Diet of yellowfin and skipjack tunas in the eastern Arabian Sea

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Abstract

Diet composition, feeding strategies and predator-prey relationships of yellowfin *Thunnus albacares* (Bonnaterre, 1788) and skipjack *Katsuwonus pelamis* (Linnaeus, 1758) tunas in the western Indian Exclusive Economic Zone (eastern Arabian Sea) were studied by stomach content analysis. Stomachs of 406 yellowfin tuna specimens in the fork length range of 48 to 165.5 cm caught during exploratory longlining conducted in the eastern Arabian Sea were examined, of which, 15.52% were empty. Purple back flying squid (*Sthenoteuthis oualaniensis*) was the dominant prey species, followed by the swimming crab (*Charybdis smithii*), bigeyecigarfish (*Cubiceps pauciradiatus*) and flyingfishes (family Exocoetidae). Diet breadth index and the Tokeshi graphical analysis showed dominance of few prey species which are available in high densities in the Arabian Sea, indicating opportunistic feeding nature of this apex predator. A total number of 72 skipjack stomachs were studied, of which, 22.22% were empty. Purple back flying squid was the dominant food item, followed by the flyingfish.

Introduction

The yellowfin (*Thunnus albacares* Bonnaterre, 1788) and skipjack (*Katsuwonus pelamis* Linnaeus, 1758) tunas constitute more than 87% of the oceanic tunas caught in the Indian Ocean Tuna Commission (IOTC) area of competence. Considering the economic returns the fisheries of these two species are realising, they are of high social and cultural importance to many Indian Ocean coastal states and distant water fishing nations. Further, these tuna species function as apex predators in the pelagic realm of world oceans, exerting substantial influence on the lower trophic levels of the ecosystems they are residing in.

Considering the ecological, economic and social importance of these resources, fisheries management, taking into consideration of the energy flow within the ecosystem and among its components are of prime importance for the perpetuity of stocks. A thorough understanding of the prey species composition of the apex predators is a basic prerequisite for these types of ecosystem based management measures. Analysis of stomach contents is a direct method of investigating diet and feeding habits, providing valuable information on the prey species of the predators, prey types and prey quantity required for supporting commercial fisheries.

The present paper is aimed to study the trophic ecology of yellowfin and skipjack tunas of Indian EEZ. This forms a part of the Doctoral thesis of the lead author and some of the results are already published earlier (Varghese *et al*., 2014; 2016).

Materials and methods

This study was carried out in the area beyond the 500 m depth of the Indian EEZ part of the eastern Arabian Sea. Predator samples for the study were collected during the exploratory survey voyages of two tuna longliners of Fishery Survey of India (FSI) *viz.*, MFV *Matsya Vrushti* and MFV *Yellow Fin*. Regular surveys were conducted in the Indian EEZ along the west coast (Lat. 5°-23°N; Long. 66-76°E) for oceanic tunas and allied resources by employing pelagic longline gear. Stomach content data, collected during the study period were pooled and analysed.

Intensity of feeding was quantified by estimating Repletion Index (RI), expressed as gram of stomach content per kilogram body weight of predators. The diet was assessed based on percent occurrence by number (%N), percent frequency of occurrence (%F), and percent occurrence by weight (%W) of prey items (Hyslop, 1980). Weight was the actual weight of the prey remains, not the reconstituted weight of prey at ingestion. The quantitative importance of each prey was determined by the Index of Relative

Importance (IRI) (Pinkas *et al.,* 1971) and to facilitate diet comparison, IRI was standardized to %IRI. The information on digestion state of prey were coupled with vacuity index of the predators and analysed to generate preliminary information on the approximate feeding time two tunas. The trophic diversity and relative level of dietary specialization were investigated by assessing the trophic niche breadth by calculating the Shannon-Wiener index (H') (Krebs, 1999) (by log e in the calculation) using the number of particular prey species.

The relationship between size of yellowfin tuna and prey size was studied by quantile regression analysis of yellowfin tuna size (forklength) and dominant prey length. Standard length (standard length) for teleost prey, dorsal mantle length (DML) for cephalopod prey and carapace width (CW) for crabs were considered for these analyses. The software packages 'vegan' and 'quantreg' of R was used for cumulative prey curve and quantile regression respectively.

