



Review

Fishery and biology of cutlass fishes from Indian EEZ with special reference to the largehead hairtail *Trichiurus lepturus* Linnaeus, 1758 - A review

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ABSTRACT

Cutlass fishes of the family Trichiuridae form an important group in the commercial fishery in India, contributing >7% to the pelagic marine fish landings of the country during 2018-19. The largehead hairtail *Trichiurus lepturus* Linnaeus, 1758 forms a significant component of marine fish landings in India and several studies have reported its length-weight relationship, growth patterns, sex ratio, population parameters and stock status. Age and growth of *T. lepturus* were reported by the authors mostly using inverse interpolation of von Bertalanffy growth equation and ageing using hard parts is desirable to validate these observations. The present review highlights the importance of applying uniform methodologies for creating fisheries biology databases and timely publication of stock assessment results. Focussed utilisation of fisheries biology databases of commercially important fishery resources, including cutlass fishes using meta-analyses to validate and base fisheries management decisions should be considered.

Keywords: Age and growth, Condition factor, Length-weight relationship, Population parameters, Ribbonfishes, Stock assessment, Trichiuridae

Introduction

Cutlass fishes belonging to the family Trichiuridae (Order: Perciformes) are distributed worldwide in tropical and temperate oceans. James (1973) mentions 'ribbon-fishes, also called the hair-tails or cutlass fishes elsewhere, occupy an important place among the food fishes of India' referring to the usage of the term ribbonfishes (Misu, 1964; Hamada, 1971) and cutlass fishes (Tsukahara, 1962; Dawson, 1967) for fishes belonging to the genera *Trichiurus*, *Lepturacanthus* and *Eupleurogrammus* of family Trichiuridae. Nelson (1984) mentions cutlass fishes as those belonging to family Trichiuridae and comprising 10 genera, including *Trichiurus*, *Eupleurogrammus* and *Lepturacanthus*, which are commonly reported in marine fish landings from Indian EEZ. Taxonomic updates and revisions of species have been periodically adopted for reporting (Silas and James, 1960; Gupta, 1967; James, 1967a, b; Wheeler, 1969; Nakamura and Parin, 1993). The predominant species of ribbonfish (henceforth mentioned as cutlass fish) landed along the Indian coast is the largehead hairtail *Trichiurus lepturus* Linnaeus, 1758 with other species like *Lepturacanthus savala*, *Eupleurogrammus muticus*, *Eupleurogrammus intermedius*, *Eupleurogrammus glossodon*, *Trichiurus russelli*, *Trichiurus gangeticus* and *Trichiurus auriga* (Silas and James, 1960; James, 1967a,b, 1973; Silas and Rajagopalan, 1975; Rao *et al.*, 1977; Sastry, 1980; Narasimham 1983a; Mathew *et al.*, 1993). Fishery and biological parameters such as length-

weight relationship, age and growth, sex ratio and population parameters have been reported for all these species and especially *T. lepturus*, an important marine fish resource forming a seasonal fishery all along the Indian coast (Table 1).

Fishery

The fishery has progressively moved from a coastal, underexploited resource to an optimally/overexploited status with catches by shore seines, boat seines and gill nets in the earlier years supplemented or replaced by mechanised trawls and purse seines operated in deeper waters up to 50 m depths (James, 1967a,b, 1973; James and Pillai, 1994; Ghosh *et al.*, 2014; Azeez *et al.*, 2016). *T. lepturus* was reported as bycatch in trawl fisheries targeting shrimps but emerging export opportunities to south Asian markets, especially China, led to targeted fishing during the post 1990s period (Chakraborty *et al.*, 1997; Khan, 2006; Ghosh *et al.*, 2014). Fishing occurs mostly in the 25-90 m depth zones as validated through spatio-temporal mapping of cutlass fish fisheries using Geographic Information System and remote sensing technologies available presently (Azeez *et al.*, 2021a,b). Important landing centres for cutlass fishes along the east coast were Kakinada and Visakhapatnam, while it was Veraval, Mumbai and Mangalore on the west coast (Thiagarajan *et al.*, 1992; Ghosh *et al.*, 2009, 2014; Azeez *et al.*, 2016). A brief account of important crafts

Table 1. Details of published reports on fishery and population characteristics of *T. lepturus* in Indian EEZ

Reference	Area	Coast	L-W	P-P	A-G	S-A	S-R
Prabhu (1955)	Madras	East	✓		✓		
Narasimham (1970)	Kakinada	East	✓				
Narasimham (1978)	Kakinada	East		✓	✓		
James <i>et al.</i> (1978)	Mangalore	West			✓		✓
Narasimham (1983)	Kakinada	East	✓		✓	✓	
Chakraborty (1990)	Mumbai	West		✓	✓		
Thiagarajan <i>et al.</i> (1992)	Indian waters	East and west	✓		✓	✓	
Swain (1993)	Gopalpur (Orissa)	East	✓				
Narasimham (1994a)	Kakinada	East				✓	
Narasimham (1994b)	Kakinada	East			✓		✓
Reuben <i>et al.</i> (1997)	Visakhapatnam	East	✓	✓			✓
Chakraborty <i>et al.</i> (1997)	Maharashtra Coast	West				✓	
Mohite and Biradar (2001)	Maharashtra Coast	West		✓			
Abdurahiman <i>et al.</i> (2004)	Southern coast of Karnataka (Mangalore)	West	✓				
Abdussamad <i>et al.</i> (2006)	Kakinada	East			✓		
Khan (2006)	Mumbai	West				✓	
Al-Nahdi <i>et al.</i> (2009)	Oman	West	✓		✓		✓
Ghosh <i>et al.</i> (2009)	Veraval	West	✓	✓	✓	✓	
Chakravarty <i>et al.</i> (2012)	Visakhapatnam	East	✓				
Fofandi (2012)	Saurashtra	West	✓		✓	✓	
Avinash <i>et al.</i> (2014)	Veraval	West	✓		✓	✓	
Ghosh <i>et al.</i> (2014)	Northern Bay of Bengal and Northern Arabian Sea	East and west	✓		✓	✓	✓
Rajesh <i>et al.</i> (2015)	South-west cost of India (Mangalore)	West		✓		✓	✓
		23	13	6	13	11	6

L-W: Length-weight relationship; P-P: Population parameters and Vital parameters; A-G: Age and growth; S-R: Sex ratio; S-A: Stock Assessment; ✓: Information available

and gears reported to catch cutlass fish is given in Table 2. The time line of fishery for cutlass fishes indicates there has been adoption of mechanised fishing boats for targeting ribbonfish resources in the deeper waters of the continental shelf region, that it progressively shifted to multi-day fishing instead of daily fishing trips, to cut fuel costs. Operation of midwater trawls with appropriate gear modifications also has significantly helped to tap the resource which was apparently underexploited until the 1990s (James, 1973; Khan, 2006; Ghosh *et al.*, 2014).

