Research Achievements

Institutional/ Divisional projects

Development of management advisories for sustaining marine fisheries of Andhra Pradesh

The total marine fish production of A.P. for 2010 was 2.53 lakh t. Pelagic resources accounted for 1.39 lakh t forming 55% of the total landings for the state. The dominant groups landed were clupeids (0.76 lakh t and 54.5%), mackerels (0.17 lakh t and 12.5%), carangids (0.14 lakh t and 10.2%), ribbonfishes (0.11 lakh t and 8.2%), tunas (0.085 lakh t and 6%) and seerfishes (0.07 lakh t and 5%). Among clupeids the major contributors were *Stolephorus* contributing 0.18 lakh t, oil sardine contributing 0.15 lakh t and lesser sardines contributing 0.26 lakh t. Carangids landed were contributed by horse mackerel (15.8%), scads (30.5%), leatherjackets (8.5%) and other carangids (45%). More than 99% of the mackerel landings were contributed solely by *Rastrelliger kanagurta*. Seerfish catch was dominated by *Scomberomorus commerson* (70%) and *Scomberomorus guttatus* (30%). Among tuna the dominant species landed were *Euthynnus affinis* (47.5%), followed by *Thunnus albacares* (38.9%), *Katsuwonus pelamis* (7.1%) and *Auxis thazard* (6.5%). The landings of billfishes and barracudas for the year were 0.01 lakh t and 0.02 lakh t, respectively. The major groups that contributed to demersal landings were sciaenids, perches, pomfrets, silverbellies, goat fish, elasmobranchs and catfish. Penaeid prawn and crab resources landed along the Andhra Coast, was monitored. Penaeid prawn catch landed at Visakhapatnam Fishing Harbour was 10,940.5 t with 3.83 kg cph. Penaeid prawn formed 14.85% of total trawl landings. *M. monoceros* dominated. The estimated crab catch was 2394.3 t with 0.93 kg cph. Crab formed 3.45% of total trawl landings. *P. sanguinolentus* dominated.The total landing of cephalopods in Andhra Pradesh was estimated at 2808 t, forming 1.09% of the total fish landings. Cuttlefish landings were estimated at 1734 t, and squid 1074 t. The mechanized trawlers (MDSOTN + MDTN + MSOTN +MTN) contributed entirely (98.9 %) to the cephalopod landings. The cephalopod (cuttlefish, squids, and octopus) fishery and biology of dominant species of the Visakhapatnam Fisheries Harbor was studied. The estimated landings of cephalopods at the VFH were 1572 t. Cuttlefish landings was estimated at 869 t and squid at 703.2 t. During the period *Sepia pharaonis, S aculeata* and *Sepiella inermis* (cuttlefish), *Loligo duvauceli*, (squids), were observed in the fishery. Octopus was not landed at all. Cuttlefishes landed 869 t (55.3 %) squids 703.2 t (44.7 %) and Octopus nil. Among cuttlefish, *S*

pharaonis (782.2 t) 45.1 %. *Sepia aculeata* landed (737.9 t) 42.6% and *Sepiella inermis (223 t)* 7 %. Among squids *Loligo duvauceli* was the only species landed. Maximum landings of cephalopods occurred during July-August.

The bivalve fishery of the Bhimili estuary was monitored during the year. The total bivalve production exploited from this estuary was estimated at 88.7 t. The total effort was 1835 units. The average catch per unit effort was 48.3 Kg. The average monthly catch was 7.4 t and average effort 153 units. Three species of clams (*Meretrix meretrix, M casta, Anadara* sp) and the oyster *Crassostrea madrasensis* are exploited from this estuary. *Meretrix casta* landed *39.98 t, M meretrix* landed 23.9 t, *Anadara* sp 1.95 t and *Crassostrea madrasensis* landed 47.8 t. The bivalve fishery declined significantly compared to previous year 2010 (113.6 t). The total bivalve catch declined by 22 % (25 t). The effort also declined by 570 units (23.7 %). However, the catch per unit effort increased during this year at 48.3 Kg as against 47.2 Kg in 2010. The catch of Meretrix *casta* declined by 62.5 %, *M meretrix* by 41.8%, *Anadara* sp.by 57.3%. However landings of *C madrasensis* increased to 58.9 t by 23.4 % from 47.8 t in 2010. The bivalve catch as well as effort in the Bhimili estuary has been declining drastically over the past 10 years. This has been mainly due to inclement weather, with frequent cyclones and thunderstorms. The bivalve and gastropod fishery of Kakinada Bay of Andhra Pradesh was monitored from two major landing centres, viz; Chollangi and Peddavalsala during the year

The estimated total bivalves landed from Kakinada Bay were 836.9 t, with an average monthly landing of 72.5 t. The total effort was 8212 units and the average catch per unit affort was 131.2 Kg. The species landed were *Anadara* sp. (276.65 t), *M meretrix* (72.83 t), *Meretrix casta* (24.71 t), *Paphia malabarica* (14 .0 t), t. *Geloina* sp. (9.3 t) *Katelysia opima* (4.5 t), and others (6.6 t). The total clam production was 401.9 t. Oysters landed were indowpane oyster, *Placuna placuna* (383.8 t), edible oyster *Crassostrea madrasensis* (51.2 t) and other oysters (5.8 t.) The total oyster production was 435 t. The price of the bivalves ranged from Rs. 5 to 12 per Kg.

The estimated total gastropod landings from Kakinada Bay were 328.8 t with average monthly landings of 23.4 t. The total effort was 5010 units and the average catch per unit effort was 48.6 Kg. The species landed were *Cerithidium* sp. (257.7 t), *Telescopium* sp (23.7 t), *Thais* sp. (15.3 t), *Murex* sp (10.3 t) *Hemifusus* sp (9.9 t), *Umbonium* sp (3.1 t), *Dolostium* sp. (0.3 t) and other gastropods (8.5 t). Maximum landings were during August- September. The price of gastropods ranged from Rs. 5 to 8 per Kg.

Production trends in Visakhapatnam- Resource wise Fishery & Biology

Sardine

The estimated catch of sardine from the trawlnets at Visakhapatnam was 1,934 t. It formed 3% of the trawl net catches with a catch rate of 0.75 kg/h. The catch and catch rates were higher during the third and first quarter. Trawl catch was composed chiefly of lesser sardines (43.1%), rainbow sardines (33.4%) and oil sardine (23.5%). In seines, the catch was 85.1 t with a catch rate of 23.4 kg/unit forming more than a quarter of the total catch. The seine catch was dominated by oil sardine (60.3%) and lesser sardines (39.7%). The length ranges recorded for *Sardinella longiceps*, *Sardinella fimbriata* and *Sardinella gibbosa* were 95 to 219 mm, 55 to 184 mm and 45 to 184 mm, respectively with mean lengths of 150.9 mm, 126.5 mm and 97 mm. A sex ratio of 1.15 was recorded for *Sardinella longiceps* with mostly immature females occurring throughout the year. For *Sardinella gibbosa*, the sex ratio was 1.14 with equal occurrence of mature and immature specimens. Immature females dominated in *Sardinella fimbriata* with a sex ratio of 1.5.

Mackerel

The estimated mackerel landings by trawlers, boat seines and gill netters in Visakhapatnam were 6130 t, 10 t and 481 t, respectively with an average catch rate of 2.5 kg/h for trawls, 2.8 kg/unit for boat seines and 40 kg/unit for gill nets. Around half of the gillnet catches at Visakhapatnam (46%) were contributed by mackerel. However in trawlnet catches the contribution of mackerel was 9%. More than 99% of the trawl catches were composed of *Rastrelliger kanagurta* while in gill nets the contribution of *Rastrelliger kanagurta* was 63.2%, the rest being constituted by *Rastrelliger faughnii*. In *Rastrelliger kanagurta* caught by trawlers the size ranged from 160 to 264 mm (mean: 209.8 mm) while in *Rastrelliger kanagurta* caught by gill netters the size ranged from 145 to 279 mm (mean: 217.5 mm). The sex ratio was 1.04 and 1.3 in trawl and gill catches with mostly immature females occurring throughout the year. *Rastrelliger faughnii* caught in trawlnets and gillnets varied from 185 to 249 mm and 175 to 259 mm, respectively with mean lengths of 222.4 mm and 217.4 mm. There was a preponderance of females in the catch of both the gears with most of them in immature state.

Ribbonfish

The estimated ribbonfish landing by trawlers at Visakhapatnam was 3,899 t (5.6 % of the trawl net catches) with the catch rate of 1.5 kg/h. The catches along with catch rates were significantly higher during the post monsoon months. *Trichiurus lepturus* was the sole species with size ranging from 280 to 919 mm (mean: 549.2 mm and mode: 609 mm) and having a sex ratio of 1.86 with mostly mature

(53.8%) females occurring throughout the year. The high IRI values of nonpenaeid *Acetes*, cephalopods, juveniles of sciaenids, ribbonfishes and other teleosts and digested fish imply that they were the principal food constituents of *Trichiurus lepturus*.

Seerfish

The seerfish landing by trawlers and gill nets at Visakhapatnam was 554.3 t and 99.2 t with catch rates of 0.2 kg/h and 8.3 kg/unit. Seerfishes contributed on an average 9.5 % to the total gill net catches at Visakhapatnam. *Scomberomorus guttatus* (92.4%) dominated the gillnet landings while the trawl fishery was supported by both *Scomberomorus guttatus* (73.2%) and *Scomberomorus commerson* (26.8%). The size of *S. guttatus* ranged from 320 to 439 mm with a mean length of 363.6 mm.

Tuna

The annual catch of tuna recorded by hooks and lines at Visakhapatnam was 641.3 t with the catch rate of 16.46 kg/unit. More than one third of the hooks and lines catches (34.2 %) at Visakhapatnam was contributed by tunas alone. The dominant species landed in hooks and lines were *Thunnus albacares* (45.8%), *Euthynnus affinis* (41.7%) and *Katsuwonus pelamis* (12.5%). The length ranges recorded for *Thunnus albacares*, *Euthynnus affinis*, *Katsuwonus pelamis* and *Sarda orientalis* were 200 to 2019 mm, 280 to 439 mm, 540 to 699 mm and 340 to 379 mm, respectively with mean lengths of 1010 mm, 357.5 mm, 634 mm and 363 mm. Females outnumbered males in *Thunnus albacares*, *Euthynnus affinis*, *Katsuwonus pelamis* and *Sarda orientalis*. Majority of the females encountered in the catch were immature in *Thunnus albacares*, *Euthynnus affinis*, *Katsuwonus pelamis* and *Sarda orientalis*. The high IRI values of young ones of clupeids, ribbonfishes, mackerel, tunas and carangids along with cephalopods, crabs and digested fish and shrimps imply that they were the principal food constituents of tunas.

Carangid

The annual estimated landings of carangids by trawlers and gill netters in Visakhapatnam were 5,449 t and 385.7 t, respectively with an average catch rate of 2.4 kg/h for trawls and 32.1 kg/unit for gill nets. It formed 37% of the gillnet catches and 8.5% of the trawl catches. Among carangids, *Selar crumenophthalmus* (43.8%) and *Megalaspis cordyla* (39.8%) dominated the gill net catches while *Decapterus russelli* (41.8%) dominated the trawl landings. The size ranges recorded for *M. cordyla* was between 440 to 499 mm with a mean size of 462 mm. The number of females in the catch was higher for *M. cordyla* with majority of them in immature condition The IRI values showed that

digested fish and crustaceans along with cephalopods, *Acetes* and fish juveniles were the major food item in the stomach contents of *M. cordyla*.

Cobia

Rachycentron canadum was the species with size ranging from 360 to 919 mm (mean: 578.1 mm) with females dominating the commercial catches. The principal food items encountered in the gut were carangids, lizardfishes, clupeids and a variety of other fin and shell fishes.

Growth parameters of pelagic resources landed at Visakhapatnam

	Linf	k	Z	M	F	E	Lc	Recruitment	Peak pulse
Sardinella longiceps	21.84 cm	1.1	5.39	2.04	3.35	0.62	18.49 cm	Bimodal Major Aug-Oct	60%
Sardinella gibbosa	19.11 cm	1.2	2.61	2.24	0.37	0.14	6.18 cm	Unimodal April-July	>90%
Rastrelliger kanagurta	27.51 cm	0.65	2.91	1.36	1.55	0.53	19.34 cm	Unimodal May-Sept	>70%
Rastrelliger faughnii	25.94 cm	0.96	4.5	1.78	2.72	0.6	22.13 cm	Unimodal June-Sept	70%
Thunnus albacares	211.05 cm	0.1	0.32	0.23	0.09	0.29	60.76 cm	Bimodal Major Oct-Nov	>30%
Trichiurus lepturus	95.55 cm	0.23	0.88	0.49	0.39	0.45	41.11 cm	Bimodal Major Aug-Nov	70%

Stock assessment of pelagic resources landed at Visakhapatnam

	Stock (t)	Biomass (t)	MSY(t)	Annual yield (t)
Sardinella longiceps	735	136	366	455
Rastrelliger kanagurta	12168	3954	5752	6128
Thunnus albacares	3817	3267	523	294
Trichiurus lepturus	15033	9997	4399	3899

The total marine fish production of A.P. for 2011 was 2.75 lakh t. Pelagic resources accounted for 1.6 lakh t (58.3% of the total landings), followed by demersal resources with 0.73 lakh t (26.6% of the total landings), crustacean resources with 0.34 lakh t (12.3% of the total landings) and cephalopods

with 0.036 lakh t (1.31% of the total fish landings). The dominant pelagic groups landed were clupeids (0.68 lakh t and 42.25%), mackerels (0.22 lakh t and 14%), tunas and billfishes (0.22 lakh t and 13.88%), carangids (0.17 lakh t and 10.53%), ribbon fishes (0.15 lakh t and 9.52%) and seer fishes (0.06 lakh t and 3.47%). The major groups that contributed to demersal landings were sciaenids (18.4%), perches (18.4%), pomfrets (13.2%), goatfish (9.2%), catfish (9.2%) and elasmobranchs (11.0%). Penaeid prawns dominated with an annual landing of 0.26 lakh t forming 78% of the crustacean catch. Crabs with an annual catch of 0.06 lakh t (17%) and nonpenaeid prawns with 0.01 lakh t (3%) were the other notable contributors to the crustacean catch. Cuttlefish landings were estimated at 0.024 lakh t, and squid 0.012 lakh t.

Among clupeids, the major contributors were lesser sardines contributing 0.34 lakh t, oil sardine contributing 0.12 lakh t and *Stolephorus* contributing 0.05 lakh t. Carangids landed were contributed by horse mackerel (21.8%), scads (22.4%), leatherjackets (8.8%) and other carangids (47.1%). The mackerel landings were contributed solely by *Rastrelliger kanagurta*. Seer fish catch was dominated by *Scomberomorus commerson* (59.4%) and *Scomberomorus guttatus* (40.6%). Among tuna, the dominant species landed were *Thunnus albacares* (34.1%), followed by *Euthynnus affinis* (28.8%), *Katsuwonus pelamis* (28%) and *Auxis thazard* (9.1%). The landings of billfishes and barracudas for the year were 0.04 lakh t and 0.04 lakh t, respectively.

0.08 lakh t of elasmobranchs was landed of which 25.6% were sharks, 1.3% was skates and 73.1% were rays. Sharks were mainly caught by hook and lines, trawl nets and gill nets. Rays were mainly landed by mechanized trawls. 0.13 lakh t of sciaenids were landed of which majority were landed by mechanized trawls. 0.07 lakh t of goat fish was landed of which more than 90% were landed by mechanized trawls alone. 0.05 lakh t of threadfin breams were landed of which around 90% was landed by mechanized trawls alone. 0.045 lakh t of lizard fish was landed of which more than 90% were landed by mechanized trawls.

The penaeid prawn landings by small mechanised trawlers at Visakhapatnam were 3417 t. The annual catch of penaeid prawns by sona boats at Visakhapatnam was 7425 t. The mechanized trawlers contributed entirely (98.9 %) to the cephalopod landings. Among cuttlefish, *S pharaonis* contributed 45.1 %, *Sepia aculeata* contributed 42.6% and *Sepiella inermis* contributed 7 %. Among squids, *Loligo duvaucelli* was the only species landed.

The catch of sardine from the trawlnets at Visakhapatnam was 2705 t. It formed 3.85% of the trawl net catches with a catch rate of 1.07 kg/h. Trawl catch was composed chiefly of lesser sardines

(44.6%), rainbow sardine (31.9%) and oil sardine (23.5%). In silk nets (33 mm mesh size), the catch was 619 t with a catch rate of 175 kg/unit forming 98.7% of the total catch. The silk net catch was dominated by lesser sardines (69.2%), oil sardine (18.7%) and rainbow sardine (12.1%).

The mackerel landings by trawlers and gill netters (55 mm mesh size) in Visakhapatnam were 7832 t and 636 t, respectively with an average catch rate of 3.1 kg/h for trawls and 53.1 kg/unit for gill nets. Around half (49%) of the gillnet catches at Visakhapatnam were contributed by mackerel. However in trawlnet catches the contribution of mackerel was 11.2%. More than 99% of the trawl catches and gill net catches were composed of *Rastrelliger kanagurta* and the rest being constituted by *Rastrelliger faughnii*.

The ribbonfish landing by trawlers at Visakhapatnam was 4316 t (6.15 % of the trawl net catches) with the catch rate of 1.71 kg/h. The catches along with catch rates were significantly higher during August - September.

The seerfish landing by trawlers at Visakhapatnam was 412 t with catch rate of 0.16 kg/h. *Scomberomorus guttatus* dominated the gillnet landings while the trawl fishery was supported by both *Scomberomorus guttatus* and *Scomberomorus commerson*.

The annual catch of tuna recorded by hooks and lines at Visakhapatnam was 2714 t with the catch rate of 42.3 kg/unit. 43.4% of the hooks and lines catches at Visakhapatnam was contributed by tunas alone. The dominant species landed in hooks and lines were *Thunnus albacares* (53%), *Katsuwonus pelamis* (31%) and *Euthynnus affinis* (16%). In gill netters at Visakhapatnam, the annual catch was 675 t, at a catch rate of 35 kg/unit forming a quarter of the total gill net catches. One third of the gill net catches was constituted by *Thunnus albacares*. The annual catch of tuna by hooks and lines at Pudimadaka was 397 t with a catch rate of 14.2 kg/unit forming 46% of the total hook and line catches. The dominant tuna species was *Thunnus albacares* contributing 59% to the total tuna catch. The annual hook and line catches of tuna at Kakinada (Dummulapeta and Bhairavapalem) amounted to 3363 t at a catch rate of 126.1 kg/unit. Tunas formed 35.4% of the total hook and line catches at Kakinada. The major contributor to the tuna fishery at Kakinada was *Thunnus albacares* contributing 37.2% to the total tuna catch.

