisheries due to the fact that, in many regions (globally), that fishery type has historically contributed a significant proportion of the overall commercial fishing mortality. A number of mitigation approaches have been studied to reduce marlin and sailfish mortality in longlining, including adjustments to hook design and size, setting depth of hooks, leader material, and fish handling/release practices. Each of these is discussed below.

However, in the IOTC, gillnetting is the major source of recent fishing mortality for three of the four species considered here. A number of papers to WPB in the past have proposed subsurface setting as a mitigation and this potential option is also reviewed below.

The key considerations in determining if any mitigation approach will be effective in reducing fishing mortality of marlin and sailfish include:

- To what degree does the mitigation reduce captures or improve survivability compared to normal gear/methods?
- What proportion (if any) of the fishery has already adopted the mitigation?
- What impact does the mitigation approach have on target species catch rates? – this can impact compliance with use of the mitigation if it reduces target species catch rates.
- Reliability of monitoring and enforcement/compliance processes

5.4.2 Longline – hook type

In hook-based fisheries—such as longline, trolling, and recreational line fisheries— research has demonstrated that fish are significantly more likely to survive capture and release when hooked in the mouth, as opposed to more traumatic deep-hooking in the throat, gills, or gut (Kerstetter & Graves, 2006). Hook type can influence both catch rates and the likelihood of mouth versus deep-hook setting (e.g. Epperly et al., 2012), although the effect varies by species.

Common hook types used in longline fisheries include Japanese tuna hook, circle hooks, or traditional J-hooks, alongside others. Over the past three decades there have been a significant number of studies that have investigated the catch rates and at vessel mortality rates of marlin and sailfish associated with different hook types, with a particular focus on circle hooks as a hook type that may reduce deep/gut hooking and reduce post release mortality. These studies have been more recently assessed via a number of meta-analyses (Curran & Bigelow, 2011; Reinhardt et al., 2018; Santos et al 2023). The results of the two most recent meta-analyses are provided in Tables 10, and 11, these being:

- **Santos et al 2023** – found for **blue marlin** that both at-vessel retention (10 studies used) and at-haulback mortality rates (8 studies used) were both significantly lower on circle hooks compared to J hooks, while for **sailfish,** only at vessel retention rates were lower on circle hooks (no analysis of at haulback mortality due to too few studies). No analyses were presented for striped marlin or black marlin.

- **Reinhardt et al 2017** had fewer studies available to include in their meta-analyses but did present results for black marlin and striped marlin. For **black marlin** they found no significant difference in catch rates between hook types (off only two studies). For **striped marlin** they found catch rates (5 studies) were significantly lower on circle hooks while there was no significant difference in at haulback mortality rates (2 studies).

Numerous studies indicate J-hooks are more likely to result in deep-hooking and therefore produce higher rates of at-haul and post-release mortality of marlin. A widely cited 2009 quantitative review of the literature on circle hooks states: *"…empirical evidence is sufficient to promote circle hook use in almost all hook-and-line fishery sectors that typically interact with istiophorids"* (Serafy et al., 2009).

There are a range of factors that can complicate the relationships between hook type and at-haul mortality or catch rates. For example, Li et al (2024) reported a relationship between size (lower jaw fork length (LJFL)) and at-haul mortality in striped marlin. With circle hooks, mortality increased with fish size, whereas the opposite trend was observed with Japanese tuna hooks. Mortality was significantly lower in striped marlin up to an LJFL of approximately 190 cm. A similar size–mortality relationship has been documented for swordfish (Xiphias gladius) (Guo et al., 2022). Such relationships should be taken into account when considering whether to implement hook-type based management options.

Overall, it appears there is reasonable evidence that circle hooks may offer a management option to reduce bycatch rates, lower at-haul mortality, and improve post-release survival rates in marlins, while in some cases maintaining or even improving catch rates of target tuna species (e.g. Santos et al 2023).

5.4.3 Longline – deep setting

Target and bycatch fish species taken by longline fisheries vary widely in their vertical habitat preferences and movements, with some preferring shallower (often warmer) water habitats and others spending more time in deeper waters. Often, these patterns change between nighttime and

Table 10 - Results of the meta-analyses (Santos et al 2023) on retention and at-haulback mortality rates when changing the hook type (circle hooks vs. J-hooks) in shallow set pelagic longlines.

	Retention rate				At-haulback mortality rate			
Species	**RR**	**CI**	I^2	***p*-Value**	**RR**	**CI**	I^2	***p*-Value**
Teleosts								
Swordfish	0.81	0.74–0.88	99%	**<0.0001**	0.96	0.92–1.00	94%	**0.0416**
Albacore tuna	1.47	1.05–2.06	96%	**0.0285**	0.98	0.91–1.05	58%	0.4655
Bigeye tuna	1.25	0.99–1.58	98%	0.0593	0.80	0.72–0.88	48%	**0.0004**
Bluefin tuna	1.26	1.03–1.55	12%	**0.0335**	–	–	–	–
Yellowfin tuna	1.05	0.84–1.33	92%	0.6304	0.81	0.69–0.95	66%	**0.0167**
Blue marlin	0.72	0.59–0.88	46%	**0.0048**	0.81	0.74–0.90	14%	**0.0012**
Sailfish	0.62	0.27–1.44	55%	0.1887	–	–	–	–
White marlin	0.75	0.43–1.28	95%	0.2550	0.84	0.79–0.89	0%	**0.0007**

Note: I^2 represents the heterogeneity and describes the percentage of total variation caused by between-study heterogeneity; *p*-values shown in bold indicate significance (at a significance level of 0.05).
Abbreviations: CI, 95% confidence interval; RR, relative risk.

Table 11 - Results of the meta-analysis (Reinhardt et al 2017) on a) catch rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI); and b) at vessel mortality.

a)

	#exp.	**RR**	**CI**	I^2	***p***	**References**	**Status**
Black marlin	2	1.11	0.78–1.58	0%	.560	Andraka et al. (2013), Promjinda et al. (2008)	DD
Sailfish	8	1.2	1.00–1.44	38%	**.048**	Andraka et al. (2013), Kim et al. (2006, 2007), Pacheco et al. (2011), Promjinda et al. (2008)	LC
Striped marlin	5	0.86	0.76–0.97	56%	**.015**	Curran & Bigelow (2011), Kim et al. (2006, 2007), Ward et al. (2009)	NT
Blue marlin	7	0.96	0.63–1.46	69%	.840	Andraka et al. (2013), Curran & Bigelow (2011), Kim et al. (2006, 2007), Pacheco et al. (2011), Ward et al. (2009)	VU

RR > 1 indicates a higher catch was calculated on circle hooks compared to J-hooks. I^2 describes the percentage of total variation caused by between-study heterogeneity rather than within-study variance. *p*-Values that are ≤.05 are in bold to indicate significance. Status refers to IUCN Red List conservation status category where LC—least concern, NT—near threatened, VU—vulnerable, EN—endangered and CR—critically endangered are categories with increasing extinction risk. The categories, DD—data deficient and NE—not evaluated, are not categorized as an extinction risk.