Among the various species of cutlass fishes, *T. lepturus* dominates on the east and west coasts of India while other species such as *T. russelli*, *L. savala*, *E. muticus*, *E. glossodon* and *L. gangeticus* were reported with varying predominance along the entire coastline (James, 1973; Sastry, 1980; Meenakshisundaram *et al.*, 1986; Reuben *et al.*, 1997; Narasimham, 1994a, b; Abdussamad *et al.*, 2006). *T. lepturus* was a significant component of a multi-species commercial trawl fishery (Chakraborty *et al.*, 1997; Abdurahiman *et al.*, 2004) while reports from exploratory fishery surveys provide historic catch per unit effort (CPUE) trends (Rao *et al.*, 1977; Bapat

et al., 1982; Reuben *et al.*, 1989; Somvanshi and Antony, 1989; James and Pillai, 1990; Vivekanandan *et al.*, 1990; Nair *et al.*, 1996). The data collected from experimental surveys were from deeper waters (>50-200 m) as compared to commercial fishery operations done in inshore waters of <50 m depths and showed differences in size ranges of the cutlass fishes inhabiting the two regions. Adult ribbonfishes have been reported to undertake breeding migration to deeper waters during winter (October-December) in specific regions of the north-eastern Arabian Sea, resulting in higher catch rates (Azeez *et al.*, 2016, 2021a). The geo-spatial modelling exercise for *T. lepturus* abundance in fishing grounds of the north-eastern Arabian Sea found that euphotic depth, sea surface temperature (SST), bathymetry and sea surface height anomalies (SSHa) affect the distribution patterns and thereby the fisheries (Azeez *et al.*, 2021b).

Among the earliest publications on cutlass fishes from India, *Trichiurus haumela* (presently *T. lepturus*) off Madras coast was reported by Prabhu (1955). Population parameters were estimated by the authors mostly using the ELEFAN (Electronic Length Frequency Analysis) method

Table 2. Coast-wise study areas, landing centres, craft and gear for cutlass fishes

Reference	Area	East coast			Reference	Area	West coast		
		Associated landing centres	Craft(s)	Gear(s)			Associated landing centres	Craft(s)	Gear(s)
Prabhu (1955)*	Madras	Fish market in Madras, Calicut, Quilandy, Mangalore	-	-	James <i>et al.</i> (1978)	Mangalore	Mangalore	Trawlers	Trawl nets
Narasimham (1970)	Kakinada	-	-	-	Chakraborty (1990)	Mumbai Coast	Mumbai	Commercial trawlers	All series trawlers
Swain (1993)	Gopalpur	-	-	-	Thiagarajan <i>et al.</i> (1992)	Indian waters	Mumbai, Vizhinjam	Commercial landings	Trawls
1972	Kakinada	Kakinada	Trawlers	Trawl nets	Chakraborty <i>et al.</i> (1997)	Maharashtra Coast	Mumbai Ferry Sassoos Docks Versova	Commercial trawlers	Trawl nets
Narasimham (1978)	Kakinada	Uppada Dummulapet Kakinada Ferry	-	Shore seines, Boat seines, other trawls	Mohite and Biradar (2001)	Maharashtra Coast	Mirkavada at Ratnagiri and New Ferry Wharf Versova	Commercial trawlers	-
Narasimham (1983)	Kakinada	Uppada Dummulapet Kakinada Fishing Harbour	Non-powered catamarans and the plank built Kakinada Nava	Shore seines, Boat seines, Gill nets				-	
Thiagarajan <i>et al.</i> (1992)	Indian waters	Visakhapatnam, Kakinada, Madras, Tuticorin	Mechanised boats/ trawlers	Trawl nets, Seines, Gill nets	Abdurahiman <i>et al.</i> (2004)	Southern coast of Karnataka	Mangalore Malpe	-	Trawl nets, Gill nets, Purse seines, Indigenous gears
Narasimham (1994a)	Kakinada	Uppada Dummulapet Kakinada Fisheries Harbour	-	Boat seines, Shore seines, Gill nets and other trawls				-	
					Khan (2006)	Mumbai	New Ferry Wharf	Shrimp trawlers	Trawl nets
Narasimham (1994b)	Kakinada	-	Dol nets and trawlers	-	Al-Nahdi <i>et al.</i> (2009)	Oman	AL-Duqum	-	Traditional fishing, Hand line, Fixed and Drift gill nets
Reuben <i>et al.</i> (1997)	Visakhapatnam	Visakhapatnam Fisheries Harbour	Trawlers	-	Ghosh <i>et al.</i> (2009)	North-west Coast	Veraval, Mumbai	Trawlers	-
Abdussamad <i>et al.</i> (2006)	Kakinada	Kakinada Fisheries Harbour	Trawlers	Gill nets and Trawl nets	Ghosh <i>et al.</i> (2014)	Saurashtra	Veraval	Trawlers, Gill nets	-
Ghosh <i>et al.</i> (2014)	Northern Bay of Bengal	Visakhapatnam, Paradeep Fisheries Harbour	Multiday trawlers	Midwater trawl nets with 2-2.5 cm codend mesh size	Ghosh <i>et al.</i> (2014)	Northern Arabian Sea	Veraval, Mangalore, Porbander & Okha Fisheries Harbours/ Landing centres	Multiday trawlers	Midwater trawlers with 4-6 codend mesh size
					Rajesh <i>et al.</i> (2015)	Off Karnataka Coast	Mangalore	-	Trawlers and Gill nets

*: For *T. haumela*; - : No information

in FAO-ICLARM Stock Assessment Tools (FiSAT) programme (Sparre and Venema, 1998). A full stock assessment exercise using the estimated parameters with Virtual Population Analysis (VPA) and Thomson and Bell Yield model was done only in a few among these reports. Age and growth of *T. lepturus* were mostly reported by the authors using inverse interpolation of von-Bertalanffy growth equation. These reports were used to deduce the best limits of L_{∞} , K and other population parameters based on the cumulative frequency method (Appendix I&II). The reports of Fofandi (2012) and Avinash *et al.* (2014) are probably based on the same database of 2008-2009 period with almost identical results and conclusions by both authors. Several studies have data pertaining to one year (James *et al.*, 1978; Swain, 1993; Narasimham *et al.*, 1994a, b; Chakravarty *et al.*, 2012; Avinash *et al.*, 2014) and results derived may be biased as data collection for at least 3 years period is considered desirable. Similarly, for studies spanning more than 5 years, fishery related factors such as 'technology creep' and shift/expansion in fishing grounds, size groups caught in gears and impacts thereof on the local stock, as well as environment related factors are to be given due consideration. Abdussamad *et al.* (2006) had reported that *T. lepturus* with spent and resting stage gonads had decreased from 36% in 1995-96 period to 7% in 1998-99 in the catch off Kakinada coast. Reports on environment and climate change disruptions that may directly or indirectly affect cutlass fish fishery resources through effect on their biological functions (feeding, reproduction, stock size and distribution) are not available but need to be looked into, considering the economic importance of *T. lepturus* resource in Indian seas.

