FRIGATE TUNA (*AUXIS THAZARD*)

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Taxonomy

Frigate tuna (*Auxis thazard*) is a species in the Kingdom Animalia. Frigate tuna was named *Auxis thazard* in 1800 by Bernard Germain de Lacépède and is one of four species part of the genus *Auxis* which itself is one of five genera which form the tribe Thunnini (collectively known as the tunas).

Table 1. Taxonomic hierarchy and nomenclature (source: ITIS)

Kingdom	Animalia
Subkingdom	Bilateria
Infrakingdom	Deuterostomia
Phylum	Chordata
Subphylum	Vertebrata
Infraphylum	Gnathostomata
Superclass	Actinopterygii- ray-finned fishes
Class	Teleostei
Subclass	Acanthopterygii
Superorder	Perciformes - perch-like fishes
Order	Scombroidei - tunas, mackerels, bonitos, albacores, ribbonfishes
Family	Scombridae
Genus	Auxis - frigate mackerels, frigate tunas
Species	Auxis thazard

Common names: Frigate tuna [English]; auxide [French]; melva [Spanish]; alagoduwa [Sri Lanka]

Synonyms: (source: WoRMS)

- *Auxis hira* (Kishinouye 1915)
- *Auxis tapeinosoma* (Bleeker 1854)
- *Auxis thazzard* (Lacépède 1800) (misspelling)
- *Scomber taso* (Cuvier 1832)
- *Scomber thazard* (Lacépède 1800)

Distribution & habitat

Geographic range

Frigate tuna is a highly migratory, epipelagic species found in both coastal and oceanic waters in the tropical and temperate waters (Recio et al. 2022). Adults inhabit coastal and near-coastal waters while juveniles are generally found in more distant oceanic waters (Recio et al. 2022).

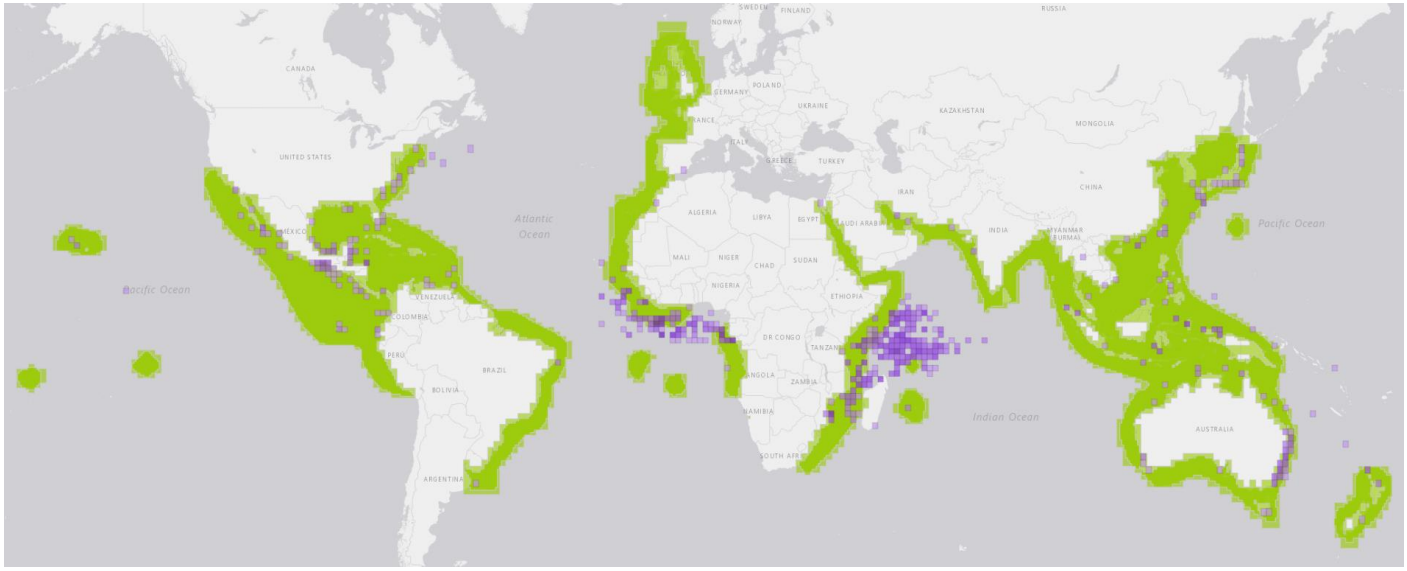

Fig. 1. Global distribution of frigate tuna according to IUCN expert range maps (green envelope) and observations (purple points) recorded in the Global Biodiversity Information Facility (purple squares). Source: www.mol.org

Movements & migrations

Frigate tuna form schools species, often with other scombrid species such as bullet tuna (Recio et al. 2022). The species usually inhabits the top 50m of the water column (Collette & Nauen 1983)**.** Adults prefer temperatures between 27-27.9°C but larvae have a wide range of temperature tolerance between 21.6°C and 30.5°C (Kumar et al. 2012). The species mainly inhabits continental shelf regions and have a localised migratory habitat (Maguire et al. 2006).