The average catch rate of sciaenids, goatfish, threadfin breams and lizardfish in mechanized trawls was 1.68 kg/hr, 1.4 kg/hr, 0.8 kg/hr and 0.95 kg/hr, respectively. The dominant species of sciaenids landed were *Otolithes ruber* (25.4%), *Protonibea diacanthus* (25.3%), *Pennahia macarophthalmus* (10.8%) and *Nibea maculata* (11.7). The major species of goatfish landed were *Upeneus vittatus*

(43.6%), *U. moluccensis* (28.7%) and *U. sulphureus* (27.1%). The major species of threadfin breams landed were *Nemipterus japonicus* (52.4%), *N. mesoprion* (18.4%), *N. delagoae* (12.1%), *N. tolu* (9.5%) and *N. luteus* (7.6%). The major species of lizardfish landed were *Saurida undosquamis* (57.4%), *S. micropectoralis* (23.3%) and *S. tumbil* (18.9%).The average catch rate of sharks, skates and rays in mechanized trawls was 0.08 kg/hr, 0.01 kg/hr and 0.8 kg/hr respectively. The most common shark species were *Iago omanensis*, *Sphyrna lewini* and *Chiloscyllium* sp. The most common ray species landed were *Gymnura poecilura*, *Himantura jenkinsii*, *Torpedo marmorata*, *Aetomylaeus nichoffii* and *Aetobatus narinari*.

The catch of small mechanized trawlers was represented by 22 species of penaeid prawns, dominated by *M. monoceros* (31.2 %), followed by *M. dobsoni* (18.9 %), *M. barbata* (6.6 %), *S. melantho* (6.5%), S. *crassicornis* (5.9 %), *P. maxillipedo* (5%), *T. curvirostris* (4.3%) and *P. stylifera* (4.2%).

The catch landed by sona boats was constituted of 15 genera/ species of penaeid prawns, dominated by *M. monoceros* (29.9%), followed by *M. dobsoni* (16.8%), *Solenocera spp* (18 %) and *Metapenaeiopsis spp* (11.4%).

The total bivalve production exploited from Bhimili estuary was 88.7 t. The average catch per unit effort was 48.3 kg. The average monthly catch was 7.4 t. Three species of clams *(Meretrix meretrix, M casta, Anadara* sp) and the oyster *Crassostrea madrasensis* are exploited from this estuary. *Meretrix casta* landed was 39.98 *t, M meretrix* landed was 23.9 t, *Anadara* sp landed was 1.95 t and *Crassostrea madrasensis* landed was 47.8 t.

The total bivalves landed from Kakinada Bay were 836.9 t, with an average monthly landing of 72.5 t. The average catch per unit effort was 131.2 kg. The species landed were *Anadara* sp. (276.65 t), *M meretrix* (72.83 t), *Meretrix casta* (24.71 t), *Paphia malabarica* (14.0 t), *Geloina* sp. (9.3 t), *Katelysia opima* (4.5 t), and others (6.6 t). The total clam production was 401.9 t. Oysters landed were windowpane oyster, *Placuna placuna* (383.8 t), edible oyster *Crassostrea madrasensis* (51.2 t) and other oysters (5.8 t).

The total gastropod landings from Kakinada Bay were 328.8 t with average monthly landings of 23.4 t. The average catch per unit effort was 48.6 kg. The species landed were *Cerithidium* sp. (257.7 t), *Telescopium* sp (23.7 t), *Thais* sp. (15.3 t), *Murex* sp (10.3 t) *Hemifusus* sp (9.9 t), *Umbonium* sp (3.1 t), *Dolostium* sp. (0.3 t) and other gastropods (8.5 t).

Length measurements and reproductive biology of major finfish and shellfish species of Andhra Pradesh

	Length range	Mean length	Annual Sex	Spawning	Fecundity	Ova diameter

	(mm)	(mm)	ratio	months		(mm)
Sardinella longiceps	57-214	143.5	1.16	May-Sept	19028-66513	0.21-0.73
Sardinella fimbriata	60-179	127.2				
Sardinella gibbosa	160-189	175.6				
Rastrelliger kanagurta	143-248	194.2	0.97	Feb-Nov	37690-170455	0.18-0.84
Rastrelliger faughnii	95-239	153.5	1.05			
Trichiurus lepturus	200-979		0.88			
Katsuwonus pelamis	300-650	504.7	1.73	Feb-March	61516-606966	0.23-0.7
Thunnus albacares	330-1980	944.5	0.61	Apr-Aug	398705-11130000	0.18-0.83
Nemipterus japonicus	95-315	177	0.6	Aug-Oct & Feb-March	18407-75874	0.17-0.58
Pennahia macrophthalmus	100-260	188	0.9			
Upeneus vittatus	83-198	138	0.8			
Saurida undosquamis	121-393	214	3.5			
Penaeus indicus	136-208	171.3	1.07	Feb-June	437500-550000	0.03-0.11
Penaeus monodon	153-295	217.8	0.84	Feb-July	323007-1072174	0.03-0.13
Metapenaeus monoceros males	83-188	138.5	1.8			
Metapenaeus monoceros females	108-218	156.1		Feb-Sept		
Metapenaeus dobsoni males	58-103	87.4	1.2			
Metapenaeus dobsoni females	53-108	81.4		Oct		

Portunus sanguinolentus males	73-168	126	2			
Portunus sanguinolentus females	68-163	120.4		Jan-March & July-Sept		
Sepia aculeata males	87-182	119.5	1.1			
Sepia aculeata females	94-279	141.8				
Sepia pharaonis	70-300	169	1.5			
Loligo duvaucelli males	50-140	76	0.82			
Loligo duvaucelli females	60-154	82.3		Round the year	11802-73464	1-1.45

Catch of major finfish and shellfish resources of Andhra Pradesh

Group	Catch (t) in 2011	Catch (t) in 2010	Increase (+) / Decrease (-) %
Clupeids	67697	75789	-10.7
Mackerel	22401	17331	29.3
Ribbon fish	15252	11432	33.4
Carangids	16873	14179	19
Tunas	18614	8458	120.1
Seer fishes	5559	7068	-21.3
Barracudas	4332	2088	107.5
Bill fishes	3624	1037	249.5
Threadfin breams	5027	5336	-5.8
Sciaenids	13488	9264	45.6
Lizardfish	4539	4956	-8.4
Goatfish	6735	7352	-8.4

Sharks	2054	1254	63.8
Rays	5872	4390	33.8
Penaeid Prawns	26368	27408	-2.3
Non penaeid Prawns	1081	2000	-46
Crabs	5703	6281	-5
Cuttlefish	2380	3020	-21.2
Squid	1209	837	44.4

Length at first maturity of the major species studied

Species	**L_m (cm)**
S. longiceps	14.5
S .gibbosa	15.0
R. kanagurta	19.5
T. lepturus	37.0
S .guttatus	28.0
T. albacares	85.0
N. japonicus	16.8
S. undosquamis	23.0
U. vittatus	13.8
J. carutta	15.4
O. ruber	20.2
M. monoceros (male)	9.5
M. monoceros (female)	11.5
P. sangunolentus	8.0
P. sanguinolentus (female)	8.6
M. dobsoni (male)	6.0
M. dobsoni (female)	7.8

Growth and mortality parameters of finfish and shellfish resources landed at Visakhapatnam

	Linf	Winf	k	Z	M	F	E	Lc
Sardinella longiceps	22.5 cm	85 g	1.1	3.38	2.03	1.36	0.4	18.73 cm
Rastrelliger kanagurta	27.4 cm	220 g	0.47	1.89	1.1	0.79	0.42	17.62 cm
Katsuwonus pelamis	68.2 cm	5.72 kg	0.34	1.26	0.69	0.57	0.45	50.58 cm
Thunnus albacares	208.9 cm	150 kg	0.08	0.48	0.2	0.28	0.59	109.8 cm
Trichiurus lepturus	114.4 cm	1.24 kg	0.13	0.74	0.32	0.42	0.57	40.26 cm
Nemipterus japonicus	34.5 cm	513.9 g	0.3	1.87	0.4	1.47	0.78	13.85 cm
Pennahia macrophthalmus	32.5 cm	530.9 g	0.32	2.05	0.43	1.62	0.79	18.03 cm
Upeneus vittatus	24.0 cm	171.5 g	0.31	2.25	0.46	1.79	0.80	12.97 cm
Saurida undosquamis	42.5 cm	578.1 g	0.34	3.25	0.41	2.84	0.87	20.2 cm
Metapenaeus monoceros males	18 cm	32.8 g	2.2	13.81	1.79	12.02	0.87	7.98 cm
Metapenaeus monoceros females	22.4 cm	79.1 g	1.78	7.03	1.49	5.54	0.79	8.39 cm
Metapenaeus dobsoni males	11.9 cm	10 g	1.4	7.62	1.52	6.11	0.8	5.33 cm
Metapenaeus dobsoni females	12.5 cm	11.9 g	1.75	7.57	1.73	5.84	0.77	5.56 cm
Portunus sanguinolentus males	23 cm	615.5 g	1.4	6.53	1.26	5.27	0.81	7.35 cm
Portunus sanguinolentus females	22 cm	508.4 g	1.3	7.82	1.22	6.6	0.84	6.85 cm
Sepia aculeata	24.2 cm	3.2 g	0.4	1.058	0.55	1.61	0.34	8.09 cm
Sepia pharaonis	28.99 cm	5.0 g	0.87	1.67	1.19	2.86	0.42	21.17 cm
Loligo duvaucelli	17.5 cm	6.08 g	0.3	0.958	0.22	1.20	0.2	6.08 cm

Stock Assessment of major finfish and shellfish resources

	Stock (t)	Biomass (t)	Biomass per recruit (g)	MSY(t)	Annual average yield (t)	Yield per recruit (g)
Sardinella longiceps (gill net & seines)	23403	6688	1.04	11303	9096	1.42
Rastrelliger kanagurta (trawl net)	17760	7977	22.43	7538	6302	17.72
Rastrelliger kanagurta (gill net)	24828	11152	22.43	10539	8810	17.72
Katsuwonus pelamis (hooks and lines)	11800	6709	506.9	4227	3824	288.94
Thunnus albacares (hooks and lines)	50284	39936	16063.16	9585	11182	4497.68

Trichiurus lepturus (trawl net)	34016	24036	100.40	8893	10095	42.17
Nemipterus japonicus (trawl net)	5507.1	2491.1	25.9	2329.2	3661.9	38.06
Pennahia macrophthalmus (trawl net)	1292.6	549.4	32.84	563.1	890.0	53.2
Upeneus vittatus (trawl net)	4762.5	1893.6	25.89	2130.3	3389.5	38.1
Saurida undosquamis (trawl net)	1604.6	474.6	17.7	771.2	1347.8	50.3
Metapenaeus monoceros males (trawl net)	191.8	176.5	0.6	1218.7	315	3.89
Metapenaeus monoceros females (trawl net)	525.7	505.3	1.97	1776.1	524.1	6.71
Metapenaeus dobsoni males (trawl net)	107.3	107.3	0.2	408.8	172.7	1.01
Metapenaeus dobsoni females (trawl net)	169.2	113.5	0.12	429.6	225.9	1.15
Portunus sanguinolentus males (trawl net)	95.5	91.9	3.64	300.1	263.8	32.4
Portunus sanguinolentus females (trawl net)	184.7	152.5	2.24	596.3	433.7	23.5
Sepia aculeata (trawl net)	0.85	0.9	0.22	0.206	0.779	0.121
Sepia pharaonis (trawl net)	2.0	0.7	0.18	0.138	0.782	0.210
Loligo duvaucelli (trawl net)	7.7	4.5	0.03	0.448	1.074	0.006

F-multipliers for maximum Yield and Yield/Recruit for species caught in trawls (2007-2011)

Species	Maximum Y/R (g)	Maximum Yield (t)	Increase in Y/R (g) from the present	Increase in Yield (t) from the present	F-multiplier at maximum Y and Y/R	Level of Exploitation
Rastrelliger kanagurta	21.45	7630	3.73	1328	1.6	Under Exploited
Trichiurus lepturus	42.34	10135.7	0.17	40.7	1.4	Under Exploited
Nemipterus japonicus	42.45	4084.3	4.39	422.4	0.4	Over exploited
Pennahia macrophthalmus	53.23	890.5	0.03	0.5	0.8	Over exploited
Upeneus vittatus	42.45	3776.5	4.35	387	0.4	Over

						exploited
Saurida undosquamis	56.07	1502.4	5.77	154.6	0.2	Over exploited
Metapenaeus monoceros males	3.90	315.3	0.01	0.3	0.8	Over exploited
Metapenaeus monoceros females	6.73	526.3	0.02	2.2	1.2	Under Exploited
Metapenaeus dobsoni males	1.02	174.65	0.01	1.95	1.4	Under Exploited
Metapenaeus dobsoni females	1.155	227.13	0.005	1.23	0.8	Over exploited
Portunus sanguinolentus males	39.19	319.1	6.79	55.3	0.4	Over exploited
Portunus sanguinolentus females	30.35	560	6.85	126.3	0.2	Over exploited
Sepia aculeata	0.18	1.17	0.06	0.39	3	Under Exploited
Sepia pharaonis	0.31	1.15	0.1	0.37	3	Under Exploited
Loligo duvaucelli	0.01	1.79	0.004	0.72	3	Under Exploited

Management Advisories:

For *Rastrelliger kanagurta*, *Trichiurus lepturus*, *Metapenaeus dobsoni* males and *Metapenaeus monoceros* females, maximum yield is obtained by increasing the present fishing effort by 20 – 60%. The increase in yield at the increased fishing effort is 1328 t for *Rastrelliger kanagurta* at 160% of the present effort, 40.7 t for *Trichiurus lepturus* at 140% of the present effort, 2.2 t for *Metapenaeus monoceros* females at 120% of the present effort and 1.95 t for *Metapenaeus dobsoni* males at 140% of the present effort. We can conclude from the above that for penaeid prawns the present effort is optimum as the change in yield and yield per recruit is negligible and balances out on increasing/decreasing present fishing effort. Similarly for *Trichiurus lepturus*, a minor increase in yield and yield per recruit is only obtained by increasing the present fishing effort by 40%. In trawls targeting *Rastrelliger kanagurta*, 21% increase in yield and yield per recruit is obtained by increasing

the present fishing effort by 60%, which is uneconomical. Therefore trawls targeting mackerel, ribbonfishes and penaeid prawns can continue to fish at the same effort.

The yield and yield per recruit of cephalopods can be increased by 50% for cuttlefishes and by 67% for squids by tripling the present fishing effort. However the lack of trawlers targeting cephalopods alone and the trifling nature of the catch necessitates that the present fishing effort is continued.

In sharp contrary to the above, for other species caught in trawls maximum yield is obtained by decreasing the present fishing effort by 20 – 80%. The increase in yield at the decreased fishing effort is 422.4 t for *Nemipterus japonicus* at 40% of the present effort, 0.5 t for *Pennahia macrophthalmus* at 80% of the present effort, 387 t for *Upeneus vittatus* at 40% of the present effort, 154.6 t for *Saurida undosquamis* at 20% of the present effort, 0.3 t for *Metapenaeus monoceros* males at 80% of the present effort, 1.23 t for *Metapenaeus dobsoni* females at 80% of the present effort, 55.3 t for *Portunus sanguinolentus males* at 40% of the present effort and 126.3 t for *Portunus sanguinolentus* females at 20% of the present effort.

However for demersal resources especially for *Nemipterus japonicus, Upeneus vittatus* and *Saurida undosquamis* and crabs, substantial increase in yield and yield per recruit is obtained by decreasing the present fishing effort by 60%. Hence, trawls targeting demersal resources and crabs should immediately reduce effort drastically so as to fish at 40% of the present effort. These management advisories if implemented will help to sustain the marine fisheries of the state on long term basis.

Strategies for sustaining tuna fishery along the coast of India

The annual catch of tuna recorded by hooks and lines at Visakhapatnam was 2714 t with the catch rate of 42.3 kg/unit. 43.4% of the hooks and lines catches at Visakhapatnam was contributed by tunas alone. The dominant species landed in hooks and lines were *Thunnus albacares* (53%), *Katsuwonus pelamis* (31%) and *Euthynnus affinis* (16%). In gill netters at Visakhapatnam, the annual catch was 675 t, at a catch rate of 35 kg/unit forming a quarter of the total gill net catches. One third of the gill net catches was constituted by *Thunnus albacares*. The annual catch of tuna by hooks and lines at Pudimadaka was 397 t with a catch rate of 14.2 kg/unit forming 46% of the total hook and line catches. The dominant tuna species was *Thunnus albacares* contributing 59% to the total tuna catch.

The annual hook and line catches of tuna at Kakinada (Dummulapeta and Bhairavapalem) amounted to 3363 t at a catch rate of 126.1 kg/unit. Tunas formed 35.4% of the total hook and line catches at Kakinada. The major contributor to the tuna fishery at Kakinada was *Thunnus albacares* contributing

37.2% to the total tuna catch. The length of skipjack tuna, *Katsuwonus pelamis* at Visakhapatnam ranged from 300 mm to 650 mm with an annual mean of 504.7 mm. The highest mean length of 572.2 mm was recorded in the month of March and the lowest mean length of 443.8 mm was recorded in November. Annual sex ratio was 1.73 with significant dominance by males in February and March and by females in rest of the months. Only mature females were recorded in February and March indicating it to be the peak breeding season. The average gonadosomatic index was 1.5 with a maximum of 2.1 recorded in February. Their fecundity ranged from 61516 to 606966 with ova diameter varying from 0.23 mm to 0.7 mm. The high IRI values of cephalopod, penaeid prawn, frigate tuna, carangids and flying fish along with digested food imply them to be the principal food constituents. The length of yellowfin tuna, *Thunnus albacares* at Visakhapatnam ranged from 330 mm to 1980 mm with an annual mean of 944.5 mm. Maximum mean length of 1411 mm was recorded in December and minimum mean length of 470.6 mm was recorded in September. Annual sex ratio was 0.61. Males dominated the catch from March – August and from October - December while females dominated the catch in January, February and September. Mature females were encountered in most months with peak occurrence during April – August (70.8% - 100%). The gonadosomatic index varied from 0.5 to 1.9 with an average of 1.1. Their fecundity ranged from 398705 to 11130000 with ova diameter varying from 0.18 mm to 0.83 mm. Cephalopods are their preferred prey, followed by mackerel, crab, squilla, balistids, carangids and flying fish.