Intact specimes of *S. oualaniensis* collected from the gut contents were subjected for beak analysis. Dorsal Mantle Length (DML) of squid specimens were measured in cm using fish measuring board and total weight measured to 0.01gm accuracy using digital weighing balance. The mantle was then cut open for studying the sex, gonad developmental stage and gut contents. Beaks were removed following Kubodera (2001).

The upper beak has a long, acute rostrum tip and large rostrum with small wings while the lower beak has a thick short rostrum tip and small rostrum with large long wings. In the lower beak, the rostrum is anterior, the lateral wall is posterior and the crest is ventral (Figure 1). Beak dimensions were measured using calipers to the nearest 0.05 mm. Measurements taken were upper and lower rostral length (URL and LRL), upper and lower hood length (UHL and LHL), upper and lower crest length (UCL and LCL), Upper and Lower Rostrum to wing base length (URW and LRW) and lower rostral tip to lateral wall free corner length (LRF) as described by Clarke (1962) and Lu and Ickernigill (2002).

For data analysis, linear regressions to describe the relationship between beak dimensions and dorsal Mantle Length and body weight were carried out. The general regression equation used was $y = c + mx$, where y is the dependent variable (Dorsal Mantle Length in cm or total weight in gm), c is the constant (or Y-intercept), m is the slope of regression and x is the beak dimensions (or independent variable). Beak dimensions used for equations are Upper and Lower rostral length, Upper and Lower hood length, upper and lower crest length, baseline length and lower rostral tip to free corner length.

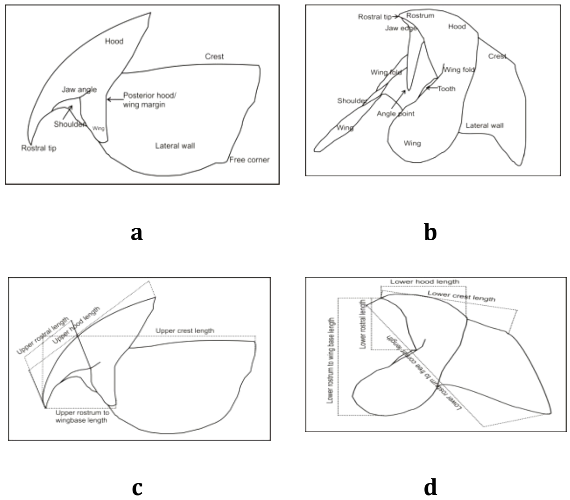


Figure 1 Diagrammatic representation of upper (a) and lower (b) squid beaks and beak measurements studied for upper (c) and lower (b) beaks

Results and discussion

i. Diet of T. albacares

Stomach contents of 406 specimens of yellowfin tuna, in the forklength of range of 48.0 to 165.5 cm (113.27±26.21 mean±standard deviation) and weight ranging from 2.3 to 88.0 kg (27.96±16.01), were analysed in this study of which, 63 specimens had empty stomachs (vacuity index - 15.52%). The percentage of empty stomachs in the present study was lower than the value reported in many of the earlier works in the region (John, 1995; Maldeniya, 1996). Weight of the stomach contents ranged from 0 to 1105 gm (104.77±181.02) and the Repletion Index were in the range 0-35.65 (3.75±5.27) g per kg body weight, which is higher than the earlier reported value of 3.5 (John, 1995; Barut, 1998). Cephalopods were the dominant prey group of yellowfin (%N = 41.12; %W = 51.97; %F = 59.3; %IRI = 51.19), followed by finfishes (%N = 39.69; %W = 37.14; %F =

61.63; %IRI = 43.91) and crustaceans (%N = 16.15; %W = 10.83; %F = 19.19; %IRI = 4.8) (Figure 2). Contribution of cephalopods to the total diet of yellowfin tuna was higher in our study than those reported in earlier studies conducted in the region (Vijayakumaran *et al.*, 1992; John and Sudarsan, 1993; Sudarsan and John, 1993, 1994; John, 1995; Govindaraj *et al.*, 2000; Rohit *et al.*, 2010).

