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Review of Billfish biology from Indian fishery

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Abstract

In India, billfish fishery is contributed by Indo-pacific sailfish, blue marlin, black marlin, striped marlin and swordfish. The landings of the billfishes along the Indian coast are showing an increasing trend since the 1990s and the estimated landing during 2012 was 11613 t. Drift gillnets-cum-longline, handlines and longlines operated from mechanized and motorized craft contributed maximum to the catches. Along the east coast, peak catches occur during July-September and along the west coast during October-March. Length-weight structure and biology of the dominant species are presented and discussed.

Keywords: Billfish, sailfish, drift gillnet, longline, by-catch

Introduction

In India, targeted fishery for billfishes does not exist, but this group constitute one of the most important components of bycatch in the longline, troll and oceanic drift gillnet fishery of Indian waters. Three species of marlins – stripped (*Tetrapturus audax*), blue (*Makaira mazara*) and black (*M. Indica*); Indo-Pacific sailfish (*Istiophorus platypterus*) and swordfish (*Xiphias gladius*) are the billfish species reported in the Indian fishery. The landings of the billfishes along the Indian coast are showing an increasing trend since the 1990s and the estimated landing during 2012 was 11613 t. Drift gillnets-cum-longline, handlines and longlines operated from mechanized and motorized craft contributed maximum to the catches.

Distribution and abundance of billfishes in the Indian waters are extensively studied (Silas and Rajagopal, 1962; Balan, 1981; Silas and Pillai, 1982;Muthiah, 1985; Siraimeetan, 1985; Sivaprakasam and Sudarsan, 1988; Sudarsan *et al*., 1988; John *et al*., 1995; Somvanshi *et al*., 1998; Bhargava *et al*., 2005; Prabhakar Raj *et al*., 2005; Sivaraj *et al*., 2005; Varghese *et al*., 2004, 2005, 2013[a,b], 2014[a,b]; Ganga *et al*., 2008; Ramalingam and Kar, 2011; Vijayakumaran and Varghese, 2011). A few of these reports describes the length structure and biology of these apex

predators from the Indian waters (Varghese *et al*., 2004, 2005, 2013[a,b], 2014[a,b], Sivaraj *et al*., 2005; Ganga *et al*., 2008, Ramalingam and Kar, 2011). Present study is aimed to give an overview of the distribution, abundance and biology of this ecologically and economically important fishes.

Distribution and abundance of major species

Vijayakumaran and Varghese (2011) reported that total catch of billfishes from the Indian waters were 8834.88 during 2010. Sailfish was the dominant species, contributing 78% of the total billfish catch. However, in the industrial longline fishery conducted in the high seas, marlins (44.48%) were the dominant group, followed by swordfish (44.31%) and sailfish (11.21%) (Prabhakar Raj *et al*., 2005). Varghese *et al*. (2013[a]) reported that the abundance of billfishes were more in the Andaman and Nicobar waters, followed by Arabian Sea and Bay of Bengal. The sailfish landings at Cochin Fisheries Harbour was 51 t during 2007 (Ganga *et al*., 2008). Ganga *et al*. (2008) reported that peak landings of billfishes occurred during July- September along the east coast of India, and during October-December and January to March along the west coast. Varghese *et al*. (2004) reported that the *I. platypterus* was caught from the northwestern Indian EEZ at a Hooking Rate (HR) of 0.16 numbers in 100 during the period 1989-2000. The seasonal variations in the abundance indices indicted that the sailfish abundance in the northwest India was maximum during April-June. Hooking rates for swordfish in the exploratory longline survey was 0.02 from the Arabian Sea, 0.01 from the Bay of Bengal and 0.02 from the Andaman and Nicobar waters (Varghese *et al*., 2013[b]). Marlins were recorded in the exploratory fishery in the Indian EEZ at a hooking arte of 0.014 (Bhargava *et al*., 2005). Varghese *et al*. (2011), while analysing the trends in the abundance indices of large pelagics in the exploratory longlining in the Indian EEZ had reported a slight decrease in the abundance of billfishes in the Indian waters during the 1984-2008 period. Table 1 details the latitude–wise details of Swordfish caught during the survey voyages of tuna longline survey vessels of FSI during 2004-2010. Figure 1 shows map showing the longline stations surveyed during the study.

Table 1. Latitude–wise details of Swordfish caught during the survey voyages of tuna longline survey vessels of FSI during 2004-2010

Latitude (˚N)	Hooking Rate (Number/100 hooks operated)			Average weight (kg)		
	EAS	**WBoB**	**AandN**	**EAS**	**WBoB**	**AandN**
6			0.017			2
7			0.035			11.6
8	0.027	0.027	0.027	2.667	60	7.667
9	0.011		0.041	1.5		19.75
10	0.053	0.046	0.026	10.611	2.833	26.462
11	0.034	0.007	0.009	40	4	15.714
12	0.051	0.007	0.01	17.5	3	13.714
13	0.069	0.015	0.01	19.231	17.786	19.5
14	0.063	0.022	0.034	5.674	2.7	47
15	0.041	0.008		5.969	12.5	
16	0.006	0.019	0.053	4	52.6	40
17	0.007	0.003		35	30	
18	0.007	0.004		2.333	70	
19	0.009	0.025		2.375	46	
20	0.008			4		
21	0.005			18		
22						
Average	**0.022**	**0.012**	**0.018**	**11.135**	**17.856**	**18.375**

EAS – Eastern Arabian Sea; WBoB – Western Bay of Bengal; AandN – Andaman and Nicobar waters

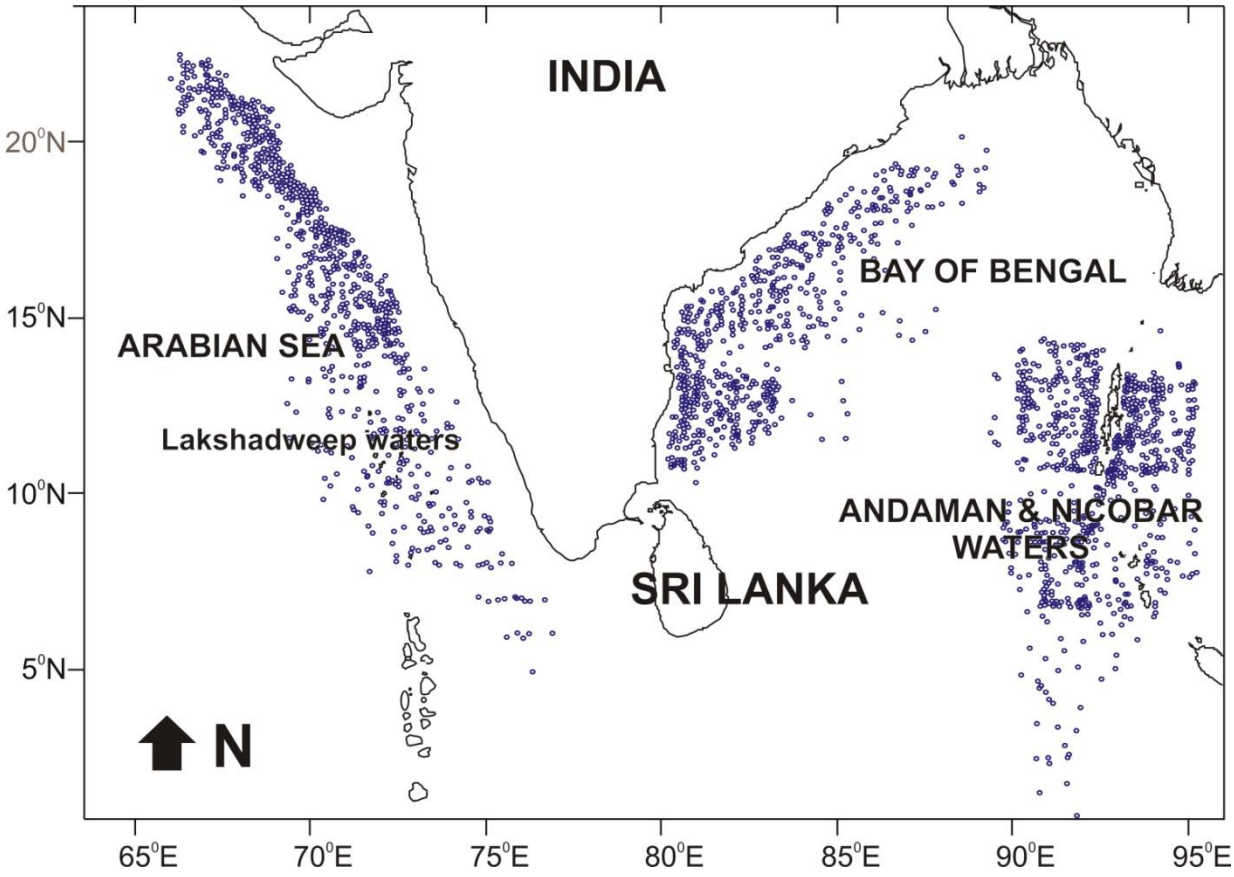

Figure 1. Map showing the longline stations surveyed during the study

Length-weight structure, growth and biology

Sailfish, *I. platypterus*

The length frequency studies of sailfish conducted in the exploratory longline catch in the north west Indian EEZ shows that the specimens caught were in the length range of 100-260 cm (fork length), majority being in the length range of 145-240 cm, with modal length class of 215-220 cm (Varghese *et al*., 2005). The dominant length group for male and female sailfish caught from the Andaman and Nicobar waters were 161-180cm and 181-200 cm (fork length) respectively (Ramalingam and Kar., 2011). The fork length of specimens caught in the north-west Indian EEZ were in the range of 100-260 cm, and the length weight relationship of 137 individuals established was $W = 0.0069L^{1.5596}$. Fork lengths of *I. platypterus* in the landings at

Cochin Fisheries Harbour during 2005-2007 ranged from 80 cm to 300 cm and were dominated by the length group 120 to 250 cm (Ganga *et al*., 2008). The length-weight relationship was estimated as 0.024L2.65. Sailfish specimens caught in the Indian EEZ during 2004-2014 was in the total length range of 84-303 cm, whereas the length-weight relationship identified was given by $W = 0.0650L^{2.3810}$ (Varghese *et al*., 2013[a]). The growth parameters (lenghth, weight) estimated were 316.5 cm, growth coefficient (K) = 0.39/yr and age at zero length (t_0) = –0.51 yr (Varghese *et al*., 2004).