Growth parameters of pelagic resources landed at Visakhapatnam

	Linf	k	Z	M	F	E	Lc	Recruitment	Peak pulse
Katsuwonus pelamis	68.2 cm	0.34	1.26	0.69	0.57	0.45	50.58 cm	Bimodal in March – June and Aug - Oct	
Thunnus albacares	208.9 cm	0.08	0.48	0.2	0.28	0.59	109.8 cm	Unimodal May – Oct with peak in July	84.4%

Stock Assessment of pelagic resources landed at Visakhapatnam

	Stock (t)	Biomass (t)	Biomass per recruit (g)	MSY(t)	Annual average yield (t)	Yield per recruit (g)
Katsuwonus pelamis (hooks and lines)	11800	6709	506.9	4227	3824	288.94
Thunnus albacares (hooks and lines)	50284	39936	16063.16	9585	11182	4497.68

Index of Relative Importance (%) of food items encountered in the gut of *Katsuwonus pelamis*

	Digested fish	*Loligo*	Penaeid prawns	Frigate tuna	Carangids	*Decapterus*	Flying fish	Others
March	3	97						
April		26	74					
June	74			26				
July	95				5			
October	70					20	11	
November	33	31				34		2
January	99							1

Index of Relative Importance (%) of food items encountered in the gut of *Thunnus albacares*

	Loligo	Mackerel	Crab	Digested fish	Flying fish	*Squilla*	Balistid	Scad	Frigate tuna	Purple back squid	Others
February	53	37	1	4							5
March	74	7		2							17
April	52			48							
June	3		2	73	18						4
July	2			26	4	19		45	4		
August	16			25	1	15	36		1		6
September				93		6					1
October	81			9							10
November	89			4				2	1		4
December	10		20	17				9		41	3
January	5	1	1	55				18		13	7

Pathogen profiling, diagnostics and health management in maricultured finfish and shellfish

Several bacterial strains isolated from sediment, seaweeds and fish gut samples exhibited clear zone of inhibition > 10 mm diameter against *Vibrio alginolyticus* in the double layer method and against *Vibrio alginolyticus* and *Vibrio anguillarum* in the cross streak method. The biochemical tests were performed and these strains were found to belong to genera *Bacillus*, *Vibrio*, *Aeromonas*, *Pseudomonas* and *Micrococcus*.

Innovations on sea cage farming and development of sustainable Capture Based Aquaculture (CBA) systems

Seed/Nursery sea cages were designed, fabricated and used for holding as well as rearing the fish seed.

(Asian seabass) fry were collected from wild in the Bay of Bengal off shore of Baliapal, Balasore, Orissa with the help of local fishermen.

Seabass fry were reared to fingerling size in seed cage with average 10.25 % survival.

Season-wise capture-based seed availability was studied along Andhra Pradesh coast.

Few species of carangid were collected and culture experiments were conducted in cage.

Broodstock development, captive breeding and seed production techniques for selected marine finfishes and ornamental fishes

Total 55 numbers live *Epinephelus coioides* (orange-spotted grouper) were collected from Bhuminipatnam and Visakhapatnam fishing area for broodstock development.

Decompressed fishes were recompressed to relieve from the barotrauma stress (A technique was developed to recompress the adult groupers to relieve from barotrauma stress with 85 % success).

Development of broodstock of *E. coioides* (wild- collected) was done in sea cages with special broodstock feed supplemented with vitamins, mineral mixture, cod liver oil, etc.

Tagging of individual brooder was carried out with Passive integrated Transponder (PIT) tags, a kind of electronic tag with radio-frequency identification.

One 6 m dia HDPE cage was installed in Bay of Bengal off Visakhaptnam for developing sex-reversed male for breeding purpose.

Sex reversal of *E. coioides* from female to male by hormonal implantation (17 alpha methyl testosterone) was successfully achieved.

For the first time, aromatase inhibitor Letrazole was successfully used for sex reversal of orange-spotted grouper.

Induced breeding of orange-spotted grouper was achieved in Visakhaptnam Regional center of CMFRI. Three induced spawning trials were carried out in mariculture hatchery of the center and in all the three spawning trials fishes were spawned after 12 hrs of last injection.

Stock culture of Phytoplankton, *Nannochloropsis* sp., *Isochrysis* sp. was being maintained and cultured in mass for producing the rotifers.

Rotifers were cultured at low salinity and high temperature to reduce the size of the rotifers.

Resource damage assessment in marine fisheries: impact of selective fishing of juveniles, bycatch and discards in trawl fisheries on stock

Low value bycatch landed at Visakhapatnam Fishing Harbour and discards thrown at sea by the trawlers based at Visakhapatnam fishing harbour were monitored. The estimated annual low value by catch was 19,385 t with 7.5 kg cph and low value by catch formed 27.7% of total trawl landings. The estimated annual discards were 40,089 t with 15.54 kg cph, and it was equivalent to 57.3 % to the total landings.

Recruitment Dynamics of Penaeid Prawns

The data collected on *M. monoceros* at VRC of CMFRI during 1997-2006 was analyzed. Two recruitment peaks were identified for *M. monoceros* off Visakhapatnam coast and Ricker model was fitted for relation between spawning stocks and recruitments. The standing stock biomass of spawning females ranged between 0.01 t to 33.6 t. The Rickers relationship showed density dependence. The spawning stock was 0.03 to 45.66 t and the size at maturity was 115 mm. The spawning peak months were during February to April. The fecundity size relationship was, F= -507+4.96 L. with peaks of egg production during February to April. The recruitment peaks was during Aug to October.

Species variation and biodiversity of the fishes of the family Lutjanidae of India

Diversity of the species of family Lutjanidae studied at Visakhapatnam. The most commonly observed species were *Lutjanus johnii*, *Lutjanus rivulatus*, *Lutjanus russelli* and *Lutjanus malabaricus*. *Lutjanus lutjanus* and *Lutjanus lunulatus* were observed occasionally.

Impact of anthropogenic activities on coastal marine environment and fisheries

Comparing the three sites chosen for the study, the sewage disposal site at Lawsons Bay showed higher values of CO^2, NH^3, and TSS.

Fishing village of Mangamaripeta exhibited comparatively low values in all the parameters (CO^2, NH^3, and TSS)

The fishing harbour samples also showed high values but lesser when compared with Lawsons bay samples.

Salinity was lower in Lawsons bay samples as there is frequent flushing of freshwater and domestic waste water.

Impact and yield study of environmental changes on the distribution shifts in small pelagic along Indian coast

The estimated catch of sardine from the trawlnets at Visakhapatnam was 2705 t. It formed 3.85% of the trawl net catches with a catch rate of 1.07 kg/h. Trawl catch was composed chiefly of lesser sardines (44.6%), rainbow sardine (31.9%) and oil sardine (23.5%). In silk nets (33 mm mesh size), the catch was 619 t with a catch rate of 175 kg/unit forming 98.7% of the total catch. The silk net catch was dominated by lesser sardines (69.2%), oil sardine (18.7%) and rainbow sardine (12.1%).

The length of oil sardine, *Sardinella longiceps* at Visakhapatnam ranged from 57 mm to 214 mm with an annual mean of 143.5 mm. The highest mean length of 196.4 mm was recorded in the month of August and the lowest mean length of 76.2 mm was recorded in October. Juveniles dominated the catches from October – January. The annual sex ratio was 1.16. Males dominated the catch in February, May, July and September while females dominated the catch in March, June and August. May - September is the breeding season of oil sardine with a peak during May - July. This is substantiated by the presence of high proportion of spawners (55.6% - 90.5%) and by high gonadosomatic index (6.3 – 8.8) in these months. Their fecundity ranged from 19028 to 66513 with ova diameter varying from 0.21 mm to 0.73 mm. The analysis of food components revealed an

abundance of planktonic matter (*Coscinodiscus*, Copepods, *Peridinium*, *Fragilaria*, Spicules, Tintinnids, Fish eggs and larvae, Bivalve larvae and oyster larvae) in the gut of oil sardine and mackerel.

The length ranges in gill nets recorded for *Sardinella fimbriata* and *Sardinella gibbosa* were from 60 to 179 mm and 160 to 189 mm, respectively with mean lengths of 127.2 mm and 175.6 mm. The highest mean length of 153.5 mm for *Sardinella fimbriata* was recorded in June and the lowest mean length of 91.7 mm was recorded in October. Females dominated the catches of *Sardinella fimbriata* and *Sardinella gibbosa* throughout the year with very few in mature states.

The estimated mackerel landings by trawlers and gill netters (55 mm mesh size) in Visakhapatnam were 7832 t and 636 t, respectively with an average catch rate of 3.1 kg/h for trawls and 53.1 kg/unit for gill nets. Around half (49%) of the gillnet catches at Visakhapatnam were contributed by mackerel. However in trawlnet catches the contribution of mackerel was 11.2%. More than 99% of the trawl catches and gill net catches were composed of *Rastrelliger kanagurta* and the rest being constituted by *Rastrelliger faughnii*.

The length of Indian mackerel, *Rastrelliger kanagurta* at Visakhapatnam ranged from 143 mm to 248 mm with an annual mean of 194.2 mm. Maximum mean length of 235 mm was recorded in February and minimum mean length of 178.4 mm was recorded in November. Annual sex ratio was 0.97. Males dominated the catch in January, February, July - October and December while females dominated the catch in March, April and November. Mature females were encountered in the catch in all the months except December and January. The gonadosomatic index varied from 3.6 to 9.1 with the highest value recorded in February. Their fecundity ranged from 37690 to 170455 with ova diameter varying from 0.18 mm to 0.84 mm. The analysis of food components revealed an abundance of copepods, decapods, ostracods, *Coscinodiscus*, Foraminifera along with minute quantities of cladocerans, fish eggs and larvae, zoea, tintinnids and nematods.

Rastrelliger faughnii caught in trawlnets and gillnets varied from 180 to 249 mm and 95 to 239 mm, respectively with mean lengths of 227 mm and 153.5 mm. There was a preponderance of females in the catch of both the gears with annual sex ratio of 1.5 in trawlnets and 1.05 in gill nets. Most of the females encountered in both the gears were in immature stages.

Growth parameters of pelagic resources landed at Visakhapatnam

	Linf	k	Z	M	F	E	Lc	Recruitment	Peak pulse
Sardinella longiceps	22.52 cm	1.1	3.38	2.03	1.36	0.4	18.73 cm	Unimodal June – Aug with peak in July	86.2%

Rastrelliger kanagurta	27.4 cm	0.47	1.89	1.1	0.79	0.42	17.62 cm	Unimodal April – July with peak in May - June	56.6%

Stock Assessment of pelagic resources landed at Visakhapatnam

	Stock (t)	Biomass (t)	Biomass per recruit (g)	MSY(t)	Annual average yield (t)	Yield per recruit (g)
Sardinella longiceps (gill net & seines)	23403	6688	1.04	11303	9096	1.42
Rastrelliger kanagurta (trawl net)	17760	7977	22.43	7538	6302	17.72
Rastrelliger kanagurta (gill net)	24828	11152	22.43	10539	8810	17.72

Monthly seawater samples from two stations were collected and analyzed for 16 parameters and were documented.

DNA samples collected from Oil Sardine and Mackerel were sent to HQ for further analysis.

Zooplankton samples were also taken from different sampling locations and preserved and sent to CMFRI HQ for further analysis

Collected data on morphometric analysis, truss analysis, food and feeding and otolith.

The mean sea surface temperatures values recorded for the four stations from which water samples were collected was 28.32°c.

Water temperatures were high during Quarter 2 (April – June) for the surface waters, which is summer months and during quarter 3 (July – Sept) for the bottom waters

Minimum water temperatures were recorded during Quarter 4 (Oct – Dec) for the surface waters, which is winter period in this part and during quarter 1 for the bottom waters

The mean value of salinity of surface waters is 30.42 ppt. The salinity values were higher during Quarter 2 and lower during quarter 4 for both the surface and bottom waters. This corroborates with the increase in the mean sea surface temperatures during summer months. A maximum salinity value of 34.50 ppt was recorded during the quarter 2. It went upto a minimum of 23 – 25 ppt during quarter 4.

Chlorophyll values collected from all the four stations were plotted in graph and compared with data collected during 2007 – 2010. The peak values were found during the 3rd quarter of 2011, which is in similarity with the previous years. Chlorophyll values were higher for the surface waters than bottom

waters. Even among the surface waters chlorophyll is higher for near shore waters than deep waters. This may be related to the deposition of nutrients from the runoff of land.

Development of Fisheries Ecosystem restoration plans for critical marine habitats

A survey was conducted / initiated for assessment of coastal habitats and recording the level of sustainability and degradation of molluscan fishery resources of Kakinada bay and bhimili estuary area of Visakhapatnam.

Technological up gradation of Molluscan mariculture

Pearl production in *Pinctada fucata*: 500 pearl oysters were nucleated during the period. Rejection of implanted nucleus was high and only 50 oysters with retention of implanted nucleus were obtained. Heavy mortality and rejection occurred due to very high temperature rise. They were maintained in the onshore rearing system for pearl production. The pearls will be harvested after a period of 8 months. Nucleus implantation was also constrained by the renovation (civil and electrical) works in the hatchery for over 8 months.

Research cum farming demonstration of mussel culture in Bhimili estuary: Hatchery produced spat of *Perna viridis* were transferred to Bhimili estuary for monitoring growth and studying the suitability of the site for mussel farming and farming demonstration. The hydrological parameters were also monitored. From an initial DVM of 17.7 mm and 0.6 g, the spat attained a growth of 51.4 mm DVM and 12.6 g total weight in 4 months. The Bhimili site was conducive for mussel farming and good growth was attained. However, during February – March there was significant mortality due to predation by crabs.

Open sea rearing of Hatchery produced spat of *Perna viridis*: Hatchery produced spat of *P viridis* was reared in the open sea in netlon cages. The spat were reared in two stocking densities at two depths. The netlon cages were suspended from the rim of the open sea grouper cage moored off the coast of Visakhapatnam. Spat of average DVM of 17.7 mm and average total weight of 0.6 g were stocked at 200 and 400 numbers each in netlon cages and suspended at 2m and 3 m from the surface and reared for 30 days. They attained average DVM of 44.8 mm, total weight of 9.1 g, meat weight of 2.6 g and meat % of 29.5 in 30 days of culture. However there was no significant difference in the growth with respect to the two stocking densities. There was also no difference in growth at the two depths. The

production after 30 days of culture was 2.3 Kg from an initial stocking of 16 g, which reflects a very good growth of the green mussel in the open sea.

Technology development for seed production of shellfish

Spawning and spat production of green mussel: Broodstock of green mussels were collected from the Kakinada fishing harbor. Spawning of the green mussel *P viridis* occurred on four occasions, 06-06-2011, 23-06-2011, 01-11-2011 and 02-11-2011. However, due to high temperature the larvae did not reach settlement stage. The marine hatchery is undergoing renovation works and therefore for over 8 months spawning trials could not be carried out. Further trials will be carried out to develop a low cost method for large scale spat production of the green mussel.

Collection and maintenance of *Pinctada margaritifera* (Development of broodstock): *P margaritifera* spat were collected from Lawson's Bay during February 2010 and 2011. They were maintained on *Isochrysis galbana, Nanochloropsis* sp and *Cheatoceros calcitrans*. The broodstock was successfully developed with a strict feeding regime and 7 successful spawnings were achieved during the year from June onwards. However, spat settlement could be achieved only in the second cycle and in all the other cases the larval rearing could not be completed up to settlement stage due to high temperatures causing total mortality of the larvae in the "D" stage. Spawning and larval rearing was also constrained due to the civil and electrical works in the hatchery.

Stock cultures of five species of microalgae, *Chaetoceros calcitrans, Isochrysis galbana, Nanochloropsis sp., Tetraselmis sp.*and *Pavlova* sp are being maintained. Mass culture of three species of microalgae viz. *C. calcitrans, I. galbana, Nanochloropsis* sp. was maintained as feed to bivalve hatchery and zooplankton production.

