E-ISSN: 2073-3720
https://doi.org/10.33997/j.afs.2024.37.1.005

SHORT COMMUNICATION

Recent Declining Trends in Pelagic Fish Catches in the Indian Ocean off Sri Lanka: Is Gill Oxygen Limitation Theory (GOLT) a Possible Explanation?

NUWAN D.P. GUNWARDANE[1], M.D.S.T. DE CROOS[2], UPALI S. AMARASINGHE[3,*]
[1]Department of Fisheries and Aquatic Resources, New Secretariat, Maligawatte, Colombo, Sri Lanka
[2]Department of Aquaculture and Fisheries, Wayamba University of Sri Lanka, Makandura, Sri Lanka
[3]Department of Zoology and Environmental Management, University of Kelaniya, Kelaniya, Sri Lanka

*E-mail: zoousa@kln.ac.lk | Received: 03/05/2023; Accepted: 22/03/2024

Abstract

Recent trends in the pelagic fish landings of multi-day fishing fleets operated from Sri Lanka indicated significant declines in many fish species. Therefore, the present preliminary analysis investigates the perceptions of fishers on recent declining trends of pelagic fish landings from offshore areas of the Indian Ocean and further investigates whether the most common pelagic species landed in Sri Lanka conform to the gill oxygen limitation theory (GOLT) and to speculate GOLT as a possible explanation to such trends. According to the perceptions of 457 skippers of fishing vessels interviewed, such declines were possibly attributed to shifting of the areas of occurrence of pelagic fish species, making them less vulnerable to multi-day fishing vessels. As climate change and deoxygenation are major stressors affecting fish stocks, there is a challenging need for disentangling the impacts of these stressors from the effects of overfishing. The 18 most common pelagic fish species harvested from the Indian Ocean confirmed to the predictions from the GOLT, suggesting that shifting of these stocks could be due to deoxygenation which may have been triggered by increased sea surface and sub-surface temperatures. Therefore, fishery-independent surveys are needed to investigate the shifting of areas of occurrence of pelagic fishes in the Indian Ocean to understand their areas of occurrence the further investigate the relevance of GOLT for defining regional fisheries management plans.

Keywords: climate change adaptations, highly migratory fish, tropical tuna, multi-day fishing

Introduction

In Sri Lanka, pelagic fish species in the offshore regions, mainly tunas and tuna-like fish, are targeted by semi-industrialised multi-day fishing vessels. The skippers of these vessels often complain that in the recent past (i.e., last 8 years), there has been a significant decline in pelagic fish catches in the pelagic longline and drift gillnet fisheries. The regional fisheries management organisation, the Indian Ocean Tuna Commission (IOTC), also raised concerns about such a decline and has taken initiatives to introduce catch quotas to the member countries (Anon., 2022a). Collins et al. (2020) highlighted the importance of adopting a socio-ecological approach to investigate drivers for the behaviour of resource users. Recognition of responding resource users to change fishing locations as adaptive mechanisms under climate change scenarios is crucial for effective resource management (Young et al., 2019). Climate change and changing ocean conditions present new challenges, mainly because shifting species distributions and changing productivity can have significant implications for effective fisheries management.

The gill oxygen limitation theory (GOLT) described by Pauly and Cheung (2018) and Chen et al. (2022), discusses the limitations of fish in meeting the requirement of oxygen for their 3-dimensional body growth because of the 2-dimensional increase of gill surface area. As a result, growth reduces or ceases (i.e., when the building up of body substances or anabolism, reaches a level equal to the breaking down of substances or catabolism, the latter generally does not require oxygen) when oxygen is only required for maintenance energy (Pauly, 1984). According to Pauly (2021), the process of sexual maturity is supposedly triggered by environmental "stimuli" or "input" experienced at the onset of the spawning season, passed on to the hypothalamus, and thenceforth to a hormonal cascade leading to maturation and spawning. Therefore, GOLT postulates that latitudinal shifts of fish communities, leading to low catch and reduced species diversity and/or movement of fish schools to deeper waters, may occur in marine fish stocks due to oxygen limitation (Young et al., 2019; Pauly, 2019).

It is therefore imperative that the production trends of pelagic fisheries in the Indian Ocean off Sri Lanka be investigated to find out possible drivers for such trends, which would facilitate fishery resource management at the regional level. The main objective of the present preliminary analysis is twofold; first, an attempt was made to investigate fishers' perceptions of the recent trends in pelagic fisheries in the offshore areas of the Indian Ocean and to identify shifts in fishing location based on the knowledge of fishers, and secondly to investigate whether the most common pelagic species landed in Sri Lankan inboard multi-day fishing boats (IMULs) would conform to the GOLT to provide preliminary information for fisheries managers, policymakers and scientists for further comprehensive investigations on possible shifting of areas of occurrence of pelagic fish stocks.

Materials and Methods

Ethical approval

Ethical review and approval were not required for the animal study reported here because this study was based on published data, and no live vertebrates or higher invertebrates were sacrificed. For the opinion survey of skippers, accepted ethnological methodologies (Reeves et al., 2008) were adopted, and the respondents willingly participated in the survey.

The fishery and production trends

In Sri Lanka, multi-day fishing operations for pelagic fish species are carried out by semi-industrial, inboard, multi-day boats (hereafter IMULs), ranging from 9–17 m in length. These IMULs, operated by crews of 3–10 fishers depending on the size of the boat, generally target pelagic tuna and tuna-like species using drift gillnets and/or longlines, while some of the IMULs, especially those operating from the fishery harbours of southern Sri Lanka (Fig. 1), target flotsam-associated fish species using surrounding nets (Ariyarathna and Amarasinghe, 2012). The total duration of a fishing trip of an IMUL varies from 5 to 30 days, which essentially depends on the limited deck space and the manual operation of fishing gear (Hewapathirana et al., 2015). For the IMULs operating on the high seas, vessels must hold a High Seas Licence (HSL) and operate a functioning vessel monitoring system (VMS).

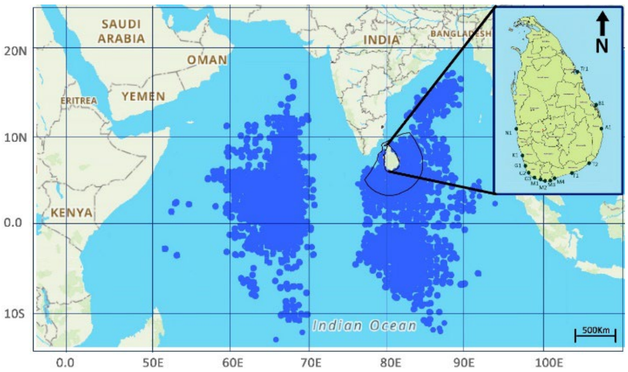

Fig. 1. Map of the Indian Ocean showing fishing locations (blue dots) of multi-day boats operated from Sri Lankan fishing harbours in 2022. Inset shows the map of Sri Lanka indicating locations of fishing harbours listed and coded in Table 1. The outer margin of the Exclusive Economic Zone of Sri Lanka is also shown here. (Source: IOTC, 2022).