Sex ratio of sailfish in the exploratory longline conducted in the north-west Indian EEZ was 1:2.2 (F:M) (Varghese *et al*., 2004), whereas Varghese *et al* (2013) reported the sex ratio of 1:1.27 (F:M). Sex ratio of sailfish caught in the Andaman and Nicobar waters was 1:0.89 (M:F) (Ramalingam and Kar, 2011). Spawning season of this species in northwest Indian EEZ is protractive extending from March to September (Varghese *et al*., 2004), whereas the spawning occurs between December to June with a peak in February and June in the Andaman and Nicobar waters (Ramalingam and Kar, 2011). Size at first maturity estimated was 175 cm (Varghese *et al*., 2004). Diet of sailfish in the eastern Arabian Sea is dominated by teleost fishes, followed by cephalopods while crustaceans were represented in limited instances. *Sthenoteuthis oualaniensis* was the dominant prey species. Diet did not varied by sex, but the ontogenetic and seasonal variations in the diet were significant (Varghese *et al*., 2014[a]). This species feed during day in the epipelagic and mesopelagic waters. Trophic level estimated was 4.37 (Varghese *et al*., 2014[b]). Trophic level of fish is the position it occupies in a food chain.

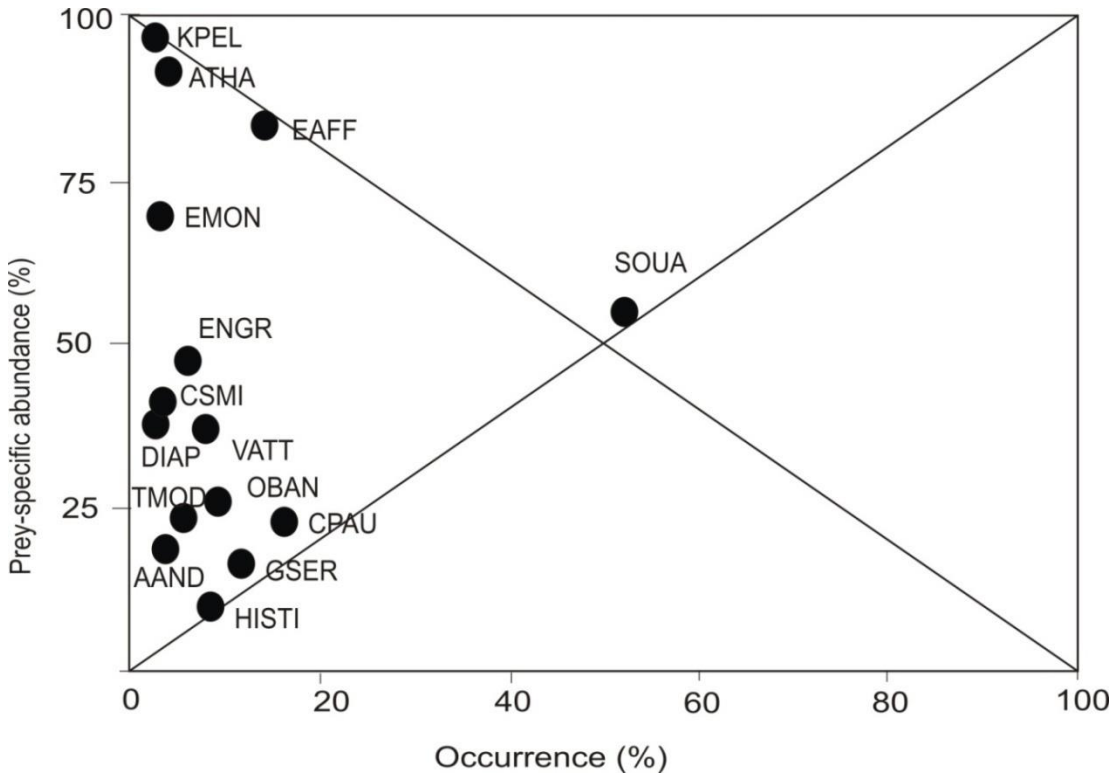

Figure 2. Modified Costello diagram showing the relative importance of important food items to the diet of *I. platypterus* (SOUA - *Sthenoteuthis oualaniensis*; EAFF - *Euthynnus affinis;* CPAU - *Cubiceps pauciradiatus*; GSER - *Gempylus serpens;* OBAN - *Onychoteuthis banksii;* VATT - *Vinciguerria attenuata;* ATHA - *Auxis thazard;* ENGR – Engraulidae n.i.; HISTI - *Histioteuthis* sp; KPEL - *Katsuwonus pelamis;* EMON - *Exocoetus monocirrhus;* AAND - *Abralia andamanica;* TMOD - *Thamnaconus modestoides;* CSMI - *Charybdis smithii;* DIAP - *Diaphus* sp)

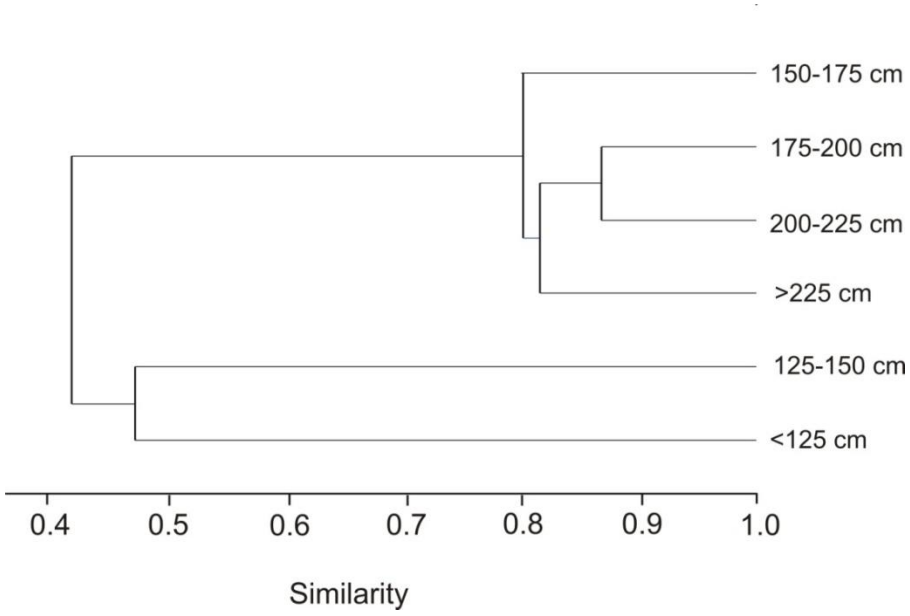

Figure 3. Dendrogram of Cluster analysis (paired group) showing Bray-Curtis similarity percentage of Index Relative Importance (%IRI) values of food items of different length classes of *I. platypterus*

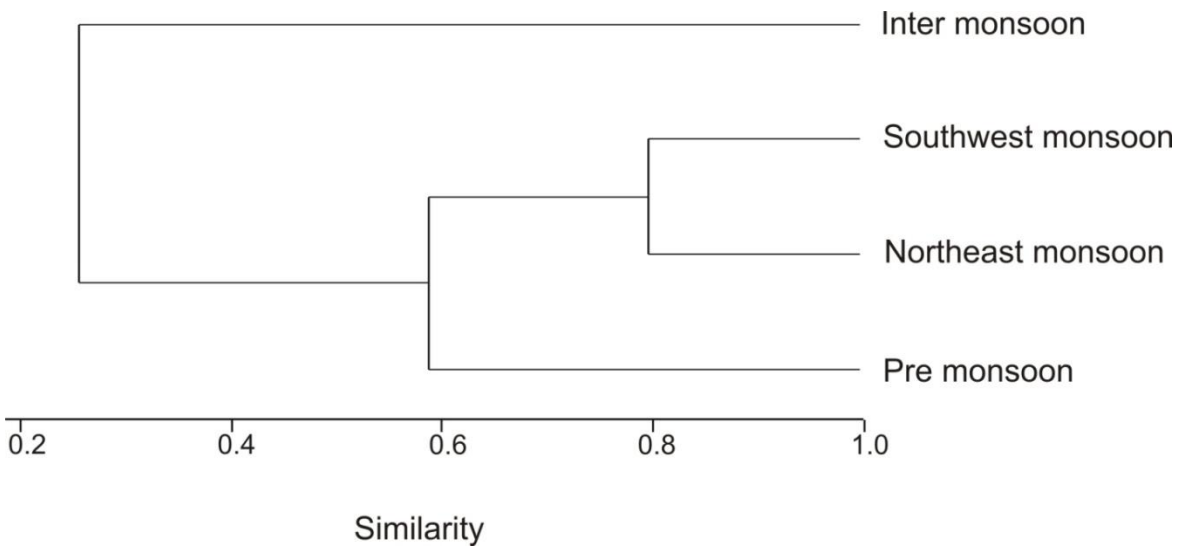

Figure 4. Dendrogram of Cluster analysis (paired group) showing Bray-Curtis similarity index of %IRI values of food items of *I. platypterus* during different seasons