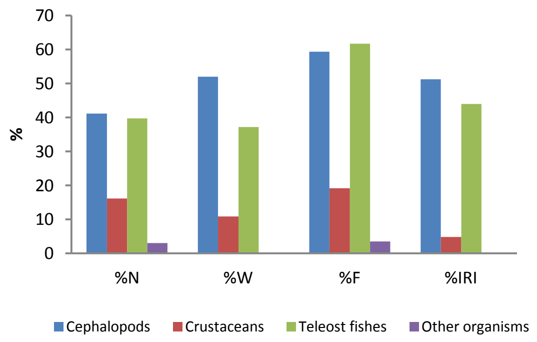


Figure 2. Dietary importance by %N, %W, %F and %IRI of prey groups of yellowfin tuna of eastern Arabian Sea

In terms of %IRI, *Sthenoteuthis oualaniensis* was the dominant prey species (%IRI = 81.76), followed by *Charybdis smithii* (%IRI = 7.27) (Table 1). Teleost fishes, including *Cubiceps pauciradiatus* (%IRI = 2.9) and *Hirundichthys coromandelensis* (%IRI = 0.5) and oceanic squid, *Onychoteuthis banksii* (%IRI = 1.14) were other principal prey species (Figure 3). The diet breadth index (Shannon-Wiener index) of yellowfin tuna was 3.1, indicating few selected species contributing substantially to the diet. The Tokeshi plot generated shows that yellowfin of Indian waters adopt generalist heterogeneous feeding strategy (Figure 4).

These results show that, although YFT prey on a wide spectrum of prey items, substantial proportion of the diet was by few prey including oceanic squids, swimming crabs and teleosts (bigeye cigarfish and flying fishes), which are available in high density in the Arabian Sea (Trotsenko and Pinchukov, 1994; Couwelaar *et al.*, 1997; Chesalin and Zuyev, 2002; Romanov *et al.*, 2009). Yellowfin tuna of Arabian Sea may be feeding mainly on these prey species, leading to low value for diet breadth index and hence showing an opportunistic feeding strategy.

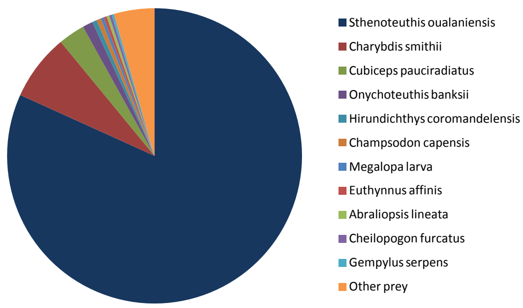


Figure 3. Dietary importance by %IRI of prey species of yellowfin tuna of eastern Arabian Sea

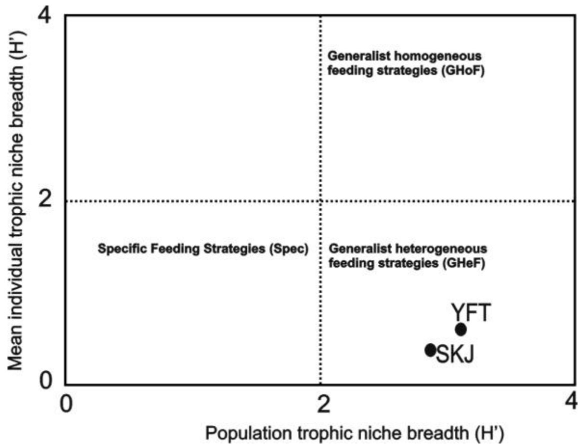


Figure 4. Yellowfin and skipjack tuna feeding strategies determined using Tokeshi graphical analysis

The predator-prey length analysis of yellowfin tuna indicates that the prey eaten by this species form small fraction of their fork length. The average prey-to-predator length ratio calculated was 7.71% (± 4.07). Of the all prey consumed, 32.12% were less than 5% of the predator length, 73 % less than 10%, and 95.75% were less than 15% of the yellowfin tuna fork length.

The maximum size of the prey species increased with predator length, while the minimum prey size remained fairly stable. Despite extensive variation between specimens, the the maximum (95th quantile), mean (50th quantile) and minimum size (5th quantile) of *S. oualaniensis* consumed by yellowfin tuna significantly increased with its size (Figure 5. In the figure, quantile regression indicate upper (95th) and lower (5th) boundaries used to describe predator and prey size relationships. Least squares regression line (50th quantile) estimates rate of change in mean prey size as a function of predator size). However, the maximum length of *C. smithii* (95th quantile) was observed to decrease with the increase in the yellowfin tuna size. Regression analysis of lengths of all prey species except *C. smithii* indicated that the mean, maximum and minimum size of prey species consumed by yellowfin tuna of increased with its size.