In Sri Lanka, the offshore and deep-sea sectors contributed 42.2–44.2 % to the total marine fish production of 449,440–326,930 MT during the 2017–2020 period (Anon., 2021). This quantity was landed by the 4,196 to 5,155 IMULs operated during the same period. Fishing locations of the IMULs are, apart from those in the Exclusive Economic Zone (EEZ) of Sri Lanka, the Arabian Sea area crossing the EEZ of Maldives and/or the equatorial Indian Ocean (i.e., the eastern part of the Indian Ocean). Due to the absence of science-based forecasting of productive fishing grounds, skippers of the IMULs in the Indian Ocean off Sri Lanka rely on traditional means of navigating to fishing locations, such as various landmarks, the behaviour of seabirds.

Fishers' perceptions

An online questionnaire was designed to gather information about the education levels and occupational history of the skippers, their fishing experience, the procedure of determining fishing area, and their perceptions and feelings about the change of productive fishing grounds in the offshore areas (Supplementary Table 1). Using this questionnaire, information was gathered from randomly selected skippers of IMULs operated from 14 fishing harbours located in eight fisheries districts (Fig. 1; Table 1). The questionnaire was administered by using Google Forms (https://www.google.com/forms/about/) for online submission of responses. As the skippers were familiar with online submission of departure time and catch log details related to the fishing trips, etc. to the fisheries monitoring offices at the harbours, using smart mobile phones, this approach of administering questionnaires was found to be effective. The native languages of skippers

Table 1. The number of skippers of inboard, multi-day boats (IMULs) and their fisheries district and harbour, participating in the online survey.

Fisheries district	Fisheries harbour	Code	Number of skippers interviewed		Percentage
			from fisheries harbours	in each district	
Negombo	Pitipana	N1	8	8	1.75
Kaluatara	Beruwala	K1	21	21	4.60
Galle	Ambalangoda	G1	22	85	4.81
	Hikkaduwa	G2	7		1.53
	Galle	G3	56		12.25
Matara	Mirissa	M1	42	112	9.19
	Dondra	M2	36		7.88
	Nilwella	M3	21		4.60
	Suduwella	M4	103		22.54
Tangalle	Kudawalla	T1	6	34	1.31
	Tangalle	T2	28		6.13
Ampara	Sahindamarudu	A1	41	41	8.97
Batticaloa	Valachchanai	B1	35	35	7.66
Trincomalee	Trincomalee	Tr1	31	31	6.78
Total			457	457	100.00

in the present study, Sinhalese and Tamil, were used in preparing the questionnaire and conducting the survey from September to November 2022.

GOLT: a possible explanation for shifting fishing grounds

As suggested by Pauly (2021), the occurrence of pelagic fish species in a given location in the sea is dependent on oxygen availability as postulated by the GOLT. Accordingly, the relevance of GOLT was investigated as a possible driver for shifting of fishing grounds of pelagic species. The biological parameters of asymptotic length (L_∞) and length at minimum size of maturity (L_m), and the length-weight relationships (LWR) of females (all length measurements determined as fork length in cm) were obtained for the 18 most common pelagic species (60 % of total targeted species, and 88.5 % by weight of landed fish; Gunawardena et al., 2023) making the most significant contributions to the catches landed by the IMULs from published literature. For each species, the gill surface factor [$D = b(1\text{-}d)$] with b being the exponent of the fish LWR, and. d being the exponent of the gill area-weight relationships, which was taken as 0.8, was estimated. The variables, $L_\infty{}^D$ and $L_m{}^D$ were estimated for each species, and subsequently, the overall ratio of $L_\infty{}^D$ to $L_m{}^D$ together with the associated 95 % confidence interval was then determined by a linear regression analysis with the intercept fitted through the origin.

Results

Fishers' perceptions

A total of 457 IMUL skippers operating from 14 fisheries harbours in eight fisheries districts responded to the online questionnaire (Table 2). Most of the participants were between 18 and 55 years old (n = 449; 98 %). Almost all of them (n = 435; 95 %) were below 50 years of age. On average, skippers had 18.9 years of experience (range: 5–42 years, median = 28 years) in multi-day fishing in the Indian Ocean off Sri Lanka. Skippers' perceptions about the change in productive fishing grounds are summarised in Table 2.

All skippers in the IMULs mainly targeted tuna species using longlines (52.9 %), drift gillnets (20.4 %) and ring nets (26.7 %). Eighty-nine per cent of the skippers mentioned that they were dependent on traditional means of guessing fishing grounds such as wave height, presence of various landmarks such as rocks, the behaviour of seabirds, etc. About 41 % of the skippers interviewed indicated that in addition to traditional means, they relied on, the information about fishing ground forecasting provided by the fisheries authorities, while 88 % per cent of the skippers believed the productive fishing locations have changed over time. Nearly two-third of the skippers (64.7 %) were of the view that the shifting of productive fishing locations of pelagic species was possibly due to changes in water temperature, and water current patterns under the climate change scenarios. From these skippers' perceptions, the majority of respondents thought that there was a shift in productive fishing grounds and that their shifts were possibly related to increased sea surface temperature.

Annual production data and catch composition of pelagic fish species in the fleet of IMULs in the Indian Ocean off Sri Lanka from 1990 to 2021, obtained from the Indian Ocean Tuna Commission (IOTC) Historical Catch database of 2021/22 (IOTC, 2022) also indicated that catches of almost all pelagic fish species declined, particularly since 2010. Annual catches of

Table 2. Skippers' perceptions about the decline of pelagic fish catch in IMULs from a total of 457 respondents to the survey administered on Google Forms.

Skippers' perceptions	% Responses
(a) Fishing grounds have been shifted (n = 457)	
Fish stocks moved to cooler, deeper areas	45.0
Fish stocks moved southward	7.7
Climatic change and changes in water current patterns	11.6
Depletion of stock sized due to overfishing	5.7
Land-based waste pollution in the sea	2.0
No clear idea	25.4
The fishing grounds have not shifted	2.6
(b) Possible reasons why fishing grounds have been shifted (n = 329)	
Fish do not occur in usual fishing depths when sea surface temperature is high	35.3
Fish moved to cooler southward areas	29.5
Climatic change and changes in water current patterns	14.8
Overfishing	5.8
Technological advancements in the fishery	6.4
No reason given	8.2

yellowfin and skipjack tuna fluctuated in a similar manner (Fig. 2). Catches of yellowfin tuna reached a peak in 2004 (total catch of ~125,000 tonnes), fluctuated between 100 and 125,000 tonnes between 2004 and 2013 and are now <80,000 tonnes (Fig. 2).