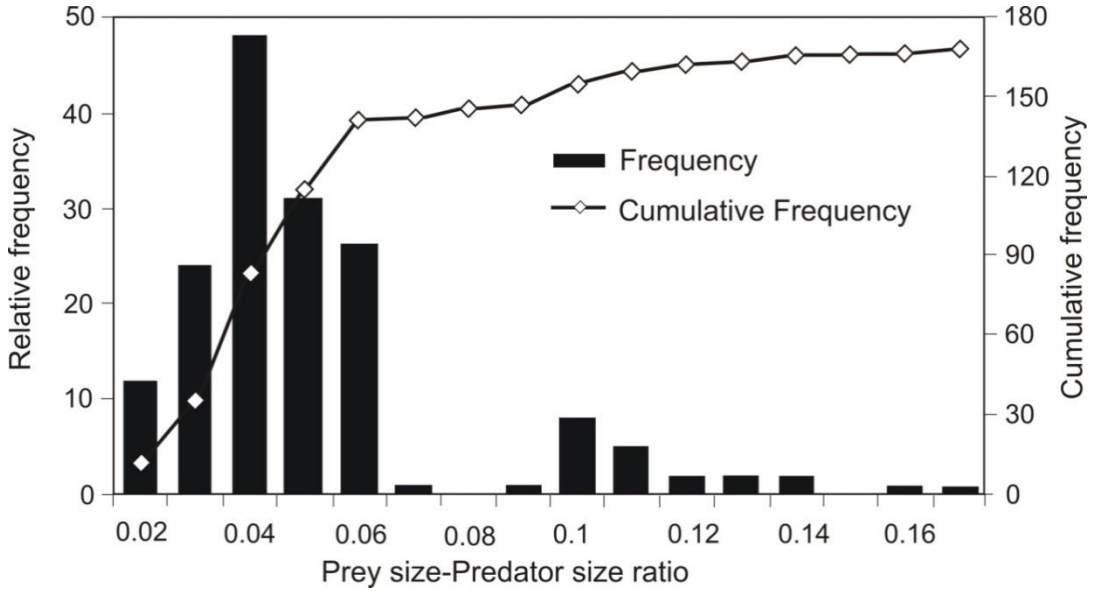

Figure 5. Relative frequency distributions of prey size-predator size ratios for *I. platypterus* in the eastern Arabian Sea

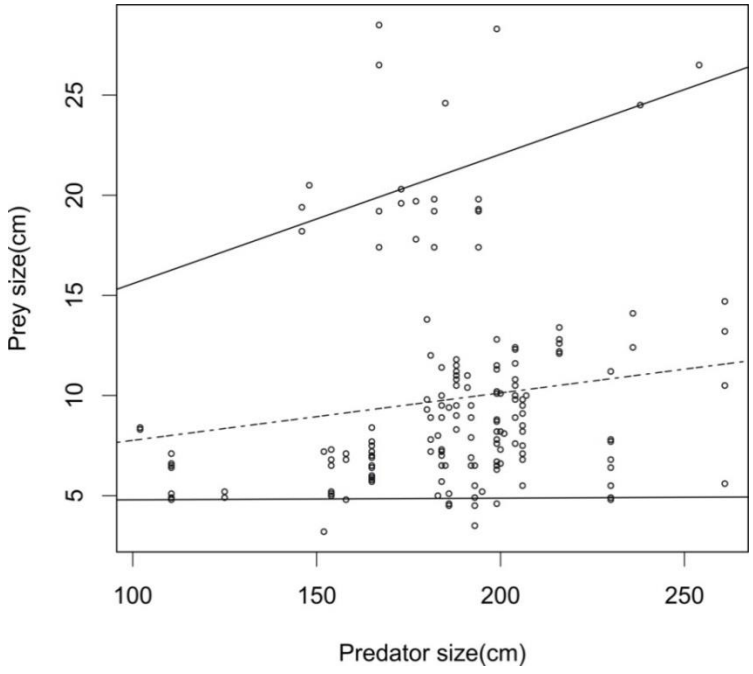

Figure 6. Scatter diagrams showing the relationship of length of *I. platypterus* and its preys in the eastern Arabian Sea. Quantile regression lines (Continuous lines) indicate upper (95th) and lower (5th) boundaries used to describe predator and prey size relationships. Least squares regression lines (dashed line) estimates rate of change in mean prey size as a function of predator size.

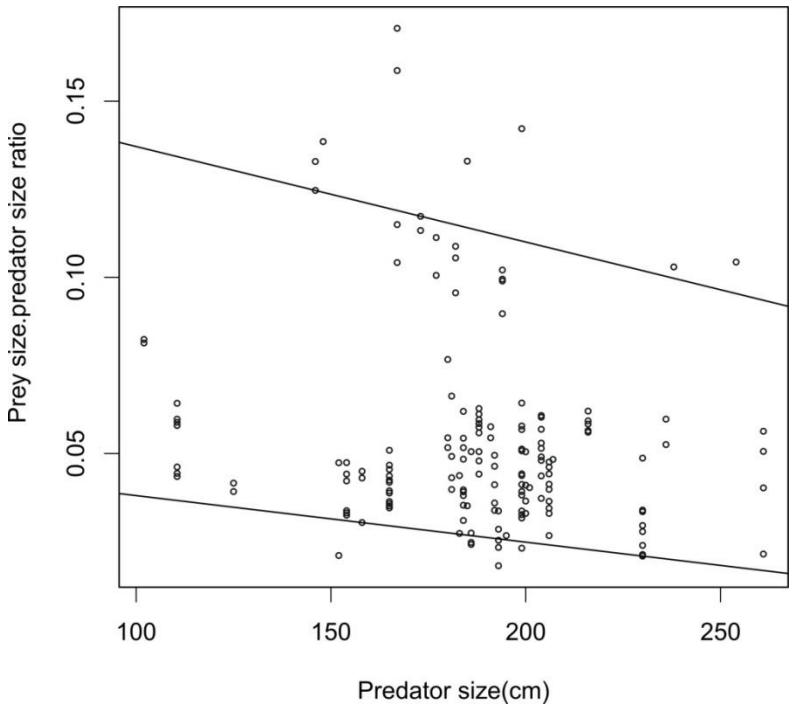

Figure 7. Scatter diagram of relative prey size (prey: predator size ratio) as a function of predator size. Fifth and 95th quantile regression lines showing potential changes in trophic-niche breadth

Table 2. Prey species consumed and their percentage contribution to the diet of *I. platypterus*

Prey family	Prey species	%N	%W	%F	%IRI
Argonautidae	*Argonauta hians*	0.944	0.531	3.968	0.138
	Argonauta bottgeri	0.42	0.221	1.587	0.024
Bolitaenidae	*Japetella diaphana*	0.21	0.443	0.794	0.012
Cranchiidae	*Liocranchia reinhardti*	0.525	0.173	2.381	0.039
	Megalocranchia abyssicola	0.315	0.12	0.794	0.008
Enoploteuthidae	*Abralia andamanica*	2.728	1.317	3.968	0.378
	Abralia marisarabica	1.364	0.257	2.381	0.091
	Abraliopsis lineata	0.63	0.312	1.587	0.035