b)

	#exp.	**RR**	**CI**	I^2	***p***	**References**	**Status**
Xiphioidei							
Sailfish	2	0.71	0.5–1	3%	**.048**	NMFS (2011), Pacheco et al. (2011)	LC
White marlin	2	0.84	0.77–0.9	0%	**<.001**	NMFS (2011), Pacheco et al. (2011)	VU
Striped marlin	2	1.06	0.8–1.41	62%	.670	Curran & Bigelow (2011)	NT
Blue marlin	4	0.82	0.75–0.9	0%	**<.001**	Curran & Bigelow (2011), NMFS (2011), Pacheco et al. (2011)	VU

RR > 1 indicates a higher at-vessel mortality was calculated on circle hooks compared to J-hooks. I^2 describes the percentage of total variation caused by between-study heterogeneity rather than within-study variance. *p*-values that are ≤.05 are in bold to indicate significance. Status refers to IUCN Red List conservation status category where LC—least concern, NT—near threatened, VU—vulnerable, EN—endangered and CR—critically endangered are categories with increasing extinction risk. The categories, DD—data deficient and NE—not evaluated, are not categorized as an extinction risk.

daylight hours, for example with deeper daytime dwelling species migrating to shallower waters at night (e.g. bigeye tuna and swordfish). As such, the depth at which longline gear is set impacts on catch rates and changing the depth of setting can provide an option in some cases to reduce fishing mortality of bycatch species (Beverly et al., 2009).

For example, a study on the Hawaii-based bigeye tuna longline fishery tested removing shallow hooks (<100 m) from longline sets to reduce bycatch of epi-pelagic species while maintaining target catch rates (Beverly et al., 2009). Operational changes were minimal, though haulback time increased slightly. Compared to standard gear, deep-set gear significantly reduced catch of striped marlin (−68%), blue marlin (−65%), and shortbill spearfish (−76%), with no reduction in target bigeye tuna catch. This reduction was attributed to the vertical distribution of marlins, which concentrate in the upper mixed layer. By shifting all hooks deeper than 100 m, overlap with these species was minimized. The findings were consistent with research on the vertical habitat use of marlin (and sailfish) species (e.g. Neiblas et al 2023; Rohner et al 2022; Williams et al 2017; Goodyear et al 2008; Freitas et al 2022; Blondin et al 2023; Carlisle et al 2016; Lam et al 2022; Hoolihan and Luo, 2007; Kerstetter et al 2006; Mourato 2014; Chiang et al 2011) that is detailed further in the “Gillnet” section below.

Although the findings suggest that deep-setting could be an effective bycatch mitigation tool in IOTC longline fisheries where marlin bycatch is a concern, IOTC CPC fishery specific CPUE modelling would likely be needed to determine if and how such an approach might be effective in any given fishery, given its fishing practices, area, time of setting etc. A key consideration would be modelling impacts on target species catches and catch rates (i.e. economic consequences) of such an approach. For example, for fleets targeting swordfish and/or bigeye tuna at night in shallower sets, fishing deeper at night may not be economically viable. Fishing deeper in the day (when those species are deeper) might be, albeit targeting gear can be more difficult at greater depths.

5.4.4 Longline – leader material

The type of leader material used in longline fisheries has been demonstrated to have a significant effect on the catch rates and at haul-back mortality of both bycatch and target species in tuna/swordfish targeting longline fisheries. A range of experimental fishing trials have focussed on examining leader effects on catch rates of pelagic shark species (Ward et al., 2008; Afonso et al., 2012; Santos et al., 2017; Scott et al 2022; Santos et al 2024) in particular and found in general that shark bycatch rates are significantly higher on wire leaders compared to monofilament leaders, but in many cases also, conversely, catch rates of the target species (tuna and swordfish) are lower or the same on wire leaders (Ward et al., 2008; Afonso et al., 2012; Santos et al., 2017; Scott et al 2022). Many of these studies have also gathered information on other bycatch species including marlin and sailfish.

A review of these studies results for marlin and sailfish indicated that in general there were no significant differences in catch rates between leader material types, including in the one study in the Indian Ocean (Santos et al 2017). The exception to this was the study of Ward et al (2008) in Western Pacific which found significantly higher catch rates of blue marlin on wire leaders ($p=0.00$), but significantly lower catch rates for black marlin ($p=0.02$).

Overall, there is not currently significant accumulated evidence that leader material type is likely to offer a mitigation option for reducing the catch and mortality of marlin and sailfish. This might be reviewed in future with further research, including as conducted in the IOTC Area.

5.4.5 **Longline – at haul handling and release**

Handling practices for bycatch species at haul and on release can have a significant impact on their post release survival likelihood and as such, improvements in such practices have the potential to reduce fishing mortality for some bycatch species (Zollet and Swimmer, 2019). The authors did not identify for this review any research testing different handling and release processes on PRM of *longline* caught marlin and sailfish specifically, but a number of studies have discussed the likely importance of this, based on studies in catch and release recreational fisheries and on research and guidelines for general principles of best practice handling/release developed for other bycatch species (Zollet and Swimmer, 2019).

Zollet and Swimmer (2019) published a review of safe handling practices to increase post-capture survival of a range of bycatch species, including billfish, in tuna fisheries. They highlighted that strategies that increase post-capture survival of marine species can be grouped into 3 primary categories: reducing immediate mortality, minimizing injury that results in delayed mortality, and reducing stress that can lead to death. For billfish they highlighted that: the fish should not be removed from the water and line should be cut and ideally hooks removed if feasible; use of circle hooks increases the likelihood of jaw or corner of mouth hooking, making hook removal easier; fish that are too weak to likely survive can be brought alongside vessel to recover while water passing over the gills (Prince et al 2002).

The importance of handling practices in reducing likelihood of mortality in marlin was highlighted in a study on white marlin caught using recreational hook gear (Schlenker et al 2016) which found that brief removal of white marlin from the water—averaging just two minutes—substantially elevated physiological stress indicators, particularly plasma potassium levels (which were the strongest predictor of post-release mortality). Their pop-up satellite tag data showed mortality rates more than ten times higher than previous estimates for fish not removed from the water, highlighting the critical role of air exposure in disrupting homeostasis and survival. It is uncertain but possible that similar stress responses occur across the *istiophorid* family.

Boat-side release and related handling practices are already recognised as having the potential to reduce post-release mortality in marlin and other billfish species, and have already been mandated by ICCAT for Blue marlin and White Marlin (ICCAT, 2019), as outlined in **Figure 4** below. While enforcement of a boat-side release mandate may be challenging, promoting and normalising boat-side release, especially if implemented in conjunction with retention bans, is considered to offer an effective strategy to lower fishing mortality in hook based fisheries.