Length-weight relationship (LWR) and condition factor (CF)

Length-weight relationships (LWR) in *T. lepturus* of the form $w=al^b$, with usual notations were fitted using the Le-Cren (1951) method in several studies (Table 3). The first report on LWR of *T. haumela* by Prabhu (1955) is pertaining to the period 1947-49 with samples from various fish markets. While most reports indicated that no significant difference exists in the growth between males and females of *T. lepturus* along both coasts, exceptions included the report of Al-Nahdi *et al.* (2009) and Ghosh *et al.* (2014). The 'b' values were more than 3 except for the report of Khan (2006) and Swain (1993) who reported 'b' value of 2.398 off Gopalpur which he related to the peculiar local conditions of food availability and feeding intensity. Since *T. lepturus* is a voracious carnivorous predatory fish, it seems to grow well in the sea with growth equally good off both the coasts. Misu (1964) studied the LWR of *T. lepturus* populations using length (snout to anal vent) and weight, in East China Sea and Yellow

Sea Pro-hai Bay and concluded that there were significant differences within sexes between the two populations. A multivariate modelling approach was used to reveal the spatio-temporal factors influencing condition factor and length-weight relationship of *T. lepturus* in the Arabian sea off Oman coast (Al Nahdi *et al.*, 2021). Reports from Indian waters suggest differences in condition factor reported to be influenced by the sampled area, size distribution, sex and maturity stage of the fishes sampled and the feeding dynamics (Narasimham, 1970; Reuben *et al.*, 1997). The productivity of the fishing grounds appears to be a major factor as the cutlass fishes are voracious, carnivorous predators (Ghosh *et al.*, 2014). Koya *et al.* (2018) reported that in *T. lepturus*, the maximum feeding intensity coincided with its spawning period, presumably to meet the high energy requirements associated with gonad maturation and breeding activities. It has been suggested that it is necessary to synthesise all length-weight relationships addressing the seasonal, geographic and inter-annual variations in a species, to decide if it shows allometric or isometric growth, based on the mean 'b' of the various LWRs (Froese, 2006). This is a valid point of action as LWR of the same species has been reported as both allometric and isometric when various subsets of the sampled fish (among sexes, east coast versus west coast, juveniles and adults) were compared (Ghosh *et al.*, 2014). Also, synthesising the information found in these often-stand-alone reports on length-weight relationship and condition factor can be factored in fisheries management strategies.

Length-weight relationship of *L. savala*, *L. gangeticus*, *E. muticus*, *E. glossodon*, *T. russelli* and *T. auriga* are available (Table 4). The length-weight relationship of *E. glossodon* was derived from a small sample of 102 fishes collected from a seasonal fishery (Narasimham, 1983a). Positive allometric growth ($b>3$) has been reported for *L. savala* in the Bay of Bengal (BOB) ecosystem in several studies (Gupta, 1967; Azadi and Ullah, 2008). The relative condition factor (k_n) reported for *L. savala* in relation to its size, sex, maturity stage and feeding intensity (Swain, 1993; Azadi and Ullah, 2008; Rizvi *et al.*, 2010; 2012; Sangita and Rathod, 2014a) indicate biological factors such as reproduction and feeding status of the fishes sampled, have a major influence on the condition factor estimates. Narasimham (1974) concluded that high feeding intensity influences high k_n values observed during October-June months and low values during March-April period for *E. muticus* off Kakinada. In a comparison of the relative condition factor among male and female *L. savala*, it was reported that females had higher k_n values (Rizvi *et al.*, 2012). It was also reported that k_n values in *L. savala* are more affected by gonadal maturation than feeding intensity and *vice versa* in *E. muticus*. In the Arabian Sea, higher k_n

Table 3. Condition factor of *T. lepturus* along Arabian Sea and Bay of Bengal

Data collection period	Reference	Area	Males			Females			Significance for sexes	Pooled value of b	Total N
			Size range (mm)	n	b	Size range (mm)	n	b			
1947-49	Prabhu (1955)	Madras	120-560*	-	-	-	-	-	-	3.0819	174
1966-69	Narasimham (1970)	Kakinada	355-960	185	3.4169	352-1090	143	3.43	Not significant	3.4258	328
1967-71	Narasimham (1983)	Kakinada	-	-	-	-	-	-	-	3.4637	-
1987	Swain (1983)	Gopalpur (Orissa)	612-291	137	2.562	75-257	79	2.48	Not Significant	2.3980	216
1985-89	Thiagarajan <i>et al.</i> (1992)	Indian waters	220-750	118	2.880	210-970	194	3.12	Not significant	3.052	312
1989-92	Reuben <i>et al.</i> (1997)	Visakhapatnam	320-810	363	3.2454	290-101	406	3.298	Not significant	3.2779	769
1999-2001	Abdurahiman <i>et al.</i> (2004)	Southern Karnataka Coast	360-900	200	2.819	390-1030	200	3.02	Not Significant	-	400
2006-07	Chakravarty <i>et al.</i> (2012)	Visakhapatnam	-	102	2.9925	-	102	2.93	Not significant	3.0348	204
2007-10	Ghosh <i>et al.</i> (2014)	Northern Bay of Bengal	200-1099*	1328	2.8702	-	1616	3.22	Significant	-	3089
1997-2001	Khan (2006)	New Ferry Warf Mumbai	200-560*	-	-	-	-	-	-	2.1518	120
2007-2010	Ghosh <i>et al.</i> (2014)	Gujarat Coast (Veraval)	260-1259*	1316	3.0547	-	1752	3.26	Significant	-	3146
2008-2009	Avinash <i>et al.</i> (2014)	Saurashtra Coast (Veraval)	520-1199	464	3.5447	-	544	3.69	Not significant	3.6163	1008

* Both sexes combined

Table 4. Condition factor in length-weight relationship of other cutlass fish species along the Indian coast

