International Journal of Applied Research 2023; 9(4): 241-250

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 8.4
IJAR 2023; 9(4): 241-250
www.allresearchjournal.com
Received: 21-03-2023
Accepted: 25-04-2023

VM Chavda
College of Fisheries Science, Veraval, Gujarat, India

DT Vaghela
College of Fisheries Science, Veraval, Gujarat, India

PV Parmar
College of Fisheries Science, Veraval, Gujarat, India

HV Parmar
College of Fisheries Science, Veraval, Gujarat, India

Corresponding Author:
VM Chavda
College of Fisheries Science, Veraval, Gujarat, India

Composite gut contest analysis and trophic modeling of fish catch from potential fishing zone, off Veraval coast

VM Chavda, DT Vaghela, PV Parmar and HV Parmar

DOI: https://www.doi.org/10.22271/allresearch.2023.v9.i4c.12927

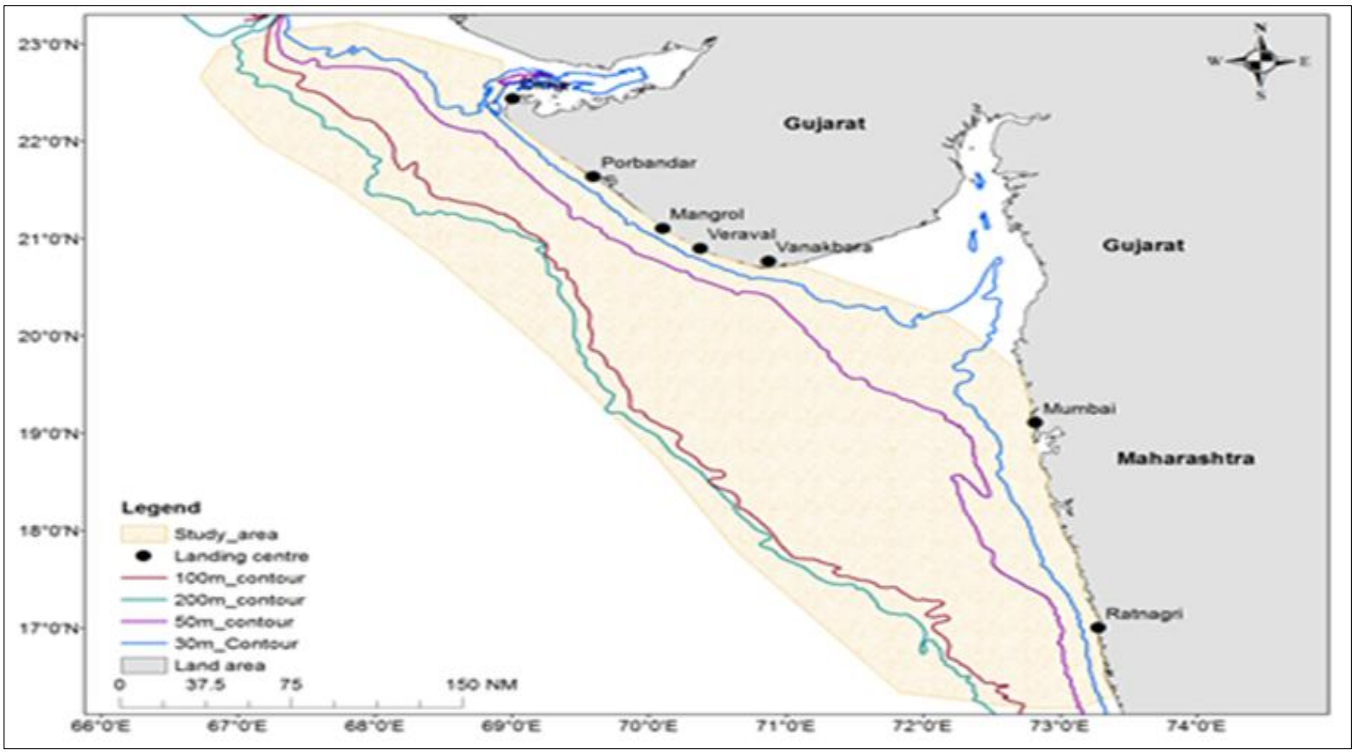
Abstract
Information on oceanographic features such as fronts, eddies, gyres, currents and upwelling derived from satellites is useful in fisheries, since fishes usually congregate in these areas for feeding and other physiological requirements. Satellite Remote Sensing techniques can be used to detect fish aggregation by measuring the parameters, which affect the distribution of fishes. Remote sensing is a time and energy saving technique for fishermen to locate fishery resources along the coast. Indian National Center for Ocean Information Services (INCOIS) provides satellite-based potential fishing zones (PFZs) forecasts using the integration of MODIS derived chlorophyll concentration and Advanced Very High Resolution Radiometer (AVHRR) derived sea surface temperatures (SST). In the present study evaluation of fish catch was carried out during 2017 - 2018 using commercial fishing vessels off Veraval coast at 20 to 50m depth in PFZ demarcated and non-PFZ areas using trawl net. The qualitative gut contect analysis was carried out for the fish species found in potential fishing zone and trophic modeling was attempted.