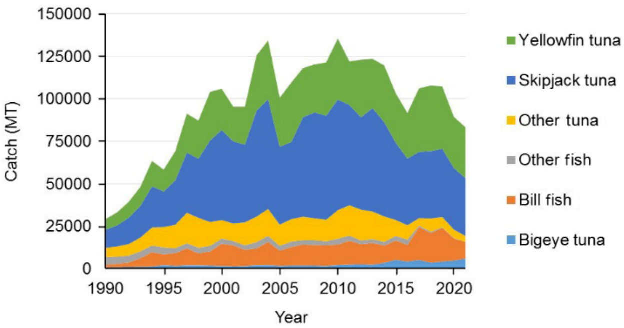

Fig. 2. Annual catches (metric tonnes) of pelagic fish species caught in the IMULs during the 1990–2020 period (Source: IOTC, 2022).

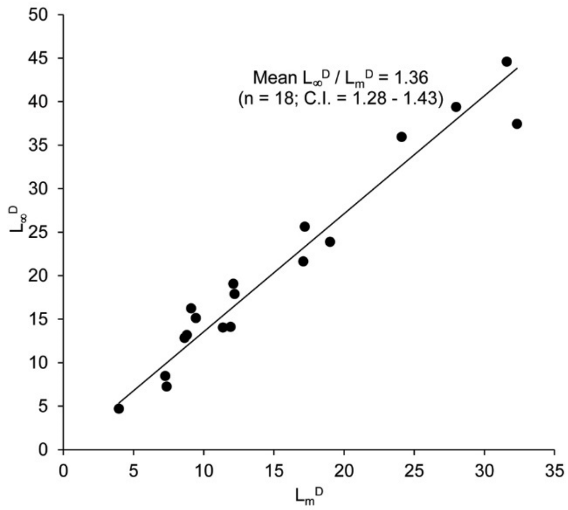

Fig. 3. Relationship between normalised length at first maturity (L_m^D) and normalised asymptotic length (L_∞^D) for 18 pelagic fish species in the Indian Ocean. All length measurements are fork lengths in cm. Species and sources of data are given in Table 3.

GOLT and pelagic fish species

The analysis was conducted to investigate whether the asymptotic lengths (L_∞), minimum sizes of maturity of females (L_m), and exponents of length-weight relationships (*b*) of 18 pelagic fish species conform to GOLT (Pauly 2021). The slope of the relationship between L_∞^D vs L_m^D, was 1.36 (95 % C.I. = 1.23 – 1.43; See Fig. 3; Table 3), which is identical to the value theorised by Pauly (1984).

Discussion

As evident from the present analysis, there has been a spectacular decline in the pelagic fish catches of IMULs operated in the Indian Ocean from the fishery harbours of Sri Lanka since 2010. Reduced catches of all major tuna and billfish species are apparently responsible for the decline of total pelagic catches. The perceptions of skippers of IMULs were consistent with the declining production trends in the catch statistics and their anecdotal insights were that due to increasing sea surface temperature, pelagic fish species moved either to deeper, cooler depths or to cooler southward regions, making the existing fishing strategies (mainly longlining and drift gillnetting) ineffective in catching them (Kleisner et al., 2016). Although in some species the spatial and temporal distributions change is more or less regular and cyclical patterns (Aro, 2002), 15 pelagic fish species under the IOTC mandate in the Indian Ocean region (Anon., 2022b) have been overexploited, except *Katsuwonus pelamis* (skipjack tuna) and *Xiphias gladius* (swordfish). Therefore, most probably these

Table 3. Asymptotic length (L_∞), the minimum size of maturity (L_m) and the exponent (*b*) of length-weight relationships (LWR) of the form $W = aL^b$ of 18 pelagic fish species in the Indian Ocean. All length measurements are fork lengths in cm. *D* is the gill surface factor, and *d* (= 0.8) is the exponent of the gill area-weight relationships. For details, see the text.

Species	L_∞ (cm)†	L_m (cm)‡	*b*⁑	$D = b*(1-d)$	L_m^D	L_∞^D	Sources of data
Thunnus alalunga (Bonnaterre, 1788)	128.0	94.0	2.727	0.545	11.917	14.103	† Dorel (1986) ‡ Anon. (2022c) ⁑ Setyadji et al. (2014)
Thunnus obesus (Lowe, 1839)	217.9	112.5	3.012	0.602	17.205	25.622	† Zhu et al. (2009) ‡ Kailola et al. (1993) ⁑ Chassot et al. (2016)
Auxis rochei (Risso, 1810)	42.3	23.60	3.408	0.682	8.625	12.838	†‡ Jasmine et al. (2013) ⁑ Herath et al. (2019)
Auxis thazard (Lacepède, 1800)	47.0	34.5	3.431	0.686	11.366	14.047	† Mudumala et al. (2018) ‡ Vieira et al. (2022) ⁑ Herath et al. (2019)
Thunnus tonggol (Bleeker, 1851)	123.5	53.5	2.820	0.564	9.436	15.125	† IOTC (2015) ‡ Griffiths et al. (2019) ⁑ Yasemi et al. (2017)
Katsuwonus pelamis (Linnaeus, 1758)	70.1	39.9	3.393	0.679	12.201	17.884	† Tadjuddah et al. (2017) ‡ Grande et al. (2014) ⁑ Chassot et al. (2016)
Thunnus albacares (Bonnaterre, 1788)	178.0	119.6	2.967	0.593	17.096	21.640	† Nurdin et al. (2016) ‡ Shi et al. (2022) ⁑ Chassot et al. (2016)
Euthynnus affinis (Cantor, 1849)	87.7	34.6	3.115	0.623	9.096	16.232	† Nurdin et al. (2016) ‡ Cruz-Castan et al. (2019) ⁑ Herath et al. (2019)
Istiompax indica (Cuvier, 1832)	396.6	227.2	3.070	0.614	27.979	39.390	† Sun et al. (2015) ‡ Sun et al. (2014) ⁑ Wang et al. (2006)
Makaira nigricans Lacepède, 1802	350.9	206.1	3.240	0.648	31.588	44.594	† Su et al. (2016); Prager et al. (1995) ‡ Sun et al. (2009); Prager et al. (1995) ⁑ Wang et al. (2006)
Rastrelliger kanagurta (Cuvier, 1816)	26.2	20.7	3.267	0.654	7.251	8.460	†‡ Oktaviani et al. (2014) ⁑ Hulkoti et al. (2013)
Decapterus russelli (Rüppell, 1830)	23.6	24.1	3.136	0.627	7.358	7.262	†⁑ Faizah et al. (2020) ‡ Costa et al. (2020)
Scomberomorus commerson (Lacepède, 1800)	140	65.4	2.983	0.597	12.107	19.064	†⁑ Shojaei et al. (2008) ‡ Devaraj (1983)
Elagatis bipinnulata (Quoy & Gaimard, 1825)	82.7	41.3	2.920	0.584	8.789	13.175	†‡⁑ Mous et al. (2020)
Istiophorus platypterus (Shaw, 1792)	246.8	166	2.880	0.576	19.001	23.878	† Kar et al. (2015) ‡ Chiang et al. (2006) ⁑ Wang et al. (2006)
Kajikia audax (Philippi, 1887)	263.4	210.0	3.250	0.650	32.323	37.449	† Sun et al. (2011) ‡ Chang et al. (2018); Sun et al. (2011) ⁑ Wang et al. (2006); Sun et al. (2011)
Xiphias gladius Linnaeus, 1758	311.1	164.0	3.120	0.624	24.105	35.940	† Oktaviani et al. (2014) ‡ Sijo et al. (2013) ⁑ Wang et al. (2006)
Acanthocybium solandri (Cuvier, 1832)	179.7	99.3	1.493	0.299	3.948	4.713	† McBride et al. (2008) ‡⁑ Widodo et al. (2012)