Data collection period	Reference	Region	Species	Males		Females		Pooled value	Size range (mm)		Total
				n	b	n	b		Males	Females	
March 1966	Narasimham (1974)	Kakinada	<i>E. muticus</i>	84	3.5560	96	3.48	3.52	-	-	180
1966-1973	Narasimham (1983a)	Kakinada	<i>E. glossodon</i>	-	-	-	-	2.82	-	-	-
1997-1999	Rizvi <i>et al.</i> (2010)	Mumbai	<i>L. savala</i>	123	3.1671	220	3.44	3.61	282-585	315-623	608
Feb-Mar 1988	Grace <i>et al.</i> (1993)	Kerala Coast	<i>T. auriga</i> *	34	3.2948	76	2.71	-	176-344	217-370	-
June 2006-May 2007	Chakravarty <i>et al.</i> (2012)	Visakhapatnam	<i>T. lepturus</i> <i>L. savala</i> *	101	2.8748	-	2.51	2.71	-	-	206
Dec 1997-May 1999	Rizvi <i>et al.</i> (2012)	Mumbai	<i>E. muticus</i> <i>L. savala</i>	-	2.8788 3.1671	-	3.07 3.44	-	-	-	217 220
Feb 2012-Mar 2013	Pallavi <i>et al.</i> (2013)	Ratnagiri coast	<i>L. savala</i>	-	3.0311	-	3.36	3.32	100-700	-	-
Feb 2012-2013	Pallavi <i>et al.</i> (2014)	Ratnagiri coast	<i>L. savala</i>	-	-	-	-	3.11	-	-	680
Dec 2011-Dec 2012	Sangita and Rathod (2014a)	Karwar Coast	<i>L. savala</i>	-	3.4406	-	3.4112	-	100-630	-	-
1974-1976	Sastry (1980)	Kakinada	<i>L. gangeticus</i>	57	2.9	54	2.8	64-143	86-157	-	-
1974-1976	Sastry (1980)	Kakinada	<i>T. russelli</i>	48	2.8	49	3.5	238-442	262-535	-	-

*Significant difference

values for *L. savala* in the length groups 321-340, 581-620 and 261-300 mm along Ratnagiri coast (Pallavi and Mohite, 2014) and 150-200, 300-350 and 500-550 mm off Karwar (Sangita and Rathod, 2014a) was reported. The length-weight relationship of *T. auriga* obtained during a trawl survey by FORV *Sagar Sampada* with HSDT III trawl net having 40 mm cod end mesh size, showed significant differences among the sexes (Mathew *et al.*, 1993). Sastry (1980) reported the LWR for *L. gangeticus* and *T. russelli* which indicated significant variation among sexes only in the latter species. In most of these reports, the terminologies length-weight relationships and condition factor are used interchangeably. Condition factor can be used to compare relative heaviness among samples of same age/season/sex while the LWR is used to estimate weight from length or *vice versa* (Froese, 2006) and both have important bearing on fish stock productivity and associated fisheries management advisories (Al Nahdi *et al.*, 2021). Information on spatio-temporal variations in condition factor and LWRs among different growth phases (juveniles, adults) in conjunction with available information on distribution patterns of cutlass fishes in the fishing grounds (Azeez *et al.*, 2021a) can be usefully employed in devising sustainable fish harvesting strategies.

Age and growth

The age-length of *T. lepturus* from available reports were compiled and increments were calculated for each year (Table 5). These growth increments seem to be closer to best median limits of lengths for each age group estimated (Table 6) as given in Appendix 1. Except for the studies by Prabhu (1955), James *et al.* (1978) and Narasimham (1978) all other authors have estimated the mean lengths at different ages by inverse interpolation of von-Bertalanffy growth equation for $t = 1, 2, 3, 4$ and 5 years. The estimates of maximum life span of more than 10 years for *T. lepturus* hint at possible incorrect estimates of K and require validation based on ageing using hard parts. Tampi *et al.* (1968) in a note on *T. lepturus* off Madras reported that it measures 30 cm at the end of 1 year and the fishes measuring more than 80 cm are at least 4 years old. Snout-ventral lengths were considered for measuring in certain studies (Prabhu, 1955; Narasimham, 1978; Reuben *et al.*, 1997; Khan, 2006), while others have used total length. When growth parameter estimates among studies are compared, due noting of the data collection protocols (gear and related catchability effects; size groups and their measurement units and seasons) employed in the respective studies is recommended. It is also suggested that the standard measurement unit of snout tip-anal vent should be uniformly adopted as the tails of ribbonfish are fragile and easily broken leading to measurement errors (Nakamura and Parin, 1993).

The comparison is among regions having different environmental and ecological conditions such as sea temperature variations, food web characteristics as well as fisheries related factors such as fishing grounds, effects of cod end mesh size and selectivity of gears, which determine the size of fish caught. Hence, due consideration of these factors is required when comparisons of the estimates are made. The report by Rajesh *et al.* (2015) mentions two sets of estimates of L_{∞} (116.75 and 134 cm) and annual growth rate K (0.65 and 0.82) for the same dataset without any apparent reason. Comparing the Kakinada (east coast, Bay of Bengal) and Mumbai (west coast, Arabian Sea) coasts, growth increment of *T. lepturus* is marginally less in the former, especially after the second year. The mean asymptotic lengths and mean K values vary for both the coasts. Life span of *T. lepturus* is found to be relatively higher along west coast (5.12 years). In another context, James (1967) and Narasimham (1978) while citing Misu's (1964) work remarked that the growth rate of *T. lepturus* from 2nd year onwards in the East China Sea and Yellow Sea appears to be much slower in comparison with the growth rate of the same species in Indian waters (Table 7). The growth performance Index, phi prime (Φ) was routinely reported by various authors with no specific explanation for the estimates. Although Φ is a widely adopted metric (Sparre and Venema, 1998), use of this metric for comparison among populations has been recommended only with due caution to bias introduced by genetic factors, environmental factors and fishing pressure operating on the respective stocks (Zivkov *et al.*, 1999; Ragonese *et al.*, 2012).

Age-length data of other cutlass fishes have also been reported. The estimates of Rizvi *et al.* (2003a) on the lengths at the end of I, II, III years for *L. savala* are 39.98, 56.73 and 67.74 cm respectively, and the corresponding estimates by Pallavi *et al.* (2013) are 43, 58 and 65 cm. Both the sets of estimated lengths indicate an average increase of 16 cm from I year to II year and 7 cm from II year to III year which are lesser than that reported for *T. lepturus* (29 and 19 cm respectively). Rizvi *et al.* (2003b) also reported the estimate of lengths of *E. muticus* as 41.9, 64.1 and 73.9 cm respectively at the end of I, II and III years with growth increments of 12.2 and 9.8 cm which are comparatively lesser than the species *L. savala* off Mumbai coast. James (1967a) estimated 21, 33 and 43 cm length-at age during 1, 2 and 3 years respectively and life span as 4+ years for *E. glossodan*.