Keywords: PFZ, potential fishing zone, qualitative gut content analysis, Veraval Coast

Introduction
India is blessed by the total of 8129 km coastlines covering 9 maritime states and 2 union territories. The marine fish landings from the coast of the mainland of India in 2017 was estimated at 3.83 million tones, showing an increase by about 5.6% compared to the landings in 2016 (CMFRI 2017-18) [1]. In the year 2016, marine fish production of the country has shown an increase of 6.6% compared to 2015 recording a total of 3.63 million tonnes. The marine fish production in the year 2015 was 3.40 million tonnes. Among the four regions of the Indian peninsular coastline, the north-west coast comprising of Maharashtra, Gujarat and Daman & Diu contributed a maximum share to 33% of the total landings (11.83 lakh tonnes) (CMFRI, 2017- 18) [1]. In Gujarat, the annual marine fish landings during 2017 registered an all-time high of 786495 t. During 2016, the fish landings were 774373 t. Maximum catch and catch per unit effort was noticed during the post-monsoon and winter seasons, which are the peak fishing seasons along the Gujarat coast. Assemblage wise marine fish landings during 2017 showed the predominance of the pelagic finfish resources (36%), followed by demersals (30%), crustaceans (26%) and molluscan resources (8%).

Material and methods
The present study was conducted off the Veraval coast of Gujarat. The precise geographical coordinates of fishing and other information on time of fishing, depth of the fishing area, catch details, etc., in a structured schedule were collected from the identified trawlers operated basing the Veraval fishing grounds (Lat- 20°51' N Long - 70°12'E) situated in the Gir-Somnath district of Gujarat, India. Veraval is the most important fish landing center along the coast of Gujarat in terms of the quantum of fish landing, area of the harbour and number of crafts. The present study was conducted in the year 2017 - 2018. Experimental commercial fishing carried out off Veraval coast from August 2017 to May 2018.
The data collection from commercial fishing vessels was restricted to the fishing coordinates (Lat- 20° N Long - 70°'E) as mentioned in potential fishing zone advisories disseminated by INCOIS, Hyderabad. The speciemens sample were collected from Veraval fishing harbour,

chilled, taken to the laboratory in sampling box for further analyses. Composite gut content analyses was carried out on the samples of selected spaecies. Petridish, Scalpel, dissection microscope, compound microscope was used for gut content analysis. The total weight of the species were recorded. The samples were collected and fixed in 5% formalin solution. The gut content analysis was carried out on at least 5% of the catch. The fishes were cut open, gastro-intestinal tract was drawn out in a petri dish. The stomach and intestine were cut opened and the gut content was collected in watch glass/slide for further analysis with dissection microscope. Only qualitative analysis was carried out. The gut content analysis for a particular species is represented as composite feed analysis. For the most frequently encountered species in the samples, the percentages of the fishes fed on with respect to their gut content, were calculated and monthly averaged for the given study period for the analysis in shift in trophic position, if any and its relevance to potential fishing zone.



Bathymetry map of study Area

Fish Samples

Coilia

Sciaenid

Osteogeneiousus militaris

Tenulosa

Lutjanid

Upenid

Results and Discussion

Species wise total biomass of fish species is given in the tropical waters for PFZ success, SST might not be the only contributing factors. The variations in the fish catch could be explained by other factors like chlorophyll cencentration, nutrient availability, oxygen content, coastal upwelling, frontal activities, current patterns etc. can also contribute towards increase in the fish catch (Narendra Nath *et al*., 1991) [10] Table 1 shows species of fish found in PFZ region off Veraval coast. Dominant species found were clupids, carangids, Ribbon fish, Seer fish. Table 2 and 3 shows composite gut contest analysis of selected species found in PFZ off Veraval coast.

Table 1: Shows species of fish found in PFZ region off Veraval coast

Species group	% in PFZ
Wolf herring	3.5
Lesser sardine	3.1
Bombay duck	1.1
Priacanthid	2.7
Clupeids	11.2
Sciaenids	2.9
Upenoids	2.6
Mullets	0.3
Barracuda	3.9
Snapper	0.9
Carangids	9.9
Horse mackerel	5.4
Elasmobranch	1.3
Ribbonfish	7.2
Mackerel	4.8
Seer fish	8.2
Lizard fishes	1.1
Catfishes	4.8
Nemipterids	4.4
Silver bellies	2.6
Terapon	1.8
Cephalopods	4.8
Tuna	4.2
Misc.	7.3
Total	100