5.4.6 Gillnet - Introduction

Gillnetting as a fishing method is known to be fairly non-selective in the species that it catches and as such typically takes a very broad range of bycatch species alongside target species (e.g. Brownell et al 2019). In recent decades there have been a range of studies conducted to investigate potential approaches to mitigating bycatch in gillnet, with the majority of these studies focussed on reducing bycatch of vulnerable cetaceans, pinnepeds, turtles, seabirds and other marine megafauna (e.g. Mangel et al 2013; Bielli et al 2020; Hembree and Harwood 1987; Kizka et al 2020; Collins et al 2025).

Annex 1

Minimum standards for safe handling and live release procedures[2]

The following steps should be followed to reduce stress and injury to incidentally caught marlins and round scale spearfish specimens for a maximum probability of survival while minimizing the safety risk to the crew. Skippers and crew should always put their personal safety first when releasing marlins and other large fish. Wear gloves and avoid working around the spear-shaped bill. These basic guidelines do not replace stricter safety rules established by CPCs national Authorities.

- Stop the vessel or substantially reduce its speed.
- Secure the far side of the longline mainline to the boat to avoid that any remaining gear in the water pulls on the line and the animal.
- Bring the marlin as close to the vessel as possible without putting too much tension on the branchline to avoid that a released hook or branchline breaks could shoot hook, weights and other parts toward the vessels at high speed.
- Do not remove the alive marlin from the water boatside, while safely removing the hook.
- Limit the number of manipulation.
- Do not gaff the fish in the body.
- If possible, avoid grabbing the marlin by the body and use gloves to grab the marlin by its snout or a snooter.
- In case the hook is visible, lightly flicking the branchline to try dislodging the hook.
- Where feasible rig a measuring device so the fish can be roughly measured in the water (e.g. mark a pole, leader and float; mark the gunwale of the boat with measurements marks).
- If the marlin is vigorously twisting and spinning making it too dangerous to use a dehooker/disgorger or the marlin swallowed the hook that cannot be seen, then use a long-handled line cutter and cut the leader/line as close to the fish as safely possible so that they are not trailing large amounts of line that could reduce post-release survival.
- Help revive the fish by slowly towing it in the water until its colour or energy returns (5 minutes or more). Most highly migratory species must keep water flowing over their gills to breathe. With the boat in gear, slowly move forward while keeping the fish's head in the water.
- If hooked, and hook is visible in the body or mouth, use a bolt cutter to remove the hook barb, and then remove the hook.
- Don't wrap your fingers, hands or arms in the line when bringing a marlin to the boat – you might get pulled overboard.
- Don't lift them using the branchline, especially if hooked.
- Do not lift using thin wires or cables or by the tail alone.

Figure 4 – Annex 1 of ICCAT measure (ICCAT 2019) - Minimum standards for safe handling and live release procedures.

Methods investigated globally to reduce gillnet bycatch have included acoustic deterrents (like acoustic pingers, e.g. Mangel et al 2013), visual deterrents/aids (like lights e.g. Bielli et al 2020) and the depths at which gillnets are set (e.g. Hembree and Harwood 1987; Kizka et al 2020). In undertaking this review, no research was identified which focussed on mitigating billfish catch specifically nor collecting/reporting *species specific* information on marlins and sailfish. However, a small number of studies reported bycatch data on "billfish" grouped.

The impacts of gillnetting on bycatch species generally has already been recognised by the IOTC Commission, which has adopted two specific measures aimed at reducing these impacts, specifically:

- **Resolution 17-07** *(On the prohibition to use large scale driftnets in the IOTC area)* which at the time was implemented (according to the preamble) in part due to overexploitation of some billfish species. This measure prohibits the use of large scale (ie >2.5km long) driftnets from 1 Jan 2022 in whole IOTC area of competence.

- **Resolution 21-01** (and 19-01) *(On an interim plan for the rebuilding the Indian Ocean yellowfin tuna stock in the IOTC area of competence)*, which requires that CPCs shall set their gillnets at 2m depth from the surface in all gillnet fisheries by 2023 to mitigate the ecological impacts of gillnets.

Subsurface setting of gillnets has been implemented in other fisheries around the world, for example the California Drift Gillnet Fishery (targeting swordfish and sharks) where fishers must set gillnets at least 10m below the surface (NOAA 1997) and no later than 2 hrs before sunset and haul no later than 2hrs after sunrise. While the primary driver was to protect cetaceans, pinnepeds, turtles and birds which use the surface waters (Forney et al 2001), Larese and Coan (2008) noted that these measures aimed to avoid bycatch of striped marlin and avoid recreational fishery conflict.

Noting all of the above, the following sections focus mainly on subsurface setting as a mitigation option (already required by the Commission), examining the scientific basis for this type of measure with respect to billfish, and if and how well it might function for the purposes of reducing fishing mortality on marlin and sailfish species, specifically. It attempts to identify additional information and research that might be required to fully evaluate and advise the Commission on the likely effectiveness of subsurface setting for reducing marlin/sailfish fishing mortality.

5.4.7 Gillnet - Subsurface setting

When gillnet fisheries for pelagic species first developed around the globe, gillnets were typically set at the surface. However due to concerns over catches of vulnerable species such as mammals (cetaceans, pinnepeds etc) and seabirds, which spend significant time living (e.g. cetaceans, turtles) or diving/foraging (e.g. birds, pinnipeds) in surface ocean waters, subsurface setting has been one method implemented in different parts of the world with an intent to reduce these species catch rates (e.g. ; NOAA 1997, IOTC 2017; IOTC 2021).

Subsurface gillnetting has been proposed as an effective method for reducing billfish bycatch in tuna gillnet fisheries (Moazzam, 2024) (and has also been associated with reduced catches of cetaceans and sea turtles e.g. Kiszka et al., 2021). The proposal is based on the observation that the marlin and sailfish species have been clearly demonstrated by many research studies to spend a very significant proportion of their time in shallower surface waters, and this is particularly so during the night (Neiblas et al 2023; Rohner et al 2022; Williams et al 2017; Goodyear et al 2008; Freitas et al 2022; Blondin et al 2023; Carlisle et al 2016; Lam et al 2022; Hoolihan and Luo, 2007; Kerstetter et al 2006; Mourato 2014; Chiang et al 2011). Table 12 provides a very preliminary review of relevant research findings, indicating that in general;

Black marlin – based on three studies, two in the Indian Ocean (65 tags - Neiblas et al 2023; Rohner et al 2022; Williams et al 2017), black marlin spend the majority of the night period in very shallow waters of <10m or <20m, depending on the study. This contrasts the daytime pattern in which the majority of the time is spent oscillatory diving to between 30-80m.

- **Blue marlin** - based on five studies, one in Indian Ocean (150 tags - Neiblas et al 2023; Goodyear et al 2008; Freitas et al 2022; Blondin et al 2023; Carlisle et al 2016), blue marlin spend the majority of the night period in the top 5-10m of surface waters. This contrasts the

Table 12 – Very preliminary review and summary of satellite tagging research findings relating to day and night time vertical habitat use patterns of black marlin, blue marlin, striped marlin and sailfish, with Indian Ocean based studies highlighted in bold (under "Region" column).