Most of the studies on age and growth of cutlass fishes in India are length-based methods using modal progression analysis and inverse interpolation of the von Bertalanffy growth equation. Validation of these results through independent ageing estimates using hard parts

Table 5. Estimated age, annual growth increments and lifespan of *T. lepturus*

Reference	Region	L _∞ (cm)	K	Length (cm) at age (years)					Growth increment (cm) for year				Estimated life span (years)	
				1	2	3	4	5	1	2	3	4		
Prabhu (1955)	Madras	-	-	18	30	-	54	-	-	-	-	-	-	4+
James <i>et al.</i> (1978)	Mangalore	-	-	39	58.7	70.8	82.8	-	-	-	-	-	-	-
Narasimham (1978)	Kakinada	145.4	0.29	41.6	69.0	88.5	102.4	113.2	25.9	19.3	14.5	10.9	10.34	
Narasimham (1983b)	Kakinada	-	0.29	-	No age length data	-	-	-	-	-	-	-	10.34	
Narasimham (1994)	Kakinada	138	-	-	No age length data	-	-	-	-	-	-	-	10	
*Thiagarajan <i>et al.</i> (1992)	Indian waters (East Coast)	132.0	0.63	55.0	87.0	105.0	115.0	-	32.0	18.0	10.0	-	4.76	
©Narasimham (1994b)	Kakinada	145.4	0.29	36.5	63.8	84.3	99.5	111	27.3	20.5	15.2	11.5	-	10.36
©Reuben <i>et al.</i> (1997)	Visakhapatnam	106.8	0.61	48.9	75.4	89.8	97.7	102	26.5	14.4	7.9	4.3	4.90	
*Abdussamad <i>et al.</i> (2006)	Kakinada	128.2	0.72	65.8	97.8	113.4	-	-	32.0	15.6	-	-	4.17	
Avinash <i>et al.</i> (2014)	Northern Bay of Bengal	114.4	0.28	29.3	50.1	65.8	77.7	86.6	20.8	15.7	-	-	10.71	
Thiagarajan <i>et al.</i> (1992)	Indian waters (West Coast)	145.5	0.62	67.0	103.2	122.0	135.0	-	36.2	18.8	13.0	-	4.90	
**Chakraborty (1990)	Mumbai	129.7	0.50	51.2	82.5	101.3	112.3	119.2	31.3	18.8	11.0	6.9	5.96	
©Chakraborty <i>et al.</i> (1997)	Maharashtra Coast	148.0	0.4	48.8	81.5	103.4	118	128	32.7	21.9	14.6	10	7.50	
** Mohite and Biradar (2001)	Maharashtra Coast	128.0	0.50	50.4	80.9	99.4	111	117	30.5	90.5	11.6	6	6.00	
**Khan (2006)	Mumbai	127.3	0.67	65.1	98.0	114.7	-	-	32.9	16.7	-	-	4.48	
©Al Nahdi <i>et al.</i> (2009)	Oman	127.4	0.39	41.1	68.9	87.9	101	109	27.8	19.0	13.1	8.0	7.00	
	Oman®	129.0	0.46	47.6	77.6	96.5	109	116	30	18.9	12.5	7		
Ghosh <i>et al.</i> (2009)	Veraval	134.1	0.29	35.3	60.2	78.8	92.7	103.1	24.9	18.6	13.9	10.4	10.35	
Avinash <i>et al.</i> (2014)	Veraval	131.25	0.13	17.2	31.1	43.2	54.0	63.4	14.7	11.3	10.8	9.4	21.0	
Avinash <i>et al.</i> (2014)	Northern Arabian Sea	131.6	0.15	19.6	35.2	48.6	60.2	70.1	15.6	13.4	11.6	9.9	20.0	
©**Rajesh <i>et al.</i> (2015)	Karnataka	134.0	0.82	74.9	108	123	129	132	33.1	15	6	3	4.4	
Median limits :-		125-134	0.4-0.7	-	-	-		Growth increments:	26.63	16.62	12.11	9.48	4-7	

* : The best set of parameters for east coast

** : The best set of parameter for west coast

® Otolith based ageing method

© As calculated from growth parameters reported by authors

such as otoliths (whole/sectioned) and vertebral centra are needed. James (1967a) noted the growth rings on otoliths were indistinct and hence difficult to decipher. However, advanced otolith processing and microscopic techniques for fish ageing are available presently and this task will be easier to accomplish, than in the past. Fish stock assessment with information on age classes is considered

more reliable than ones that use length based estimates of age (Hoggarth *et al.*, 2006). Studies on ageing of *T. lepturus* from South China sea, suggested rings formed in sagittal otoliths were in response to reduced water temperatures and not correlated to spawning period as previously believed and a 15-year life span was estimated (Kwok and Ni, 2000). Al Nahdi *et al.* (2009) counted up to

Table 6. Centres along the Indian coast for which best age, length and life span of *T. lepturus* have been reported

Length at age	East coast						West coast						Best median limits of lengths (cm)	Growth increments
	Kakinada (Thiagarajan <i>et al.</i> , 1992)		Kakinada (Abdussamad <i>et al.</i> , 2006)		Mean		Mumbai (Chakraborty, 1990)		Mumbai (Khan, 2006)		Mean			
	L	I	L	I	L	I	L	I	L	I	L	I		
1 year	55	32	65.8	32	60.4	32	51.2	31.3	65.1	32.9	58.15	32.1	Less than 59	-
2 years	87	18	97.8	15.6	92.4	16.8	82.5	18.8	98.0	16.7	90.25	17.8	60-89	29
3 years	105	10	113.4	7.6	109.2	8.8	101.0	110	114.7	11.2	108.0	11.0	90-109	19
4 years	115	6.3	121.0	5.5	118.0	5.9	112.3	6.9	125.9	7.5	119.0	7.2	110-119	9
5 years	121.3	4.0	126.5	3.9	123.9	4.0	119.2	3.5	133.4	5.0	126.3	4.23	120-126	6
6 years	125.3	-	130.4	-	127.9	-	122.65	-	138.4	-	130.5	-	127-131	4
L_{∞}	132	-	128.2	-	130.1	-	129.7	-	127.3	-	128.5	-	-	-
K	0.63	-	0.72	-	0.675	-	0.50	-	0.67	-	0.59	-	-	-
Estimated age (years)	4.76	-	4.17	-	4.65	-	5.96	-	4.48	-	5.12	-	-	-

Note: Though Mohite and Biradar (2001) for Maharashtra coast and Rajesh *et al.* (2015) for South-west coast of India (Mangalore) reported the best values of L_{∞} , K and T_{max} (Table 5), these were not considered here to get the best estimate of age length data, since the authors have not reported the mean lengths for each age.