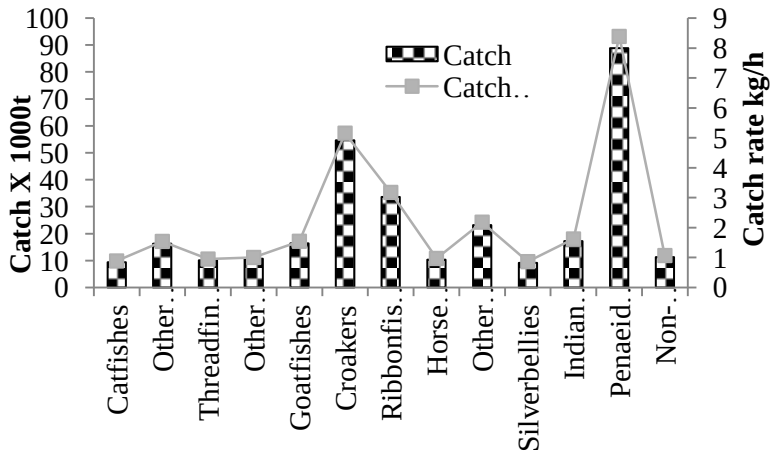
Assessment of Elasmobranch Resources in the Indian Seas

Contribution of elasmobranch resources to demersal resources of Andhra Pradesh declined drastically by 37% from 11.15% in 2012 to 6.7% in 2013. Contribution of elasmobranchs to the demersal landings of the state has been decreasing from 18.8% in 1985 to 6.7% in 2013. Composition of elasmobranch landings in the state has changed over the past 26 years. In 1985 sharks contributed 77% and rays 19.6% to elasmobranch landings. By 2012 contribution of sharks has declined to 16% and that of rays has increased to 83%. Rays have replaced sharks as the dominant elasmobranch group landed in the state. The major sharks groups landed in the state are the houndsharks,

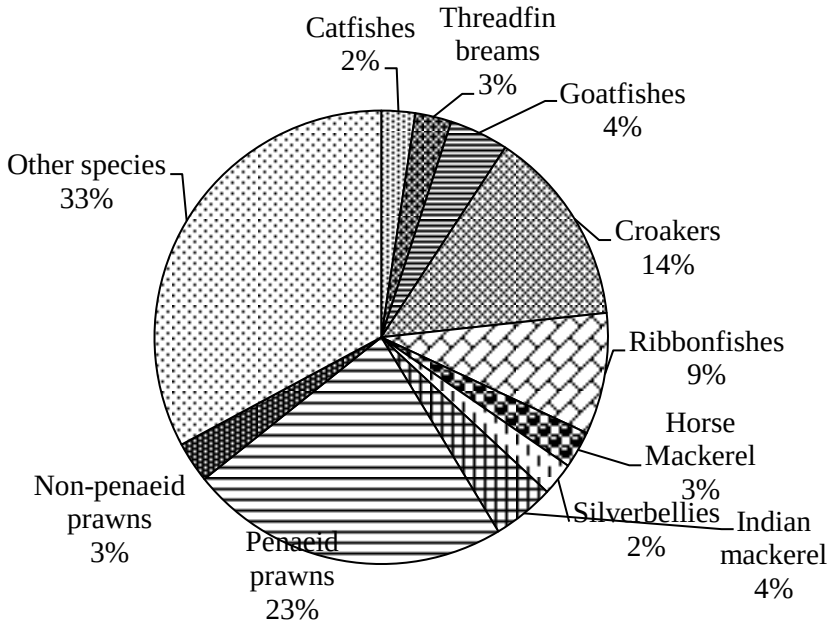
hammerhead sharks and the cat sharks. The major species landed are *Iago sp*, *Sphyrna lewini*, *Scoliodon laticaudus*, *Chiloscyllium sp* and *Carcharhinus sorrah*. The major rays landed in the state are *Gymnura poecilura*, *Himantura jenkinsii*, *Neotrygon kuhlii* and *Aetobatus narinari*. The major skates landed in the state are *Rhinobatos obtusus* and *Rhinobatos granulatus*.

Trawl fishery of the North east coast of India: An appraisal

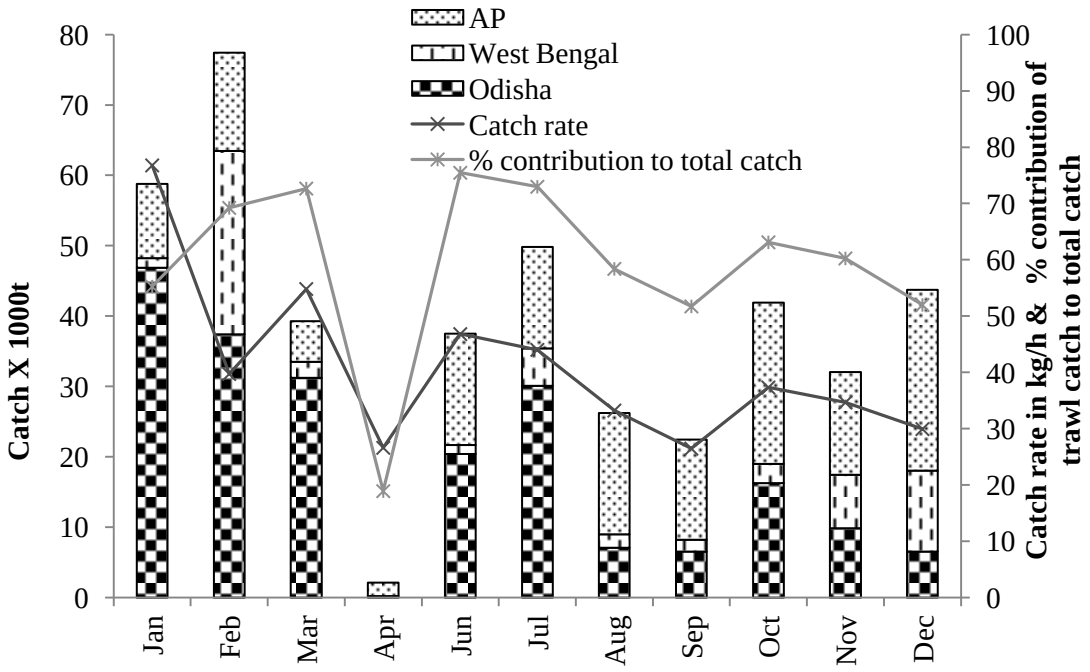
The project is an appraisal of the trawl fishery of three states namely, Andhra Pradesh, Odisha and West Bengal. The total production by trawlers during 2012 along the north east coast of India was 4.315 lakh t. The catch rate was 40.7 kg / h.



Catch and catch rate of major resources in trawls along north east coast of India



Catch composition in trawlers along north east coast of India



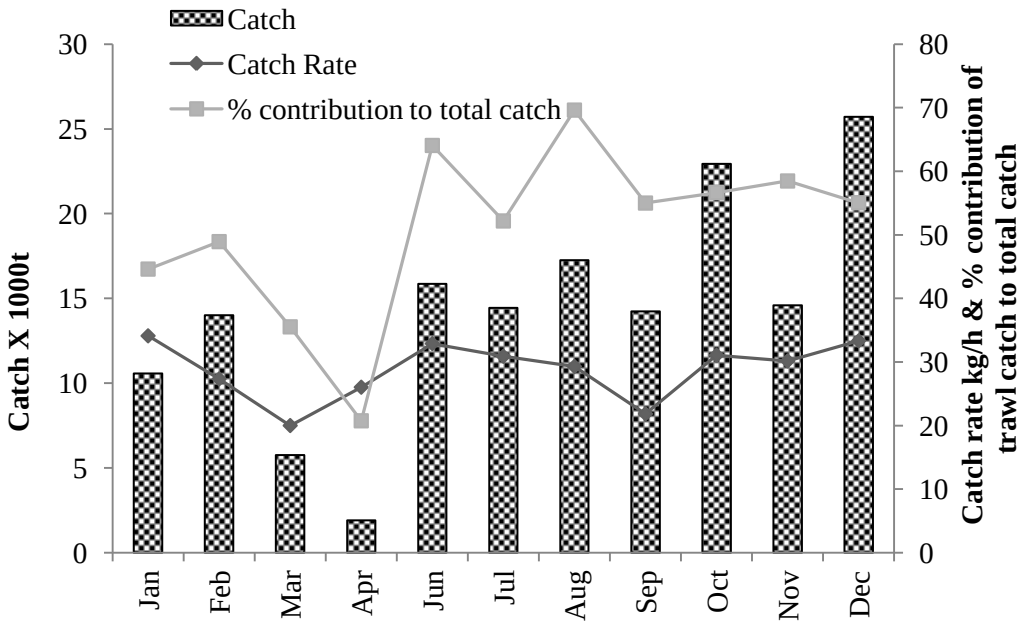
Monthwise landing by trawlers along with their catch rates and their % contribution to total catch along north east coast of India

Trawl landings and catch rate

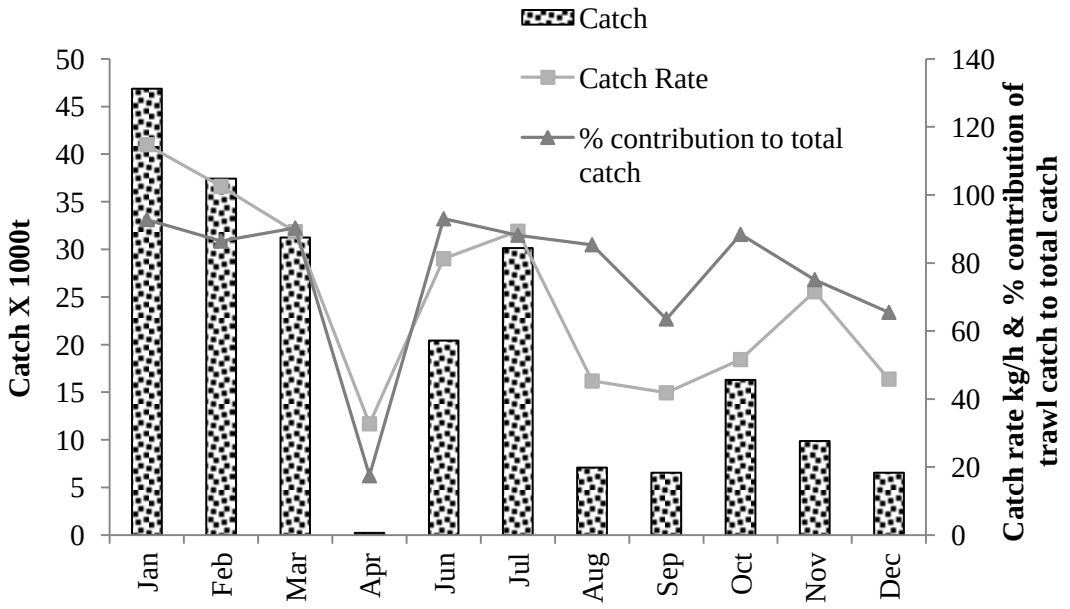
Trawl landings in Andhra Pradesh was 1.57 lakh t forming 51.6 % of the total marine landings. The overall catch rate was 29.3 kg/h for the state. The contribution of sona boats to the trawl landings of Andhra Pradesh was 66 % and the contribution of small mechanized trawlers was 34%. The catch rate in sona boats was 30.6 kg / h and in small mechanized trawlers was 27.1 kg / h.

In Odisha, the trawl catch was 2.13 lakh t forming 85.95 % of the annual marine catches. The overall catch rate in Odisha was 80.9 kg / h. More than 95 % of the catches were contributed by multiday trawlers and less than 5 % were contributed by singleday trawlers. The catch rate in multiday trawlers was 79.3 kg / h and in singleday trawlers was 147.8 kg / h.

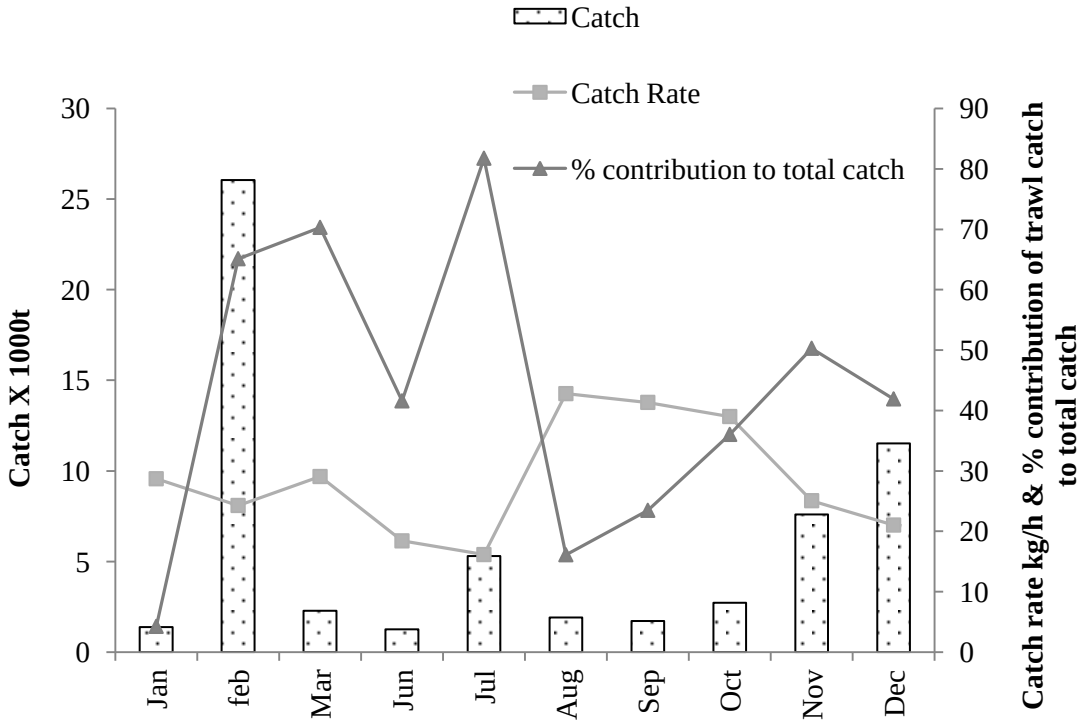
In West Bengal, 0.62 lakh t was landed by trawlers forming 39.8 % of the total marine landings. The overall catch rate in West Bengal was 23.7 kg / h.



Monthwise landing by trawlers along with their catch rates and their % contribution to total catch in Andhra Pradesh



Monthwise landing by trawlers along with their catch rates and their % contribution to total catch in Odisha



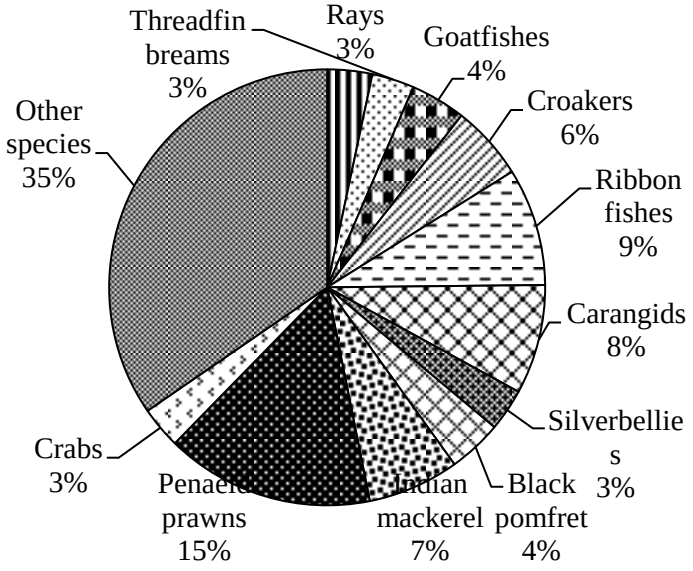
Monthwise landing by trawlers along with their catch rates and their % contribution to total catch in West Bengal

Catch composition of trawl landings

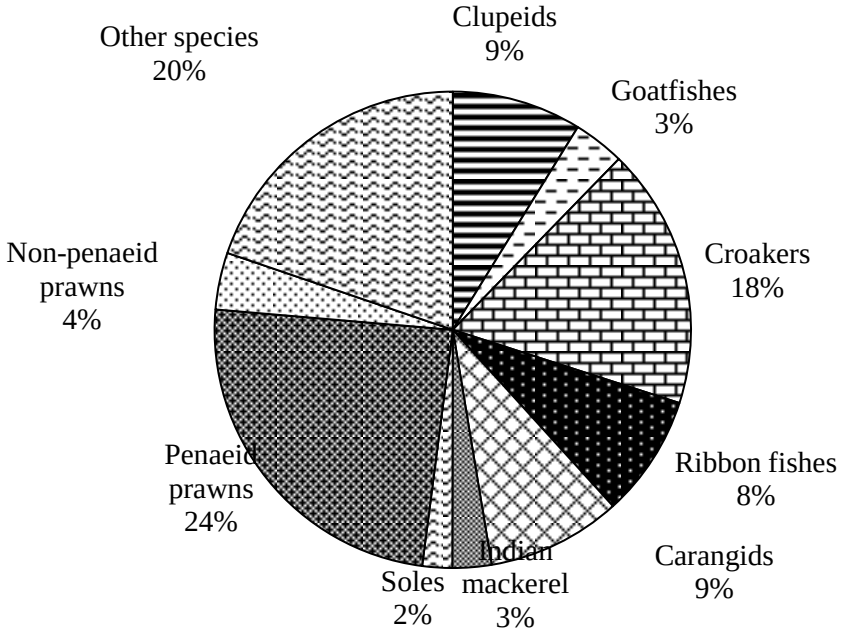
Penaeid prawns, croakers, ribbonfish, scads, mackerel and goatfish were common dominant groups in the trawl catch composition across all the three states.