Species	Reference	Region	No. of tags	Night typical depth	Night - typical dive behaviour	Day - typical depth	Day - typical dive behaviour
Black Marlin (*Istiompax indica*)	Nieblas et al. (2023)	**Indian Ocean (wide range)**	16 satellite tags	~60% time <10 m	Very surface oriented; occasional dives to ~40–60 m	75% of time 30–80 m	Frequent surface excursions; ~20% time near surface
	Rohner et al. (2022)	**Western Indian Ocean (Kenya)**	34 miniPATs	<20 m for most of night	Limited diving	~40–60 m	Oscillatory diving with active use of thermocline
	Williams et al. (2017)	Coral Sea, Great Barrier Reef (Eastern Australia)	15 PSATs	<20 m	Limited diving	~40–80 m	Oscillatory diving with active use of thermocline
Blue Marlin (*Makaira nigricans*)	Nieblas et al. (2023)	**Indian Ocean (wide range)**	43 satellite tags	~50% <5 m; ~80% <10 m	Very surface oriented; occasional dives to ~30–70 m	~40 m; 40% time 30–70 m	Frequent surface excursions; ~15% time near surface
	Goodyear et al. (2008)	Atlantic Ocean (Caribbean, Bahamas, Western & Eastern Atlantic)	51 PSATs	Mostly at surface; ~50% in top 10 m; ~86% in top 30 m	Occasional dives to ~65 m	~40–100 m	Deeper use of water column; frequent dives below thermocline; occasional deep dives >300 m (max
	Freitas et al. (2022)	Eastern North Atlantic (Madeira)	3 PSATs	~90% time <5 m	Limited diving	~75% time <5 m	Frequent dives to 25–50 m
	Blondin et al. (2023)	Eastern Pacific (Central America)	13 miniPATs	90.4% of nighttime hours above 10 m		93.1% of daytime hours above 50 m; 73.2% above 30 m; 48.8% above 10 m	Frequent dives to 25–50 m
	Carlisle et al. (2016)	Central Pacific (Hawaii & French Polynesia)	41 MK10 PAT & miniPAT	Majority <5–10 m (very surface oriented)	Stay in shallow, warm waters; relatively quiescent	25–100 m (most time ~50–100 m)	Frequent movement through water column; deeper excursions associated with foraging
Striped Marlin (*Kajikia audax*)	Nieblas et al. (2023)	**Indian Ocean (wide range)**	5 satellite tags	~45% <10 m; 50% >30 m	Frequent dives to ~100 m	~82% <10 m	Occasional dives to ~40 m
	Lam et al. (2022)	**Central North Pacific (Hawaii)**	31 PSATs	81% <5 m and ~87% <20 m at night		38% <5 m; 41% <20 m at day	
	Rohner et al. (2022)	**Western Indian Ocean (Kenya)**	39 miniPATs	Mean depth 17 m; <30 m most of night	Limited diving	~50–150 m	Strong diel pattern; frequent daytime yo-yo dives
Sailfish (*Istiophorus platypterus*)	Nieblas et al. (2023)	**Indian Ocean (wide range)**	30 satellite tags	~25% <10 m	Frequent dives to ~40 m	~70% time <10 m	Frequent dives to ~30 m
	Hoolihan & Luo (2007)	**Persian Gulf / Arabian Gulf**	18 PSATs	No significant day/night difference: 84% time <10 m; 72% <5 m. Occasional dives to maximum ~80 m			
	Kerstetter et al. (2006)	Western North Atlantic	9 PSATs	<10 m	Limited diving	~20 m	Limited diving behaviour
	Mourato, B.L. (2014)	Equatorial Atlantic (NE Brazil)	4 PSATs	<15 m	Limited diving	~20–40 m	Some dives to ~50 m
	Blondin et al. (2023)	Eastern Pacific (Central America)	11 miniPATs	85.9% of nighttime hours above 10 m		86.9% of daytime hours above 50 m; 65.6% above 30 m; 43.1%	Frequent dives to 25–50 m
	Chiang et al. (2011)	Eastern Taiwan / East China Sea	3 PSATs	~67% of nighttime hours above 10 m; mean depth 60 m	Deeper diving excursions at night	~82% time above 10 m	Dives to 40–100 m

daytime pattern in which the majority of the daytime is spent between 25-100m (varies slightly by study) with frequent diving, some below thermocline (max 800m in one study).

- **Striped marlin** - based on three studies, two in Indian Ocean (75 tags - Neiblas et al 2023; Rohner et al 2022; Lam et al 2022), striped marlin spend the majority of the night period in the top 10m to 30m, depending on the study. Daytime patterns showed significant variation between studies, from a majority of time very shallow (<10m) to deeper waters (50-150m).
- **Sailfish** – based on six studies, two in the Indian Ocean (74 tags - Neiblas et al 2023; Hoolihan and Luo, 2007; Kerstetter et al 2006; Mourato 2014; Blondin et al 2023; Chiang et al 2011), sailfish spend the majority of the night period in the top 5 or 10m. Some studies indicated this was similar during the day while others suggested that there were increased time spent at slightly greater depths (eg 20-40m) during the day.

A more thorough and detailed review of this research is needed to understand more precisely the differing depth patterns of these species, with a focus on Indian Ocean studies, but based on this preliminary review, it is reasonable to assume that subsurface setting *might* provide a viable option to explore (to reduce catches of marlin). At the same time, its clear from Table 13 that for marlin and sailfish at least, habitat use extends below 2m, even at night. Therefore, the depth of setting which might achieve the ideal combination of reduced catch of vulnerable species (including marlin subject to overfishing) while maintaining acceptable levels of target species catches, is still uncertain. Ideally, this could be explored via experimental fishing trials.

To date, it appears there is yet to be conducted trials on subsurface setting that report effects on marlin and sailfish at a species-specific level. However, a small number of papers have reported results relating to “grouped” billfish (e.g. Hembree and Harwood, 1987; Khan and Moazzam 2019), in fisheries where marlin and sailfish are known to comprise a significant component or the majority of the billfish bycatch[6].

Hembree and Harwood (1987) published results from joint Australian-Taiwanese research comparing bycatch taken from surface and 4.5m subsurface gillnets deployed from a Taiwanese gillnet vessel fishing off northern Australia. Based on 37 sets where both net types were fished, the study reported reductions in catch of all species in the subsurface gillnet (compared to surface sets). While they reported that mean “billfish” catch (species composition unknown) per set was nearly half that of the surface set nets, the reduction was not statistically significant.

In the Indian Ocean, data has been collected by a WWF-Pakistan funded/coordinated study from crew-based observers on Pakistan gillnet vessels in the periods both pre- and post-transition (spanning 2013-2019) of the fishery to subsurface setting of gillnets (minimum 2m subsurface). That data has been analysed and described in a number of papers (Kizka et al 2020; Khan and Moazzam, 2019; Moazzam 2024), including two that consider changes in billfish catch levels before and after the transition (Khan and Moazzam, 2019; Moazzam 2024).