Table 2: Composite Gut content analysis

Species	Sample size	Food composition	Percentage
Gerrus filamentous	130	Crustacean appendages	50
		Semi digested matter	50
Stolephorus	140	Completely digested matter	30
		Plankton	70
Remora	70	Semi digested matter (plant)	50
		Empty	50
Trichurus	60	Fish remains	18
		Fish vertebrae	56
		Nemipterus	26
Mene maculata	*50*	*Stolephorus*	20
		Digested material	20
		Fish remains	60
Sphyraena obtusata	50	*Stolephorus*	50
		Saurida	50
Horse mackerel	50	Crustacean appendages	35
		Plankton	38
		Spines	27
Chirocentrus dorab	50	*Stolephorus*	23
		Clupeids	20
		Semi digested matter	57
Lactarius lactarius	50	Crustacean appendages	38
		Fish remains	38
		Shrimps	24
Thryssa mystax	60	Crustacean appendages	38
		Shrimps	23
		Semi digested material	38
Secutor ruconius	50	Detritus	13
		zooplankton	10
		Crustacean appendages	41
		Semi digested matter	36
Carangid	160	Fish remains	67
		Fish eggs	11
		Semi digested matter	22
Trachinotus spp.	40	Plankton	37.5
		Semi digested matter	50
Ilisha melastoma	40	Crustacean appendages	100
Sciaenidae	70	Zooplankton	60
		Crustacean appendages	26
		Organic matter	14
		Debris	60
Saurida gracilis	40	Fish remains	70
		Semi digested matter	30
Thryssa	30	Fish remains	100
Uroteuthis	40	Empty	100
Nemipterus	50	Semi digested matter	58
		Fish scales	42
Paraupeneopsis	40	Crustacean appendages	100
Scomberomorus	40	Semi digested Matter	50
		Fish remains	50
Platycephalus	40	Fish vertebrae	20
		Fish remains	27
		Semi digested matter	24
		Completely digested matter	29
Leiognathus	40	Crustacean appendages	34
		Plankton	36
		Detritus	30
Dussumieria accuta	40	Completely digested matter	22
		Crustacean appendages	27
		Fish egg	15
		Detritus	36
Sardinella sp.	40	Planktons	100

The study of food and feeding habits of marine fishes can be attempted from the standpoint of transfer of energy from one trophic level to another. The relationships can be attempted to be interpreted as food chain models showing the groups of organisms which directly form a part of the food chain. Studies on gut content would give an insight into the temporal and spatial trophic position of the species and its relevance to potential fishing zone.

In the present studies, the group of fishes like *Sardinella, Rastrelliger, and Ilisha* were found to be feeding on planktoninc organisms. This group can be placed in the grazing food chain as their chief food consisted of zooplankton and phytoplankton.

Lesser sardines were observed to feed on phytoplankton. Gut content revealed presence of planktons in the food. Stolephorus forms a food of fishes like Carangids, Ribbon fishes, Tunas, Seer fishes, Barracudas, Sciaenids, Sharks, Wolf herring, etc. *Stolephorus* gut content showed the presence of diatoms and remains of crustacean zooplankton.

Among the molluscan species, *U. dauvaceli* and *Sepia sp* dominated the catch, they seem to be feeding on crustaceans and small fishes near mid pelagic. Studies by Ramanathan *et al.* (1976) [13], Datta and Das (1983) [2], Kuthlingam (1957) [8] showed presence of crustacean as highly favoured item followed by bivalves, polychaetes, fish larvae etc.

Fishes like *Scomberomorus, Trichiurus, Lepturacanthus, Chirocentrus, Lactarius, Mene maculata, Sphyraena* showed a piscivorous carnivorous preference of food. It feeds both on the fishes of the herbivorous and benthivore group.

Scomberomorus spp. was dominant in winter and summer months in notified zone, and in lesser biomass in non-notified zone. The occurrence of the species in the respective months is in accordance with the Vijayaraghavan (1987) [21], as it stays in surface waters near the shore during July to February, when they breed and descend to midwater during the summer months of March to June. According to him it is found to feed on *Leiognathus spp., Lates calcarifer, Caranx spp., Lactarius lactarius* and larval eel and other crustacean and molluscan. Gut content analysis showed stomach filled with fish remains in the present investigation.

Trichuirus lepturus was found to feed on teleostean fish, as fish remains were found in the gut content, James (1967) [5], James *et al.* (1983) [6] and Prabhu (1958) [12] found similar results with the Ribbon fish feeding on Leiognathus, Sardinella, *Stolephorus* and Saurida. They also found the presence of crustaceans like shrimp and squilla, which did not find in the present study.

Chirocentrus dorab was found to feed on *Stolephorus* in the present studies, which is in accordance with Venkataraman (1961) [20]. He mentioned the fish is a diurnal predator feeding on *Stolephorus*, sardine, young ribbonfish, adult sardine, etc.

Gut content of Lactarius showed fish and crustacean remains, the result, which is in accordance with Venkataraman (1960) [20]. According to him the fish feeds on *Stolephorus, Thryssa, Leiognathus, Saurid*a and crustacean like *Squilla* and *Acetes*.

Sphyraena obtusata was found to feed on *Stolephorus*, Saurida, *Platycephalus* and *Nemipterus* whereas *Mene maculata* gut content showed presence of *Stolephorus* and other unidentified fish remains.

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Gut content of *Megalapspis cordyla* showed highly carnivorous habit feeding on juvenile Sciaenids and Sardinella (Venkataraman, 1960) [20] while Caranx kalla, *Caranx djedaba* showed the presence of zooplankton, diatoms, detritus and fish eggs (Venkataraman, 1960, Kagwade, 1971) [20, 7].