Histioteuthidae	*Histioteuthis hoylei*	0.105	0.063	0.794	0.003
	Histioteuthis sp	2.099	0.709	8.73	0.577
Ommastrephidae	*Sthenoteuthis oualaniensis*	34.627	29.566	52.381	79.122
Onychoteuthidae	*Onychoteuthis banksii*	3.987	1.805	9.524	1.298
Lepidoteuthidae	*Pholidoteuthis boschmai*	0.105	1.314	0.794	0.027
Tremoctopodidae	*Tremoctopus violaceus*	0.21	0.081	1.587	0.011
	Squids n.i.	3.568	0.454	9.524	0.901
	Cephalopods Total	**51.836**	**37.367**	**73.81**	**42.221**
Nannosquillidae	*Acanthosquilla* sp	0.105	0.003	0.794	0.002
Portunidae	*Charybdis (Goniohellenus) smithii*	2.099	1.603	3.175	0.277
	Isopod n.i.	0.105	0.002	0.794	0.002
	Crustaceans Total	**2.308**	**1.608**	**4.762**	**0.12**
Acropomatidae	*Acropoma japonicum*	0.525	0.501	1.587	0.038
Alepisauridae	*Alepisaurus ferox*	0.315	0.486	2.381	0.045
Apogonidae	Apogonidae n.i.	0.315	0.044	1.587	0.013
Balistidae	*Canthidermis maculata*	0.21	0.915	1.587	0.042
	Odonus niger	0.21	0.037	0.794	0.005
	Sufflamen sp	0.315	0.13	0.794	0.008
Berycidae	*Beryx splendens*	0.735	0.277	1.587	0.038
Bramidae	*Brama* sp	0.105	0.29	0.794	0.007
Carangidae	*Decapterus macrosoma*	1.049	1.02	2.381	0.116
	Decapterus kurroides	0.105	0.633	0.794	0.014
	Elagatis bipinnulata	0.315	0.526	1.587	0.031
Centrolophidae	Centrolophidae n.i.	0.21	0.056	0.794	0.005
Stomiidae	*Chauliodus sloani*	0.105	0.025	0.794	0.002
Coryphaenidae	*Coryphaena equiselis*	0.105	1.769	0.794	0.035

	Coryphaena sp	0.105	0.617	0.794	0.013
Diretmidae	*Diretmus* sp	0.105	0.011	0.794	0.002
Engraulidae	Engraulidae n.i.	4.827	0.653	5.556	0.716
Exocoetidae	*Cheilopogon nigricans*	0.105	0.399	0.794	0.009
	Cheilopogon furcatus	0.105	0.36	0.794	0.009
	Cheliopogon sp	0.21	0.333	0.794	0.01
	Exocoetus monocirrhus	2.728	2.784	3.175	0.412
Gempylidae	*Gempylus serpens*	6.191	1.938	11.905	2.277
	Lepidocybium flavobrunneum	0.42	1.49	3.175	0.143
	Neoepinnula orientalis	0.105	0.088	0.794	0.004
	Ruvettus pretiosus	0.105	0.13	0.794	0.004
	Rexea prometheoides	0.21	0.261	1.587	0.018
	Gempylidae n.i.	0.105	0.035	0.794	0.003
Microstomatidae	*Nansenia macrolepis*	0.21	0.228	1.587	0.016
	Nansenia obscura	0.105	0.06	0.794	0.003
Monacanthidae	*Thamnaconus modestoides*	1.784	0.215	3.175	0.149
	Monacanthidae n.i.	1.469	0.672	5.556	0.28
Muraenesocidae	*Gavialiceps taeniola*	0.42	0.963	1.587	0.052
Myctophidae	*Lampanyctodes* sp	0.315	0.038	0.794	0.007
	Diaphus sp	2.938	0.461	3.175	0.254
Nomeidae	*Cubiceps pauciradiatus*	6.716	3.58	15.873	3.845
	Cubiceps capensis	1.049	0.059	0.794	0.021
Omosudidae	*Omosudis* sp	0.21	0.017	0.794	0.004
Paralepididae	*Paralepis* sp	0.735	0.335	3.175	0.08
Phosichthyidae	*Vinciguerria attenuata*	2.728	4.166	7.937	1.288
Scombridae	*Auxis rochei*	0.21	0.818	0.794	0.019

	Auxis thazard	1.259	6.884	3.968	0.76
	Auxis sp	0.105	0.988	0.794	0.02
	Euthynnus affinis	2.728	12.817	14.286	5.226
	Katsuwonus pelamis	0.525	7.878	2.381	0.471
	Thunnus tonggol	0.21	2.617	1.587	0.106
	Tunas n.i.	0.315	0.669	1.587	0.037
	Scombridae n.i.	0.105	0.195	0.794	0.006
Tetraodontidae	*Lagocephalus lagocephalus*	0.21	0.717	1.587	0.035
Trichiuridae	*Trichiurus auriga*	0.105	0.216	0.794	0.006
	Finfish n. i.	1.469	0.625	7.143	0.352
	Finfishes total	**45.855**	**61.025**	**84.127**	**57.659**

n.i. – not identified

Table 3. Sex-wise and seasonal differences in the %IRI of different food items of *I. platypterus* of eastern Arabian Sea

Prey family	Prey species	Females	Males	Pre monsoon	SW monsoon	Inter monsoon	NE monsoon
Argonautidae	*Argonauta hians*	0.321	0.073	0.035	0.316	2.296	
	Argonauta bottgeri	0.131			0.126		
Bolitaenidae	*Japetella diaphana*		0.036		0.064		
Cranchiidae	*Liocranchia reinhardti*	0.016	0.061	0.289			0.026
	Megalocranchia abyssicola		0.024	0.114			
Enoploteuthidae	*Abralia andamanica*	0.22	0.533	2.398			0.373
	Abralia marisarabica	0.056	0.076		0.293		0.026
	Abraliopsis lineata		0.106		0.014		0.146

Histioteuthidae	*Histioteuthis hoylei*	0.017		0.045			
	Histioteuthis sp	0.487	0.5	0.982	0.951		0.032
Ommastrephidae	*Sthenoteuthis oualaniensis*	77.26	77.156	51.178	83.679	17.955	76.248
Onychoteuthidae	*Onychoteuthis banksii*	0.852	1.626	0.5	0.684		2.252
Lepidoteuthidae	*Pholidoteuthis boschmai*	0.144					0.258
Tremoctopodidae	*Tremoctopus violaceus*	0.015	0.008	2.438		7.252	
	Squids n.i.	0.708	1.168		0.068		1.266
	Cephalopods Total	**44.95**	**38.02**	**28.411**	**55.064**	**20.997**	**42.155**
Nannosquillidae	*Acanthosquilla* sp		0.006			1.67	
Portunidae	*Charybdis (Goniohellenus) smithii*	0.117	0.431				3.389
	Isopod n.i.		0.006		0.011		
	Crustaceans Total	**0.042**	**0.197**		**0.004**	**0.471**	**0.946**
Acropomatidae	*Acropoma japonicum*	0.078	0.015	0.208			0.048
Alepisauridae	*Alepisaurus ferox*		0.134		0.021		0.214
Apogonidae	Apogonidae n.i.	0.012	0.014				0.132
Balistidae	*Canthidermis maculata*	0.229				2.789	0.132
	Odonus niger		0.014		0.024		
	Sufflamen sp		0.025		0.044		
Berycidae	*Beryx splendens*	0.047	0.031	0.376			
Bramidae	*Brama* sp	0.04			0.039		
Carangidae	*Decapterus macrosoma*	0.014	0.217	0.412			0.204
	Decapterus kurroides		0.041		0.072		

	Elagatis bipinnulata		0.141				0.307
Centrolophidae	Centrolophidae n.i.	0.027			0.026		
Stomiidae	*Chauliodus sloani*		0.007				0.024
Coryphaenidae	*Coryphaena equiselis*		0.104		0.183		
	Coryphaena sp		0.04		0.071		
Diretmidae	*Diretmus* sp		0.007				0.021
Engraulidae	Engraulidae n.i.		1.418	1.08	1.226		0.043
Exocoetidae	*Cheilopogon nigricans*		0.028		0.049		
	Cheilopogon furcatus		0.026	0.137			
	Cheliopogon sp	0.055			0.053		
	Exocoetus monocirrhus	0.057	1.051	0.165	1.463		
Gempylidae	*Gempylus serpens*	2.727	1.875	1.691	4.409	2.061	0.261
	Lepidocybium flavobrunneum	0.082	0.185		0.079	4.308	0.056
	Neoepinnula orientalis		0.011		0.019		
	Ruvettus pretiosus		0.013				0.043
	Rexea prometheoides	0.02	0.031	0.052	0.027		
	Gempylidae n.i.	0.014				1.789	
Microstomatidae	*Nansenia macrolepis*	0.034	0.006		0.011		0.06
	Nansenia obscura		0.009	0.044			
Monacanthidae	*Thamnaconus modestoides*	0.17	0.025		0.103		0.304
	Monacanthidae n.i.	0.371	0.208		1.201		0.021
Muraenesocidae	*Gavialiceps taeniola*	0.282		0.364	0.014		
Myctophidae	*Lampanyctodes* sp		0.02	0.088			
	Diaphus sp		0.767		0.012		2.41

Nomeidae	*Cubiceps pauciradiatus*	3.269	4.512	12.961	1.548	2.39	1.174
	Cubiceps capensis	0.114					0.204
Omosudidae	*Omosudis* sp		0.013				0.042
Paralepididae	*Paralepis* sp	0.025	0.14	0.364		2.127	0.026
Phosichthyidae	*Vinciguerria attenuata*	0.295	1.565	0.906	0.09		5.279
Scombridae	*Auxis rochei*		0.057	0.305			
	Auxis thazard	0.837	0.672	2.508			2.151
	Auxis sp		0.061				0.199
	Euthynnus affinis	10.36	2.633	17.757	2.863	6.583	0.94
	Katsuwonus pelamis		1.4	0.909		48.779	
	Thunnus tonggol	0.141					1.029
	Tunas n.i.		0.08				0.087
	Scombridae n.i.	0.031	0.11		0.05		0.055
Tetraodontidae	*Lagocephalus lagocephalus*	0.095					0.338
Trichiuridae	*Trichiurus auriga*	0.033			0.031		
	Finfish n. i.	0.203	0.484	1.693	0.065		0.181
	Finfishes total	**55.01**	**61.783**	**71.589**	**44.932**	**78.532**	**56.899**
Predator information							
	Total stomachs analysed	172	118	66	88	16	120
	% of empty stomachs	18.64	9.3	6.06	2.27	12.5	25
	Mean (± SD) predator Forklength (cm)	191.5 (± 31.31)	182.27 (± 31.43)	188.90 (± 34.30)	175.86 (± 38.51)	196.88 (± 14.44)	188.78 (± 27.10)
	Mean (± SD) predator weight (kg)	28.89 (±	25.24 (±	28.92 (± 12.09)	23.09 (± 10.96)	23.25 (±	28.1 (± 4.79)