[6] An additional paper (Samaranayaka et al 1996) describes experimental fishing trials in Sri Lanka that tested gillnet hanging ratios and fishing depths, recorded catches of marlin and sailfish but grouped them for analyses into a broader “other” category including non billfish species (and so is not considered further here).

Kizka et al. (2020) research focussed on using GLMMs to examine differences catches/catch rates of three species groups (being tuna, "tuna-like" and cetacean species groups), for data collected by five participating skippers, in the period 2013-2015 (using surface setting) and 2015-2017 (using subsurface setting). The study did not find that set type drove significant differences in target species CPUE, but did predict significantly lower cetacean catches from subsurface setting. While the paper did not consider marlin and sailfish species specifically, nor billfish grouped, it is worth noting that they identified a number of uncertainties associated with interpreting the data collected, that are relevant to interpretation of billfish data included in other papers below (Khan and Moazzam, 2019; Moazzam 2024). They stressed the study was opportunistic and preliminary in nature and stressed caution in interpreting the data due to, firstly, the lack of a proper experimental design to account for differences in area or timing of use of subsurface and surface nets, along with the small study sample size (5 skippers relative to entire Pakistan gillnet fishery); secondly the non-independent data collection approach; and thirdly, potential improvements needed in species identification and data accuracy. Overall they recommended a more in-depth investigation of the acceptability of this potential mitigation method should be carried out in the future.

Two other papers (Khan and Moazzam, 2019; Moazzam 2024) have looked more closely at billfish catch data specifically, from pre- and post-transition to subsurface setting in the Pakistan gillnet fishery.

Khan and Moazzam (2019) reported a reduction in billfish catches and catch rate (kg/boat/month) between 2013 (from 4 vessels with crew observer) and 2017 (30 of 85 vessels with crew observer) and concluded this was likely as a result of the adoption of sub-surface setting in the fishery, due to the surface habitat use of billfish. They also noted contrasting increases in catches of yellowfin, longtail and skipjack tunas in subsurface gillnet (reported by Shahid et al 2018) which compensate somewhat for lost billfish catch. Moazzam (2024) presented further information on billfish catch in the Pakistan gillnet fishery. The paper stated that *the average CPUE (kg per month) of billfish decreases from 6,107 kg/month in 2013 to only 2,750 kg/month in 2019, therefore, a reduction 54.97 % was noticed in the catches of billfish in subsurface gillnet as compared to catches of surface gillnets.* The interpretation of these data are likely subject to many of the same uncertainties identified by Kizka et al (2020). With respect to both Moazzam (2019) and Moazzam (2024) it would be worth clarifying if catch rates are standardised for fishing effort (or other factors). In each paper, total annual billfish catch estimates show a different trend to catch rates in the period pre and post subsurface fishing transition.

Moazzam (2024) noted a number of strong practical benefits of subsurface gillnet setting that has led to the entire fleet in Pakistan shifting to that methodology, including less tangles, less fouling during deployment and hauling, less positional drift (less impacted by surface winds), less roll down and breakage/gear loss in rough seas, and finally cheaper costs (less floats).

5.4.8 **Gillnet - Acoustic and visual mitigation**

This review only briefly considered published research regarding acoustic and visual mitigation approaches for gillnets. It did not identify any research that provided evidence for acoustic or visual mitigation approaches that would reduce captures of marlin and sailfish specifically. Kizka et al (2020) noted that these approaches had mixed success across taxa and typically had a higher cost that may not be feasible in small scale fisheries in developing CPCs. However, WPB could choose to discuss and review such options further if it wishes.

5.4.9 Gillnet - Conclusions and recommendations

The IOTC Commission has already mandated the prohibition on largescale driftnet gillnet fishing by 2022 (IOTC 2017) and requiring subsurface setting (at a minimum of two meters below surface) by 2023 (IOTC 2019, 2021).

While research globally and in IOTC to date on subsurface setting is not yet able to verify the efficacy of subsurface setting measure (Res 21-01) for reducing fishing mortality of marlin and sailfish, specifically, it is reasonable to assume based on the well-defined surface water habitat preferences of these four species (particularly during night periods), that subsurface setting has at least the potential to contribute to reductions in fishing mortality for these species. This will also in part depend on the degree to which different CPCs fleets have already adopted sub-surface setting (and when) relative to recent estimates of fishing mortality for each stock. In addition to the widespread adoption of subsurface setting nearly a decade ago in Pakistan, Anderson et al (2020) noted anecdotal reports from Sri Lanka regarding the use of both surface and subsurface gillnets by fishers depending on currents, and that in recent years there has been some uptake of subsurface setting by gillnet fishers in Iran and India.

As such and noting all of the above, a more comprehensive understanding of the potential effectiveness of this type of measure would be significantly assisted by:

- Gathering further information from CPCs to understand:
    - the proportions of each CPCs gillnet fleet that has is currently using surface or subsurface setting (including understanding certainty/uncertainty around this) and if possible how this has changed over time.
    - the typical setting/soaking/hauling times (of day/night) of gillnets by each CPC fleets, noting the differing vertical habitat use patterns seen in these species between day and night

Conducting experimental designed fishing trial(s) to assess the catch rates of target and bycatch (including marlin and sailfish) species in gillnets set at the surface and different subsurface depths, (e.g. 2m, 5m, 10m) and possibly different times of day/night, to better understand catch rates all different species including marlins, vulnerable species and target species. A high level of accuracy in species identification will be required in any such trial.

One final note on gillnet. A number of CPCs have been encouraging their gillnet fishers to switch to line based fishing methods such as longline (e.g. Roshan, 2024). The extent to which this has happened, and the implications for shifting catch rates and mortality if it did happen, has not been considered as part of this review. WPB could consider if this should be included in a review of options.

5.4.10 Purse seine

In recent years, purse seine fishing in the Indian Ocean has accounted for roughly 5% of retained black marlin catches. Blue and striped marlin catches were minimal but not zero. Despite this, research on reducing marlin bycatch in purse seine fisheries appears to be limited.