In younger specimens of Sciaenids gut content was found to be zooplankton mainly copepod, lower crustacean forms, and detritus while in older specimens were observed with fish remains and crustacean forms including shrimps (Venkataraman, 1960) [20].

Gut content of *Nemipterus* showed a wide feeding carnivorous, prefence with crustaceans like *squilla, acetes*, shrimps, crab. Among zooplankton copepods were dominant along with ostracods. Molluscan remains, annelid worms and detritus along with Leiognathus and other teleostean were also present. Sometime they also feed on vegetable matter. Present study results of *Nemipterus* gut content are in accordance with Eggleston (1971) [3] and Kuthalingam (1959) [9].

Saurida gracilis, in present study found to feed voraciously on Leiognathids, Nemipterus, *Stolephorus*, Platycephalus, Lolligo and shrimp with cannibalistic tendency. Our findings are similar to Kuthalingam (1959) [9] and Rao (1981) [14].

In the present studies *Thryssa mystax* was found to be carnivorous preying mainly on fishes and shrimps, which is in accordance with Venkararaman (1956) and Hussain and Ali (1987) [19, 4].

In the Leiognathids, *Secutor ruconius* was found to feed on plankton, with copepods most favoured. *Leiognathus bindus* found to be a zooplankton feeder along with carnivorus tendency. Our results on Leiognathids are in accordance with Venkataraman (1960) [20].

Thus, gut content analysis shows the presence of grazing food chain, benthic food chain, and the presence of the group of fishes feeding on both of them, i.e. piscivorous carnivorous fishes.

Analysis of percentage composition food of fish didn't give any clear conclusive importance and shift of food regime in trophic structure and spectrum, which can be positively related to the stability of food chain related to thermal/chlorophyll fronts which forms the potential fishing zone forecast. The study indicates higher fish catch can be obtained for selected species with incorporation of more oceanographic or biological parameters of species. Nurdin *et al.* (2012) [11] was successful in locating fish aggregation of *Rastrelliger kanagurta* based on reclassified PFZ maps after recalibrating oceanographic parameters SST and ocean color in Indonesian waters.

Table 3: Catch rates of predator-prey species in PFZ

	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18
Seer fish	65	74	107	93	99	114	86	78	60	52
Carangids	96	106	149	128	121	108	97	85	61	49
Ribbonfish	67	90	107	98	87	67	67	59	47	39
Clupeids	153	135	138	126	137	130	97	91	65	59
Lesser sardine	43	45	29	30	42	39	29	23	19	13
Wolf herring	44	42	37	35	45	40	31	30	26	25
Barracuda	26	37	42	45	53	49	41	38	32	29
Horse mackerel	55	69	74	76	71	57	44	40	32	28
Nemipterids	27	38	58	49	62	60	33	29	47	43
Silver bellies	18	23	22	29	33	40	19	26	22	29