† Sources of L_∞ values; ‡ Sources of L_m values; ⁑ Sources of *b* values of LWR.

catch reductions would have resulted from the low abundance of fish in traditional fishing grounds as they would have been migrated to new locations in optimising the surrounding environment as an adaptive response (Aro, 2002).

The occurrence of pelagic fish species in a given location in the sea is dependent on oxygen availability as postulated by the GOLT (Pauly, 2021). According to GOLT, the ability of fish to absorb oxygen is proportional to their gill surface area, which essentially increases two-dimensionally with the growth of fish. In contrast, the body size of fish grows volumetrically, hence, having a three-dimensional increase in body weight while gill surface area increases in only two dimensions. Consequently, their ability to extract oxygen from the water reduces as they grow bigger. The GOLT, therefore, postulates that the growth of fish reaches a point where this diminished oxygen supply is only sufficient to meet maintenance metabolism, achieving its asymptotic body size (Pauly, 2021).

Hence, reducing trends of pelagic fish catches andthe experience and attitudes of fishers on shifting fishing grounds of pelagic species in the Indian Ocean, could perhaps be explained by GOLT. As suggested by Young et al. (2019) and Pauly (2019) oxygen limitation drives fishes to shift to deeper waters and higher latitudes resulting in low catch rates and species diversities in the tropics and shallower water.

In contrast, environmental changes leading to ocean warming may affect the behaviour (Pershing et al., 2015) and metabolism (Deutsch et al., 2015) of the majority of marine species as they are water-breathing ectotherms. Poloczanska et al. (2016), who reviewed the evidence for the responses of marine life to recent climate change across ocean regions, from tropical seas to polar oceans, have shown that general trends in their responses are consistent, including, amongst others, shifts in distribution to higher latitudes and deeper locations. Ariza et al. (2022) also indicated that ocean warming would result in a massive expansion of temperate species towards high-latitude regions. These increased seawater temperatures result in low dissolved oxygen (Ito et al., 2017). During the past 50 years, the oxygen levels in the surface and sub-surface layers in the world's oceans have decreased by 0.5-3.3 % (Schmidtko et al., 2017; Breitburg et al., 2018). As evident by the present analysis, 18 pelagic fish species in the Indian Ocean, conform to predictions of the GOLT. As such, pelagic fish species in the Indian Ocean off Sri Lanka can be considered to be further susceptible to deoxygenation due to elevated sea temperature.

The significantly reduced pelagic fish catches during the last 7–8 years could also have been influenced by shifting of the area of occurrence of major pelagic fish species targeted by multiday fishing off Sri Lanka. Fishing restrictions due to the COVID-19 lockdown and introduction of the Vessel Monitoring System to deep sea fisheries off Sri Lanka in 2015 may also have contributed to apparent declining trends in multiday fish catches to some extent. Fish, being water-breathing ectotherms, require more oxygen for metabolic activities in high-temperature habitats, and on the other hand, the limited availability of oxygen in the water due to increased sea surface and sub-surface temperature, may have created further difficulties for fish to acquire oxygen through their respiratory surfaces. Pauly (2021) mentioned that sexual maturity is initiated when a threshold ratio of $L_{max}{}^{D}$ or $L_{\infty}{}^{D}$ to $L_{m}{}^{D}$ of approximately 1.35 is achieved. The present analysis is also consistent with this phenomenon. Pauly (2019) mentioned that sensitivity to temperature extremes forces the poleward migration of fish, and/or increases in the depth in which they occur. Pauly (2020) further indicated that in the case of tropical fish species such as tuna, the possibilities are that they might increase the depth that they occur as a response to oxygen limitation due to elevated environmental temperature. The declining catch trends of pelagic fish species in the Indian Ocean off Sri Lanka may possibly be due to such habitat shifting, resulting in reduced catches in IMULs because pelagic fish schools, such as tuna, having unique temperature affinities might move to deeper, cooler waters. It is known that multiday fishermen in Sri Lanka normally set their long lines targeting tunas at the depths lower than 45 m (Rajapaksha, 2010). However, it is evident that yellowfin tuna is abundant at relatively low temperature ranges in deeper areas up to about 75 m in depth (Maddumage et al., 2021).

Also, the commercial fishing fleets are reported to set conventional longlines to a depth of about 175 m and deep longlines targeting bigeye tuna or billfish are set at a depth of up to 300 m (FAO, 2023). It can therefore be postulated that the fishing depths of longlines targeting tuna and tuna-like pelagic fish species by the IMULs operating from the Sri Lankan fishery harbours are much shallower than the current depth distributions of these species, resulting in low catches.

It has been reported that commercial trawl fishing communities in the northwest Atlantic experienced poleward shifts of fish species that they targeted and changed their fishing patterns as an adaptation strategy to fish in higher latitudes (Young et al., 2019). Further, Gamito et al. (2016) have shown the trends in landings and vulnerability to climate change in different fleet components along the Portuguese coast. According to Ouled-Cheikh et al. (2022) and Morée et al. (2023), climate-change-driven losses of the contemporary habitat of fish are evident across the oceans. Alteration of fishing locations by fisher communities with fleets of large vessels in the mid-Atlantic has been reported to occur over the past two decades (Young et al., 2019). Accordingly, large-vessel fleets from North Carolina and Virginia in particular, which used to fish near their ports of origin, are now fishing 800 km north, off the coast of New Jersey.