5.4.11 Line fisheries (troll and handline)

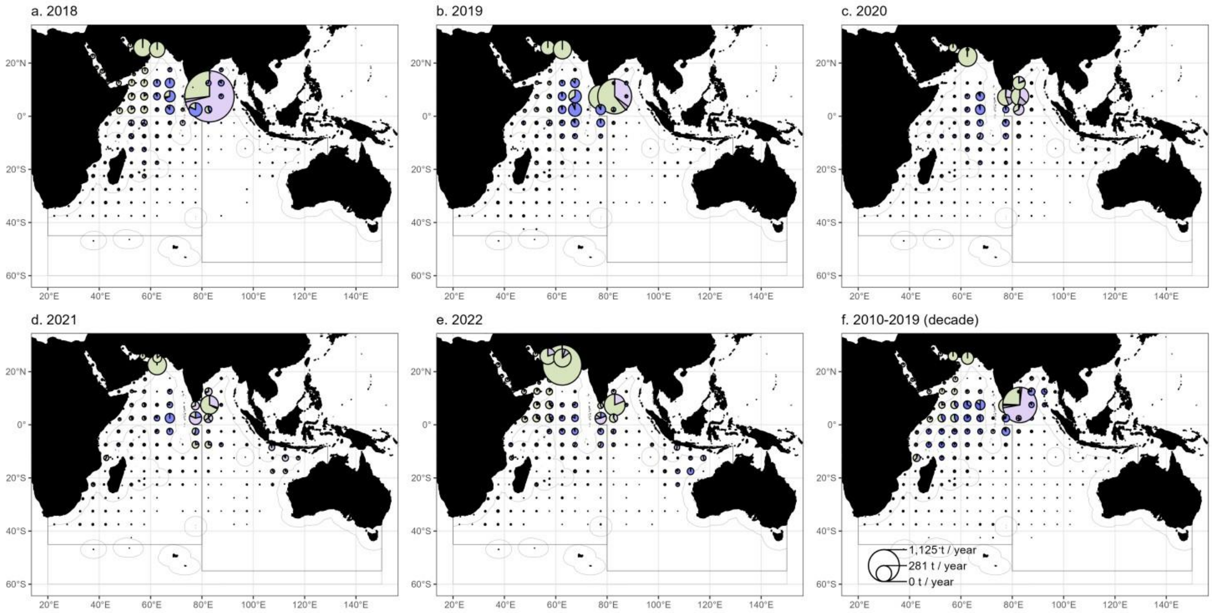
Catches of marlin and sailfish by troll and handline are very low compared to gillnet and longline, however, in some cases they are not entirely insignificant. If the Commission wished to consider gear/method based options to reduce fishing mortality in these fisheries then further scientific review of options relating to hook type (e.g. use of circle hooks) and handling and release practices (to improve post capture survival) could be warranted. This review has not looked into these for this fishery but notes that information on hook type and handling under the longline sections (above) may be relevant.

5.5 Spatial-temporal and other management options

As noted in the introduction to this review, there are a broad range of other potential management options, not considered in this review, that the Commission could consider in order to reduce fishing mortality on marlin stocks subject to overfishing (and/or overfished). This review did not have time to include additional options but could be expanded in future to do so.

One approach often adopted in fisheries management is to implement spatial and temporal (e.g. seasonal) elements to management measures and certainly such approaches could be considered in the IOTC. For example, implement a specific gear mitigation in a specific area. Figures 5-6show the spatial distribution of catches (at least as currently reported) of each marlin and sailfish species in the IOTC. These figures demonstrate that there are specific areas of much higher catch, opening the possibility for such considerations to be built into future management measures. Other considerations, such as specific areas of aggregation (eg to spawn, feed etc) can potentially be taken into account if the scientific information exists. But as noted above, this was not in scope for the current review.

a) Black marlin



b) Blue marlin

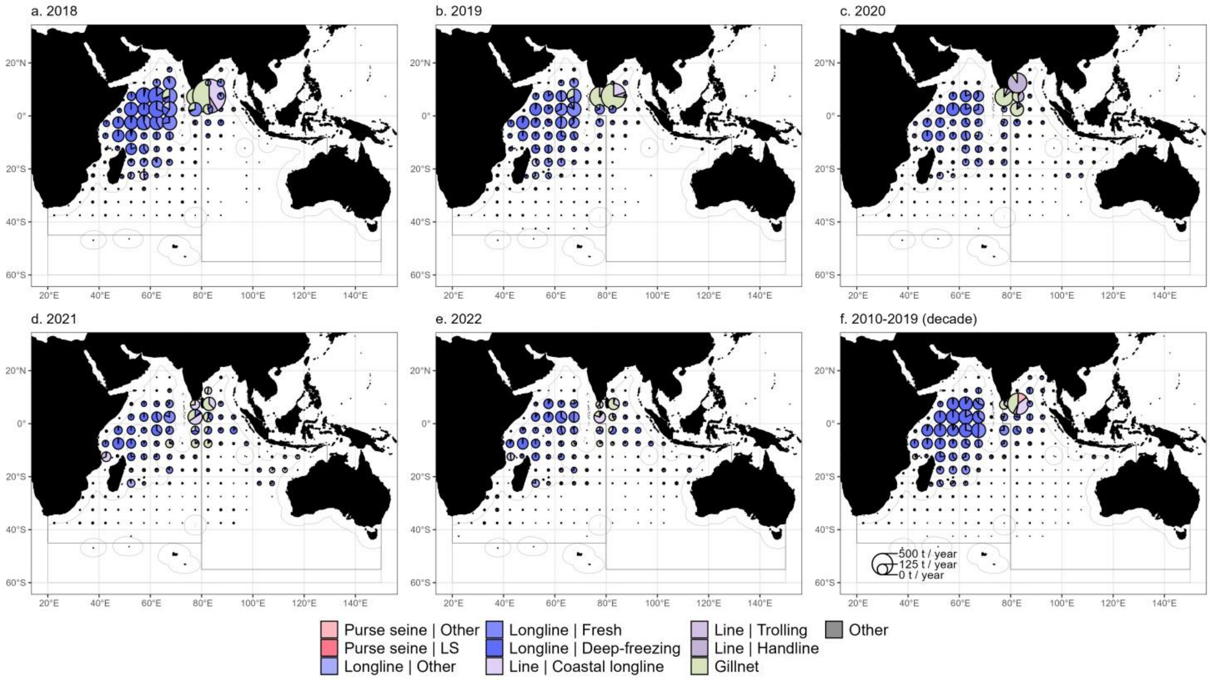
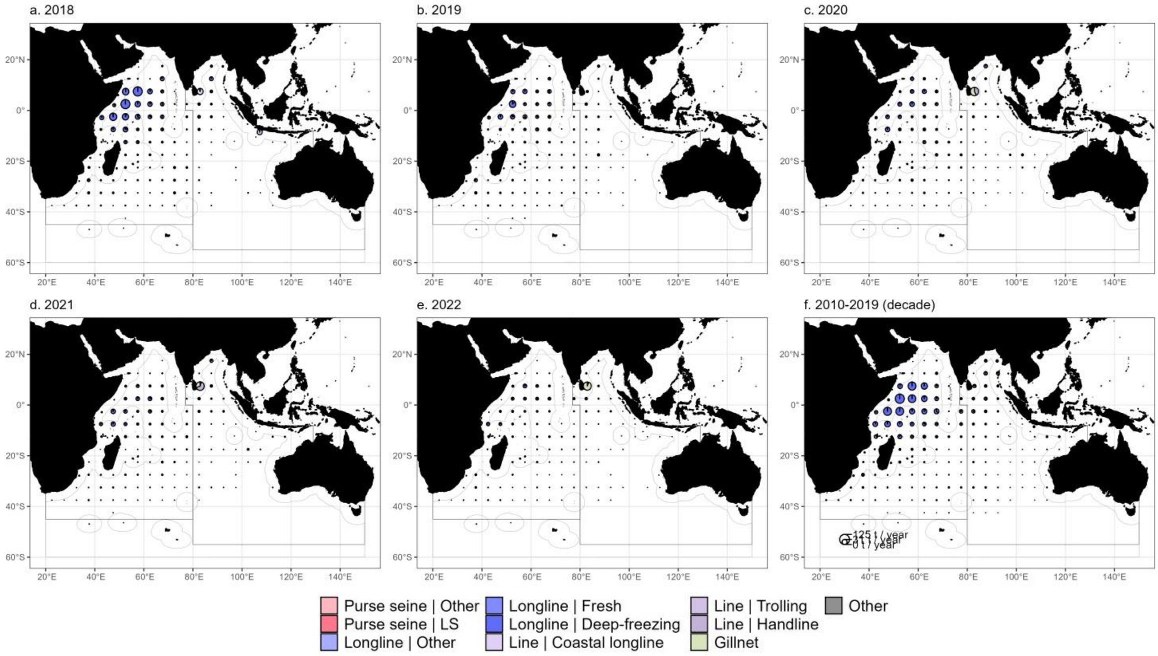