Trawl catch composition (dominant groups and species) along the north east coast of India

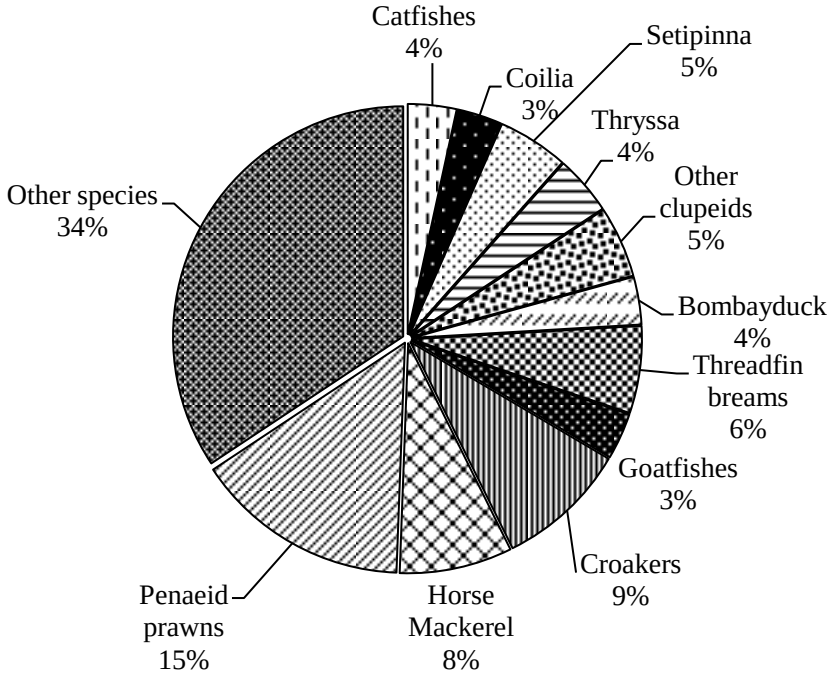
	Andhra Pradesh	Odisha	West Bengal
Catch composition	Penaeid prawns (15%)	Penaeid prawns (24%)	Penaeid prawns (15%)
	Ribbonfishes (9%)	Croakers (18 %)	Croakers (9 %)
	Carangids (8%)	Clupeids (9%)	*Megalaspis cordyla* (8%)
	Rastrelliger kanagurta (7%)	Carangids (9%)	Threadfin breams (6 %)
	Croakers (6%)	Ribbonfishes (8%)	Other clupeids (5%)
	Goatfishes (4%)	Non-penaeid prawns (4%)	*Setipinna* spp (5%)
	Black pomfret (4%)	Goatfishes (3%)	*Harpadon nehereus* (4%)
	Threadfin breams (3%)	*Rastrelliger kanagurta* (3 %)	*Thryssa* spp (4%)
	Rays (3%)	Soles (2%)	Catfishes (4%)
	Silverbellies (3%)		*Coilia dussumieri* (3%)
	Crabs (3%)		Goatfishes (3%)



Species composition in the trawl landings of Andhra Pradesh



Species composition in the trawl landings of Odisha



Species composition in the trawl landings of West Bengal

Andhra Pradesh

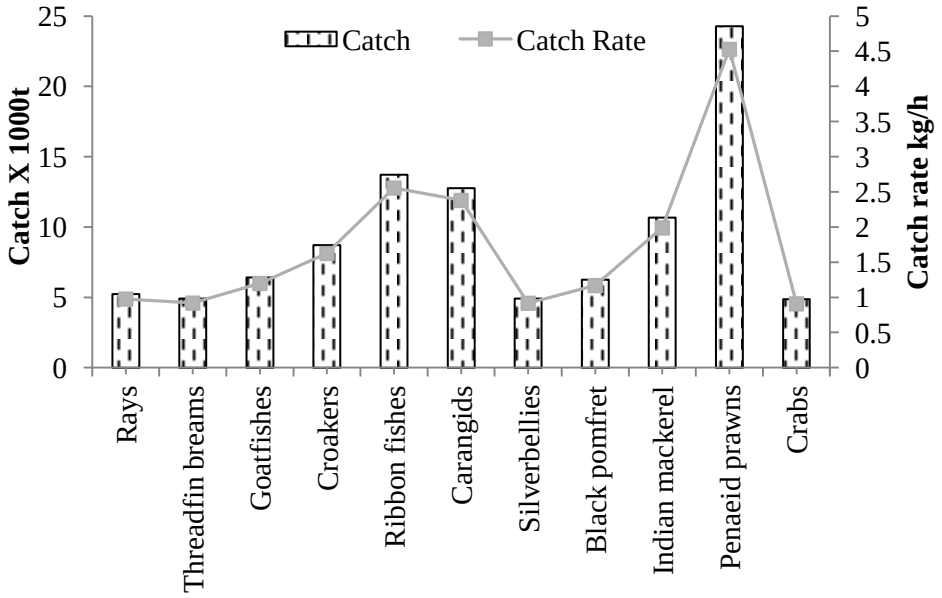
The landings of ribbonfishes, mackerel, croakers, goat fishes, threadfin breams and lizardfishes were 13718 t, 10671 t, 8719 t, 6433 t, 4933 t and 4374 t at catch rates of 2.56 kg / h, 1.99

kg / h, 1.62 kg / h, 1.20 kg / h, 0.92 kg / h and 0.82 kg / h. Croakers landed were contributed chiefly by *Otolithes ruber* (22.8%), *Protonibea diacanthus* (24.2%), *Pennahia macarophthalmus* (12.3%), *Nibea maculata* (10.2%) and *Johnius carutta* (7.9%). *Upeneus vittatus* (47.1%) dominated the goatfish landings followed by *U. sulphureus* (24.6%) and *U. moluccensis* (27.3%). Threadfin bream and lizardfish landings were composed chiefly of *Nemipterus japonicus* (51.1%) and *N. mesoprion* (36.5%) and *Saurida undosquamis* (60%), *S. micropectoralis* (24.4%) and *S. tumbil* (12.7%), respectively. The catch of carangids was 12763 t with almost half of the catches being supported by scads. Pomfret landed was 9073 t with black pomfret (68.5 %) dominating the landings. Elasmobranch landing amounted to 6030 t of which rays contributed 86.9 %. The catch rate of scads, black pomfret and rays were 1.02 kg / h, 1.17 kg / h and 0.98 kg / h. Around 13704 t of clupeids were landed and *Stolephorus* spp accounted for more than a quarter of the total landings at a catch rate of 0.68 kg / h. The other major groups of fin fishes landed were silverbellies (4926 t), catfishes (3303 t), barracudas (2934 t) and flat fishes (1648 t). Their catch rates were 0.92 kg / h, 0.62 kg / h, 0.55 kg / h and 0.31 kg / h, respectively. The total crustacean landing was 31951 t of which the contribution of penaeid prawns, non penaeid prawns and crabs were 24296 t, 1943 t and 4879 t. Their catch rates were 4.53 kg / h, 0.36 kg / h and 0.91 kg / h, respectively. *Metapenaeus monoceros* dominated (49.6 %) the penaeid prawn catches in sona boats followed by *Solenocera* spp (17.3 %), *Metapenaeopsis* spp (15.1 %) and *Penaeus monodon* (5.2 %). In the catches of small mechanised trawls, *Metapenaeus monoceros* (31.8 %), *Solenocera* spp (29.4 %) and *Trachypenaeus curvirostris* (9.5 %) were the chief contributors. More than 80 % of the edible crabs landed by sona boats and small mechanised trawls were constituted by *Portunus sanguinolentus*. Among cephalopods, the catches of cuttlefish was 2484 t at a catch rate of 0.46 kg / h and the catches of squid was 1544 t at a catch rate of 0.29 kg / h. Cuttlefish landing was contributed by *Sepia aculeata* (47.6 %), *S. pharaonis* (45 %) and *Sepiella inermis* (7.3 %) while squid landing was contributed entirely by *Loligo duvaucelli*.

Odisha

The landings of croakers, ribbonfishes, goat fishes, mackerel, soles and catfishes were 40226 t, 18848 t, 7902 t, 6007 t, 4597 t and 3962 t at catch rates of 15.31 kg / h, 7.17 kg / h, 3.01 kg / h, 2.29 kg / h, 1.75 kg / h and 1.51 kg / h. Carangids landed amounted to 20737 t with a catch rate of 7.89 kg / h. Among carangids, the landings of *Megalaspis cordyla* was 3297 t at a catch rate of 1.25 kg / h. The catch of clupeids was 20013 t with *Stolephorus* spp (2942 t), *Setipinna* spp (2897 t) and *Coilia dussumieri* (2140 t) being the dominant species. Their catch rates were 1.12 kg / h, 1.10 kg / h and

0.81 kg / h, respectively. Pomfret landing (3640 t) was shared more or less equally by black pomfret and silver pomfret. The catch rates of black pomfret and silver pomfret was 0.68 kg / h and0.64 kg / h.



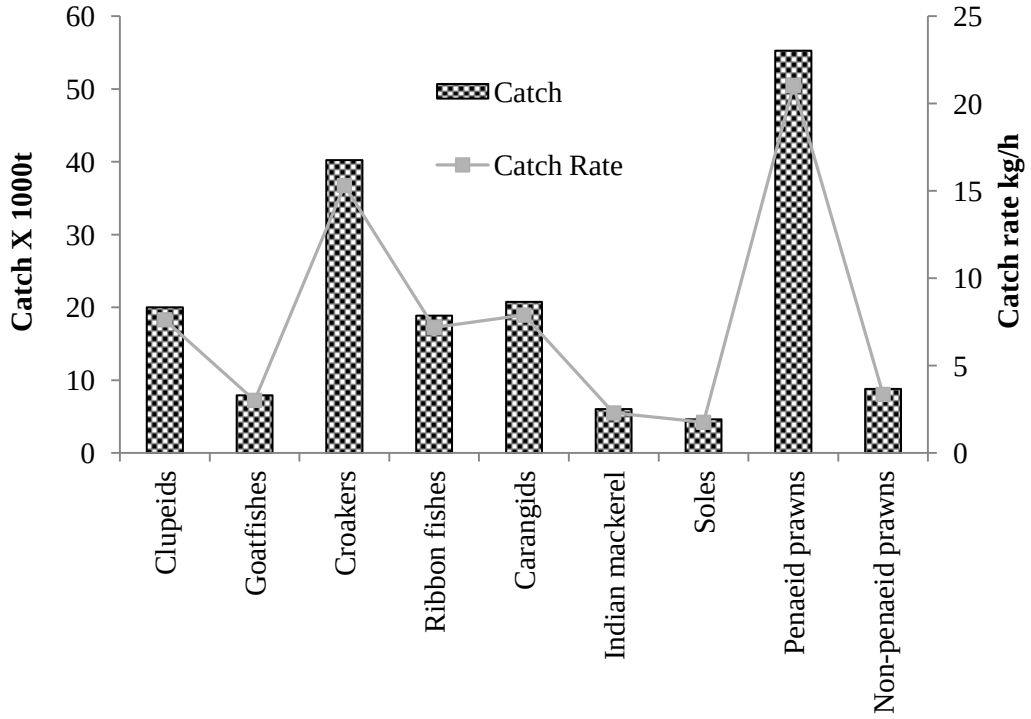
Catch and catch rate of major resources in the trawl landings of Andhra Pradesh

Similarly, elasmobranch catch (1491 t) was shared between rays (962 t) and sharks (524 t). Catch rates for rays and sharks was 0.37 kg / h and 0.20 kg / h. The other major groups of fin fishes landed were silverbellies (2805 t), lizardfishes (2800 t) and threadfin breams (1350 t). Their catch rates were 1.07 kg / h, 1.07 kg / h and 0.51 kg / h, respectively. Crustacean landing was 67076 t of which penaeid prawns landed was 55257 t, non penaeid prawns landed was 8791 t and crabs landed was 2152 t. Their catch rates were 21.03 kg / h, 3.35 kg / h and 0.82 kg / h, respectively. Around 2519 t of cephalopods were caught in which the contribution of squid was 1244 t and cuttlefish was 1275 t. The catch rate for squids was 0.47 kg / h and for cuttlefish was 0.49 kg / h.

West Bengal

The landings of croakers, threadfin breams, catfishes, bombay duck, goatfishes, soles, silverbellies and ribbonfishes were 5680 t, 3776 t, 2108 t, 2067 t, 2020 t, 1712 t. 1412 t and 1081 t at catch rates of 2.18 kg / h, 1.45 kg / h, 0.81 kg / h, 0.79 kg / h, 0.78 kg / h, 0.66 kg / h, 0.54 kg / h and 0.42 kg / h.. The catch of clupeids was 14046 t in which the major species encountered were *Setipinna* spp (3068 t), *Thryssa* spp (2567 t), *Coilia dussumieri* (1943 t), *Chirocentrus dorab* (1488 t)

and sardines (1073 t). Their catch rates were 1.18 kg / h, 0.99 kg / h, 0.75 kg / h, 0.57 kg / h and 0.41 kg / h, respectively. Carangids landing amounted to 7307 t of which two thirds were represented by



Catch and catch rate of major resources in the trawl landings of Odisha

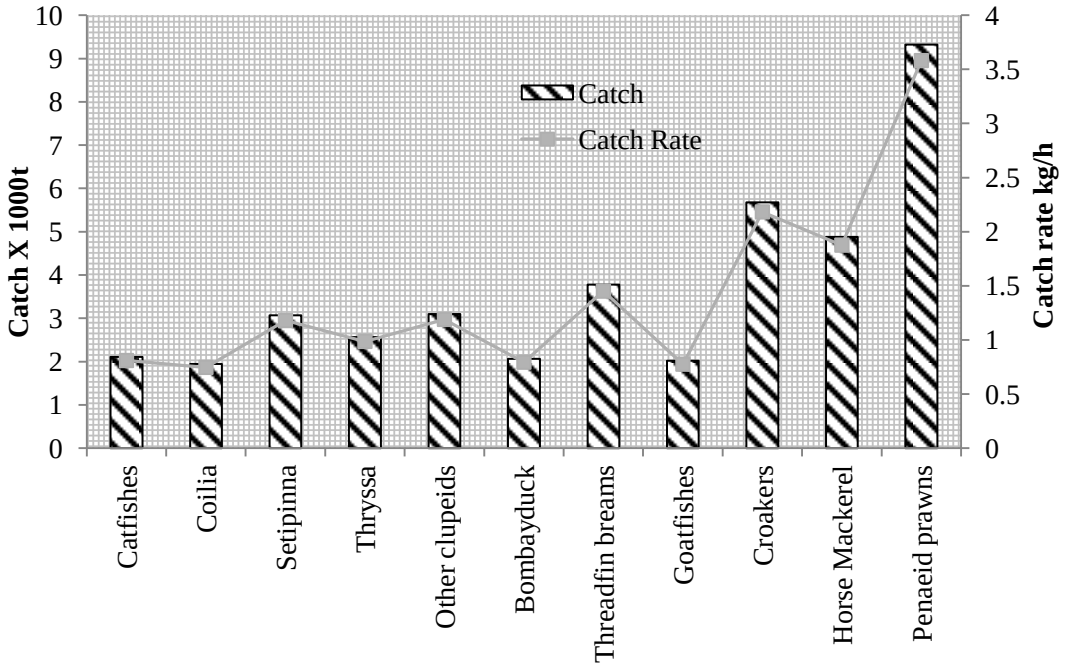
Megalaspis cordyla (4881 t). The catch rate of *Megalaspis cordyla* was 1.88 kg / h. Silver pomfret (1280 t) dominated the pomfret landings (1319 t) with an annual catch rate of 0.49 kg / h. Similarly, elasmobranch catch (492 t) was dominated mostly by sharks. Around 10445 t of crustacean resources were landed in which the share of penaeid prawns was 9318 t, non penaeid prawns was 566 t and crabs was 398 t. The catch rates of penaeid prawns, non penaeid prawns and crabs were 3.58 kg / h, 0.22 kg / h and 0.15 kg / h. The catch of cephalopods was 1141 t in which cuttlefish landed was 1021 t and squid landed was 120 t. The catch rates for cuttlefish and squid was 0.39 kg / h and 0.05 kg / h.

Biology of dominant species landed by trawls

Andhra Pradesh

The length of *Trichiurus lepturus* ranged from 360 to 1099 mm with peak spawning activity in August and average fecundity of 87753 and ova diameter varying from 0.35 to 0.85 mm. For *Rastrelliger kanagurta*, the length range was 110 – 249 mm, spawning season was from February to

June with average fecundity of 96980 and ova diameter of 0.16 – 0.64 mm. The length ranges recorded for *Otolithes ruber*, *Upeneus vittatus*, *Nemipterus japonicus* and *Saurida undosquamis* were



Catch and catch rate of major resources in the trawl landings of West Bengal

190 – 399 mm, 110 – 199 mm, 120 – 249 mm and 110 – 399 mm. Spawning season for *Upeneus vittatus*, *Nemipterus japonicus* and *Saurida undosquamis* was during July – August, December – February and November – December. Their average fecundity was 99759, 38487, 44004 and 72747 and their ova diameter ranged from 0.28 mm – 0.59 mm, 0.23 mm to 0.47 mm, 0.15 mm to 0.58 mm and 0.24 mm to 1.35 mm. The mean length of *Sphyraena obtusata* was 265.5 mm with gonadosomatic index of 3.4. The average fecundity was 75901 with ova diameter varying from 0.35 mm to 0.48 mm. Around half of the fishes possessed empty stomachs. The lengths for *Penaeus monodon* and *Penaeus indicus* ranged from 168 – 278 mm and 132 – 203 mm with peak spawning during February – March and ova diameter varying from 0.03 – 0.1 mm and 0.03 – 0.06 mm. Mean length for *Metapenaeus dobsoni* was 75.1 mm for males and 83.5 mm for females with sex ratio favouring males and majority (80 %) of the females in immature state. In *Portunus sanguinolentus*, the mean length was 126.9 mm for males and 126.1 mm for females with dominance of mature females in the catches. Length range for *Sepia aculeata* varied from 89 mm to 278 mm with preponderance of females in the catch. More than half of the females were found to be mature. For *Loligo duvaucelli*, the size varied from 65 mm to 159 mm with mature females encountered in most

months of the year and ova diameter ranging from 0.78 mm to 1.3 mm. Juveniles of *Sepia aculeata* and *Loligo duvaucelli* were encountered in the fishery throughout the year in high numbers.

Odisha

Length recorded varied from 260 mm to 349 mm for *Otolithes ruber*, 540 mm to 719 mm for *Trichiurus lepturus*, 120 mm to 179 mm for *Upeneus vittatus*, 160 mm to 209 mm for *Rastrelliger kanagurta*, 200 mm to 309 mm for *Nemipterus japonicus* and 280 mm to 439 mm for *Saurida undosquamis*. Peak spawning months for *Rastrelliger kanagurta*, *Nemipterus japonicus* and *Saurida undosquamis* was August, July – August and November – December. Mature females of *Penaeus monodon* and *Penaeus indicus* were recorded in most months with peak during August – December. *Loligo duvaucelli* ranged in length from 65 mm to 169 mm and high proportion of mature females was recorded in all months of the year.

West Bengal

Lengths for *Otolithes ruber*, *Johnius dussumieri*, *Trichiurus lepturus*, *Nemipterus japonicus*, *Rastrelliger kanagurta*, *Saurida tumbil*, *Upeneus sulphureus* and *Saurida undosquamis* varied from 200 mm to 329 mm, 160 mm to 259 mm, 440 mm to 659 mm, 130 mm to 319 mm, 140 mm to 229 mm, 170 mm to 369 mm, 110 mm to 189 mm and 210 mm to 279 mm. Peak spawning was observed during September – December for *Johnius dussumieri*, December for *Trichiurus lepturus* and *Saurida undosquamis*, April for *Nemipterus japonicus*, April and July – September for *Rastrelliger kanagurta*, October – December for *Saurida tumbil* and July for *Upeneus sulphureus.* Mean length of *Cynoglossus arel* was 248 mm with length ranging from 200 mm to 289 mm and preponderance of males in the catch. For *Penaeus monodon* and *Penaeus indicus*, the length ranged from 155 mm to 247 mm and 119 mm to 175 mm. Breeding season was February – July for *Penaeus monodon* and March – August for *Penaeus indicus*. The length for *Loligo duvaucelli* varied from 60 mm to 189 mm with peak spawning observed in July.