Population structure

Few genetic studies on the population structure of frigate tuna in the Indian ocean have been carried out to date.

Kumar et al. (2012) used PCR-RFLP to analyse the mtDNA D-loop region to determine the genetic variability between eight sampling locations along the Indian coast and found the presence of at least two genetic stocks of the species among these sampling locations - one in the Andaman Sea and a second around the rest of the Indian coast. However, low numbers of samples from certain regions and the limited resolution of the RFLP marker may have prevented the detection of further genetic stocks which were later identified by Kumar et al. (2012b) who concluded that there may be three genetically differentiated units along the Indian coast - one around the Andaman Sea, one around the south-

west coast of India and the last around the rest of the Indian coast by conducting sequencing of the mtDNA D-loop region using the same sample lot.

Meanwhile Johnson et al. (2015) used mitochondrial DNA analyses to investigate the genetic diversity of frigate tuna sampled from different locations in the coastal waters of northern Tanzania and found no significant genetic differentiation between locations so concluded that there is a single population in this region. However, the study had a very low sample size of 35 specimens and the spatial sample coverage was limited and so further work may be required to verify the results.

The topic of population structure has been discussed at the IOTC's Working Party on Neritic Tuna who noted that there is an absence of reliable evidence relating to the stock structure of frigate tunas and other neritic species so currently each species is assumed to exist as a single stock throughout the Indian Ocean.

Biology

Growth & morphometrics

The maximum recorded size of frigate tuna is 65 cm fork length and 1.6kg (Collette & Graves 2019). The length-weight relationships estimated by Ghosh et al. (2012) show that the species exhibits isometric growth. A summary of the length-weight and growth relationships estimated by various studies can be found in **Table 2** and **Table 3.** Estimates of maximum longevity range from 2 to 4 years (Yesaki & Arce 1991, Juan-Jordá et al. 2013, Collette & Graves 2019).

Table 2. Morphometric relationships for frigate tuna. Dressed weight (aka carcass weight) corresponds to headed and caudal peduncle-off weight (PD), i.e., the body without head, gills, guts, tail, and fins

Source measure	Target measure	Equation type	a	b	N	Source and location
Total Weight	Length L	$TW = a \times L^b$	2.462x 10^{-5}	2.8969	120	Silas and Pillai 1985 Lakshadweep Islands, India
Total Weight	Fork Length FL	$TW = a \times FL^b$	1.121x 10^{-6}	3.4649		Muthiah 1985 Mangalore, India
Total Weight	Fork Length FL	$TW = a \times FL^b$	2.196x 10^{-6}	3.5923		Balan and Yohannan 1985 Calicut, India
Total Weight	Length L	$TW = a \times L^b$	8.266x 10^{-3}	3.1718	844	Ghosh et al. 2012 India
Total Weight	Fork Length FL	$TW = a \times FL^b$	1.25 10^{-1}	3.17		Ghosh et al. 2010 India
Total Weight	Length L	$TW = a \times L^b$	5.24x 10^{-3}	3.3034		*Males* Kasim 2000 Tuticorin, India
Total Weight	Length L	$TW = a \times L^b$	1.39x 10^{-2}	3.0251		*Females* Kasim 2000 Tuticorin, India