		9.81)	8.25)			6.61)	
	Mean (± SD) food wt (g)	112.78 (± 115.23)	110.89 (± 121.92)	136.49 (± 14.21)	129.73 (± 115.15)	167.9 (± 189.74)	83.25 (± 100.77)
	Mean (± SD) Repletion Index (g/kg)	4.47 (± 4.69)	4.68 (± 5.52)	8.30 (± 20.88)	5.48 (± 4.24)	7.90 (± 9.38)	3.29 (± 4.33)

n.i. – not identified

Table 4. Ontogenetic differences in the %IRI of different food items of *I. platypterus* of eastern Arabian Sea

Prey family	Prey species	<125 L_F	125-150 L_F	150-175 L_F	175-200 L_F	200-225 L_F	>225 L_F
Argonautidae	*Argonauta hians*			0.755	0.022	0.086	0.185
	Argonauta bottgeri			0.201			0.2
Bolitaenidae	*Japetella diaphana*			0.263			
Cranchiidae	*Liocranchia reinhardti*				0.021	0.122	0.207
	Megalocranchia abyssicola					0.133	
Enoploteuthidae	*Abralia andamanica*		7.278	0.064	0.066	1.764	
	Abralia marisarabica	4.833		0.053	0.021		
	Abraliopsis lineata				0.28		
Histioteuthidae	*Histioteuthis hoylei*					0.052	
	Histioteuthis sp		2.845	0.319	1.171	0.202	0.192
Ommastrephidae	*Sthenoteuthis oualaniensis*	30.19	37.78	69.906	79.08	78.498	72.45
Onychoteuthidae	*Onychoteuthis banksii*	0.562		0.056	2.059	0.682	6.352
Lepidoteuthidae	*Pholidoteuthis boschmai*					0.463	

Tremoctopodidae	*Tremoctopus violaceus*				0.022		0.197
	Squids n.i.	0.933		1.403	0.594	0.458	2.22
	Cephalopods Total	**27.57**	**25.41**	**38.85**	**43.77**	**41.61**	**48.79**
Nannosquillidae	*Acanthosquilla* sp					0.032	
Portunidae	*Charybdis (Goniohellenus) smithii*	28.32				0.355	
	Isopod n.i.			0.045			
	Crustaceans Total	**9.526**		**0.014**		**0.222**	
Acropomatidae	*Acropoma japonicum*			0.31	0.039		
Alepisauridae	*Alepisaurus ferox*					0.76	
Apogonidae	Apogonidae n.i.					0.216	
Balistidae	*Canthidermis maculata*					0.726	
	Odonus niger			0.101			
	Sufflamen sp						0.6
Berycidae	*Beryx splendens*					0.744	
Bramidae	*Brama* sp			0.158			
Carangidae	*Decapterus macrosoma*			0.615	0.166		
	Decapterus kurroides						0.908
	Elagatis bipinnulata		2.92		0.075		
Centrolophidae	Centrolophidae n.i.		2.483				
Stomiidae	*Chauliodus sloani*			0.053			
Coryphaenidae	*Coryphaena equiselis*						2.272
	Coryphaena sp						0.889
Diretmidae	*Diretmus* sp					0.035	
Engraulidae	Engraulidae n.i.	0.418	7.557	1.806		1.091	0.799
Exocoetidae	*Cheilopogon nigricans*			0.202			
	Cheilopogon furcatus					0.149	

	Cheliopogon sp				0.08		
	Exocoetus monocirrhus			0.825		2.798	
Gempylidae	*Gempylus serpens*	1.303		10.153	1.674	0.532	
	Lepidocybium flavobrunneum			0.563	0.06	0.26	
	Neoepinnula orientalis			0.079			
	Ruvettus pretiosus				0.035		
	Rexea prometheoides			0.113	0.028		
	Gempylidae n.i.					0.043	0.275
Microstomatidae	*Nansenia macrolepis*	0.382			0.049		
	Nansenia obscura			0.067			
Monacanthidae	*Thamnaconus modestoides*	0.418			0.522		0.17
	Monacanthidae n.i.		3.442	0.779	0.017	0.242	0.333
Muraenesocidae	*Gavialiceps taeniola*		1.318		0.184		
Myctophidae	*Lampanyctodes* sp				0.052		
	Diaphus sp	2.476			0.77	0.037	
Nomeidae	*Cubiceps pauciradiatus*	2.653		5.199	3.174	3.469	2.727
	Cubiceps capensis					0.331	
Omosudidae	*Omosudis* sp				0.034		
Paralepididae	*Paralepis* sp			0.1	0.369		
Phosichthyidae	*Vinciguerria attenuata*	10.64		0.106	1.36	1.457	
Scombridae	*Auxis rochei*		7.419			0.331	
	Auxis thazard			0.734	1.217		1.603
	Auxis sp				0.162		
	Euthynnus affinis	16.87	24.16	3.218	4.22	1.498	7.199
	Katsuwonus pelamis			1.186	1.605		
	Thunnus tonggol					1.845	

	Tunas n.i.					0.095	
	Scombridae n.i.			0.203	0.071	0.095	
Tetraodontidae	*Lagocephalus lagocephalus*					0.298	
Trichiuridae	*Trichiurus auriga*		2.797				
	Finfish n. i.			0.347	0.707	0.193	0.222
	Finfishes total	**62.91**	**74.59**	**61.14**	**56.24**	**58.17**	**51.21**
Predator information							
	Total stomachs analysed	18	10	56	104	76	26
	% of empty stomachs	0	0	7.14	15.38	23.68	0
	Mean (± SD) predator Forklength (cm)	104.78 (± 11.11)	144 (± 4.30)	161.75 (± 6.84)	187.38 (± 6.56)	208.71 (± 5.83)	238.69 (± 12.22)
	Mean (± SD) predator weight (kg)	11.56 (± 1.88)	12.80 (±1.30)	17.96 (± 3.78)	26.72 (± 5.08)	32.95 (± 4.68)	39.38 (± 6.54)
	Mean (± SD) food wt (g)	121.44 (± 147.96)	122.98 (± 102.67)	117.52 (± 113.32)	92.02 (± 115.08)	111.76 (± 126.36)	145.94 (± 99.12)
	Mean (± SD) Repletion Index (g/kg)	11.98 (± 14.95)	9.51 (± 8.28)	6.37 (± 5.80)	3.50 (± 4.81)	3.38 (± 3.69)	3.90 (± 2.88)

n.i. – not identified

Table 5. Hooking rate (HR, number of specimens/100 hooks) and Catch Rate (kg/1000 hooks) of billfish bycatch in the tuna longline survey off India

Family	Species Name	ARABIAN SEA			BAY OF BENGAL			A&N WATERS		
		HR	%by no	CR	HR	%by no	CR	HR	%by no	CR
Istiophoridae	*Istiophorus platypterus*	0.107	15.965	25.864	0.042	6.630	10.548	0.029	4.626	6.922
Istiophoridae	*Makaira nigricans*	0.005	0.765	2.594	0.006	0.941	3.830	0.006	0.925	3.765
Istiophoridae	*Istiompax indica*	0.005	0.730	2.528	0.005	0.855	2.017	0.000	0.040	0.093
Istiophoridae	*Kajikia audax*	<0.001	0.035	0.142				<0.001	0.040	0.121

Table 6. Distribution pattern (HR, number of specimens/100 hooks) of sailfish and swordfish in the tuna longline fisheries off India

Latitude (˚N)	*I. platypterus*			*X. gladius*		
	AS	BoB	A&N	AS	BoB	A&N
0						
1						
2						
3						
4						
5						
6	0.07	0.05	0.03			0.02
7	0.06	0.05	0.01			0.03
8	0.25	0.03	0.01	0.03	0.03	0.03
9	0.22	0.03	0.01	0.01		0.04

10	0.09	0.05	0.04	0.05	0.05	0.03
11	0.13	0.03	0.05	0.03	0.01	0.01
12	0.1	0.02	0.03	0.05	0.01	0.01
13	0.13	0.03	0.03	0.07	0.01	0.01
14	0.09	0.03		0.06	0.02	0.03
15	0.1	0.05		0.04	0.01	
16	0.12	0.02	0.05	0.01	0.02	0.05
17	0.1	0.08		0.01	0	
18	0.12	0.09		0.01	0	
19	0.09	0.06		0.01	0.02	
20	0.08	0.16		0.01		
21	0.08			0.01		
22	0.02					
Average	**0.11**	**0.04**	**0.03**	**0.02**	**0.01**	**0.02**