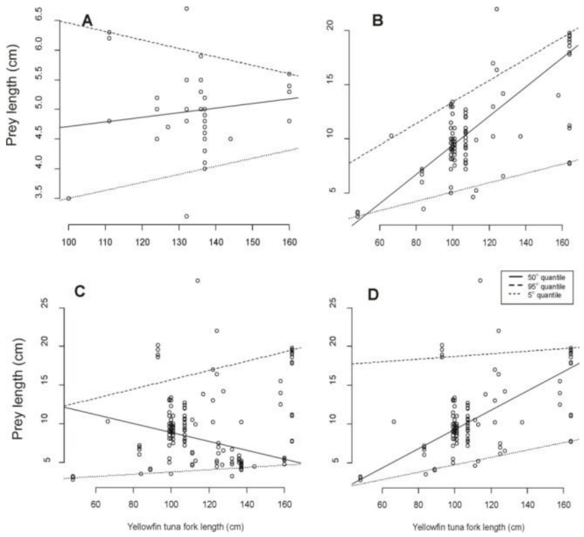


Figure 5 (adapted from Varghese et al, 2016). Scatter diagrams of the relationships of length of yellowfin tuna and its preys (A) *Charybdis smithii*, (B) *Sthenoteuthis oualaniensis* (C) all prey (D) all prey except *C. smithii*.

ii. Diet of K. pelamis

A total number of 72 skipjack stomachs were analysed in this study of which, 16 were empty (vacuity index – 22.22%). The predator specimens examined were in the forklength of range of 43.5-79.0 (65.04±7.50) and weight ranging from 1.25 to 10 kg (5.36±1.94). The average weight of gut contents was 30.66 g and the mean Repletion Index was 5.91 (±8.22) g per kg predator body weight. Substantial proportion of skipjack diet was contributed by teleosts (%N = 55.14; %W = 67.76; %F = 85.71; %IRI = 83.82). Cephalopods were the next dominant prey group (%N = 35.51; %W = 32.06; %F = 28.57; %IRI = 15.36). Contribution of crustaceans to the diet of skipjack was marginal (%N = 9.35; %W = 0.19; %F = 10.71; %IRI = 0.81) (Figure 6).

Results of present study do not agree with the earlier studies on the skipjack tuna diet undertaken from Lakshadweep waters (Raju, 1964), where the crustaceans were the dominant food item, making up 59% of the total volume, molluscs 22%, and finfishes 10%. However, the studies undertaken from the Minicoy Island revealed that finfishes formed 48%, crustaceans 47%, and miscellaneous items, mostly molluscs, 5%, of the food of skipjack tuna caught by Pole and Line (Thomas 1964). Sivadas and Wesley (2007), while studying the feeding habits of skipjack associated with flotsam in minicoy, Lakshadweep observed that Caridian shrimps were the main food in all size groups. However, the pelagic shrimps were not reported as a food item of skipjacks in the present study which deserves special attention. Roger (1994) reported that the gut contents of skipjack caught by trolling in the Mozambique area was dominated by finfishes (87% by volume), followed by crustaceans (9%) and cephalopods (4%), while the diet of those caught by purse seine in Seychelles and Mozambique areas, was contributed almost entirely by finfishes. Although teleost fishes comprise the most important source of food for skipjack tuna in most of the regions, variation in the order of importance of the major groups of food organisms are observed in different areas and seasons.

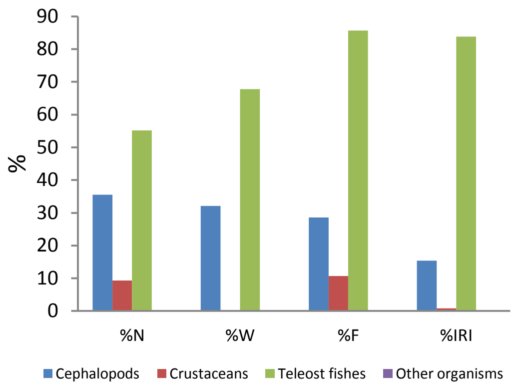


Figure 6. Dietary importance by %N, %W, %F and %IRI of prey groups of skipjack tuna of eastern Arabian Sea