Mean length, sex ratio, gonado somatic index and maturity % of major species caught in trawlers at Visakhapatnam, Paradeep and Digha

	Mean length (mm)			Sex ratio			Gonado somatic index			% Maturity		
Species Name	Vizag	Paradip	Digha	Vizag	Paradip	Digha	Vizag	Paradip	Digha	Vizag	Paradip	Digha
Rastrelliger kanagurta	186.9	181.2	195.2	1.5	0.8	0.9	2.71		5.7	19.3		25.7
Nemipterus japonicus	183.6	235.2	193.9	4.4	1.3		2.98		3	35.1		6.46
Trichiurus lepturus	186.9	181.2	195.6	1.5	0.8	0.9	2.71		5.6	19.3		25.7
Upeneus vittatus	148.1	140.7		1.6	1.1		3.24	0.5		40.6	2.2	

Upeneus sulphureus			143.6			2.5			5.9			14.5
Otolithes ruber	263.8	310.7	255.1	2.7	1.1	2.4	1.41			8.3		
Saurida tumbil			250.6			1.6			3.08			13.6
Saurida undosquamis	271.3	330.3	233.3	2.6	1.5	5.7	2.4	2.94	4.86	33.7	17.4	12.7
Johnius dussumieri			194.7			1.2			5.39			38.0
Penaeus monodon	218.2		193.7	0.5		1.8	7.2		9.73	43.6		19.1
Penaeus indicus	173.7		152.6	2.9		1	8.1		11.1	33.0		12.7
Metapenaeus monoceros	146.8			17			7.85			17.7		
Loligo duvaucelli	98.2	92.4	104.3	1.7	1.3	2.1	9.4		12.28	57.6	87.9	17.9

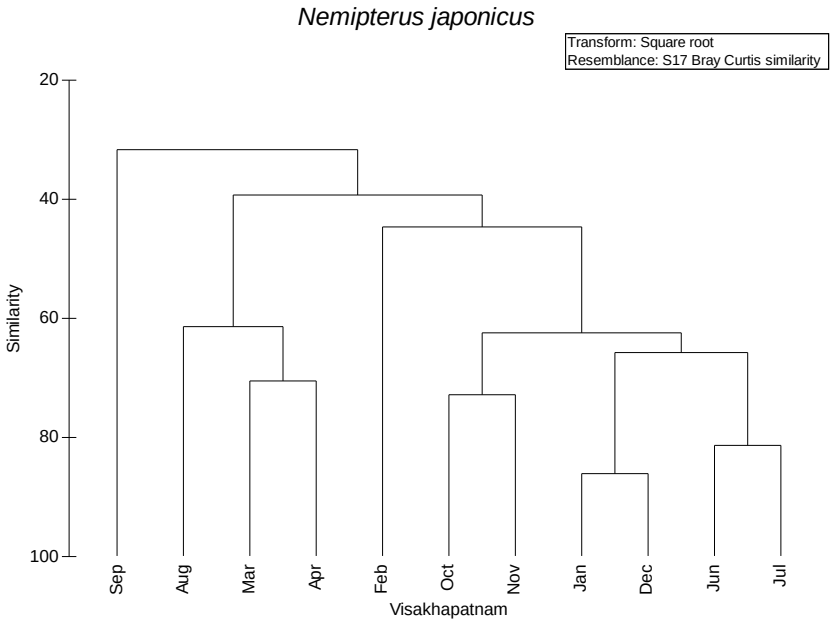
Index of Relative Importance (%) of various prey items encountered in the stomach contents of major species caught in trawlers at Visakhapatnam, Paradeep and Digha

IRI % Values	*Nemipterus japonicus*			*Upeneus vittatus*			*Trichiurus lepturus*			*Saurida undosquamis*			*Otolithes ruber*		
Diet Contents	Vizag	Paradip	Digha	Vizag	Paradip	Digha	Vizag	Paradip	Digha	Vizag	Paradip	Digha	Vizag	Paradip	Digha
Digested fish	36.9	63.9	84.4	76.0	71.7		56.8	70.4	71.8	43.0	54.1	87.0	46.5	67.0	64.3
Metapaeneus sps	4.2	7.9	1.1	3.0	25.6		1.0	11.4		1.5	14.9		1.9	10.5	0.0
Crab	26.1	0.7	13.2	0.7											
Squilla	12.5	0.3	1.1	0.1						0.1					6.0
Loligo	9.0	1.4		0.4			1.8	0.9	1.0		5.1	13.0	0.3	1.3	
Leiognathus			0.2										0.7		
Fish Juveniles		25.3		2.3	2.7			17.3			25.9			21.0	
Upeneus vittatus		0.3								1.2					
Octopus		0.4													
Eel	0.1									0.5					
Nemipterus sps	0.5									0.1					
Lactarius lactarius	0.2														
Acetes sps	5.6			16.5					15.6	0.4			4.4	0.0	29.6
Anchovies	4.7												19.7		
Lesser sardine				0.6			17.8		10.1						
Saurida sps				0.2			7.1			1.1					
Gastropod				0.3											
Seerfish							0.4								
Barracuda							3.4								
Ribbon fish							2.6			3.1				0.1	
Silver bellies							0.6								
Other clupeids							8.0						2.1		

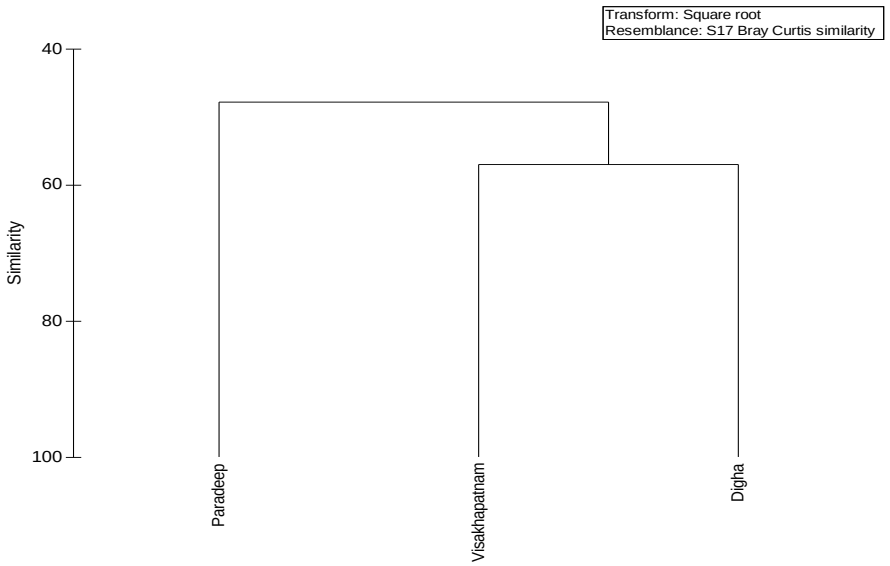
Decapterus sps	0.5	2.4	
Coilia dussumieri	1.5		
Stolephorus sps		13.1	5.3
Solenocera sps		0.2	17.0
Apogon sps		1.6	
Oil sardine		20.5	
Otolithes ruber		11.3	
Pentaprion sps			1.4
Parapenaeopsis sps			0.2

Feeding intensity (%) of major species caught in trawlers at Visakhapatnam, Paradeep and Digha

Feeding Intensity (%)	Empty-Trace			Quarter Full-Half Full			Three fourth-Full		
Species Name	Vizag	Paradip	Digha	Vizag	Paradip	Digha	Vizag	Paradip	Digha
Rastrelliger kanagurta	30.04	53.74	53.79	58.64	36.61	35.60	25.22	9.64	12.72
Nemipterus japonicus	55.9	49.6	54.08	28.69	37.34	20.95	16.63	13.04	24.95
Trichiurus lepturus	40.77	59.49	75.42	37.88	14.82	10.18	21.33	5.43	14.39
Upeneus vittatus	61.3	39.08		32.07	33.18		6.59	1.04	
Upeneus sulphureus			87.67			9.11			3.2
Otolithes ruber	56.02	29.4	55.05	25.67	16.66	19.19	16.66	3.88	25.75
Saurida tumbil			78.25			5.85			14.3
Saurida undosquamis	49.04	65.87	79.28	31.41	13.18	2.5	19.04	3.87	18.21
Johnius dussumieri			88.98			4.92			8.19
Penaeus monodon	44.56		76.88	38.69		24.75	16.74		10.66
Penaeus indicus	26.27		73.85	41.35		22.81	32.37		3.33
Metapenaeus monoceros	19.61			44.69			40.59		
Loligo duvaucelli	78.54	77.07		14.03	20.77		8.16	2.15	



Dendrogram showing similarity of diet of *Nemipterus japonicus* for different months at Visakhapatnam



Dendrogram reflecting the regional differences in the pooled diet contents of five major finfishes (*Nemipterus japonicus*, *Upeneus vittatus*, *Saurida undosquamis*, *Otolithes ruber* and *Trichiurus lepturus*) caught in trawls.

Stock Assessment of flagship species landed in trawls

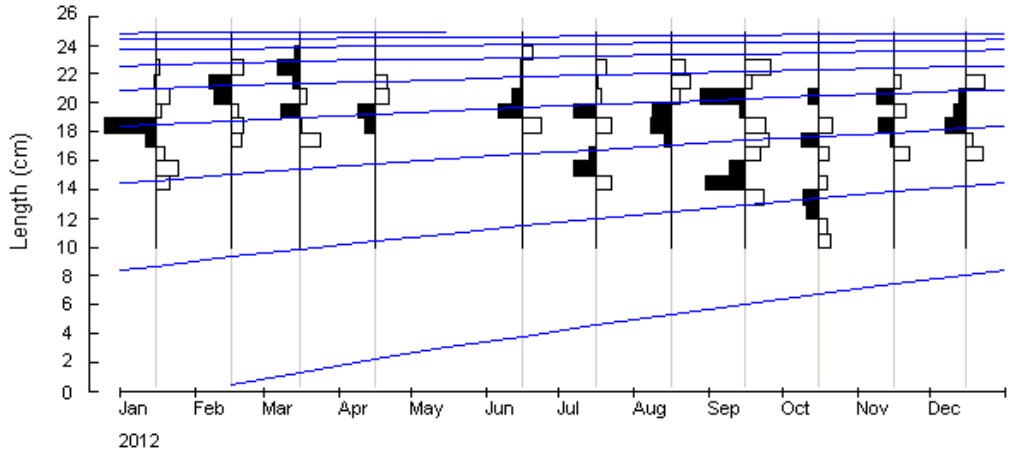
The growth parameters and stock estimates of three flagship species viz., *Rastrelliger kanagurtha, Nemipterus japonicus* and *Loligo duvaucelli* landed in trawls along the north east coast of India are depicted in tables. It is imperative from the tables that since the present exploitation level for all are less than their E_{max} and the annual average yield is less than the maximum sustainable yield, all the three species are underexploited with possible scope for increasing their exploitation. Recruitment was unimodal in *Rastrelliger kanagurtha* and *Nemipterus japonicus* and bimodal in *Loligo duvaucelli*. The peak months of recruitment were March – July for *Rastrelliger kanagurtha*, March – August for *Nemipterus japonicus* and January – February and April – June for *Loligo duvaucelli*. The peak pulse produced on an average 73% of the recruits for *Rastrelliger kanagurtha* and *Nemipterus japonicus* and 72% of the recruits for *Loligo duvaucelli*. Virtual Population Analysis indicated that the main loss in the stocks for *Rastrelliger kanagurtha* upto 17.5 cm was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality because of fishing increased.

Growth parameters of flagship resources landed in trawls along north east coast

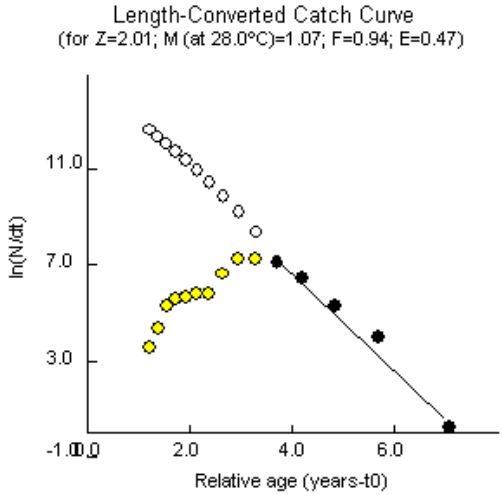
	Linf (cm)	k	Z	M	F	E	Emax	Lc (cm)	Lr (cm)
Rastrelliger kanagurta	25.67	0.43	2.01	1.07	0.94	0.47	0.71	19.48	10.45
Nemipterus japonicus	33.02	0.22	1.18	0.65	0.53	0.45	1	17.24	12.45
Loligo duvaucelli	19.63	0.16	0.88	0.61	0.27	0.31	1	9.33	5.7

Stock Assessment of flagship resources landed in trawls along north east coast

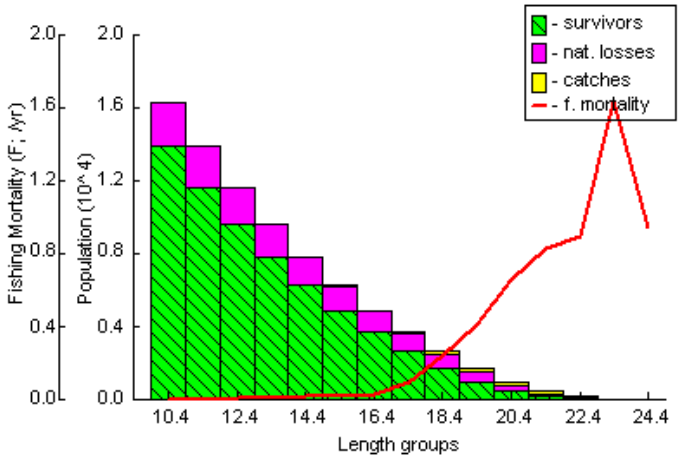
	Recruitment (in millions)	Standing Stock / Biomass (t)	Biomass per recruit (g)	Annual average yield (t)	MSY (t)	Yield per recruit (g)
Rastrelliger kanagurta	2609	18264	7	17168	18355	6.58
Nemipterus japonicus	366	11387	31.1	6035	6719	16.49
Loligo duvaucelli	874.5	10767	12.31	2907	4737	3.32



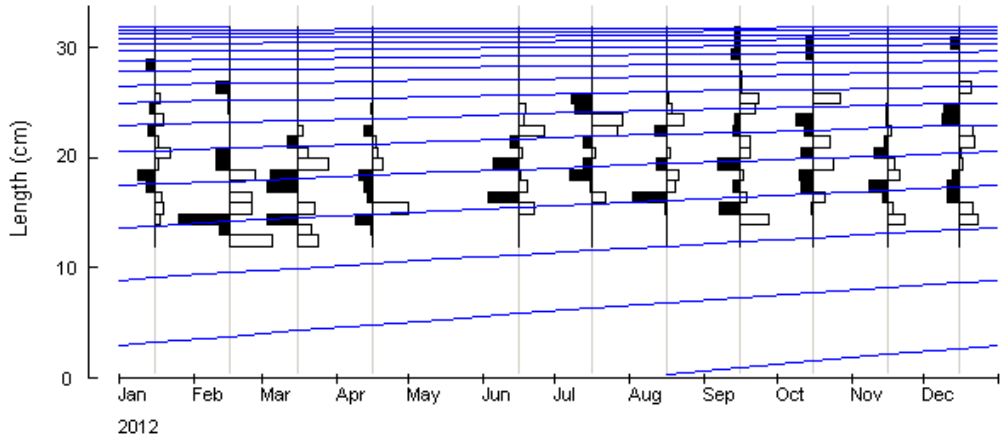
Restructured growth curve of *Rastrelliger kanagurta*



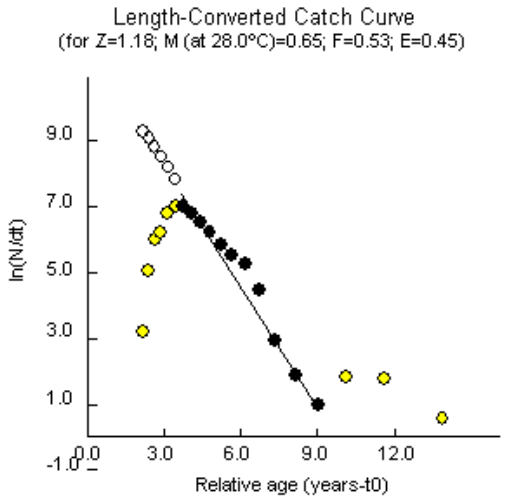
Length converted catch curve of *Rastrelliger kanagurtha*



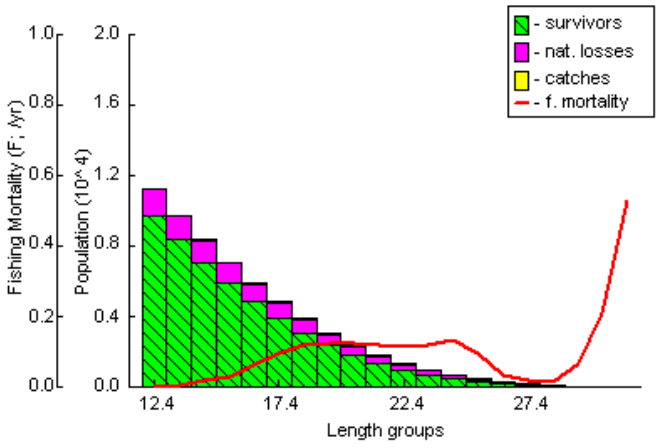
Length structured Virtual Population Analysis for *Rastrelliger kanagurtha*



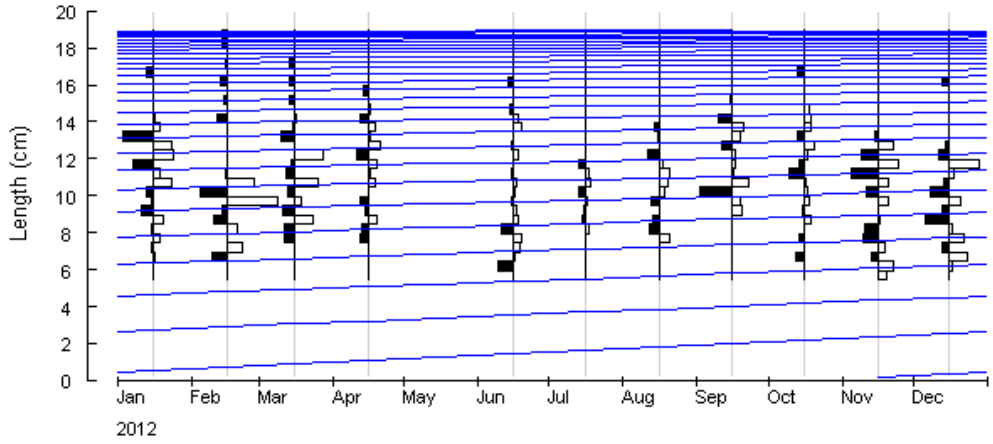
Restructured growth curve of *Nemipterus japonicus*