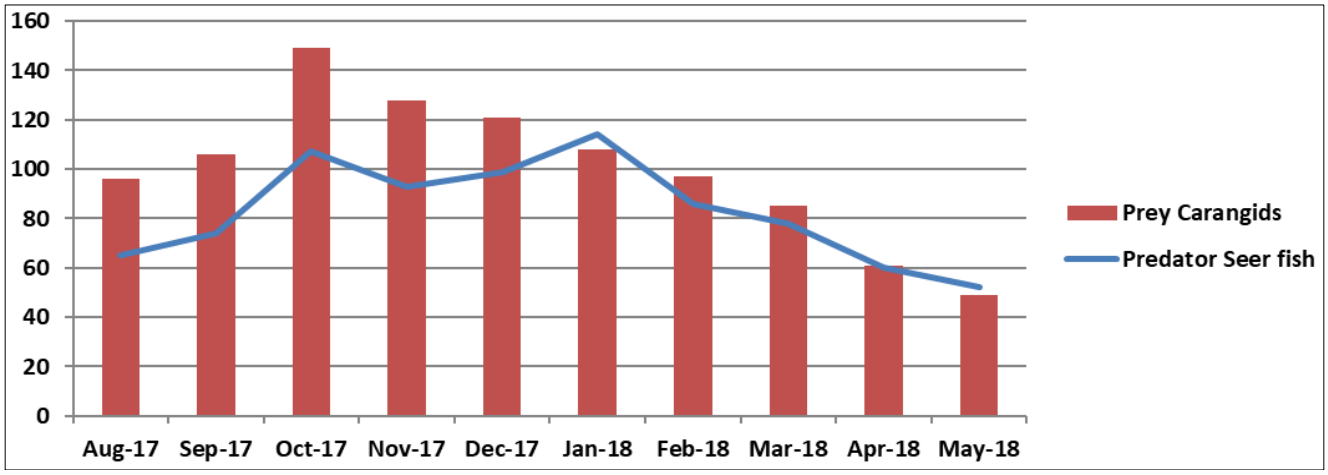

Fig 1: Trend of Carangid and Seer fish

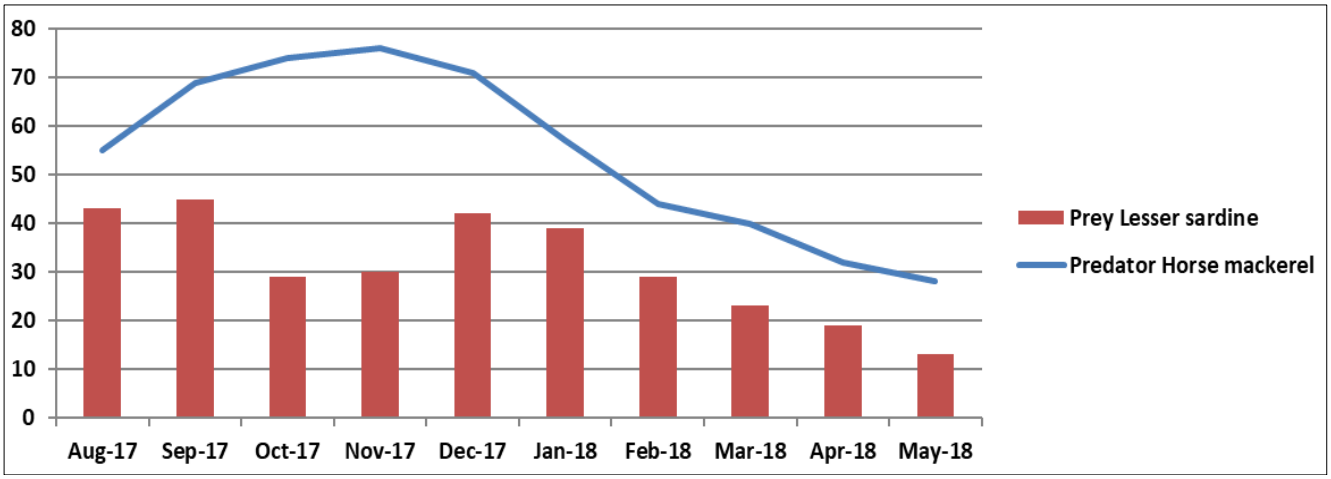

Fig 2: Trend of Horse mackerel and Lesser sardine

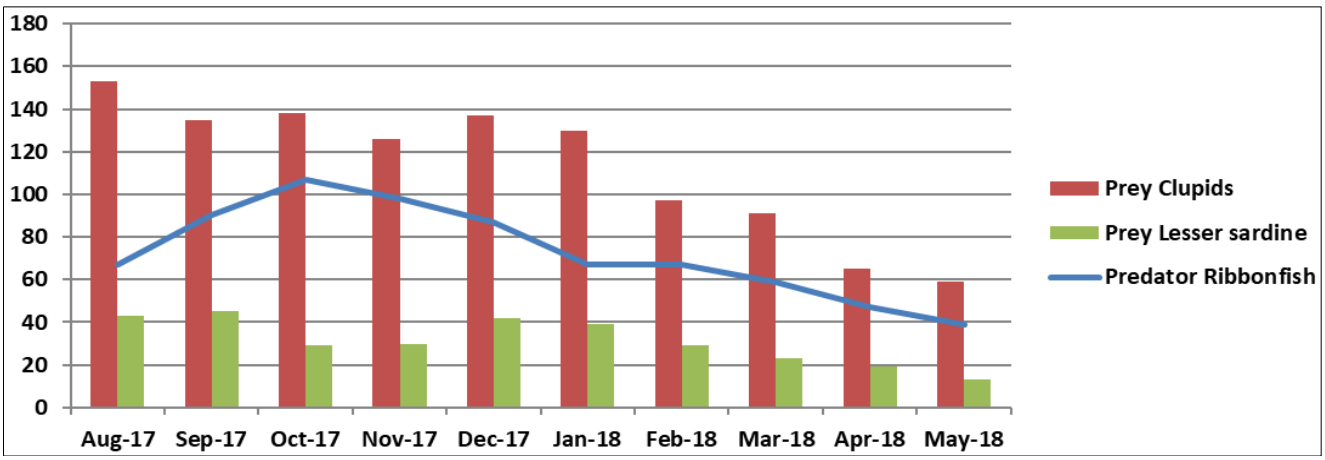

Fig 3: Trends of Ribbon fish, Clupid and Lesser sardine

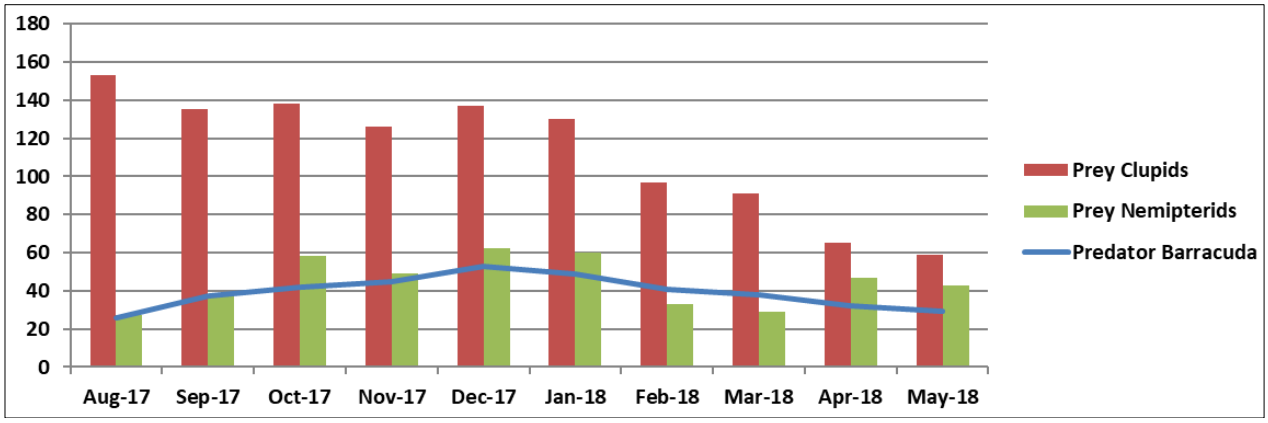

Fig 4: Trend of Barracuda on Clupeids and Nemipterids

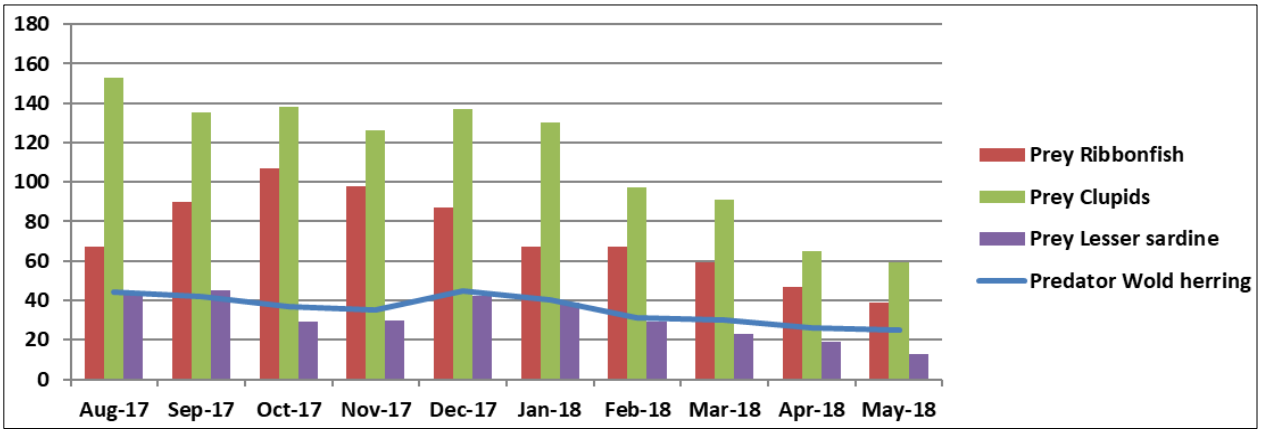

Fig 5: Trend of Wolf Herring on Ribbon fish, Clupeids and Lesser sardine.

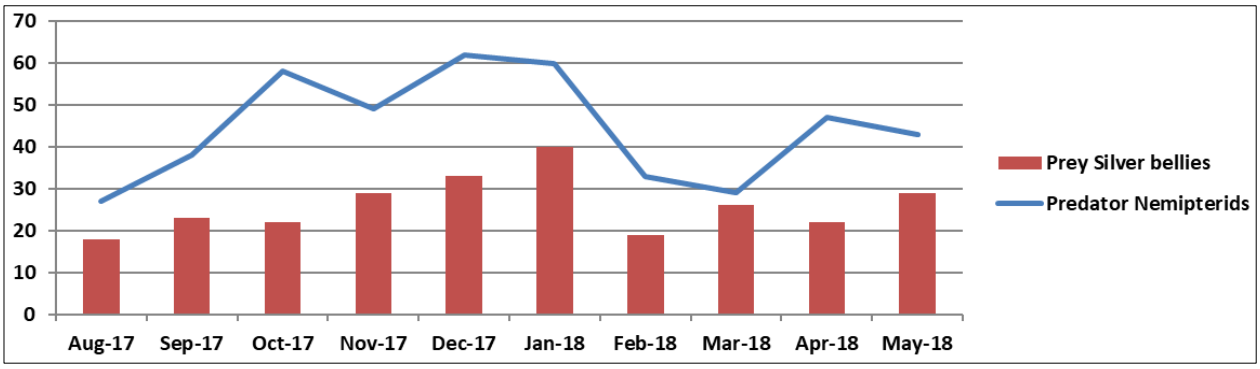

Fig 6: Trend of Nemipterids on Silver bellies.

Predator - Prey trends in PFZ.

The study of gut content analysis of marine fishes was attempted from the standpoint of transfer of energy from one trophic level to another. Table 3 shows the catch rates of various predator - prey species groups captures in notified zone.

Fig. 4.29 shows Scombrid catch on Carangid. The Carangid forms the food of Seer fish. The Seer fish catch trends co-insides with that of the catch trends of Carangids in PFZ during the study period.