Total Weight	Fork Length FL	$TW = a \times FL^b$	2.4321×10^{-1}	2.27658		Mudumala et al. 2018 North-West India
Total Weight	Total Length TL	$TW = a \times TL^b$	2.1×10^{-2}	2.90		Rugpan et al. 2007 Bengal, India
Total Weight	Length L	$TW = a \times L^b$	2.37×10^{-3}	3.081		Abdussamad et al. 2013 India
Total Weight	Fork Length FL	$TW = a \times FL^b$	3×10^{-6}	3.51		Siraimeetan 1985 Tuticorin, India
Total Weight	Length L	$TW = a \times L^b$	1.501×10^{-5}	3.0433		Silas et al. 1985 Cochin, India
Total Weight	Total Length TL	$TW = a \times TL^b$	8×10^{-3}	3.23		Abdurahiman et al. 2004 Karnataka, India
Total Weight	Fork Length FL	$TW = a \times FL^b$	1.8×10^{-3}	3.334		Sivasubramaniam 1966 Sri Lanka
Total Weight	Standard Length SL	$TW = a \times SL^b$	1.09×10^{-1}	3.3385	405	Herath et al. 2019 Sri Lanka
Total Weight	Total Length TL	$TW = a \times TL^b$	3×10^{-3}	3.428	373	Using commercial catch Dalpathadu et al. 2019 Sri Lanka
Total Weight	Total Length TL	$TW = a \times TL^b$	3×10^{-3}	2.540	253	Using fishery independent catch Dalpathadu et al. 2019 Sri Lanka
Total Weight	Fork Length FL	$TW = a \times FL^b$	2.8×10^{-2}	2.805		Noegroho et al. 2013 West Sumatra February
Total Weight	Fork Length FL	$TW = a \times FL^b$	2.2×10^{-2}	2.827		Noegroho et al. 2013 West Sumatra April
Total Weight	Fork Length FL	$TW = a \times FL^b$	9×10^{-6}	3.1489		Tampubolon et al. 2016 West Sumatra
Total Weight	Fork Length FL	$TW = a \times FL^b$	3.6×10^{-3}	3.4424		Tampubolon et al. 2021 West Sumatra
Total Weight	Length L	$TW = a \times L^b$	1.100×10^{-5}	3.1190		Yesaki 1982 West coast of Thailand

Table 3: Summary of von Bertalanffy growth parameters, longevity and length-at-age (in cm) estimated in studies of frigate tuna in the Indian Ocean where growth was characterised using otoliths or length-frequency (LF) analysis

					von Bertalanffy growth parameters			Length-at-age			
Area	References	Ageing method	Length range (cm)	Sample size	L_{inf} (cm)	K ($year^{-1}$)	t_o ($year^{-1}$)	1	2	3	Longevity (years)
North-West India	Mudumala et al. 2018		16-50	924	47.38	1.35	-0.23	27	42	50	
India	Ghosh et al. 2012	ELEFAN	18-55.9		57.95	1.20	-0.0075	40.7	52.7		2.49
India	Ghosh et al. 2010	ELEFAN	20-69.9	1788	46.6	0.93	-0.015	28.5	39.5	43.8	3.23
East Coast India	Kasim & Abdussamad 2003	ELEFAN			53.8	1.04		33.5	46.6		
Tuticorin, India	Kasim 2000	ELEFAN			49.0 (M) 51.2 (F)	1.30 1.30	-0.003 -0.004	35.7 37.4	45.4 57.4	48.0 50.2	
India	Pillai & Ganga 1985				54	0.9		31.4	44.5	50.0	
India	Silas et al. 1985	ELEFAN			63.0	0.49	-0.270	29.2	42.2	50.3	
West coast Thailand	Yesaki 1982	Modal progressions			47.2	0.80		26	37	43	
West Aceh, Sumatra	Hamidi & Rizal 2018		19-46	936	48.3	0.86	0.119				
West Java	Dwiponggo et al. 1986	ELEFAN			47.5	0.70		24	36	42	
West Java	Dwiponggo et al. 1986	ELEFAN			51.5	1.00		33	45	49	
Sri Lanka	Joseph & Maldeniya 1988	ELEFAN	20-49		58.0	0.54		25	39	47	
Sri Lanka	Joseph & Maldeniya 1988	ELEFAN	20-49		59.0	0.51					

Reproduction

The size at which 50% of the bullet tuna population reaches maturity (L_{50}) has been estimated to be between 29-39 cm FL which is reached at around 2 years of age (Yesaki 1982, Muthiah 1985, Ghosh et al. 2012, Tampubolon et al. 2016, Collette & Graves 2019, Recio et al. 2022).

Frigate tuna are thought to spawn throughout their range near shore and the spawning period appears to vary depending on location (Kumar et al. 2012). Spawning has been reported to occur from August to April in the southern Indian Ocean and from January to April to the north of the equator in waters with sea surface temperatures of 24°C and above (Klawe 1963, Ghosh et al. 2012, Calicdan-Villarao et al. 2017, Collette & Graves 2019). However there appear to be a few outliers to this general rule such as in Indian waters where Ghosh et al. (2012) found gravid females in Indian water in all months with the exception of December suggesting a prolonged spawning season for the species and Herath et al. (2019) found that for fish sampled around Sri Lanka, their gonadosomatic index (GSI) peaked between May-August suggesting that this is the spawning period in this region. These deviations may be due to temperature variations in different parts of the Indian Ocean (Herath et al. 2019).