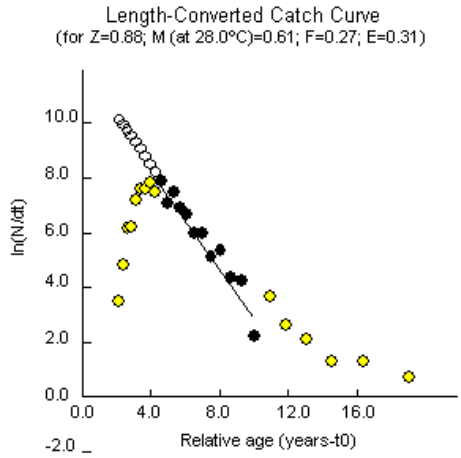
Length converted catch curve of *Nemipterus japonicus*



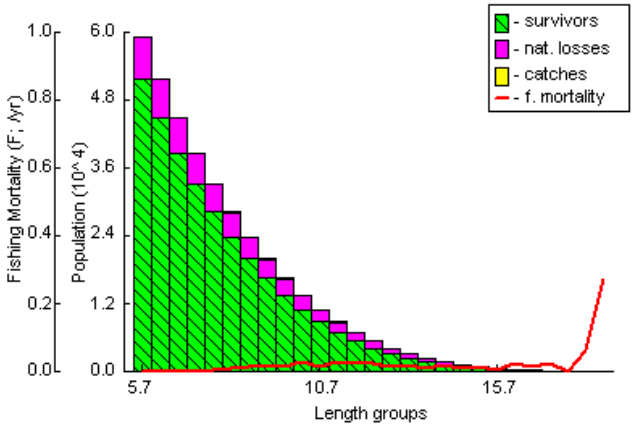
Length structured Virtual Population Analysis for *Nemipterus japonicus*



Restructured growth curve of *Loligo duvaucelli*



Length converted catch curve of *Loligo duvaucelli*



Length structured Virtual Population Analysis for *Loligo duvaucelli*

Biodiversity analysis

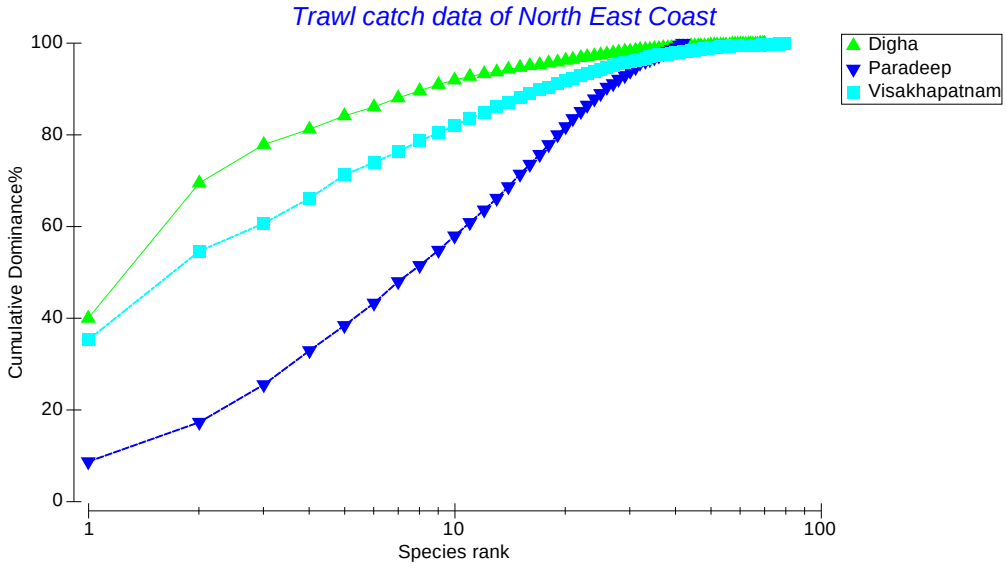
Trawl samples were collected from trawlers operating off Visakhapatnam in Andhra Pradesh, Paradeep in Odisha and Digha in West Bengal and the data was analyzed with respect to diversity indices, dominance plot, Bray–Curtis similarity and abundance and biomass comparison plot.

Diversity Indices - In line with the higher number of species, Shannon diversity {H'(log 2)} was more in Paradeep (4.82) as compared to Digha (2.82) and Visakhapatnam (3.63) reflecting the diverse nature of these centres. The Simpson species richness index for Paradeep (0.95) was also found to be more than that of Digha (0.74) and Visakhapatnam (0.82).

Diversity indices of trawl catches at Visakhapatnam, Digha and Paradeep

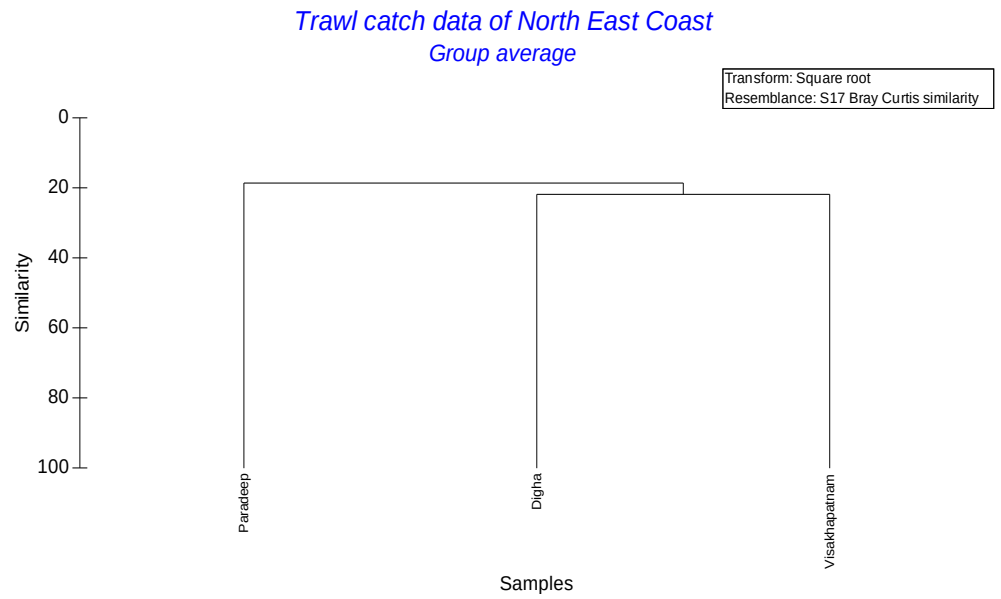
Stations/Indices	Species richness (d)	Pielou's evenness (J')	Shannon H'(log2)	Simpsons 1-Lambda'	Hill abundances (N1)
Digha	7.99	0.46	2.82	0.74	7.07
Paradeep	7.53	0.89	4.82	0.95	28.43
Visakhapatnam	9.32	0.57	3.63	0.82	12.45

Dominance plot – The species dominance plot indicates the rich diversity of trawl catches in Paradeep as compared to Digha and Visakhapatnam with respect to the number of species.



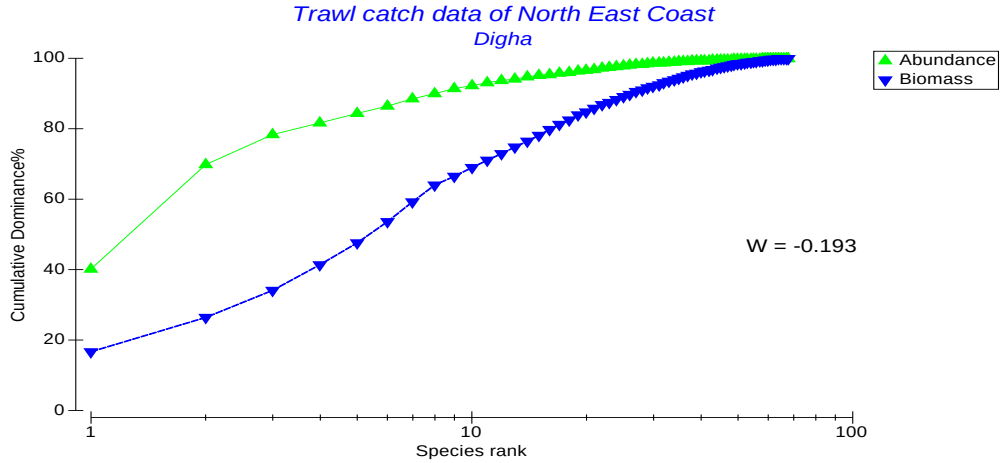
Dominance plot showing higher diversity in Paradeep as compared to Visakhapatnam and Digha

Bray–Curtis similarity analysis - The Bray–Curtis similarity in species composition and abundance among Digha, Paradeep and Visakhapatnam was 16.67-21.87%.

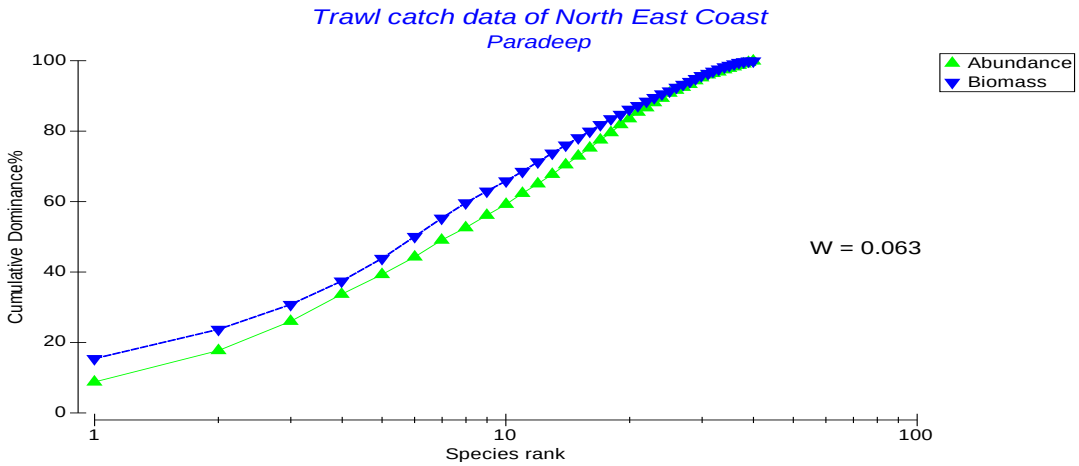


Species composition and abundance similarity in trawl catches at Visakhapatnam, Paradeep and Digha

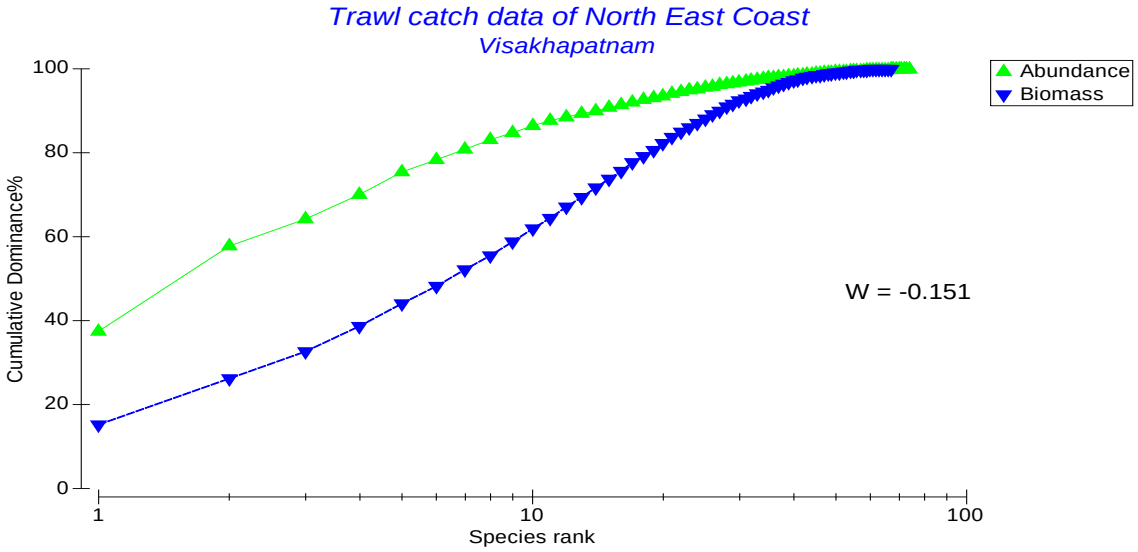
Abundance/biomass comparison plots - The abundance/biomass comparison (ABC) plot for Paradeep showed the K dominance curve for biomass to be above the curve for abundance. W statistics value was highest in Paradeep (0.063). These indicate higher degree of evenness and lower degree of disturbance at Paradeep. The ABC plot for Digha and Visakhapatnam showed the K dominance curve for abundance to be above the curve for biomass. W statistics values for Digha and Visakhapatnam were -0.193 and -0.151. These indicate lower degree of evenness with higher disturbance level at Digha and Visakhapatnam.



Species abundance biomass curve for Digha



Species abundance biomass curve for Paradeep



The total production by trawlers during 2013 along the north east coast of India was 4.28 lakh t. The catch rate was 39.49 kg / h. Trawl landings in Andhra Pradesh was 1.34 lakh t forming 51.8 % of the total marine landings. The overall catch rate was 25.2 kg/h for the state. The contribution of sona boats to the trawl landings of Andhra Pradesh was 96.1 % and the contribution of small mechanized trawlers was 3.9 %. The catch rate in sona boats was 25.3 kg / h and in small mechanized trawlers was 24.4 kg / h. In Odisha, the trawl catch was 2.13 lakh t forming 85.9 % of the annual marine catches. The overall catch rate in Odisha was 80.91 kg / h. More than 95 % of the catches were contributed by multiday trawlers and less than 5 % were contributed by singleday trawlers. The catch rate in multiday trawlers was 79.32 kg / h and in singleday trawlers was 147.78 kg / h. In West

Bengal, 0.67 lakh t was landed by trawlers at catch rate of 25.25 kg/h forming 31.4 % of the total marine landings.

	Andhra Pradesh	Odisha	West Bengal
Catch composition	Penaeid prawns (18.3%)	Penaeid prawns (22.32%)	Penaeid prawns (14.55%)
	Ribbonfishes (8.5 %)	Croakers (19.69 %)	Croakers (12.37 %)
	Croakers (5.7 %)	Ribbonfishes (10.32 %)	*Coilia dussumieri* (5.56 %)
	Black pomfret (5.0%)	Non-penaeid prawns (5.9 %)	*Harpadon nehereus* (4.57 %)
	Rastrelliger kanagurta (4.2 %)		
	Silverbellies (3.6 %)	Setipinna (3.28 %)	*Setipinna* (4.53 %)
	Stolephorus (3.7%)	Stolephorus (2.95 %)	Lesser sardines (3.43%)
	Goatfishes (3.5 %)	Thryssa (2.86 %)	Silverbellies (3.41 %)
	Scads (3.4 %)	Crabs (2.32 %)	Catfishes (3.32 %)
	Threadfin breams (3.2%)		Thryssa (3.14 %)
	Catfishes (3.1%)		Ribbonfish (2.68 %).
	Crabs (2.9 %)		
	Lizardfishes (2.9%)		

Species Name	Fecundity	Ova diameter (microns)
Rastrelliger kanagurta	153505	0.28-1.02
Sardinella longiceps	31200	0.38-0.54
Trichiurus lepturus	139290	0.31-0.74
Otolithes ruber	147458	0.2-0.53
Nemipterus japonicus	84396	0.2-0.56
Saurida undosquamis	75932	0.26-0.67
Sphyraena jello	270606	0.20-0.50

	Length range (mm)		Mean length (mm)		Sex ratio		Mature %		GSI	
Species Name	Vizag	Digha	Vizag	Digha	Vizag	Digha	Vizag	Digha	Vizag	Digha
Rastrelliger kanagurta	110-269	140-259	189.9	199.3	2.3	1.1	32.7	49.8	5.5	4.4
Sardinella longiceps	60-219	130-209	126.2	168.2	1.0	1.2	4.3	27.6	5.9	7.8
Trichiurus lepturus	380-1059	480-819	582.3	596.6	3.5	1.8	24.3	24.9	3.5	4.8
Otolithes ruber	150-419	180-409	276.3	267.6	1.8	1.9	21.3	19.7	2.4	3.2
Nemipterus japonicus	110-289	110-319	184.6	200.6	1.8	3.8	39.1	13.2	3.8	3.9
Loligo duvaucelli	55-194	60-194	95.7	95.2	2.7	1.3	63.3	31.9	11.7	16.0
Saurida undosquamis	120-389		213.9		3.4		14.4		4.1	
Scomberomorus guttatus	200-379		304.2		2.4		0.0			
Katsuwonus pelamis	360-679		511.7		1.0		10.7		1.2	
Sphyraena jello	180-599		335.3		0.8		20.4		2.6	
Sphyraena obtusata	210-299		238.8		6.0		61.7		4.2	
Upeneus vittatus	100-199		146.4		1.2		33.0		3.3	
Metapenaeus monoceros	104-196		148.0		1.1		47.4		10.4	
Upeneus sulphureus		110-179		134.0		1.1		40.1		4.5
Saurida tumbil		180-379		263.1		2.0		18.3		7.0
Cynoglossus arel		160-299		235.5		1.8		13.3		5.1
Penaeus monodon		149-258		190.9		1.4		47.5		7.1

Feeding intensity (%)	Empty - Trace %		One fourth - One half %		Three fourth - Full %	
Species Name	Vizag	Digha	Vizag	Digha	Vizag	Digha
Rastrelliger kanagurta	11.7	49.0	62.0	42.5	26.3	8.5
Sardinella longiceps	61.1	70.2	32.2	15.6	6.7	14.1
Trichiurus lepturus	56.8	78.4	20.3	7.1	22.8	14.5
Otolithes ruber	68.5	78.0	27.8	12.8	3.6	9.1
Nemipterus japonicus	41.7	57.9	38.1	22.6	20.2	19.5
Loligo duvaucelli	70.0		21.0		9.0	
Saurida undosquamis	68.9		18.9		12.2	
Scomberomorus guttatus	59.6		20.0		20.4	
Katsuwonus pelamis	62.1		22.4		15.5	
Sphyraena jello	49.7		37.8		12.5	

Sphyraena obtusata	83.3		8.3		8.3	
Upeneus vittatus	58.7		30.3		11.1	
Metapenaeus monoceros	12.7		56.0		31.3	
Upeneus sulphureus		91.4		2.6		6.0
Saurida tumbil		70.9		12.5		16.7
Cynoglossus arel		96.2		3.8		0.0
Penaeus monodon		49.0		34.8		16.2

IRI % values	*Trichiurus lepturus*		*Otolithes ruber*		*Nemipterus japonicus*		*Loligo duvaucelli*	
Food contents	Vizag	Digha	Vizag	Digha	Vizag	Digha	Vizag	Digha
Acetes			12.9				9.5	
Apogon			0.7		0.1			
Carangids	11.0		5.7					
Clupeids					1.5			
Coilia				3.6				
Crab			0.7		8.1	0.4		
Dig fish	37.3	95.7					57.1	99.1
Dig matter			37.8	78.2	45.0	78.2		
Eel			0.2		1.5			
Fish juvenile		1.0		6.5	3.3	2.0		
Goatfish					0.4			
Leiognathus					1.9			
Lizardfish					0.5			
Mackerel	0.5				0.8			
Myctophids					0.1			
Octopus					0.2			
Polynemus	2.5							
Ponyfish			4.0					
Puffer fish	0.2							
Sardine	38.0				1.3		15.3	
Saurida			0.1					
Sciaenid			1.5		1.4			
Shrimp		1.4	27.7	9.9	16.5	17.4		0.9
Sillago								
Silverbellies	3.0							
Solenocera				1.7	6.5			
Squid		0.3	0.5		6.0	0.3		

squilla				4.4	1.7		
Stolephorus	7.5	1.7	0.1	0.5		18.1	
Threadfin bream			0.1				
Thryssa							
Upeneus			8.0				

Remote sensing assisted biodynamic forecasting paradigm for Indian marine fishery resources

Experimental fishing was conducted for the collection of fishing data off Visakhapatnam coast and data was collected from 26 hauls (11 trips) by using commercial trawlers.