Fig. 4.30 shows Horse mackerel catch trends on Lesser sardine. Lesser sardine is prey species of Horse mackerel. The two species groups shows similar catch trends. Fig. 4.31 shows trends of Predator Ribbon fish on prey Clupeids and Lesser sardine. Fig..4.32 shows Barracuda catch rates coinsiding to that of Clupeids and Nemipterids. Fig 4.33 shows trends of Wolf Herring on Ribbon fish, Clupeids and Lesser sardines. Fig. 4.34 shows trends of Nemipterids on Silver bellies.

Based on the present results, presence of predator-prey pairs on spatial and temporal domain was found. Graphical presentation (Fig. 4.29 to 4.34) indicates the co-occurrences of herbivore and carnivore species in varying ratios. The results of present study are similar with Seki (2002) [16]. According to him the sword fish diet studies identified the predilection of the species for Squid (Toll and Hess, 1981; Stiwell and Kohler, 1985; Seki, 1993) [18, 17] and research surveys suggested higher squid abundance in cold side of the southern front of the STFZ (North Pacific Subtropical Frontal Zone), correspondingly swordfish catch rates were also highest in the vicinity along the same front during the time period. It may be possible that the dependency as a predator-prey front may concentrate Clupeids, Lesser sardine, Nemipterids, Horse mackerel and Ribbon fish spatio-temporal closer to each other. Gut content analysis as

well as occurrence of planktivore and carnivore species indicates that the presence of chlorophyll and availability of planktivore fish can attract the large carnivores along the with SST supported favourable temperature. Fish behaviour as well as age of fish also plays role in its availability in PFZ. Romeo *et al.* (2011) [15] studied the relationship between SST, fish catch, CPUE and fish swimming behaviour of adult and juveniles. Using data from AVHRR SST, and direct observation established the courtship behaviour of sword tail in mature adult specimens. Hence it is imperative to incorporate multiple criteria for delineation of PFZ.

The predator - prey relationships in terms of catch trends of combination of species as found in PFZ region can be interpreted as food chain models showing the groups of organisms which directly form a part of food chain. Studies on gut content would give an insight into the temporal and spatial trophic position and trophic interaction of the species and its relevance to potential fishing zone.

Trophic modelling

A large assemblage of animals with a similar food requirement gives rise to competition within the same trophic level, which makes food chain long and complex. Such kind of inclusion of parameter like predator-prey interaction through food and feeding habits along with physico-biological preference give rise to ecological modelling for better species specific catch prediction.

The fish resources may be regarded as a part of an ecological system in which physical, chemical and biological forces of great complexity operate and fluctuate. These resources are the links in the food chain - starting with the sun's energy and its conversation by plant communities into organic matter and ending up with exploitable fish, crustaceans and molluscs.

The group of fishes like *Sardinella, Rastrelliger, Tenulosa, Thryssa, Ilisha melastoma* was found to be feeding on planktonic organisms. This group can be placed in the Grazing food chain as their chief food consisted of zooplankton and phytoplankton. The presence of debris and other benthic forms of food proves the presence of vertical migration of these fishes.

Among the cephalopods, midwater species like *Sepia* and *U. duvauceli* seem to be feeding on crustaceans and small fishes near the bottom. The catch analysis has revealed that there was a lack of presence of shrimp. Those present were of very minute wild species. Among the shellfish, cephalopods dominated the catch. The fishes like *Leiognathus, Carangid, Sciaenid* were found to be feeding on benthic forms as mentioned in food chain model.

Fishes like *Scomberomorus, Lepturacanthus, Chirocentrus, Lactarius, Mene maculata, Sphyraena* showed a piscivorous carnivorous preference of food. It feeds both on the fishes of the herbivorous and benthivour group.

Thus, gut content analysis leads to the trophic model as depicted in Fig 7 and 8, showing the presence of grazing food chain, benthic food chain, and the presence of the group of fishes feeding on both of them, i.e., piscivorous carnivorous fishes. The study on life history, physiology and behavior towards oceanographic parameters of species play an important role in the availability of biomass in notified zone.