L: Length (cm); I: Growth increment from previous to next age (cm). Details of estimation of best median limits of lengths given in Appendix 1

Table 7. Length (cm) at age (year) of *T. lepturus* other than Indian seas and based on hard parts ageing

Study period	Reference	Region	L_{∞} (cm)	K (Annual)	t_0	Age (Years)				
						1	2	3	4	5
1954-57	Misu (1964)	Japanese Seas	45.6	0.41	0.44	15.3	25.4	32.1	36.7	39.6
1962-64	Du <i>et al.</i> (1988)	Taiwan Strait	47.7	0.29	-0.634	4.8	15.6	23.7	29.7	34.2
1965	Kosaka <i>et al.</i> (1967)	Suruga Bay, Japan	43.9	0.52	-0.413	14.7	22.0	27.5	31.6	34.7
1968-69	Hamada (1971)	East China and Yellow Sea	76.6	0.14	-0.266	12.4	20.8	28.1	34.4	40.0
1976-77	Chen and Lee (1982)	Taiwan coastal sea	50.2	0.27	-0.220	14.0	22.6	29.2	34.1	38.0
1996-97	Kwok and Ni (2000)	Hong Kong coastal waters	58.9	0.17	-0.682	14.6	21.6	27.4	32.3	36.5
-	Tsukahara, 1962	Japan Seas	-	-	-	24.0	56.8			
1958 -60	Dawson (1967) ^{1*}	Northern Gulf of Mexico	-	-	-	40.0	70.0			

Adapted from Kwok and Ni (2000)

@ Pre anal/ snout-vent lengths

^{1*} Length total length frequency based modal progression analysis estimate

7 rings in the sagittal otoliths of *T. lepturus* and assuming them to be annual rings reported its maximum age as seven years. The age of *T. lepturus* from Indian waters is estimated at 5-6 years only based on von Bertalanffy growth function applied to length frequency data (Table 5). Chang and Maunder (2012) have found large variations in growth parameters of dolphinfish estimated by different methods (otolith, scale, length frequency) as well as that among different regional stocks. Considering the similar wide range of possible life spans reported by various authors using growth parameters from otolith and length frequency based methods, a validation of the same following standard methodology is desirable.

Sex ratio

Sex ratio of *T. lepturus* has been reported in several studies with size-wise and seasonal variations (James

et al., 1978; Reuben *et al.*, 1997; Ghosh *et al.*, 2014; Rajesh *et al.*, 2015). Narasimham (1994a) reported the sex ratio for *T. lepturus* in relation to lengths with males dominating in the range of 26-70 cm, equal proportion of males and females at 74 cm, and females dominating in the 78-94 cm length groups. According to Reuben (1997), during periods of intense seasonal monsoon upwelling, cutlass fishes move to upper waters and are more vulnerable to fishing by seines, which are operated in shallow waters, than in trawls. There is regular migration of *T. lepturus* in relation to spawning and feeding activities, which in turn determines their vulnerability to various fishing gears in the different fishing grounds. The larger sized spawning component is reported to move to deeper waters and become vulnerable to fishing by mid-water trawls. Although sex-specific depth preferences of cutlass fishes were not reported, further investigations may be required.

Sangita and Rathod (2014b) have reported seasonal and size-wise differences in sex ratio in *L. savala* samples collected from trawls for a period of one year.

Population parameters

Stock parameters that include details on lengths at recruitment (L_r), first capture (L_c) and first maturity (L_m) have been reported for *T. lepturus* based on fish samples at different fishery centres (Table 5) and mostly reflect the fishery characteristics of the particular locality. The length frequency based methods estimated by various authors were in the range of 20.9-26.9; 32.04-59.8 and 42.5-61.2 cm respectively for length at recruitment, length at first capture and length at first maturity. Mean lengths for L_r , L_c and L_m were calculated to be 24.2, 44.9 and 50.6 cm

respectively. Variations (random and non-random) exist in the periodically estimated parameters and the ranges for growth parameters and other population parameters estimated were 125 to 134 cm for L_∞ , 0.4 - 0.7 per year for K and 4-7 years for life span of *T. lepturus*. Similarly, for other parameters, the median value lies in the following limits: $M=0.8 - 1.1$; $Z=2.4 - 3.0$, $F=1.6 - 1.9$; $E=0.60 - 0.79$ and $E_{max}=0.4 - 0.6$. It is observed from Table 8 that there was higher fishing pressure during the period 1985-1987 and 1990-2000 in certain fishing areas. The authors attributed the reason for higher pressure mainly to the operation of industrial trawlers for catching shrimps. Population parameters of *E. muticus* were reportedly estimated with Bhattacharya method and Gulland's plot (Pauly, 1983) with L_∞ estimated at 872 mm and annual

Table 8. Estimated population parameters of *T. lepturus*

Reference	Data collection period (years)	Area / Region	Estimated parameters									
			M	F	Z	$E = \left[\frac{F}{Z} \right]$	L_∞ (cm)	K (Per year)	$\left[\frac{3}{K} \right]$ year	E_{max}	Φ	
Narasimham (1978)	1965-70	Kakinada	-	-	-	-	145.4	0.29	-	-	3.786	
Narasimham (1983)	1967-71	Kakinada	0.90	0.30	1.20	0.25	-	0.29	10.3	-	-	
Chakraborty (1990)	1979-82	Mumbai	1.05	0.91	1.96	0.46	129.7	0.50	5.36	-	3.92	
Thiagarajan <i>et al.</i> (1992)	1985-89	Indian waters (East Coast)	1.04	2.20	3.23	0.66	132.0	0.63	4.6	0.63	-	
Thiagarajan <i>et al.</i> (1992)	1985-89	Indian waters (West Coast)	1.04	2.7	3.74	0.72	135.5	0.5	6.0	0.4	-	
Narasimham (1994b)	5/1986- 4/87	Kakinada	0.46	2.70	3.16	0.82	145.4	0.29	10.1	-	-	
Reuben <i>et al.</i> (1997)	1989-92	Visakhapatnam	0.89	1.52	2.42	0.63	106.8	0.61	4.9	-	3.84	
Chakraborty <i>et al.</i> (1997)	1982-90	Maharashtra Coast	0.75	1.87	2.62	0.71	148.0	0.4	7.5	0.68	3.86	
Mohite and Biradar (2001)	1995-97	Maharashtra Coast	0.77	1.89	2.66	0.71	128.0	0.5	6.0	-	-	
Khan (2006)	1997-2001	Mumbai	0.93	2.96	3.64	0.78	127.3	0.67	4.48	0.60	-	
Abdussamad <i>et al.</i> (2006)	1995-2000	Kakinada	0.98	3.34	4.32	0.77	128.2	0.72	4.17	0.53	-	
Ghosh <i>et al.</i> (2009)	2003-06	Veraval	0.51	0.93	1.44	0.64	134.1	0.29	10.29	0.40	3.72	
Al-Nahdi <i>et al.</i> (2009)	1/2001-1/2002	Arabian Sea (Oman)	-	-	-	-	127.4	0.39	-	-	-	
Ghosh <i>et al.</i> (2014)	2007-2010	Northern Arabian Sea	0.34	0.18	0.52	0.35	131.6	0.15	20.0	0.75	3.41	
Ghosh <i>et al.</i> (2014)	2007-2010	Northern Bay of Bengal	0.54	0.81	1.34	0.60	114.4	0.28	10.71	0.58	3.56	
Rajesh <i>et al.</i> (2015)	2007-2012	Mangalore	0.91	2.41	3.32	0.70	134.0	0.82	4.6	0.70	3.94	
Somvanshi and Antony (1989)	1977	Indian EEZ (North-West Coast)	0.80	0.99	2.16	0.55	109.0	0.64	-	-	3.8810	
Meenakshisundaram <i>et al.</i> (1986)	1967-71	Andhra Coast	0.90	0.30	1.20	0.17	-	-	-	-	-	
Best range			0.8-1.1	1.6-1.9	2.6-3.0	0.60-0.79	125-134	0.4-0.7	4-7	0.4 - 0.6	3.7-3.8	

- : Not available

K as 0.78 (Rizvi *et al.*, 2003b). The maximum life span estimates of the two species *L. savala* and *E. muticus* are between 4-6 years based on modal length progression of the size groups landed (Rizvi *et al.*, 2003a,b, 2005, 2010; Pallavi *et al.*, 2013).