Figure 5: Mean annual time-area catches in weight (metric tonnes; t) of a) black marlin and b) blue marlin, by year / decade, 5x5 grid, and fishery. (IOTC WPB22 2024 INFO5 and INFO6 - Data source: time-area catches)

c) Striped marlin



d) Indo-Pacific Sailfish

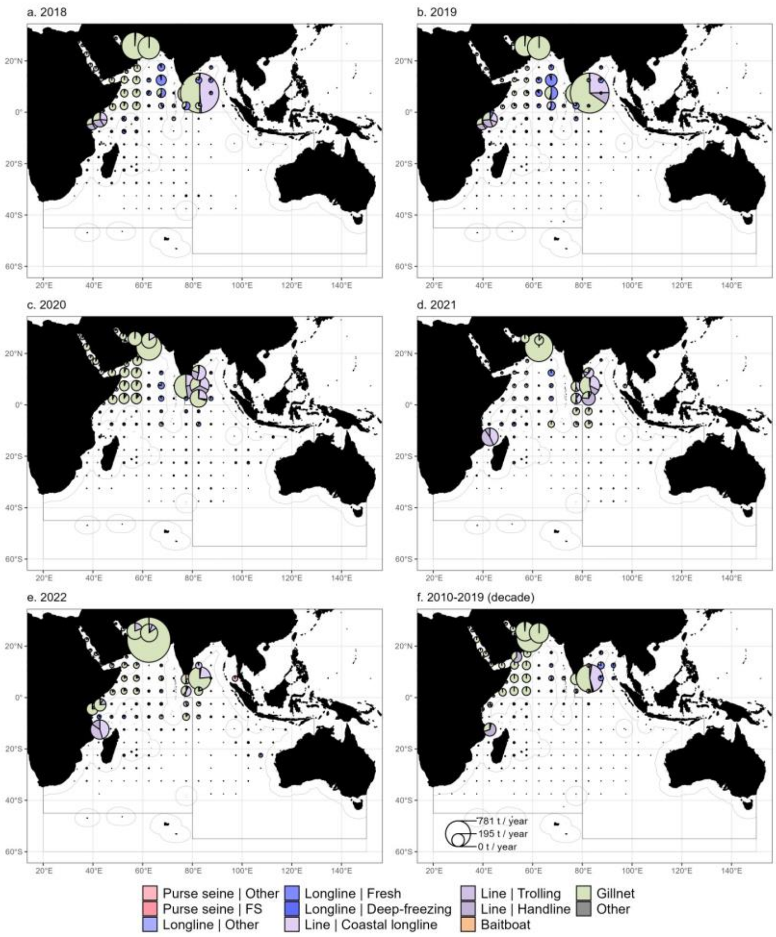


Figure 6: Mean annual time-area catches in weight (metric tonnes; t) of a) striped marlin and b) sailfish, by year / decade, 5x5 grid, and fishery. (IOTC WPB22 2024 INFO7 and INFO8 - Data source: time-area catches)

6 Summary and Discussion

This paper has attempted to provide a **preliminary** review of relevant data and scientific research to support the Working Party on Billfish (WPB) develop advice to the Scientific Committee (SC) relating to:

c. the potential effectiveness of a range of different management tools (specifically **catch limits**, **non-retention**, and **gear/method-based options)** for reducing fishing mortality on marlin and, if needed, sailfish stocks, and;
d. the need to address any gaps and uncertainties in available data and research to assist further consideration of these and other potential management options.

It's provided an initial summary of catch by fishery type to highlight, from a fishing mortality perspective, for which fishery types/gears, might the implementation of chosen management options be most effective in achieving the overall required reductions. The management options reviewed were chosen on the basis of those referenced in the current Resolution 18/05 and based on management practices taken in other RFMOs for managing non-target billfish catch levels, being a) Catch/bycatch limits; b) Non-retention, and c) Fishing gear/method options.

Fishery catches

For **blue marlin**, the majority of recent (2018-2022) catch has been taken by longline (66.8%), followed by gillnet (22.5%), and handline (6.4%). For **black marlin** and **striped marlin** the majority is taken by gillnet (63.3% and 66% respectively) followed by longline (26.9% and 27.7%). with lesser contributions by purse seine and handline (for black marlin). **Sailfish** catches are predominantly gillnet (70.9%) with lower contributions by longline (14.4%), trolling (8.6%) and handline (5.3%). On the basis of catch proportions alone, effective measures applied to reduce fishing mortality by gillnet and longline are likely to have the greatest impact on overall fishing mortality on these stocks.

Option 1 – Catch limits

The IOTC SC has provided advice to the Commission on stock level catch limits for marlins and sailfish, within which the Commission could potentially agree to determine CPC catch limits, similar to the approach adopted for some marlin stocks in other RFMOs (e.g. WCPFC, ICCAT). The most effective type of catch limit is that which accounts for both retained and discarded catch mortality, which requires information on at haul and post-release mortality (summarised in Option 2 below) or which require retention of all catch (no discarding). However, there are a range of challenges associated with catch limits for bycatch species. These include the creation of a "choke" on target catches (with associated economic consequences), subsequent non-compliance, high levels of unmonitored discarding (unaccounted mortality), and a lack of required monitoring/enforcement for some fisheries, all which can reduce effectiveness of this type of measure.

Option 2 – Non-retention options

Prohibiting the retention of species subject to overfishing can be an effective measure to reduce fishing mortality (e.g. ICCAT blue marlin and white marlin) in cases where discarding, at-haul mortality (AHM) and post-release mortality (PRM) rates are low or moderate (and handling/release practices are good). Very preliminary information on each of these factors, from observer data (IOTC

Secretariat) and published research and other papers, for each species and fishery type, was reviewed and assessed in the context of the potential effectiveness of non-retention options.