Fecundity appears to vary by region and size. Ghosh et al. (2012) estimated the total fecundity of fish sampled from Indian waters to be between 697,531 - 1,163,438 with an average of 807,986 by raising the number of ova in all subsamples of mature and ripe ovaries to the total ovary weight. Fish sampled from Sri Lankan waters were estimated by Herath et al. (2019) to have a fecundity range of between 48,000-267,000 eggs while Tampubolon et al. (2016) estimated the fecundity range of fish sampled from the west coast of Sumatra to be between 24,700-220,000 eggs.

Natural Mortality

Ghosh et al. (2012) estimated natural mortality to be 1.65 in Indian waters and their analyses indicated that frigate tuna becomes more vulnerable to fishing gears after reaching 20.9cm FL and that losses to the stock before this size were due to natural causes. Hamidi & Rizal (2018) estimated natural mortality M of 1.46 per year from fish caught in the waters around Sumatra,

Trophic ecology

Frigate tuna is a nonselective feeder that feeds on small fish, squids and planktonic crustaceans (e.g., decapods and stomatopods) (Collette & Nauen 1983). Ghosh et al. (2012) found that the food items in the diet of frigate tuna comprised three major groups: crustaceans, cephalopods and finfishes. Crustacean species mainly included non-penaeid prawn, *Acetes* species and crabs while the squid *Loligo duvaucelli* dominated among the cephalopod prey species and sardines, anchovies, mackerels, scads and juvenile tunas were dominant among finfish prey species. Frigate tuna are also considered to be an important prey for a range of species, especially the commercial tunas, due to their high abundance (Collette & Nauen 1983).

The trophic level of frigate tunas has been estimated by Fishbase to be around 4.4 based on diet studies.

Markets

Frigate tuna is an important species for food security in coastal communities. Fish which are destined for international trade are often sent to canneries due to the mild taste and low cholesterol content of the flesh (Infante et al. 2004).

In the Maldives, frigate tuna is generally used to make dried or smoked fish or to make the local fish paste *rihaakuru* (Ahusan & Adam 2011). Processed dried or smoked fish is targeted to local and neighbouring overseas markets (Ahusan & Adam 2011).

Stock status

Stock status.

A new assessment was carried out in 2021 using the data-limited techniques (CMSY and LB-SPR), however the catch data for frigate tuna are very uncertain given the high percentage of the catches that had to be estimated due to a range of reporting issues. Due to a lack of fishery data for several gears, only preliminary stock status indicators can be used. Aspects of the fisheries for frigate tuna combined with the lack of data on which to base an assessment of the stock are a cause for considerable concern. Stock status in relation to the Commission's BMSY and FMSY reference points remains unknown.

Table 4. Frigate tuna (*Auxis thazard*) key management quantities.

Management Quantity	**Indian Ocean**
Most recent catch estimate (2020)	98,875 t
Mean catch over last 5 years[1] (2016-20)	98,017 t
MSY (plausible range)	unknown
Data period used in assessment	-
F_{MSY} (plausible range)	-
B_{MSY} (plausible range)	-
$F_{current}/F_{MSY}$ (plausible range)	-
$B_{current}/B_{MSY}$ (plausible range)	-

Outlook

Estimated catches have increased steadily since the late-1970s, reaching around 30,000 t in the late-1980s, to between 51,000 and 58,000 t by the mid-1990s, and steadily increasing to over 90,000 t in the following ten years. Between 2010 and 2014 catches have increased to over 105,000 t, rising to the highest levels recorded; although catches have since declined marginally to between 90,000 – 102,000 t since 2014. There is insufficient information to evaluate the effect that this level of catch or a further increase in catches may have on the resource. Research emphasis should be focused on collating catch per unit effort (CPUE) time series for the main fleets, size compositions and life trait history parameters (e.g., estimates of growth, natural mortality, maturity, etc.).