Froese et al. (2022) pointed out that disentangling the impacts of these environmental stressors from the effects of overfishing is challenging. According to Young et al. (2019), recognition of responding resource users to change fishing locations under climate change scenarios is critical for adaptive planning and effective resource management. Climate change and changing ocean conditions present new challenges, mainly because shifting species distributions and changing productivity can have significant implications for effective fisheries management, which need to be overcome by including climate-informed decision-making in the fisheries management process (Karp et al., 2019). This is particularly important because management efforts for pelagic fish stocks are largely towards control of fishing pressure such as reducing overcapacity and introducing catch quotas (Pons et al., 2018). It is therefore imperative that the regional fisheries management organisations such as IOTC consider, when defining regional fisheries management plans, the possible shifting of pelagic fish stocks due to deoxygenation associated with increased sea surface and sub-surface temperature as an area of concern in addition to control of the amount of fishing. This preliminary analysis also calls for concerted efforts investigating oceanographic drivers responsible for the occurrence of marine pelagic fish species together with experimental fishing trials to identify more productive fishing grounds and depths, and appropriate modifications of fishing gear and vessels.

Conclusion

The recent declining trends in pelagic fish landings from the multiday fishing boats operating from the fishery harbours of Sri Lanka are suspected to be due to shifting of their areas of occurrence towards either deeper, cooler areas or to polar ward regions, as an adaptive mechanism to oxygen depletion. The conformity of the most commonly harvested 18 pelagic fish species from the Indian Ocean to the GOLT, perhaps provides an explanation for these declining trends in pelagic fish landings as possible shifting of those stocks as a result of oxygen depletion which could have been triggered by increased sea surface and sub-surface temperatures. Therefore, fishery-independent surveys are needed to be carried out to investigate the shifting and migration of pelagic fishes in the Indian Ocean to understand their new habitats and further conduct comprehensive studies to understand the effect of oceanographic events on pelagic fish stocks (apart from fishing pressure) for the effective management of pelagic fish stocks at the regional level.

Acknowledgements

The authors are thankful to former Director General, Mr. M.C.L. Fernando and the present Director General, Mr. S.J. Kahawatta of the Department of Fisheries and Aquatic Resources for providing necessary approval for the study and information gathering. Special thanks are due to officials of the High Seas Operation Units at Fisheries Harbours and the Information Technology Division of the Department of Fisheries and Aquatic Resources for their kind assistance during the data collection process. The authors would like to express their gratitude to the boat owners and the skippers who supported them during the data collection process.

Conflict of interest: The authors declare that they have no conflict of interest.

Author contributions: Nuwan D.P. Gunwardane: Data collection and analysis. M.D.S.T. de Croos: Data analysis, writing. Upali S. Amarasinghe: Conceptualisation, methodology, writing.

References

Anon. 2021. Fisheries Statistics 2021. Ministry of Fisheries, Colombo, Sri Lanka. https://fisheries.gov.lk/web/images/statistics/annual_report/Fisheries_Statistics_2021_FINAL_PDF_compressed.pdf (Accessed 10 November 2022).

Anon. 2022a. Tenth meeting of the technical committee on allocation criteria (tcac10). Chair's draft proposal for an allocation regime (V4), IOTC-2022-TCAC10-03_Rev1. Indian Ocean Tuna Commission, Victoria, Mahé, Seychelles. https://iotc.org/meetings/10th-meeting-technical-committee-allocation-criteria-tcac10 (Accessed 09 January 2023).

Anon. 2022b. Co-chairperson's report: 33rd session of the G16 like-minded coastal states of the Indian Ocean. G-16-2022-S33-R. Indian Ocean Tuna Commission, Victoria, Mahé, Seychelles. https://io-g16.org/meetings/s33g16-coastal-states-meeting-in-bangkokthailand/ (Accessed 09 January 2023).

Anon. 2022c. Characteristics features and biology of *Thunnus alalunga*. https://fishider.org/en/guide/osteichthyes/scombridae/thunnus/thunnus-alalunga (Accessed 6 September 2022).

Ariyarathna, M.M., Amarasinghe, U.S. 2012. A fishery associated with floating objects in the Indian Ocean off Southern Sri Lanka. Asian Fisheries Science 25:278–289. https://doi.org/10.33997/j.afs.2012.25.4.001

Ariza, A., Lengaigne, M., Menkes, C., Lebourges-Dhaussy, A., Receveur, A., Gorgues, T., Habasque, J., Gutiérrez, M., Maury, O., Bertrand, A. 2022. Global decline of pelagic fauna in a warmer ocean. Nature Climate Change 12:928–934. https://doi.org/10.1038/s41558-022-01479-2

Aro, E. 2002. Fish migration studies in the Baltic Sea—a historical review. ICES Marine Science Symposia 215:361–370. https://doi.org/10.17895/ices.pub.8875

Breitburg, D., Levin, L.A., Oschlies, A., Gregoire, M., Chavez, F.P., Conley, D.J., Garçon, V., Gilbert, D., Gutiérrez, D., Isensee, K., Jacinto, G.S., Limburg, K.E., Montes, I., Naqvi, S.W.A., Pitcher, G.C., Rabalais, N.N., Roman, M.R., Rose, K.A., Seibel, B.A., Telszewski, M., Yasuhara, M., Zhang, J. 018. Declining oxygen in the global ocean and coastal waters. Science 359:eaam7240. https://doi.org/10.1126/science.aam7240

Chang, H-Y., Sun, C-L., Yeh, S-Z., Chang, Y-J., Su N-J., DiNardo. G. 2018. Reproductive biology of female striped marlin, *Kajikia audax* in the western Pacific Ocean. Journal of Fish Biology 92:105–130. https://doi.org/10.1111/jfb.13497

Chassot, E., Assan, C., Esparon, J., Tirant, A., Delgado, A., Dewals, P., Augustin, E., Bodin, N. 2016. Length-weight relationships for tropical tunas caught with purse seine in the Indian Ocean: Update and lessons learned. IOTC Conference Paper. December 2016. Indian Ocean Tuna Commission, Victoria, Mahé, Seychelles. IOTC-2016-WPCDS12-INF05. https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers17-01/010067418.pdf (Accessed 9 January 2023).

Chen, Z., Bigman, J., Xian, W., Liang, C., Chu, E., Pauly, D. 2022. The ratio of length at first maturity to maximum length in marine and freshwater fish. Journal of Fish Biology 101:400–407. https://doi.org/10.1111/jfb.14970

Chiang, W., Sun, C-L., Yeh, S.Z., Su, W-C., Liu D-C., Chen, W-Y. 2006. Sex ratios, size at sexual maturity, and spawning seasonality of sailfish *Istiophorus platypterus* from eastern Taiwan. Bulletin of Marine Science 79:727–737.