AS – eastern Arabian Sea; **BoB** – western Bay of Bengal; **A&N** – Andaman and Nicobar waters

Table 7. Length-weight relationship of dominant billfish bycatch species in the tuna longline fisheries off India

Species	Total Length (cm)		Weight (kg)		Length-weight relationship			K (Av±SD)	Kn (Av±SD)	n
	Min	Max	Min	Max	Constant (a)	Exponent (b)	r^2			
Istiompax indica	102	294	5	128	0.0010	3.2180	0.7630	0.40±0.15	1.26±0.45	68
Istiophorus platypterus	84	303	3	58	0.0650	2.3810	0.7170	0.25±0.07	1.04±0.25	1053
Makaira nigricans	106	310	15	180	0.0930	2.4560	0.8010	0.50±0.16	1.03±0.23	71
Xiphias gladius	61	319	1	150	0.0008	3.4112	0.8587	0.56±0.22	1.02±0.38	295

Table 8. Sex ratio of dominant billfish bycatch species in the tuna longline fisheries off India

Family	Common name	Species Name	Sex ratio	
			F/M	F:M
Istiophoridae	Black marlin	*Istiompax indica*	0.579	1:1.727
Istiophoridae	Indo-Pacific sailfish	*Istiophorus platypterus*	0.788	1:1.269
Istiophoridae	Indo-Pacific blue marlin	*Makaira nigricans*	0.333	1:3
Xiphiidae	Swordfish	*Xiphias gladius*	0.388	1:2.579

Marlins

Varghese *et al*. (2013[a]) reported that the total lengths of marlins caught by exploratory longlining in the Indian waters were 102-294 cm (black marlin), 106-310 cm (blue marlin) and the length-weight relationship estimated were $0.0010L^{3.2180}$ (black marlin) $0.0930L^{2.4560}$ (blue marlin). Diet of black marlin in the Arabian Sea is dominated by teleost fishes, followed by cephalopods, whereas cephalopods, mainly *S. oualaniensis* was dominant prey of blue marlin.

Blue marlin forage in the epipelagic and mesopelagic waters mainly during night, but occasionally during day, whereas black marlin feeds in the epipelagic waters during daylight hours (Varghese *et al*., 2014[b]).

Swordfish

Varghese *et al* (2013[b]) reported that the swordfish caught in the exploratory longlining in the Indian waters were in the LJFL range of 53 to 301 cm. About 16% of the specimens caught were juveniles and the global sex ratio of specimens collected was 1:0.47 (M : F). While sex ratio of small fish indicated predominance of males, females were dominating in larger specimens (>160 cm. Significant differences in the average sizes were observed between sexes. Length-weight relationship established was $0.00000182L^{3.307}$. Growth parameters of Von Bertalanffy growth equation for female specimens were estimated as $L\infty = 311.11$ cm, K = 0.17, t0 = -0.53 and $\phi' = 4.22$, whereas, those for male specimens were $L\infty = 243.79$ cm, K = 0.22, t0 = -0.37 and $\phi' = 4.12$ (Varghese *et al*., 2013[b]). *Sthenoteuthis oualaniensis* was the dominant prey species, followed by *Paralepis* sp., *Myctophum* sp., *Carcharhinus falciformis*, *Alepisaurus ferox* and *Decapterus macrosoma.* Trophic level estimated was 4.36 and this species feed in the epipelagic waters at night and in deep waters during day (Varghese *et al*., 2014[b]). Spawning area was identified in the Lakshadweep waters from where mature females with hydrated oocytes were caught during December to April (Varghese *et al*., 2013[b]). Size at 50% maturity for females was estimated at 164.03 cm, which is reached at about four years of age. Mean batch fecundity was 4.5 million, while the relative fecundity was 37.5 hydrated oocytes per gram of body weight and the diameters of mature oocytes were in the range of 0.9-1.6 mm (Varghese *et al*., 2013[b]).

Table 9. Prey species consumed, and their percentage contribution to the diet of *X. gladius*

Prey family	Prey species/group	%N	%W	%F	%IRI
Histioteuthidae	*Histioteuthis hoylei*	1.087	0.925	8.333	0.552
Histioteuthidae	*Histioteuthis* sp	2.174	0.578	16.667	1.509
Ommastrephidae	*Sthenoteuthis oualaniensis*	8.696	15.995	41.667	33.855
Thysanoteuthidae	*Thysanoteuthis rhombus*	1.087	2.436	8.333	0.966
	Unidentified squids	2.174	0.463	8.333	0.723
	Total Cephalopods	**15.217**	**20.397**	**58.333**	**12.183**

Nannosquillidae	*Acanthosquilla* sp	1.087	0.039	8.333	0.309
	Total Crustaceans	**1.087**	**0.039**	**8.333**	**0.055**
Alepisauridae	*Alepisaurus ferox*	1.087	19.425	8.333	5.625
Berycidae	*Beryx splendens*	4.348	1.21	16.667	3.048
Bramidae	*Brama* sp	1.087	1.549	8.333	0.723
Bramidae	*Brama brama*	2.174	2.521	16.667	2.575
Carangidae	*Decapterus macrosoma*	2.174	7.847	16.667	5.496
Carcharhinidae	*Carcharhinus falciformis*	1.087	21.969	8.333	6.323
Diretmidae	*Diretmus* sp	2.174	1.179	8.333	0.92
Exocoetidae	*Exocoetus monocirrhus*	1.087	4.109	8.333	1.425
Gempylidae	*Gempylus serpens*	3.261	1.287	16.667	2.495
Gempylidae	*Rexea prometheoides*	6.522	3.415	8.333	2.725
Myctophidae	*Lampanyctodes* sp	3.261	0.578	8.333	1.053
Myctophidae	*Myctophum* sp	41.304	1.84	8.333	11.832
Omosudidae	*Omosudis* sp	2.174	2.081	16.667	2.334
Paralepididae	*Paralepis* sp	10.87	6.159	25	14.01
Scombridae	*Euthynnus affinis*	1.087	4.394	8.333	1.503
	Total Finfishes	**83.696**	**79.565**	**91.667**	**87.762**