For **longline**, this review notes: 1) that longline accounts for a high proportion of total IOTC catch of blue marlin, and a lower but significant component of black and striped marlin catch (**Table E2**), and; 2) evidence for high retention rates across species (>95%), low to moderate AHM (varying by fleet), and low-moderate PRM (but limited studies). As such, non-retention approaches in longline fisheries may have potential to contribute to reductions in overall fishing mortality for the three marlin species (especially blue marlin). However, further analyses should aim to gather more information on discard proportions and AHM by fleet and quantify potential mortality reductions, using also information on PRM and other key factors (e.g. hook type). Model based analyses of condition/AHM at a fleet level could identify factors driving AHM/condition and subsequently, additional method/gear mitigation options.

For **gillnet**, despite contributing a high proportion of catches (and retention) of black and striped marlin and sailfish, non-retention options are unlikely to be effective. This is based on information indicating that at haul mortality is very high (near 100%) across all four species. However, confirming this with direct observational data will be important.

Purse seine takes a more minor component of the total catch of these species, has lower retention levels (preliminary data*), and initial information indicates very high AHM. If confirmed by further data from across the IOTC fishery, non-retention appears unlikely to be an effective management option for that fishery type.

For line fisheries such as **troll and handline**, which contribute much lower but not insignificant catches of marlins and sailfish, further information on AHM and PRM is ideally needed. WPB experts could consider if AHM and PRM rates are likely to be similar to those in recreational game fisheries using trolling methods, and from which significant research is summarised in this paper.

Option 3 – Fishing gear/method options

For **longline** fisheries, four fishing gear/measure related options were considered, being hook type, setting depth, leader material and handling practices.

- **Hook type** - Two separate meta-analyses of numerous published research studies concluded evidence that the use of circle hooks (relative to J hooks) results in significantly lower at haulback mortality of blue marlin, and significantly lower catch rates for blue marlin, sailfish and striped marlin**. Further review to identify hook type use by fleets, hook size effects, and more clearly quantify likely changes in fishing mortality from circle hook adoption, as well as target species implications, could assist in assessing this option further.
- **Depth of setting** – Switching longline gear from shallow to deeper sets has been demonstrated to also provide an option by which to reduce catch rates of marlin and sailfish (due to the significant time spent by these species in shallower waters). Fleet specific CPUE analyses using depth proxy indicators (e.g. HPB) could assist in assessing this option further.
- **Leader material** - There is not strong evidence from experimental fishing trials that leader material type (eg monofilament nylon or wire) has a significant impact on marlin and sailfish catch rates.

- **Handling practices** – studies of good handling practices in recreational game fisheries (and for other large species in commercial fisheries) has demonstrated a number of principles of handling and release that could assist hook based commercial fisheries improving post release survival.

For **gillnet** fisheries, the review noted some CPCs are trying to shift fishing effort from gillnet to line fisheries, which *may* have as yet unquantified benefits for reducing mortality on marlin and sailfish. Otherwise, the review focussed on gillnet depth of setting-based options, due to firstly, the existing requirement (Resolution 21/01) for all gillnet fisheries to implement subsurface setting (minimum 2m) by 2023, and secondly, research confirming the substantial time spent by marlin and sailfish in surface waters, particularly at night (when gillnets are soaked in some* fisheries). Globally and in IOTC, subsurface setting of gillnets has been promoted largely on the basis of reducing interactions/mortality of cetaceans, and/or turtles, pinnipeds, and seabirds, but there has been relatively little research on the implications for billfish catches. Noting previously reported reductions in average monthly billfish catch by gillnetters in Pakistan, following adoption of subsurface setting, the potential effectiveness of subsurface setting in reducing billfish mortality in the broader IOTC fishery remains very uncertain. It is recommended that experimental research trials be prioritised to test different depths of setting, times of setting/soaking, and to collect accurate species-specific catch/mortality data across the full range of interacting species, including billfish, target tuna and vulnerable bycatch species (e.g. cetaceans, turtles) to provide the SC and Commission a more quantified understanding of likely effects and possible trade-offs.

The review did not have time to consider potential gear/method related options for **purse seine** and **troll/handline** fisheries, although it is possible hook type research (covered under longline) is relevant to the latter.

Other management options

The authors are aware of a range of other potential management options (e.g. spatial temporal options) that could be considered by the Commission but for which there was insufficient time to include in this initial preliminary review.

Conclusions

The aim of this paper was to provide a preliminary review of available data, information and research relevant to assessing a number of potential management options for reducing fishing mortality of marlins (and sailfish) in IOTC. Where possible, it makes comment on both the potential effectiveness of each option for each species and fishery type, and the key gaps in information and knowledge that create uncertainty in our ability to assess the likely effectiveness of some options in some fisheries.

It does not aim to advocate that the Commission adopt any specific option in any specific fishery.

7 Recommendations

The authors note that this is a preliminary review, with an intention to update either prior to SC or prior to WPB in 2026. As such the authors are seeking initially that WPB discuss and provide feedback on:

g) New information on stock status relevant to a future updated paper.
h) Any errors or misinterpretations of fishery data/information contained in the preliminary review.
i) Additional sources of relevant fishery data, information and published research that should be included in an updated review paper
j) Additional management tools/options for which relevant data/research should be reviewed and included in an updated paper.
k) Discuss the potential relevance of game fishing (troll) based estimates of AHM and PRM to commercial troll and handline fisheries in IOTC.
l) The papers preliminary recommendations (below).

Noting the preliminary nature of the review, and pending WPB feedback on points a – d above, the authors suggest that the WPB consider:

- firstly, highlighting to the SC some of the key preliminary findings of this review, and
- secondly, where appropriate, incorporating relevant information into the draft species executive summaries
- thirdly, recommending to the IOTC Scientific Committee that the Scientific Committee should request the following:
    - CPCs (and/or IOTC Secretariat) provide summary data and/or information, to WPB (or IOTC Secretariat to compile), pertaining to:
        - **All gear/fishery types** – discarding/retention rates and at-haul mortality (%) for each marlin and sailfish species, by fishery/gear type.
        - **Longline** – proportion of fleet using different hook types and sizes (Japanese tuna, J hook, Circle hook, other)
        - **Longline** – proportion of fleet setting shallow or deep, at night or during day.
        - **Gillnet** – proportion of the gillnet fleet using subsurface setting, night and day setting and if possible, preferred depths used in fishery.
        - Any other information or data the WPB considers would assist WPB in providing advice to the SC in future
    - CPCs individually or collaboratively conduct gillnet experimental fishing trials to test different setting depths and times of setting/soaking (e.g. day/night), on catch rates and mortality of the full range of interacting species, including billfish bycatch, target tuna and vulnerable species (e.g. cetaceans, turtles), in order to provide the Commission a quantified understanding of likely effects and possible trade-offs of various subsurface setting options, on each species. Collection of accurate data at a species-specific level should be a high priority. The SC should recommend that the Commission give consideration to how such a trial might be supported financially and logistically.

- CPCS to consider undertaking model-based analyses of condition/AHM at a longline fleet level to identify key factors driving AHM/condition and subsequently, additional potential method/gear mitigation options.

Following the conclusion of WPB the authors will be reaching out to interested WPB scientists to discuss some of these issues further and potentially collaborate on updating of the review in future.

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