In the present study, *S. oualaniensis* (%IRI = 48.93) remained the dominant prey species for skipjack also (Figure 7). *C. smithii*, the second dominant prey species of yellowfin tuna in the present study was not encountered as a food item of skipjack. Among the teleostean prey, juveniles of *Coryphaena hippurus* was the principal species (Table 1). Cannibalism was prevalent in skipjack tuna studied, being reported in 7.14% of the non-empty stomachs examined. In the central Pacific Ocean, Nakamura (1965) reported juvenile skipjack tuna in l2.4% of the skipjck tuna stomachs containing food. Juvenile skipjack tuna are reported in 7.8% of skipjack stomachs collected by Waldron arid King (1963). Conand and Argue (1980) reported that 3.3% of skipjack stomachscollected from the western Pacific Ocean contained juvenile skipjack tuna. In the Atlantic Ocean, Suarez-Caabro and Duarte-Bello (1961) and Dragovich (1972) also reported the occurrence of juvenile skipjack in stomachs of skipjack tuna.

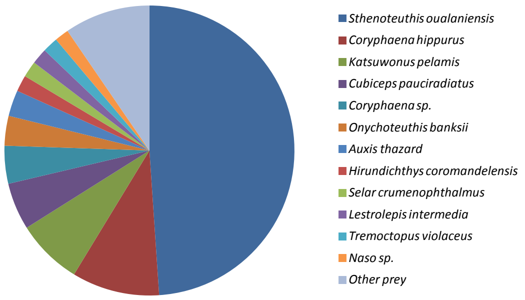


Figure 7. Dietary importance by %IRI of prey species of skipjack tuna of eastern Arabian Sea

Bigeye cigarfish (*C. pauciradiatus*), snake mackerel (*Gempylus serpens*) and flyingfish (*H. coromandelensis*) were the other dominant teleost preys of skipjack in the present study, whereas megalopa larva of decapods was the dominant crustacean prey. The wide spectrum of food organisms in the stomach contents and the variations in the importance of the major food groups have led to the conclusion that skipjack tuna are opportunistic feeders and will prey upon any forage organisms that are available to them. The diet breadth index estimated for this species was 2.87 and the analysis of diet using Tokeshi plot revealed that similar to the yellowfin, skipjack also adopt generalist heterogeneous feeding strategy (Figure 5).

iii. Trophic levels and diet overlap

The prey species of yellowfin and skipjack were analysed based on the percentage contribution by weight to the diet. Accordingly, it was assessed that for yellowfin tuna, 2.31% of the prey were categorised as benthic invertebrates, 0.17% (large zooplankton), 3.04% (small squids), 46.36% (large squids), 10.72% (pelagic crabs), 9.26% (Small pelagic fishes), 6.99% (mesopelagic fishes) and 21.15% (miscellaneous fishes). Based on the trophic levels of these groups and their percentage contribution to the diet, the trophic level of yellowfin is estimated to be 4.37. Similarly, the trophic level of skipjack was estimated to 4.28, since 5.95% of the skipjack prey were benthic invertebrates, 0.19% (large zooplankton), 2.34% (small squids), 23.76% (large squids), 9.19% (Small pelagic fishes), 12.56 (mesopelagic fishes) and 46.00% (miscellaneous fishes). Morisita-Horn index (0.6) indicated moderate overlap of the diets of these two tropical tuna species. Combining the vacuity indices of the predators and the digestion state of prey, it is inferred that both yellowfin and skipjack of eastern Arabian Sea feed mainly during day, but occasionally during night (Varghese *et al*., 2014).

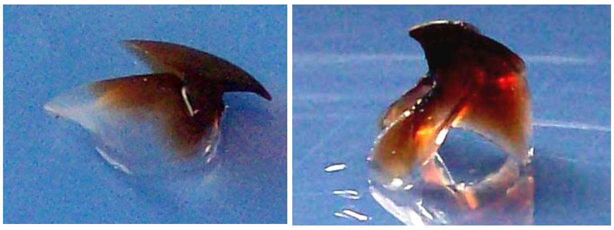
iv. Prey species biology

iv.i. Sthenoteuthis oualaniensis

The *S. oualaniensis* samples collected during the course of study were subjected for detailed analysis with the aim of establishing beak measurements-DML relationship. The intact specimens of the *S. oualaniensis* collected were in the length (DML) range of 10.5 to 14.9 cm, having total weight varying between 19.1 and 64.2 g. The sex ratio was 86:14 (F: M) and the examined specimens were in the advanced stage of sexual maturity.