Benthic Food Chain

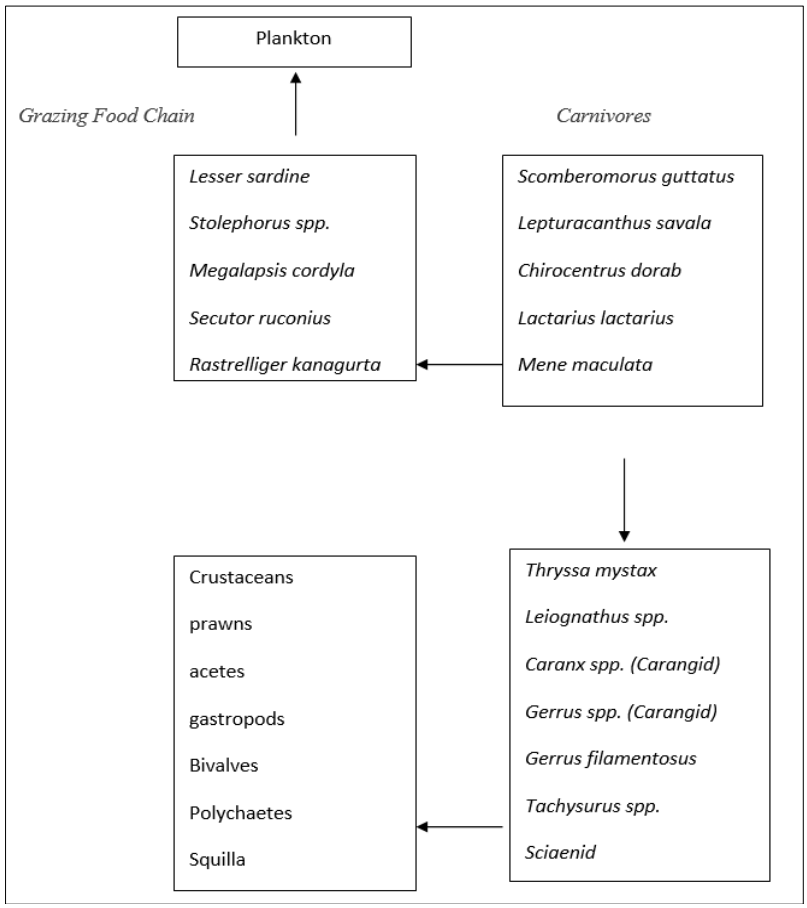

Fig 7: Food chain in PFZ

Trophic Model for PFZ demarcation

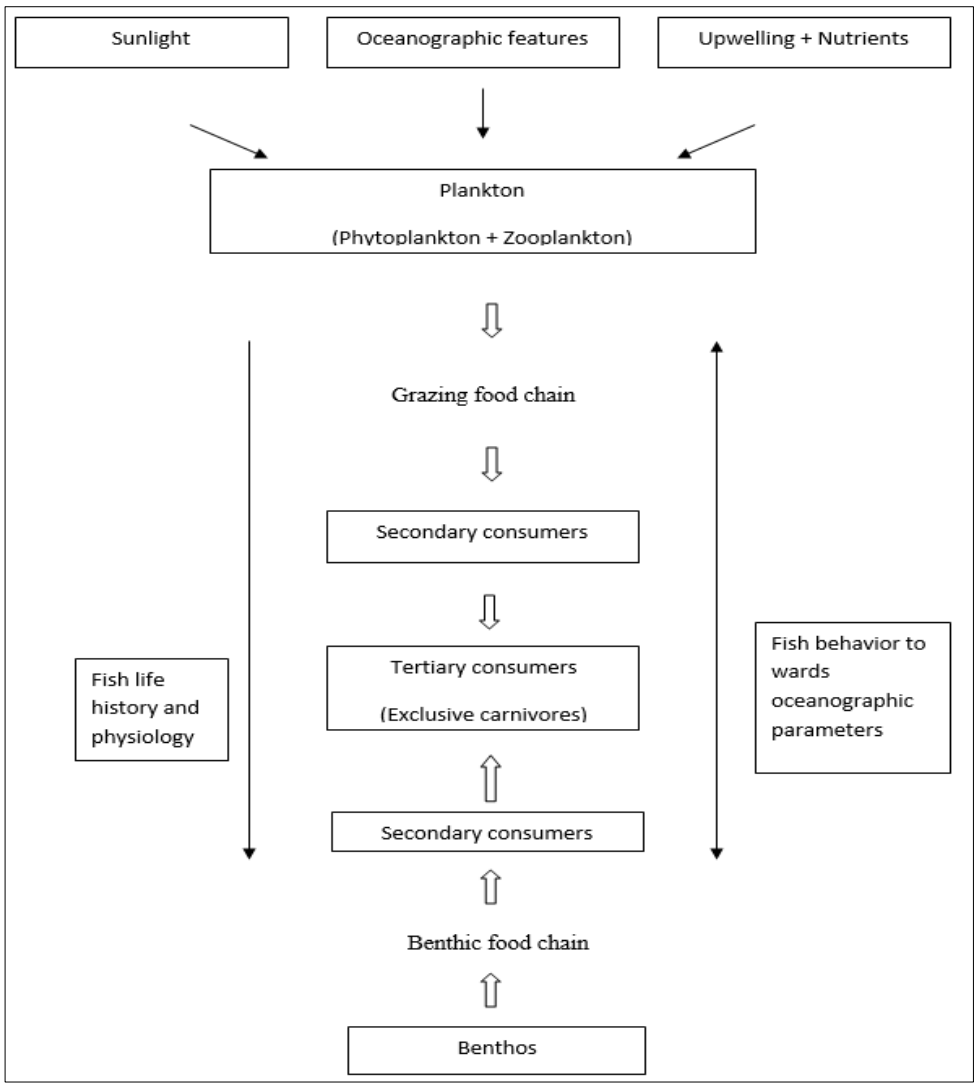

Fig 8: *PFZ* Trophic model

Conclusion

Affinity towards oceanographic features and trophic interactions play important role for distribution and availability of desired fish species in the sea. Based on the trophic model and interactions among species, PFZ maps can be attempted for species specific potential fishing zone.

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