Stock assessment

There are three situations which explain the exploitation status of a fishery. If the present effort (E_{pre}) is more than E_{max} (estimated from relative yield per recruit curve or MSY curve), or annual average catch is more than MSY or relatively high estimates of fishing mortality (F) from length converted catch curve of the virtual population analysis (VPA) procedure, the fishery is said to be under higher fishing pressure. Exploitation rate (E) up to 0.5 has been considered as sustainable (Chakraborty, 1990; Hoggarth *et al.*, 2006) and by this metric most of the fisheries were reported as overexploited since $E > 0.5$ (Reuben *et al.*, 1997; Abdussamad *et al.*, 2006; Ghosh *et al.*, 2014). Some studies that have covered just one year of data collection have also reported the fishery as underexploited (Avinash *et al.*, 2014) justifying the suggestion for data collection over a longer period of 3-5 years. It is observed that the authors have explained the stock assessment results and compared it with earlier studies irrespective of time lag, area of fishing and methods used for assessing the stock status. Most reports claim overexploitation of the resource (except in 2014) and suggest measures such as reduction of effort for the said fishing area by certain percentage of present effort (E_{pre}), reduction of fishing mortality F or adjust cod-end mesh size singly or in combination with effort reduction in number of fishing units operated or fishing hours (Table 9). *T. lepturus* is often bycatch in trawl fishing operations for shrimps with 10-15 or 15-20 mm cod-end mesh size within 50 m depth zones and forms part of a multispecies catch mix (Dineshbabu *et al.*, 2012). Reduction in fishing effort and increase in mesh size of cod end of trawl nets targeting cephalopods, shrimps and other demersal resources from 10-40 mm have been suggested (Ghosh *et al.*, 2009), but such suggestions can hardly be implemented effectively in multi-species, multi-gear fisheries. Whether the suggestions made by the authors regarding reduction of effort are equally applicable to all the species occurring in these mixed fisheries and the socio-economic consequences thereof when the sector is subject to such uniform effort reduction, is the moot point and requires suitable prediction models to be developed.

Multi-day fishing boats fishing in different parts of the Indian EEZ are landing cutlass fishes in multiple maritime states, with no associated geolocation data of the fishing areas. Hence, adequate caution should be exercised in using estimated marine fish landings data *per se* to estimate fish stock status and attribute overexploited/

underexploited status. Validated fish landings data following spatio-temporal sampling designs and procedures have been investigated for small-scale single haul/single day fishing fleets (Padua *et al.*, 2021) but does not apply adequately to multi-day trawl fishing fleets, which account for major volumes of cutlass fishes landed in India. In the absence of onboard observer programmes of fisheries management bodies (presently State Fisheries Departments), collection of geo-spatial data from fishermen/ fleet operators with incentives provided in return for such data sharing is an option. This can be used to supplement data from catch sampling programmes at landing centres.

Conclusion

Cutlass fishery in India is a multi-species, multi-gear and multi-locational seasonal fishery and mostly single species stock assessments are made based on fishery data collected from the fishery centres. Several stock assessment models suited for data rich to data-limited situations are now available (Cadurin and Dickey-Collas, 2014) and these have to be applied appropriately. Adequate attention to the species specific population dynamics (growth, natural mortality, recruitment, migratory behaviour, genetic stocks and mixing patterns), fishery related factors (selectivity, temporal variation in catchability) as well as sampling procedures employed have to be factored in the conclusions drawn from regional stock assessments. Considering the unique traits of the cutlass fishes (*e. g.*, tails easily broken, migratory behaviour affecting distribution patterns and availability to fishing gears, prolonged spawning period) a Good Practices guidelines for data collection of length frequency and biological data that is used for assessments, is suggested to enable database uniformity among regions. Minimum data collection period of 3 years (considering medium life span of <15 years for this group) and periodical regional assessments based on such data collected is required. Lack of any conclusive regional information of the age and growth of *T. lepturus* and other cutlass fishes based on hard parts, is to be addressed, as most reliable stock assessment models are age based. Several species of trichiurid fishes are represented in the fishery and identification of closely resembling species is sometimes difficult with catches often denoted as *Trichiurus* spp. in such databases. Correct species level identifications are a pre-requisite to advanced stock assessment routines and mitogenomic sequence data generated for *T. lepturus* (Mukundan *et al.*, 2020) may be helpful to confirm the dominance of *T. lepturus* in the fisheries along the Indian coast. Technologies such as remote sensing and GIS mapping, satellite tags and population genetic studies can also be used to enhance the understanding of the cutlass fishes and their management as a valuable fishery resource in the Indian EEZ.

Table 9. Conclusions drawn from length based stock assessment for *T. lepturus* along Indian coast