The rostrum and hood of upper beak of studied specimens of *S. oualaniensis* were fully darkened, while crest is not fully pigmented. Inner rostral surface was smooth. Jaw angle slightly recessed and wing extends two-third length to base anterior margin of lateral wall. The lower beak was fully pigmented except on the borders or wing and crest, strong ridge runs obliquely on lateral wall, jaw edge sharply curved at rostral tip, rostral length greater than hood length (Figure 8). Rostrum is straight and middle pointed. Hood with shallow broad notch. Shoulder tooth absent. Angle point indistinct to dorsal margin of darkened lateral wall. Crest is very short, curved and not thickened. Lateral wall is short and rhombic in shape. Lateral wall ridge running towards free corner, not reaching posterior margin. No indentation of posterior darkened lateral wall to sides of crest.

It was observed that, all beak measurements show significant correlation with DML and body weight with coefficients of determination (r^2) greater than 0.66. The regression equations calculated are given in table 2. All length measurements are in cm.



a b

Figure 8. Upper (a) and lower (b) beaks of *Stenoteuthis oualaniensis* sampled from the gut contents of yellowfin tuna from eastern Arabian Sea

iv.ii. Charybdis smithii

Although the aim of the study was to study the biology of *C. smithii* samples collected among the food contents, no conclusive inferences could be reached except establishing the length-weight relationship of this species and, as shown in the Figure 9, the carapace width (CW) was plotted against the weight of *C. smithii* and the regression formula derived was Weight (in gm) = 0.256CW (in cm)$^{2.611}$.

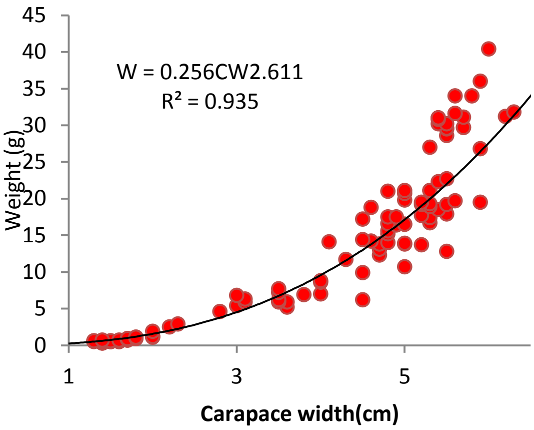


Figure 9. Carapace width - weight relationship of *Charybdis smithii* sampled from the stomach contents of yellowfin tuna

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Table 1. Relative dietary importance (%*N*, %*W*, %*F* and %*IRI*) of prey species of *K. pelamis* (SKJ) and *T. albacares* (YFT).