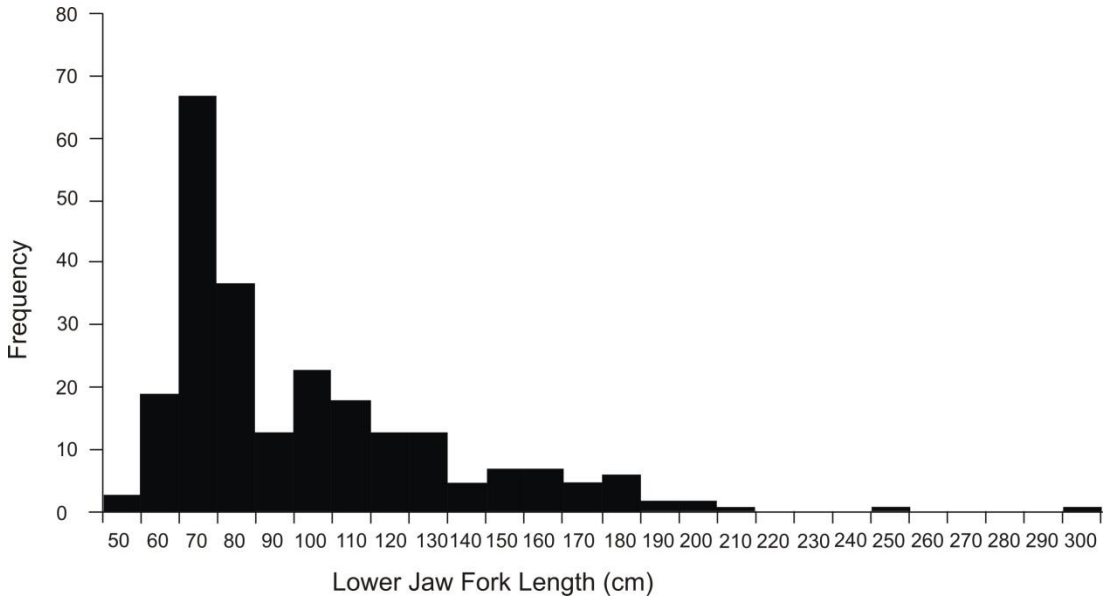

Figure 8. Length frequency distribution of *X. gladius* of the Indian waters

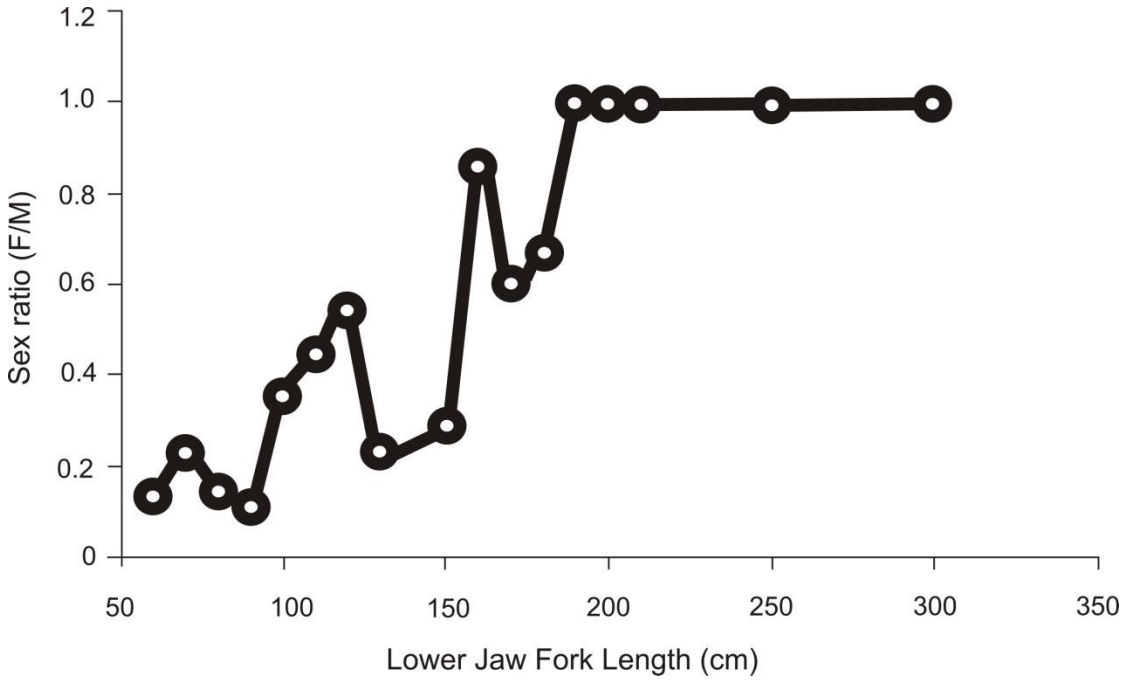

Figure 9. Relationship between sex ratio and LJFL of *X. gladius* of the Indian waters

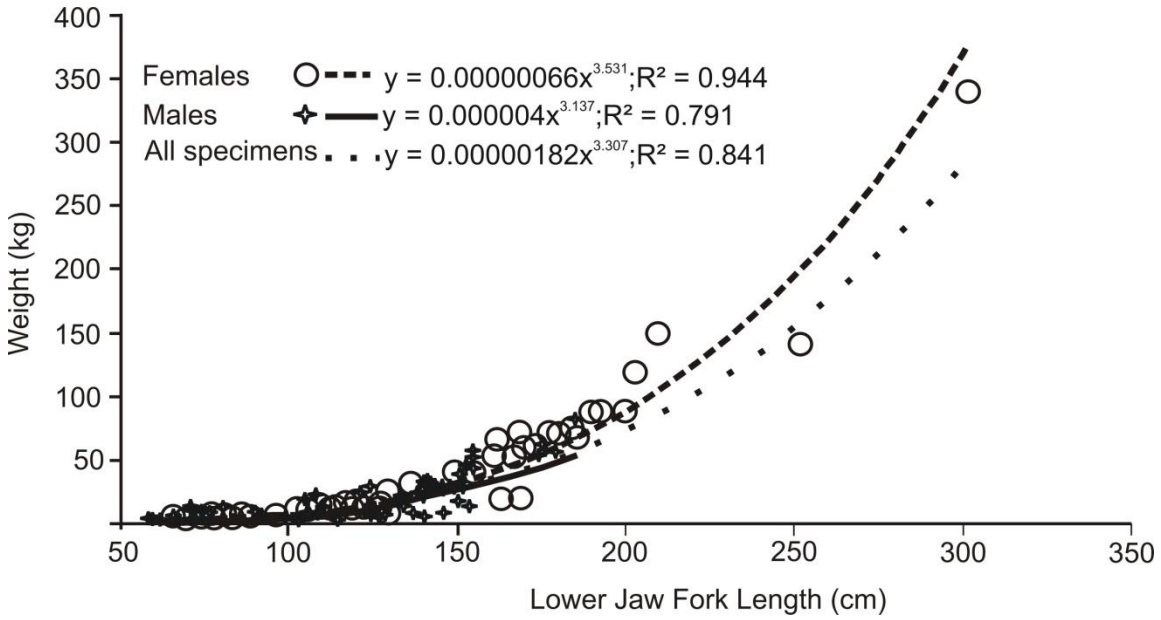

Figure 10. Length-weight relationship of *X. gladius* of the Indian waters

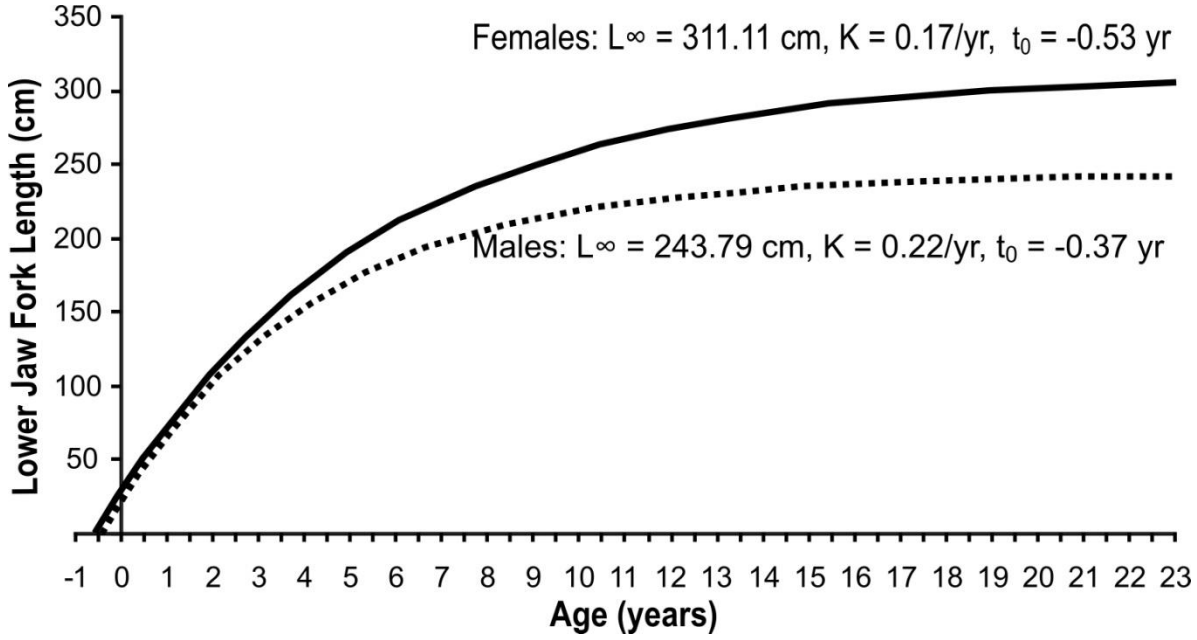

Figure 11. Von Bertalanffy growth curves for male (dashed line) and female (continuous line) *X. gladius* in the Indian waters.

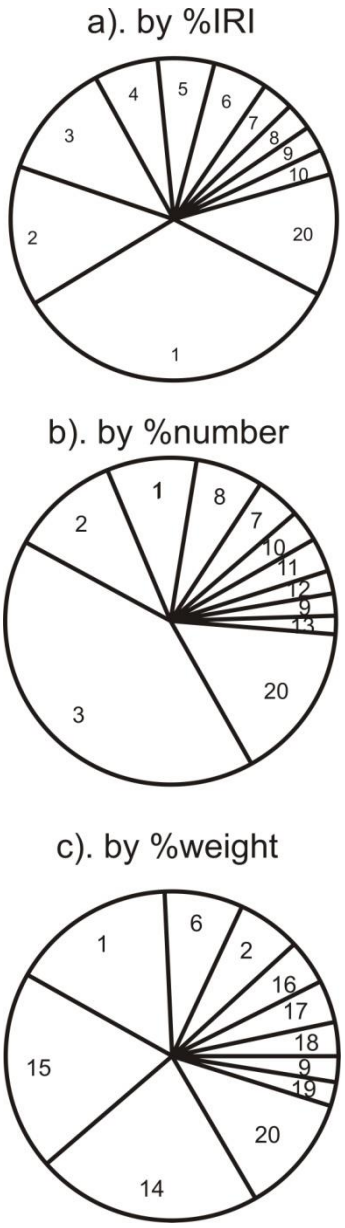

Figure 12 a-c. Prey species dominating the diet of *X. gladius* of eastern Arabian Sea (1-*Sthenoteuthis oualaniensis*; 2. *Paralepis* sp; 3. *Myctophum* sp; 4. *Carcharhinus falciformis*; 5. *Alepisaurus ferox*; 6. *Decapterus macrosoma*; 7. *Beryx splendens*; 8. *Rexea prometheoides*; 9. *Brama brama*; 10. *Gempylus serpens*; 11. *Lampanyctodes* sp 12. *Decapterus macrosoma*; 13. *Omosudis* sp 14. *Carcharhinus falciformis*; 15. *Alepisaurus ferox*; 16. *Euthynnus affinis*; 17. *Exocoetus monocirrhus* 18. *Rexea prometheoides*; 19. *Thysanoteuthis rhombus*; 20. other prey).