Collins, C., Nuno, A., Benaragama, A., Broderick, A., Wijesundara, I., Wijetunge, D., Letessier, T.B. 2021. Ocean-scale footprint of a highly mobile fishing fleet: Social-ecological drivers of fleet behaviour and evidence of illegal fishing. People and Nature 3:740–755. https://doi.org/10.1002/pan3.10213

Costa, M.P.V., Cruz, D.R.S., Monteiro, L.S., Evora, K.S.M., Cardoso, L.G. 2020. Reproductive biology of the mackerel scad, *Decapterus macarellus* from Cabo Verde and the implications for its fishery management. African Journal of Marine Science 42:35–42. https://doi.org/10.2989/1814232X.2020.1721328

Cruz-Castán, R., Meiners-Mandujano, C., Macías, D., Jiménez-Badillo, L., Curiel-Ramírez, S. 2019. Reproductive biology of little tunny, *Euthynnus alletteratus* (Rafinesque, 1810) in the southwest Gulf of Mexico. PeerJ – Life and Environment 7:e6558. https://doi.org/10.7717/peerj.6558

Deutsch, C., Ferrel, A., Seibel, B., Pörtner, H.O., Huey, R.B. 2015. Climate change tightens a metabolic constraint on marine habitats. Science 348:1132–1135. https://doi.org/10.1126/science.aaa1605

Devaraj, M. 1983. Maturity, spawning and fecundity of the king seer, *Scomberomorus commerson* (Lacepede), in the seas around the Indian peninsula. Indian Journal of Fisheries 30:203–230.

Dorel, D. 1986. Poissons de l'Atlantique nord-est relations taille-poids. Institut Francais de Recherche pour l' Exploitation de la Mer, Nantes, France. 165 pp. (in French).

Faizah, R., Sadiyah L. 2020. Some biology aspects of Indian scad, *Decapterus russelli* (Rupell, 1928) in Pemangkat fisheries port, west Kalimantan. IOP Conference Series: Earth and Environmental Science 429:012063. https://doi.org/10.1088/1755-1315/429/1/012063

FAO. 2023. Fishing techniques. Industrial tuna longlining. Technology Fact Sheets. Fisheries and Aquaculture Division, Food and Agriculture Organization of the United Nations, Rome https://www.fao.org/figis/pdf/fishery/fishtech/1010/en?title=FAO%20Fisheries%20%26amp%3B%20Aquaculture%20-%20Fishing%20Techniques%20-%20Industrial%20Tuna%20Longlining (Accessed 11 March 2023).

Froese, R., Papaioannou, E., Scotti, M. 2022. Climate change or mismanagement? Environmental Biology of Fishes 105:1363–1380. https://doi.org/10.1007/s10641-021-01209-1

Gamito, R., Pita, C., Teixeira, C., Costa, M.J., Cabral, H.N. 2016. Trends in landings and vulnerability to climate change in different fleet components in the Portuguese coast. Fisheries Research 181:93–101. https://doi.org/10.1016/j.fishres.2016.04.008

Grande, M., Murua, H., Zudaire, I., Goni, N. 2014. Reproductive timing and reproductive capacity of the skipjack tuna, *Katsuwonus pelamis* in the western Indian Ocean. Fisheries Research 156:14–22. https://doi.org/10.1016/j.fishres.2014.04.011

Griffiths, S.P., Zischke, M.T., van der Velde, T., Fry, G.C. 2019. Reproductive biology and estimates of length and age at maturity of longtail tuna, *Thunnus tonggol* in Australian waters based on histological assessment. Marine and Freshwater Research 70:1419–1426. https://doi.org/10.1071/MF18469

Herath, D., Hettiarachchi, C., Murphy, B., Perera, C. 2019. Length-weight and length-length relationships of three neritic tuna species of Sri Lankan coastal waters. International Journal of Fisheries and Aquatic Studies 7:129–133.

Hewapathirana, H.P.K., Maldeniya, R., Perera, U.L.K. 2015. Sri Lanka: National report to the scientific committee of the Indian Ocean Tuna Commission, 2015. IOTC-2015-SC18-NR26. Indian Ocean Tuna Commission, Victoria, Mahé, Seychelles. https://iotc.org/sites/default/files/documents/2015/11/IOTC-2015-SC18-NR26_-_Sri_Lanka_0.pdf (Accessed 09 January 2023).

Hulkoti, S., Shivaprakash, S., Anjanayappa, H., Somashekara, S., Benakappa, S., Naik, K., L. Prasad, L., Kumar, J. 2013. Length-weight relationship of *Rastrelliger kanagurta* (Cuvier) from Mangalore region. Environment and Ecology 31(2A):676–678.

IOTC. 2015. Population parameters: longtail tuna, *Thunnus tonggol*. Working Party Paper, IOTC-2015-WPNT05-DATA13. Indian Ocean Tuna Commission, Victoria, Mahé, Seychelles. https://www.fao.org/3/bf017e/bf017e.pdf (Accessed 10 December 2022).

IOTC. 2022. Nominal catch by species and gear, by vessel flag reporting country. IOTC-2022-DATASETS-NCDB. Indian Ocean Tuna Commission, Victoria, Mahé, Seychelles., http://www.iotc.org/data/datasets/latest/NC (Accessed 10 December 2022).

Ito, T., Minobe, S., Long, M.C., Deutsch, C. 2017. Upper ocean O_2 trends: 1958–2015. Geophysical Research Letters 44:4214–4223. https://doi.org/10.1002/2017GL073613

Jasmine, S., Rohith, P., Abdussamad, E.M., Koya, K.P.S., Joshi, K.K., Kemparaju, S., Prakashan, D., Elayathu, M.N.K., Sebastine, M. 2013. Biology and fishery of the bullet tuna, *Auxis rochei* (Risso, 1810) in Indian waters. Indian Journal of Fisheries 60:13–20.

Kailola, P.J., Williams, M.J., Stewart, P.C., Reichelt, R.E., McNee, A., Grieve, C. 1993. Australian fisheries resources. Bureau of Resource Sciences, Canberra, Australia. 422 pp.

Kar, A.B., Ramalingam, L., Govindaraj, K. 2015. Age and growth of Indo-Pacific Sailfish, *Istiophorus platypterus* (Shaw and Nodder, 1792) in the Andaman and Nicobar waters. Indian Journal of Geo-Marine Sciences 44:42–48.