Prey family	Prey species/group	%N		%W		%F		%IRI	
		SKJ	YFT	SKJ	YFT	SKJ	YFT	SKJ	YFT
Ancistrocheiridae	*Ancistrocheirus lesueurii*		0.97		2.66		1.74		0.14
Argonautidae	*Argonauta hians*		0.39		0.21		3.49		0.05
Argonautidae	*Argonauta* sp.		0.13		0.05		1.16		>0.01
Bolitaenidae	*Japetella diaphana*		0.97		0.54		4.65		0.16
Cranchiidae	*Liocranchia reinhardti*	3.74	0.19	1.73	0.08	3.57	1.74	0.89	0.01
Cranchiidae	*Megalocranchia abyssicola*		0.26		0.11		1.74		0.01
Enoploteuthidae	*Abralia andamanica*	0.93		0.61		3.57		0.25	
Enoploteuthidae	*Abralia marisarabica*		0.13		0.05		1.16		>0.01
Enoploteuthidae	*Abraliopsis lineata*		1.1		1.18		5.81		0.3
Histioteuthidae	*Histioteuthis hoylei*		1.56		0.56		2.91		0.14
Histioteuthidae	*Histioteuthis* sp.		0.13		0.17		0.58		>0.01
Octopodidae	*Benthoctopus behni*		0.13		0.11		0.58		>0.01
Ommastrephidae	*Sthenoteuthis oualaniensis*	23.36	27.5	19.74	39.45	25	53.49	48.93	81.76
Onychoteuthidae	*Onychoteuthis banksii*	2.8	1.82	4.02	2.95	10.71	10.47	3.32	1.14
Spirulidae	*Spirula spirula*		0.06		0.09		0.58		>0.01
Thysanoteuthidae	*Pholidoteuthis boschmai*		0.32		1.3		1.74		0.06
Tremoctopodidae	*Tremoctopus violaceus*	4.67	0.39	5.95	0.19	3.57	2.33	1.72	0.03
	Octopus n.i.		0.71		1.39		4.07		0.2
	Squid n.i.		4.35		0.9		10.47		1.25
	Total Cephalopods	**35.51**	**41.12**	**32.06**	**51.97**	**28.57**	**59.3**	**15.36**	**51.19**
Nannosquillidae	*Acanthosquilla* sp.		0.06		0.01		0.58		>0.01
Portunidae	*Charybdis smithii*		13.1		10.72		13.37		7.27
	Alima larva	0.93		0.04		3.57		0.16	
	Megalopa larva	7.48	2.79	0.13	0.09	3.57	5.23	1.23	0.34
	Squilla n.i.	0.93	0.19	0.03	0.01	3.57	1.74	0.16	0.01
	Total Crustaceans	**9.35**	**16.15**	**0.19**	**10.83**	**10.71**	**19.19**	**0.81**	**4.8**
Acanthuridae	Naso sp.	3.74	0.19	1.13	0.31	7.14	0.58	1.58	0.01
Acropomatidae	*Acropoma japonicum*		0.13		0.01		0.58		>0.01
Apogonidae	*Apogonidae* n.i.	0.93		0.13		3.57		0.17	>0.01
Acropomatidae	*Acropomatidae* n.i.	6.54	0.45	1.73	0.08	3.57	1.16	1.34	0.01
Alepisauridae	*Alepisaurus ferox*								>0.01
Balistidae	*Canthidermis maculata*	1.87	0.06	0.57	0.09	3.57	0.58	0.4	>0.01
Balistidae	*Odonus niger*		0.19		0.04		1.74		0.01
Balistidae	*Sufflamen* sp.		0.13		0.03		0.58		>0.01
Balistidae	Balistidae n.i.		0.13		0.03		1.16		>0.01
Berycidae	*Beryx* sp.		0.71		1.25		2.33		0.1
Bramidae	*Brama* sp.		0.58		0.07		0.58		0.01

Carangidae	*Decapterus macrosoma*	0.93	0.06	2.53	0.45	3.57	0.58	0.56	0.01
Carangidae	*Elagatis bipinnulata*		0.06		0.14		0.58		>0.01
Carangidae	*Naucrates ductor*	0.93		1.3		3.57		0.36	
Carangidae	*Selar crumenophthalmus*	1.87	0.32	3.69	4.12	7.14	1.74	1.8	0.18
Centrolophidae	Centrolophidae n.i.		0.91		0.63		2.91		0.1
Champsodontidae	*Champsodon capensis*		2.53		0.56		6.98		0.49
Stomiidae	*Chauliodus sloani*		0.32		0.16		1.16		0.01
clupeidae	Clupeidae n.i.	2.8		1.8		7.14		1.49	
Coryphaenidae	*Coryphaena equiselis*		0.06		0.05		0.58		>0.01
Coryphaenidae	*Coryphaena hippurus*	5.61		9.45		14.29		9.77	
Coryphaenidae	*Coryphaena* sp.	6.54		2.13		10.71		4.22	
Diodontidae	*Diodon* sp.	0.93		0.04		3.57		0.16	
Diretmidae	*Diretmus argenteus*		0.26		0.16		1.16		0.01
Diretmidae	*Diretmus* sp.		0.06		0.04		0.58		>0.01
Engraulidae	*Engraulidae* n.i.		0.52		0.13		0.58		0.01
Exocoetidae	*Cheilopogon furcatus*		1.23		1.39		4.65		0.28
Exocoetidae	*Cheilopogon* sp.		0.06		0.02		0.58		>0.01
Exocoetidae	*Exocoetus monocirrhus*		0.39		1.35		2.91		0.12
Exocoetidae	*Hirundichthys coromandelensis*	1.87	1.43	3.74	3.94	7.14	4.07	1.82	0.5
Exocoetidae	*Hirundichthys sp.*		0.13		0.33		1.16		0.01
Exocoetidae	*Exocoetus* sp.		0.13		0.04		0.58		>0.01
Gempylidae	*Gempylus serpens*	1.87	1.43	1.8	0.45	7.14	5.81	1.19	0.25
Gempylidae	*Lepidocybium flavobrunneum*		0.19		3.35		1.74		0.14
Gempylidae	*Neoepinnula orientalis*		0.06		0.06		0.58		>0.01
Leiognathidae	*Leiognathidae* n.i.	4.67		1.72		3.57		1.04	
Microstomatidae	*Nansenia macrolepis*		1.04		0.12		0.58		0.02
Microstomatidae	*Nansenia obscura*		1.3		0.04		0.58		0.02
Monacanthidae	*Aluterus monoceros*		0.78		0.03		0.58		0.01
Monacanthidae	*Thamnaconus modestoides*		2.01		0.67		2.33		0.14
Monacanthidae	*Monacanthidae* n.i.		0.06		>0.01		0.58		>0.01
Muraenesocidae	*Gavialiceps taeniola*		0.19		0.48		0.58		0.01
Myctophidae	*Diaphus* sp.		1.62		0.15		1.74		0.07
Myctophidae	*Lampanyctus* sp.		5.77		0.66		1.16		0.17
Myctophidae	*Myctophum* sp.								>0.01
Nomeidae	*Cubiceps capensis*		0.65		0.79		0.58		0.02
Nomeidae	*Cubiceps pauciradiatus*	4.67	5.19	1.8	2.61	17.86	16.28	5.25	2.9
Omosudidae	*Omosudis* sp.		0.78		0.58		1.16		0.04
Ostraciidae	*Lactoria diaphana*		0.06		>0.01		0.58		>0.01
Paralepididae	*Paralepis* sp.		1.62		0.24		1.74		0.07
Paralepididae	*Lestrolepis intermedia*	3.74		7.18		3.57		1.77	