Authors (s)	Area and data period (yrs)	Annual average catch (t)	F	MSY (t)	E Present	E Maximum	Reported status of exploitation	Conclusions drawn and management measures suggested	
East Coast	Narasimham (1983)	Kakinada 1966-73	0.3	-	0.25		Under-exploitation	At present F of 0.3 with Lc of 20 cm (approx. 4 month old fish), the Y/R is 23 g. Maximum Y/R of 26 g at F=0.6 is possible.	
	Thiagarajan <i>et al.</i> (1992)	Bay of Bengal 1985 -89				0.66		There is overfishing and effort to be reduced by 33%	
	Narasimham (1994)	Kakinada 1986-87	1501	2.7	-	0.82	Heavy exploitation in present fishing grounds of <50 m depths	Present Lc is 42 cm and increasing it to 87.2 cm will give maximum Y/R at current F levels. No further increase in effort recommended. MSY = 196.7 g is obtainable at F =0.46	
	Abdussamad (2006)	Kakinada 1995-2000	3500	3.34	3886	0.77	0.53	Over-exploitation	Deviate surplus effort to unexploited deeper waters
	Ghosh <i>et al.</i> (2014)	Northern BoB 2007-10	31944	0.81	26423	0.60	0.58	Over-exploitation	Present F marginally above optimum, Reduce F from 0.8 to 0.73- 0.76 range
West Coast	Thiagarajan <i>et al.</i> (1992)	Arabian Sea 1985-89	65666	2.70	-	0.71	0.41	Under-exploitation	To increase the effort as the present yield is not even 50% of the estimated biomass
	Chakraborty (1997)	Maharashtra 1987-90	23965	1.87	22986	0.71	0.68	Overfishing	Not mentioned
	Khan (2006)	Mumbai 1997-2001	33000	2.96	-	0.74	0.60	Overfishing	Increasing fishing pressure trends. Yield can be optimised at 70% of current fishing effort. Reduce effort by 30% for optimum yield
	Ghosh (2009)	Mumbai 2003-06	18813	0.93	14565	0.64	0.4	Over-exploitation	Reduce fishing effort by 60%
	Avinash <i>et al.</i> (2014)	Saurashtra 2008-09	20186	0.31	34161	0.3	0.48	Under-exploitation	Increase fishing pressure by 120%
	Ghosh <i>et al.</i> (2014)	North Arabian Sea 2007-10	42649	0.19	61604	0.35	0.75	Under-exploitation	Present F below optimum. Increase F from 0.18 to 0.34 for optimal exploitation
	Rajesh <i>et al.</i> (2015)	Mangalore 2007-12	-	2.41	18291	0.73	0.70	Resource has already reached MSY at current effort levels	Reduce effort by 20% to maintain spawning stock biomass at 20% precautionary reference level, for sustainable fishing

Appendix I. Estimation of best median limits of L_{∞} , K and T_{max}

Frequency distribution table of L_{∞} values with class interval as 5 cm was prepared from available reports. The cumulative frequencies of L_{∞} , K and T_{max} were written and the median limits identified as, where $\frac{N}{2}$ cumulative frequency lies (N = Total no. of reports for each). Also, the size range where 50% of the frequencies concentrate was also located

Frequency distribution table for L_{∞} , K and T_{max} values

Size range of L_{∞}	L_{∞}		K			T_{max}			
	No of reports (N)	Cumulative values	Limits of K	No of reports (N)	Cumulative values	Limits of life span	No of reports (N)	Cumulative values	
105-109	1	1	0.1-0.19	3	3	4-4.9	6	6	
110-114	1	2	0.2-0.29	5	8	5-5.9	1	7	
115-119	0	2	0.3-0.39	0	$\frac{8}{9} \rightarrow \frac{N}{2}$	6-6.9	1	$\frac{8}{10} \rightarrow \frac{N}{2}$	
120-124	0	$\frac{2}{7} \rightarrow \frac{N}{2}$	0.4-0.49	1	11	7-7.9	2	10	
125-129	5	7	0.5-0.59	2	16	8-8.9	0	10	
130-134	5	12	0.6-0.69	5	17	9-19.9	0	10	
140-144	0	12	0.7-0.79	1	17	more than 10	7	17	
145-149	4	16	0.8-0.89	0	17	10			
Limits	125-134 (cm)		0.4-0.7				4-7 (years)		

For L_{∞} , out of 16 reports, 10 reports suggest the optimum value is in the size range of 125-134 cm. For K, out of 17 reports, 8 reports have K values less than 0.4 and 9 reports have K values more than 0.4. So the median limits are 0.4-0.69 to cover about 50% reports. For T_{max} , though the median limits are more than 7 years, this requires validation with ageing done with hard parts. Half of the reports reviewed suggest that the limits for T_{max} are 4-7 years.

Appendix II. Estimation of best median limits for each age

Frequency distribution table for size range and number of reports was constructed for age 1,2,3,4 and 5 and respective cumulative frequencies were determined for each age.

Size range (cm)	Age (in years)										Best median limits
	1		2		3		4		5		
	No.	C.No	No	C.No	No	C.No	No	C.No	No	C.No	
10-19	2	2	-	-	-	-	-	-	-	-	
20-29	2	4	-	-	-	-	-	-	-	-	
30-39	2	$\frac{6}{10} \rightarrow \frac{N}{2}$	1	1	-	-	-	-	-	-	
40-49	4	10	2	3	2	2	-	-	-	-	
50-59	2	12	2	$\frac{5}{10} \rightarrow \frac{N}{2}$	-	2	1	1	-	-	
60-69	3	15	5	10	2	4	2	3	1	1	End of 1 year less than 59 cm
70-79	-	-	-	10	3	$\frac{7}{10} \rightarrow \frac{N}{2}$	1	4	2	3	End of 2 year 60-89 cm
80-89	-	-	2	12	3	10	1	$\frac{5}{7} \rightarrow \frac{N}{2}$	-	3	End of 3 year 90-109 cm
90-99	-	-	2	14	-	10	2	7	3	$\frac{3}{4} \rightarrow \frac{N}{2}$	End of 4 year 110-119 cm
100-109	-	-	1	15	3	13	1	8	1	4	End of 5 year 120-126 cm
110-119	-	-	-	-	1	14	3	11	2	6	End of 6 year 127-131 cm
120-129	-	-	-	-	1	15	-	11	-	6	End of 7 year 132-134 cm
130-139	-	-	-	-	-	-	1	12	-	6	

The median class was identified where $\frac{N}{2}$ cumulative frequency lies for each age as well as the range where 50% frequencies concentrate as shown in the Table (N = Total number of reports). For 1st year age group after median class, about 50% of the observations lie in between 40-69 cm. For 2nd year group after median class, 50% of the frequencies lie in the range of 60-89 cm. Since there are higher number of reports in age 2 than age 1, the range 60-69 cm is carried over for age 2. Hence the size range for age 1 and 2 are 40-59 and 60-89 cm respectively. Again, the size range 80-89 cm is overlapping with age 3 and taking into account the growth, the range is 89-109 cm.

After the median class in 4th year of age, about 50% observed in between the range 90-119 cm. Due to overlapping and considering the growth increment between 3rd and 4th year, 110-119 cm is the acceptable limits for 4th year. Since lesser number of lengths are recorded beyond 4th year, reliable best median limits could not be estimated. One report each is recorded under 3rd (120-129 cm) and 4th (130-139 cm) year. For age 5 no record is available beyond 120 cm.

The growth constant K = 0.7 per year. So, if the growth increment for 4th year (110-119 cm) is 9 cm, then for age 5, the increase in growth is 6.3 (9 x 0.7) cm. Thus, the range for age 5 is 120-126 cm. Similarly projecting the length range for 6th year (6 x 0.7 = 4.2), 4.2 cm is the average increase in growth. Hence, projected length for the 6th year would be 127-131 cm. Similarly for 7th year, the limits are 132-134 cm and ribbonfish ceases to grow since L_{∞} = 134 cm.

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