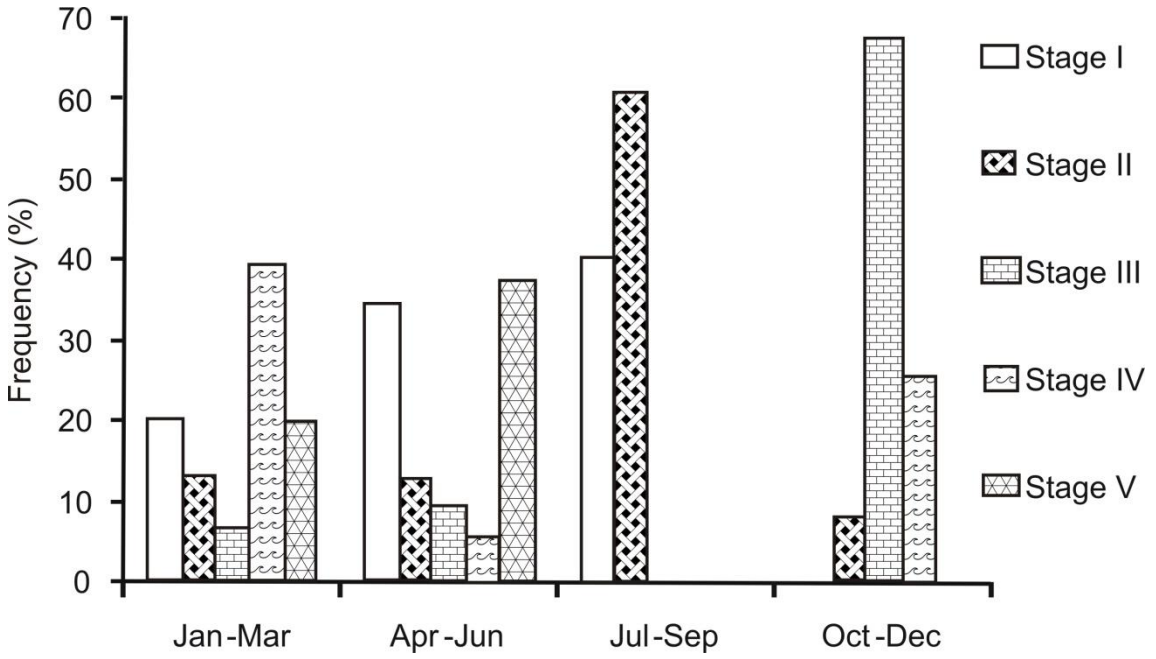

Figure 13. Quarterly percentage frequency of maturity stages (female) of *X. gladius* of eastern Arabian Sea

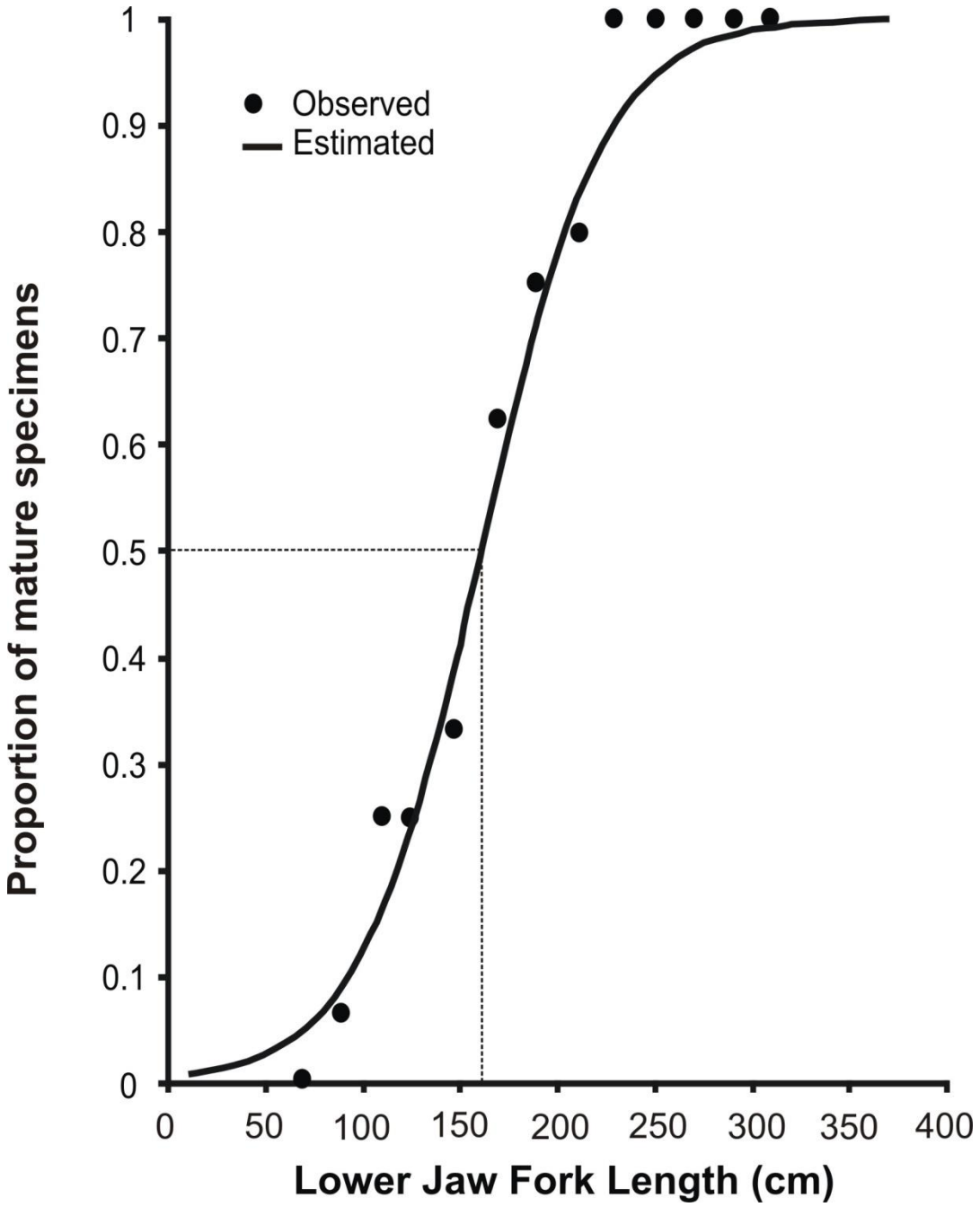

Figure 14. Logistic curve fitted to the proportion of mature females in relation to LJFL of *X. gladius* of Indian waters. Dashed line indicates the length at first maturity.

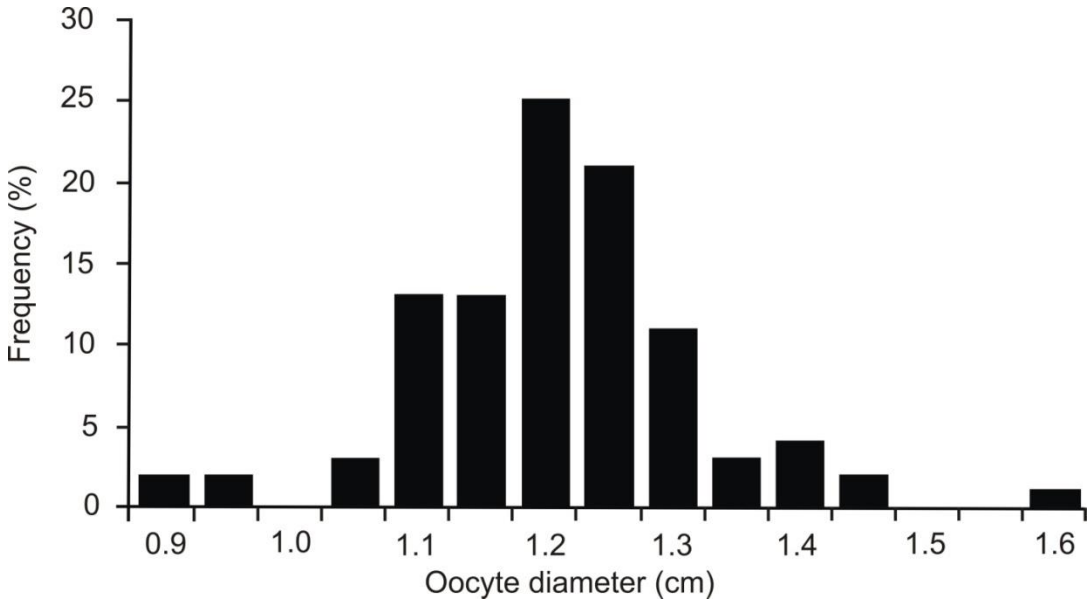

Figure 15. Oocyte diameter frequency distribution in ripe ovaries of *X. gladius* of eastern Arabian Sea

Conclusion:

Billfishes are ecologically and economically important group of fishes, since they constitute major part of catch in longline and oceanic drift gillnet fishery and function as apex predators in the oceanic food web. Since the billfishes are highly migratory, the management of these fish stocks needs the cooperation of all the nations engaged in tuna fishing. Continuous monitoring of the stock status and biological parameters are required for identifying management measures for these ecologically and economically important group.

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