Phosichthyidae	*Vinciguerria attenuata*		0.45		0.34		2.33		0.04
Scombridae	*Auxis rochei*		0.06		1.36		0.58		0.02
Scombridae	*Auxis* sp.		0.06		0.1		0.58		>0.01
Scombridae	*Auxis thazard*	2.8	0.13	6.12	1.04	7.14	1.16	2.9	0.03
Scombridae	*Euthynnus affinis*		0.58		5.53		2.33		0.32
Scombridae	*Katsuwonus pelamis*	1.87		20.83		7.14		7.36	
Scombridae	Tuna n.i.		0.13		0.79		1.16		0.02
Scombridae	Scombridae n.i.		0.06		1.04		0.58		0.01
Scopelarchidae	*Scopelarchus analis*		0.13		0.04		0.58		>0.01
Scopelarchidae	*Scopelarchus guntheri*		0.06		0.03		0.58		>0.01
Sternoptychidae	*Argyropelecus gigas*		0.06		0.02		0.58		>0.01
Sternoptychidae	*Sternoptyx diaphana*		0.06		0.03		0.58		>0.01
Sternoptychidae	Hatchetfish n.i.		1.36		0.3		5.81		0.22
	Finfishes n.i.		1.95		0.81		7.56		0.48
	Fish larva n.i.	0.93	0.71	0.04	0.03	3.57	2.33	0.16	0.04
	Total Finfishes	**55.14**	**39.69**	**67.76**	**37.14**	**85.71**	**61.63**	**83.82**	**43.91**
	Salpa n.i.		1.1		0.04		2.91		0.08
	Chaetognatha n.i.		1.95		0.03		1.74		0.08
	Total other organisms		**3.05**		**0.06**		**3.49**		**0.1**
	Predator diet breadth (H')							2.87	3.1

n.i. – not identified

Table2. Formulae for back calculation of DML of *S. Oualaniensis* from beak measurements

Beak measurement	Formula	r^2
Upper Rostral length	DML (cm) = 1.272 + 33.069 URL	0.8329
Upper Hood length	DML (cm) = -0.7089 + 13.97 UHL	0.8254
Upper Crest length	DML (cm) = 0.3023 + 9.9363 UCL	0.82
Upper Rostrum to wing base length	DML (cm) = 3.4731 + 20.765 URW	0.7822
Baseline length	DML (cm) = 0.9455 + 14.542 BLL	0.6891
Lower Rostral length	DML (cm) = 5.8013 + 22.236 LRL	0.619
Lower Hood length	DML (cm) = 5.0649 + 27.567 LHL	0.6885
Lower Crest length	DML (cm) = 4.1144 + 14.802 LCL	0.6698
Lower Rostrum to wing base length	DML (cm) = 0.8201 + 16.322 LRW	0.702
Lower Rostrum to free corner length	DML (cm) = 2.8361 + 11.278 LRF	0.7342