Karp, M.A., Peterson, J.O., Lynch, P.D., Griffis, R.B., Adams, C.F., Arnold, W.S., Barnett, L.A.K., deReynier,Y., DiCosimo, J., Fenske, K.H., Gaichas, S.H., Hollowed, A., Holsman, K., Karnauskas, M., Kobayashi, D., Leising, A., Manderson, J.P., McClure, M., Morrison, W.E., Schnettler, E., Thompson, A., Thorson, J.T., Walter, III, J.F., Yau, A.Y., Methot, R.D., Link, J.S. 2019. Accounting for shifting distributions and changing productivity in the development of scientific advice for fishery management. ICES Journal of Marine Science 76:1305–1315. https://doi.org/10.1093/icesjms/fsz048

Maddumage, U.S., Rajapaksha, J., Gunatilake, J. 2023. Effect of ocean circulation and chlorophyll-a concentration on yellowfin tuna catch rates in Sri Lankan longline fishery. Ceylon Journal of Science 52:371–379. https://doi.org/10.4038/cjs.v52i3.8208

McBride, R.S., Adam, K.R., Kristen, L.M. 2008. Age, growth, and mortality of wahoo, *Acanthocybium solandri*, from the Atlantic coast of Florida and the Bahamas. Marine and Freshwater Research 59:799–807. https://doi.org/10.1071/MF08021

Morée, A.L., Clarke, T.M., Cheung, W.W.L., Frölicher, T.L. 2023. Impact of deoxygenation and warming on global marine species in the 21st century. Biogeosciences 20:2425–2454. https://doi.org/10.5194/bg-20-2425-2023

Mous, P.J., Gede, W.B.I., Pet, J.S. 2020. Length-based stock assessment of a species complex caught in deep water demersal fisheries targeting snappers in Indonesia, Fishery Management Area 711. Yayasan Konservasi Alam Nusantara and People and Nature Consulting, Jakarta, Indonesia. Report AR_711_280622 711. 90 pp.

Mudumala, V., Farejiya, M., Mali, D.R.K., Rao, R.K., Uikey, D., Sawant, P., Siva, A. 2018. Studies on population characteristics of frigate tuna, *Auxis thazard* (Lacepede,1800) occurring in the north west coast of India. International Journal of Life-Sciences Scientific Research 4:1639–1643. https://doi.org/10.21276/ijlssr.2018.4.2.3

Nurdin, E., Sondita, F., Yusfiandayani R., Baskoro, M. 2016. Growth and mortality parameters of yellowfin tuna, *Thunnus albacares* in Palabuhanratu waters, west Java (eastern Indian Ocean). AACL Bioflux 9:741–747.

Oktaviani, D., Supriatna, J., Erdmann, M., Abinawanto, A. 2014. Maturity stages of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1817) in Mayalibit bay, Raja Ampat, West Papua. International Journal of Aquatic Science 5:67–76.

Ouled-Cheikh, J., Coll, M., Cardona, L., Steenbeek, J., Ramírez, F. 2022. Fisheries-enhanced pressure on Mediterranean regions and pelagic species already impacted by climate change. Elementa: Science of the Anthropocene 10:00028. https://doi.org/10.1525/elementa.2022.00028

Pauly, D. 1984. A mechanism for the juvenile-to-adult transition in fishes. ICES Journal of Marine Science 41:280–284. https://doi.org/10.1093/icesjms/41.3.280

Pauly, D. 2019. A précis of Gill-Oxygen Limitation Theory (GOLT), with some emphasis on the Eastern Mediterranean. Mediterranean Marine Science 20:660–668. https://doi.org/10.12681/mms.19285

Pauly, D. 2020. The gill-oxygen limitation theory (GOLT) and its application to Australian fish and marine invertebrates. Presentation to the Australian Marine Sciences Association, South Queensland Branch, 15 July 2020. https://fb.watch/kebvCwCinA/

Pauly, D. 2021. The gill-oxygen limitation theory (GOLT) and its critics. Science Advances 7:eabc6050. https://doi.org/10.1126/sciadv.abc6050

Pauly, D., Cheung, W.W.L. 2018. On confusing cause and effect in the oxygen limitation of fish. Global Change Biology 24:e743–e744. https://doi.org/10.1111/gcb.14383

Pershing, A.J., Alexander, M.A., Hernandez, C.M., Kerr, L.A., Le Bris, A., Mills, K.E., Nye, J.A., Record, N.R., Scannell, H.A., Scott, J.D., Sherwood, G.D., Thomas, A.C. 2015. Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. Science 350:809–812. https://doi.org/10.1126/science.aac9819

Poloczanska, E.S., Burrows, M.T., Brown, C.J., Molinos, J.G., Halpern, B.S., Hoegh-Guldberg, O., Kappel, C.V., Moore, P.J., Richardson, A.J., Shoeman, D.S., Sydeman, W.J. 2016. Responses of marine organisms to climate change across oceans. Frontiers in Marine Science 3:62. https://doi.org/10.3389/fmars.2016.00062

Pons, M., Melnychuk, M.C., Hilborn, R. 2018. Management effectiveness of large pelagic fisheries in the high seas. Fish and Fisheries 19:260–270. https://doi.org/10.1111/faf.12253

Prager, M.H., Prince, E.D., Lee, D.W. 1995. Empirical length and weight conversion equation for blue marlin, white marlin and sail fish from the North Atlantic Ocean. Bulletin of Marine Science 56:201–210.

Rajapaksha, J. 2010. Evaluation and improvement of satellite-based forecast system for Sri Lanka yellowfin tuna fishery [final project]. United Nations University Fisheries Training Programme, Iceland. http://www.unuftp.is/static/fellows/document/jagath09prf.pdf

Reeves, S., Kuper, A., Hodges, B.D. 2008. Qualitative research methodologies: ethnography. BMJ 337:a1020. https://doi.org/10.1136/bmj.a1020

Schmidtko, S., Stramma, L., Visbeck, M. 2017. Decline in global oceanic oxygen content during the past five decades. Nature 542:335–339. https://doi.org/10.1038/nature21399

Setyadji, B., Budi, N., Duto, N. 2014. Length-weight relationship, size distribution and annual CPUEs of albacore in Eastern Indian Ocean. Indonesian Fisheries Research Journal 20:17–22. https://doi.org/10.15578/ifrj.20.1.2014.17-22

Shi, X., Zhang, J., Wang, X., Wang, Y., Li, C., Shi, J. 2022. Reproductive biology of yellowfin tuna. *Thunnus albacares* in tropical western and central Pacific Ocean. Fishes 7:162. https://doi.org/10.3390/fishes7040162

Shojaei, M., Motlagh, S., Seyfabadi, J., Abtahi, B., Dehghani, R. 2008. Age, growth and mortality rate of the narrow-barred Spanish mackerel, *Scomberomerus commerson* (Lacepède, 1800) in coastal waters of Iran from length frequency data introduction. Turkish Journal of Fisheries and Aquatic Sciences 7:115–121.

Sijo, P., Varghese, K., Vijayakumaran, A., Anrose, V., Mhatre, D. 2013. Biological aspects of swordfish, *Xiphias gladius* (Linnaeus, 1758) caught during tuna long line survey in the Indian Seas. Turkish Journal of Fisheries and Aquatic Sciences 13:529–540. http://doi.org/10.4194/1303-2712-v13_3_18

Su, N-J., Sun, C-L., Tai, C-Y., Yeh, S-Z. 2016. Length-based estimates of growth and natural mortality for blue marlin (*Makaira nigricans*) in the northwest Pacific Ocean. Journal of Marine Science and Technology 24:370–378. https://doi.org/10.6119/JMST-015-0728-1

Sun, C-L., Chang, Y-J., Tszeng, C-C., Yeh, S.-Z., Su, N-J. 2009. Reproductive biology of blue marlin (*Makaira nigricans*) in the western Pacific Ocean. Fishery Bulletin 107:420–432.