Management advice

For assessed species of neritic tunas in Indian Ocean (longtail tuna, kawakawa and narrow-barred Spanish mackerel), the MSY was estimated to have been reached between 2009 and 2011 and both F_{MSY} and B_{MSY} were breached thereafter. Therefore, in the absence of a stock assessment of frigate tuna a limit to the catches should be considered by the Commission, by ensuring that future catches do not exceed the average catches estimated between 2009 and 2011 (101,260 t). The reference period (2009-2011) was chosen based on the most recent assessments of those neritic species in the Indian Ocean for which an assessment is available under the assumption that also for frigate tuna MSY was reached between 2009 and 2011. This catch advice should be maintained until an assessment of frigate tuna is available. Considering that MSY-based reference points for assessed species can change over time, the stock should be closely monitored. Mechanisms need to be developed by the Commission to improve current statistics by encouraging CPCs to comply with their recording and reporting requirements, so as to better inform scientific advice.

The following should be also noted:

- The Maximum Sustainable Yield estimate for the Indian Ocean stock is unknown.
- Limit reference points: The Commission has not adopted limit reference points for any of the neritic tunas under its mandate.
- Further work is needed to improve the reliability of the catch series, such as verification or estimation based on expert knowledge of the history of the various fisheries or through statistical extrapolation methods.
- Research emphasis should be focused on collating catch per unit effort (CPUE) time series for the main fleets, size compositions and life trait history parameters (e.g., estimates of growth, natural mortality, maturity, etc.).
- Species identification, data collection and reporting urgently need to be improved.
- There is limited information submitted by CPCs on total catches, catch and effort and size data for neritic tunas, despite their mandatory reporting status. In the case of 2020 catches (reference year 2019), 40% of the total catches were either fully or partially estimated by the IOTC Secretariat, which increases the uncertainty of the stock assessments using these data. Therefore, the management advice to the Commission includes the need for CPCs to comply with IOTC data requirements per Resolution 15/01 and 15/02.
- **Main fishing gear (average catches 2015-2019)**: frigate tuna is mainly caught using gillnets (~40%), coastal longline and trolling, handlines and trolling (~33%), and to a lesser extent coastal purse seine nets. The species is also a bycatch for industrial purse seine vessels and the target of some ring net fisheries.
- **Main fleets (average catches 2015-2019)**: Catches of frigate tuna are highly concentrated: Indonesia accounts for around 60% of the catches, while 90% of catches are accounted for by four countries (Indonesia, Pakistan, I.R. Iran and India).

Management Measures

Conservation and Management Measures

Bullet tuna in the Indian Ocean is currently subject to a number of Conservation and Management Measures adopted by the Commission:

- Resolution 19/05 *On a ban on discards of bigeye tuna, skipjack tuna, yellowfin tuna and non-targeted species caught by purse seine vessels in the IOTC are of competence* states that all purse seiners must retain and land all dead non-targeted species including other tunas except when the fish are 'unfit for human consumption'
- Resolution 15/01 *On the recording of catch and effort data by fishing vessels in the IOTC area of competence* sets out the minimum logbook requirements for purse seine, longline, gillnet, pole and line, handline and trolling fishing vessels over 24 metres length overall and those under 24 metres if they fish outside the EEZs of their flag States within the IOTC area of competence.
- Resolution 15/02 *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPCs)* indicated that the provision are applicable to tuna and tuna-like species
- Resolution 14/05 *Concerning a record of licensed foreign vessels fishing for IOTC species in the IOTC area of competence and access agreement information* which sets out the requirements for licensing foreign vessels in the IOTC area of competence
- Resolution 10/08 *Concerning a record of active vessels fishing for tunas and swordfish in the IOTC area* which sets out the requirement for CPCs to submit a list of active vessels to the Secretariat yearly
- Resolution 11/04 *On a Regional Observer Scheme* which details the observer programme which should be implemented by CPCs to improve the collection of verified catch data and other scientific data related to fisheries for tuna and tuna-like species in the IOTC Area of Competence

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Identification guides

Identification of tuna and tuna-like species in the Indian Ocean:
https://iotc.org/sites/default/files/documents/2014/04/IOTC_IDTuna_vfinal4%28E%29.pdf

FAO Species Catalogue, Vol. 2. Scombrids of the World (1983). Courtesy of Fisheries and Aquaculture Department/Food and Agriculture Organization of the United Nations: http://www.fao.org/3/ac478e/ac478e00.htm

SPC Offshore fish identification cards for small-scale fishermen:
http://www.spc.int/DigitalLibrary/Doc/FAME/Manuals/Anon_13_TunaIDCards.pdf

Tuna caught in Indonesian waters:
https://static1.squarespace.com/static/52c1c633e4b035d7c738b56a/t/5aaa8b93f9619ada929e0366/1521126295989/Tuna-Types-Caught-in-Indonesian-Waters.pdf

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