Sun, C-L., Hsu, W-H., Su, N-J., Yeh, S-Z., Chang, Y-J., Chiang, W-C. 2011. Age and growth of striped marlin (*Kajikia audax*) in the waters off Taiwan: A revision. ISC/11/BILLWG-2/07. Working document submitted to the ISC Billfish Working Group Workshop, 24 May – 1 June 2011, Chinese Taipei, Taiwan. 12 pp.

Sun, C.-L., Hsiao, Y., Chang, T., Sung-Yun, L., Su-Zan, Y., Yi-Jay, C. 2014. Reproductive biology of the black marlin, *Istiompax indica*, off southwestern and eastern Taiwan. Fisheries Research 166:12–20. https://doi.org/10.1016/j.fishres.2014.09.006

Sun, C-L., Yeh, S-Z., Liu, C-S., Su, N-J., Chiang, W. 2015. Age and growth of black marlin (*Istiompax indica*) off eastern Taiwan. Fisheries Research 166:4–11. https://doi.org/10.1016/j.fishres.2014.09.005

Tadjuddah, M., Anadi, L., Mustafa, A., Arami, H., Kamri, S., Wianti, N. 2017. Growth pattern and size structure of skipjack tuna caught in Banda Sea, Indonesia. AACL Bioflux 10:227–233.

Vieira, J.M.S., Costa, P.A.S., Braga, A.C., São-Clemente, R.R.B., Ferreira, C.E.L., Silva, J.P. 2022. Correction notice: Age, growth and maturity of frigate tuna (*Auxis thazard* Lacepède, 1800) in the southeastern Brazilian coast. Aquatic Living Resources 35:17. https://doi.org/10.1051/alr/2022015

Wang, S-P., Sun, C-L., Yeh, S-Z., Chiang, W., Su, N-J., Chang, Y-J., Liu, C-H. 2006. Length distributions, weight-length relationships, and sex ratios at lengths for the billfishes in Taiwan waters. Bulletin of Marine Science 79:865–869.

Widodo, A.A., Satria, F., Nugraha, B. 2012. Size and fishing ground of wahoo, *Acanthocybium solandri* (Cuvier, 1832) from catch data of tuna long line operated in Indian Ocean. Indonesian Fisheries Research Journal 18:101–106. https://doi.org/10.15578/ifrj.18.2.2012.101-106

Yasemi, M., Bajgan, A.N., Parsa, M. 2017. Determining the growth and mortality parameters of longtail tuna, *Thunnus tonggol* (Bleeker, 1851), using length frequency data in coastal waters of the northern

Persian Gulf and Oman Sea, Iran. International Aquatic Research 9:215–224. https://doi.org/10.1007/s40071-017-0170-5

Young, T., Fuller, E.C., Provost, M.M., Coleman, K.E., St. Martin, K., McCay, B.J., Pinsky, M.L. 2019. Adaptation strategies of coastal fishing communities as species shift poleward. ICES Journal of Marine Science 76:93–103. https://doi.org/10.1093/icesjms/fsy140

Zhu, G., Xu, L., Zhou, Y., Chen, X. 2009. Growth and mortality rates of bigeye tuna, *Thunnus obesus* (Perciformes: Scombridae) in the central Atlantic Ocean. Revista de Biologia Tropical 57:79–88. https://doi.org/10.15517/rbt.v57i1-2.11292

Supplementary Table 1. List of questions included in the online questionnaire adopted to collect data on Fishers' perceptions (English translation).

1.	Residential District – (District drop down List)- Single Choice)	
2.	Operated harbour – (Harbour drop down List – Single Choice)	
3.	Have you been employed in a small-scale fishing boat as a crew member before starting work as a skipper ___	
4.	In which year did you start working on multi-day boats as a skipper? _____	
5.	Length (approximate feet) of the first multi-day fishing vessel you worked on___	
6.	The main fishing gear used on the first fishing vessel you worked on (Gillnets/ Longlines/ Ring Net- single choice)	
7.	As the skipper, what information do you use to choose the most productive fishing grounds? (Dropdown list- Multiple choice)	
	a.	Fisheries Department /NARA fishing ground forecasting information
	b.	Traditional knowledge (folk oceanography, i.e., sea surface colour, sea bird behaviour, etc.)
	c.	Various landmarks (rocks, etc.)
	d.	Other (describe)
8.	Choose 03 types of fish that were most abundant as you noticed throughout your time when you started serving as a skipper (multiple choice)	
	a)	Yellowfin tuns
	b)	Bigeye tuna
	c)	Marlins/ swordfish/ sail fish
	d)	Skipjack
	e)	Indian scads
	f)	Rainbow runner
	g)	Frigate tuna
	h)	Bullet tuna
	i)	Shear fish
	j)	Sharks
	k)	Trevally and related
	l)	Other fish (mention names)
9.	Mark the months of the year that fish were most abundant as you noticed throughout your time when you started serving as a skipper (List of Months- multiple choice)	
10.	Length (approximate feet) of the multi-day fishing vessel you are working now (at present)	
11.	The main fishing gear used in your vessel (Gillnets/Longlines/Ring Net- single choice)	
12.	The other (additional) fishing gear used in your vessel (Gillnets/Longlines/Ring Net- single choice)	
13.	Mark the months of the year when you can harvest the largest catches as of now (List of Months- multiple choice)	
14.	Choose 03 types of fish that are most abundant in the fish catch as you notice currently (multiple choice)	
	a)	Yellowfin tuns
	b)	Bigeye tuna
	c)	Marlins/ swordfish/ sail fish
	d)	Skipjack
	e)	Indian scads
	f)	Rainbow runner
	g)	Frigate tuna
	h)	Bullet tuna
	i)	Shear fish
	j)	Sharks
	k)	Trevally and related
	l)	Other fish (mention names)
15.	Do you notice a shift/ change of location where you could harvest a large fish catch (compared to the time you start working as a skipper)? (Yes/No)	
16.	If yes, in your opinion, what could be the reason?	
	a.	Fish moved to cooler southward areas

	b.	Fish moved to cooler deeper areas
	c.	Other (specify)
	d.	I do not know
17.	Do you observe any change in the months when you could harvest a large fish catch (compared to the time you start working as a skipper)? (Yes/No)	
18.	If yes, in your opinion, what could be the reason for the change in the high catch months?	
	a.	Fish do not occur in usual fishing depths during sea surface temperature is high
	b.	Fish do not occur in usual fishing area but moved to southward during when sea surface temperature is high
	c.	Other (specify)
	d.	I do not know