Gangavaram (27%), Rushikonda (23%) and Yarada (23%) were the main places covered for the fishing. Trawl net was the single major gear used for the fishing.

Mesh size varied between 12 mm, 15 mm and 20 mm. 15 mm mesh size was used for fishing for most of the time. Depth of operation ranged from 20-66 m and 38 m was the average depth. 2.2 Nautical miles was the average speed maintained during fishing. Total fish catch was about 415 kg out of which 167 kg was the discarded catch. Discarded catch varied from 17-66% and 41% was the average discard catch. Catch per hour (cph) varied from 1.6 to 26.3 kg and 9.7 kg was the average cph. 2.10 hr was the average haul duration of fishing.

Around 82 species contributed to the single day fishery, among that *Lapturacanthus savala* (14%), *Leiognathus bindus* (8%), *Johnius carruta* (5.4%), *Gazza minuta* (4.9%), *Pennahia macrophthalmus* (4.85%), *Pomadasys maculata* (3.9%), *Saurida undosuamis* (3.5%), *Apogon sps* (3.16%) and *Upeneus vittatus* (3.13%) were the major fishery resources.

About 76 species were observed in discard catch, among that *Lapturacanthus savala* (21%), *Apogon sps* (12.64%), *Leiognathus bindus* (10%), other crabs (9.1%), Lagocephalus sps (6.4%), Squilla (3.95%), *Pomadasys maculata* (3.55%) and Secutor (3%) were the major discard fishes.

Development and standardization of seed production technologies of selected high value fin fishes and shellfishes

Protocol for female broodstock development of *E. coioides* in cage was standardized with successful year round female broodstock availability.

Successful sex reversal (female grouper to male) was achieved with the hormonal and enzymatic manipulation and 60% of the implanted fishes were sex reversed after 4 months.

Female and male brooders of orange spotted grouper in re-circulatory system successfully matured with 450 µ ova size in cannulated female and milt in sex reversed male.

Persistent sex reversed male orange spotted grouper**:** Orange spotted grouper with oocytes in the perinucleolus stage were implanted with 5 mg 17 α-MT kg $^{-1}$ body weight (T_1), 5 mg 17 α-MT and 0.2 mg letrozole kg $^{-1}$ body weight (T_2) and 5 mg 17 α-MT with 0.4 mg letrozole kg $^{-1}$ body weight (T_3) and no androgens/enzyme inhibitor implanted. The 17 α-MT alone and in combination of letrozole-induced sex reversal in orange spotted grouper, whereas untreated control fish showed normal ovarian development. Sex-reversed males successfully fertilized the eggs during induced spawning. Thus 17 α-MT (5.0 mg kg $^{-1}$ BW) in combination with letrozole (0.2 mg kg^{-1} BW) has the potential to produce 100% sex- reversed male in short period in orange spotted grouper.

Induced spawning of orange spotted grouper was achieved and fertilized eggs were produced. Hormonal doses for induced breeding of orange spotted grouper were standardized. Larval rearing of orange-spotted grouper was carried out successfully for the first time in India. Two cycle of larval rearing were completed and seed were produced.

Thirteen number of adult *Trachinotous mookalee* were collected and stocked in cage for broodstock development. Two male and two mature female broodstock was developed. Induced spawning of Indian pompano was carried first time in world. Successful larval rearing of Indian pompano was carried out and seed were produced for the first time in the world.

Phytoplankton, *Nannochloropsis* sp., *Chlorela sp.* and *Isochrysis sp.* were cultured for feeding to rotifers.

Stock culture of *Cheatocerous* sp. and *Thallasocera sp.* was maintained and a revenue of Rs. 5.79 lakhs were generated by selling different phytoplankton species.

The mass production method of copepod (*Calanoid* spp.) culture was developed for producing copepod nauplii for larval rearing of grouper.

A method for small rotifers production of less than 100 µ size was standardized.

Innovations in Sea Cage Farming and Coastal Mariculture

Hatchery produced fingerlings of 6 cm size (0.57g) were stocked in hapa of 2 mm mesh size attached to cage and it has grown to 12.11 cm (18.93 g) after 2 months of cultured period.

Orange spotted grouper seed of 12.11 cm in length and 18.93 g in weight were stocked in cage and fed with trash fish and have grown to 28.44 cm in length and 410.38 gm in weight after 6 month of culture period. The survival rate during the culture period was 100%.

Wild grouper seed (6-7 cm) were collected along Nagayalanka coast of West Godavari Dist. of Andhra Pradesh and stocked in pond for growth monitoring. They were fed with trash fish and artificial pellet @ 8-10 % body weight. After six month of culture period, they have grown to 20.5 cm in average length and 134.0 g in average weight.

Live ageing to revalidate growth parameters of Oil sardine and Indian Mackerel: An experiment was conducted in open sea cage to revalidate the growth parameters of Oil sardine and Mackerel from 14th December 2013 to 22nd March, 2014 at VRC of CMFRI, Visakhapatnam. About two hundred numbers of Oil sardines of average length of 86 mm and two numbers of Mackerel of average length of 159 mm was collected from wild and stocked in cage. Random sampling of forty species was taken for measuring the length and weight at an interval of 15 days. An average length of 146 mm and 222 mm for Oil sardine and Mackerel was obtained after three months of stocking. The increase in length of about 60 mm and 63 mm was obtained for Oil sardine and Mackerel after three months of stocking.

Health management in selected finfish and shellfish for mariculture and aquariculture & bioprospecting from marine resources

Regular survey for parasitic infection in grouper revealed sea lice, *Lepeophtheirus kabatai* infestation among wild collected orange spotted grouper (*Epinephelus coioides*) which is reared in captive condition.

A method for controlling sea lice infestation in orange-spotted grouper with formalin of 200 ppm for 30 minutes followed by freshwater bath for 5 minutes was found best among different treatment groups carried out.

Infestation with the Isopod spp. was recorded among the Orange spotted grouper (*Epinephelus coioides*) broodstock during the winter period.

The formalin treatment with 200 ppm for 30 minutes followed by freshwater bath for 5 minutes was the best among different treatment groups to control this parasite.

Development of Fisheries Management Plans (FMPs) for sustaining marine fisheries of Andhra Pradesh

The total marine fish production of A.P. for 2012 was 3.05 lakh t. Pelagic resources accounted for 1.68 lakh t forming 55% of the total landings for the state. The dominant groups landed were clupeids (0.67 lakh t and 39.9%), mackerels (0.28 lakh t and 16.95%), ribbon fishes (0.22 lakh t and 13%), carangids (0.21 lakh t and 12.25%), tunas and billfishes (0.15 lakh t and 9.16%) and seer fishes (0.07 lakh t and 4.21%). Among clupeids, the major contributors were lesser sardines contributing 0.25 lakh t, oil sardine contributing 0.09 lakh t and *Stolephorus* contributing 0.10 lakh t. The catch rate of oil sardines, lesser sardines and *Stolephorus* in trawlers were 0.15 kg/h, 0.40 kg/h and 0.68 kg/h. The catch rate of ribbon fishes in trawlers was 2.56 kg/h. Carangids landed were contributed by horse mackerel (23.3%), scads (26.8%), leatherjackets (5.3%) and other carangids (44.6%). The catch rate of horse mackerel, scads and other carangids in trawl nets were 0.39 kg/h, 1.02 kg/h and 0.89 kg/h. The mackerel landings were contributed solely by *Rastrelliger kanagurta*. The catch rate in trawlers was 1.99 kg/h. Seer fish catch was dominated by *Scomberomorus commerson* (66.9%) and *Scomberomorus guttatus* (33.1%). Among tuna, the dominant species landed were *Thunnus albacares* (45.5%), followed by *Euthynnus affinis* (27.5%), *Katsuwonus pelamis* (23.2%) and *Auxis thazard* (3.8%). The landings of billfishes and barracudas for the year were 0.025 lakh t and 0.04 lakh t, respectively. The catch rate of barracudas in trawlers was 0.55 kg/h.

Production trends in Visakhapatnam: Resource wise Fishery & Biology

Sardine

The estimated catch of sardine from the trawlnets at Visakhapatnam was 1177.5 t. It formed 1.8% of the trawl net catches with a catch rate of 0.43 kg/h. Trawl catch was composed chiefly of lesser sardines, rainbow sardine and oil sardine. In silk nets (33 mm mesh size), the catch was 408.5 t with a catch rate of 126 kg/unit forming 66% of the total catch. The silk net catch was dominated by *Sardinella longiceps* (45.85%), *Sardinella fimbriata* (42.06%) and *Sardinella gibbosa* (12.09%). The length of oil sardine, *Sardinella longiceps* at Visakhapatnam ranged from 80 mm to 219 mm with an annual mean of 166.85 mm. The highest mean length of 206.13 mm was recorded in the month of May and the lowest mean length of 106.26 mm was recorded in January. The annual sex ratio was 1.55. Males dominated the catch in February and March while females dominated the catch in rest of the months. May - August is the peak breeding season of oil sardine. This is substantiated by the presence of high proportion of spawners (66.11%) and by high gonadosomatic index (6.55) in these

months. Their fecundity ranged from 12253 to 91992 with ova diameter varying from 0.24 mm to 0.68 mm. Food component analysis in gut revealed an abundance of planktonic matter.

Mackerel

The estimated mackerel landings by trawlers and gill netters (55 mm mesh size) in Visakhapatnam were 6992.8 t and 824.8 t, respectively with an average catch rate of 2.45 kg/h for trawls and 44 kg/unit for gill nets. More than half (58%) of the gillnet catches at Visakhapatnam were contributed by mackerel. However in trawlnet catches the contribution of mackerel was 10.15%. 80% of the gill net catches and 70% of the trawl catches were composed of *Rastrelliger kanagurta* and the rest being constituted by *Rastrelliger faughnii*. The length of Indian mackerel, *Rastrelliger kanagurta* at Visakhapatnam ranged from 110 mm to 249 mm with an annual mean of 186.97 mm. Maximum mean length of 221.28 mm was recorded in March and minimum mean length of 143.19 mm was recorded in October. Annual sex ratio was 1.54. Males dominated the catch in January - March and July while females dominated the catch in rest of the months. June appears to be the peak breeding month with two third of the females in mature condition and high gonadosomatic index value of 4.6. Their fecundity ranged from 37714 to 298953 with ova diameter varying from 0.16 mm to 0.64 mm. The analysis of food components revealed an abundance of copepods, decapods, ostracods, *Coscinodiscus*, Foraminifera along with minute quantities of cladocerans, fish eggs and larvae, zoea, tintinnids and nematods.

Ribbonfish

The estimated ribbonfish landing by trawlers at Visakhapatnam was 4672.6 t (6.77 % of the trawl net catches) with the catch rate of 1.69 kg/h. The catches along with catch rates were significantly higher during August - September. *Trichiurus lepturus* was the sole species with size ranging from 360 to 1099 mm and having mean length of 590.71 mm. There was a preponderance of females in the catch with mature females encountered only in August, November and December. Fecundity varied from 22533 to 186667 with ova diameter ranging from 0.35 mm to 0.85 mm. The high IRI values of nonpenaeids, cephalopods, penaeids, clupeids, juveniles of sciaenids, ribbon fishes, scombrids and carangids and other teleosts and digested fish imply that they were the principal food constituents of *Trichiurus lepturus*.

Seerfish

The seerfish landing by trawlers at Visakhapatnam was 414.85 t with catch rate of 0.15 kg/h. *Scomberomorus guttatus* dominated the gillnet landings while the trawl fishery was supported by

both *Scomberomorus guttatus* and *Scomberomorus commerson*. The catch in gill nets was 119 t at a catch rate of 8.38 kg/unit forming 6.3% of the gill net landings. The length of *Scomberomorus guttatus* at Visakhapatnam ranged from 280 mm to 479 mm with an annual mean of 369.09 mm. Significant dominance of females in catch was recorded in all the months. Mackerel, sardine, anchovies and squid were the principal food components encountered in their gut.

Tuna

The annual catch of tuna recorded by hooks and lines at Visakhapatnam was 611.1 t with the catch rate of 18.4 kg/unit. 30.94% of the hooks and lines catches at Visakhapatnam was contributed by tunas alone. The dominant species landed in hooks and lines were *Thunnus albacares* (53.4%), *Euthynnus affinis* (24.56%) and *Katsuwonus pelamis* (22.03%). The length of skipjack tuna, *Katsuwonus pelamis* at Visakhapatnam ranged from 380 mm to 679 mm with an annual mean of 519.5 mm. The highest mean length of 600.16 mm was recorded in the month of October and the lowest mean length of 489.2 mm was recorded in March. Annual sex ratio was 1.35 with significant dominance by males in September and by females in February – March and November - December. More than 80% of the females were mature in March indicating it to be the peak breeding season. Average gonadosomatic index was 1.47. Their fecundity ranged from 205947 to 1758204 with ova diameter varying from 0.18 mm to 0.7 mm. The high IRI values of cephalopod, penaeid prawn, carangids, sardines and anchovies along with digested food imply them to be the principal food constituents. The length of yellow fin tuna, *Thunnus albacares* at Visakhapatnam ranged from 120 mm to 1719 mm with an annual mean of 783.05 mm. Maximum mean length of 1182.4 mm was recorded in April and minimum mean length of 434.62 mm was recorded in December. Annual sex ratio was 2.82. Males dominated the catch in January and October while females dominated the catch in January, September and December. High percentage (83.33%) of mature females was observed in October. Their fecundity ranged from 2306062 to 3815101 with ova diameter varying from 0.2 mm to 0.56 mm. Cephalopods are their preferred prey, followed by mackerel, crab, squilla, coastal tunas, carangids and other scombrids.

Growth parameters of pelagic resources landed at Visakhapatnam

	Linf (cm)	Winf (g)	k	Z	M	F	E	Lc (cm)	Lr (cm)
Sardinella longiceps	22.52	85.3	1.19	8.39	2.95	5.45	0.65	9.86	8.45

Rastrelliger kanagurta	25.67	189.9	0.55	2.49	1.26	1.23	0.49	20.74	10.45
Katsuwonus pelamis	89.2	13834.9	0.59	2.63	0.93	1.7	0.65	43.43	38.95
Thunnus albacares	179.5	95428.3	0.06	0.4	0.17	0.23	0.57	157.6	12.95
Trichiurus lepturus	114.4	1243.4	0.12	0.87	0.31	0.56	0.65	56.15	36.95

Stock Assessment of pelagic resources landed at Visakhapatnam

	Recruitment (in millions)	Standing Stock / Biomass (t)	Biomass per recruit (g)	Annual average yield (t)	Yield per recruit (g)
Sardinella longiceps	1135	1678	1.48	9146	8.06
Rastrelliger kanagurta	6003.4	20786	3.46	25567	4.26
Katsuwonus pelamis	2	1904	940.72	3237	1599.23
Thunnus albacares	46	25157	546.79	5786	125.76
Trichiurus lepturus	297.7	35434	119.04	19843	66.66

Index of Relative Importance (%) of food items encountered in the gut of *Thunnus albacares*						
	January	July	August	September	October	December
Digested fish	54.8	0.0	86.9	94.0	0.0	65.4
Squid	4.9	0.0	1.6	0.0	0.2	4.1
Sthenoteuthis	13.2	0.0	0.0	0.0	0.0	0.0
Crabs	1.0	2.5	0.0	0.0	99.8	0.0
Shrimp	0.0	0.0	10.2	0.0	0.0	0.0
Squilla	0.0	97.5	0.0	0.0	0.0	4.8
Mackerel	1.3	0.0	0.0	4.0	0.0	0.0

Auxis	0.0	0.0	1.3	0.0	0.0	0.0
Euthynnus	0.0	0.0	0.0	0.0	0.0	0.0
Carangid	0.0	0.0	0.0	2.0	0.0	0.0
Priacanthus	0.0	0.0	0.0	0.0	0.0	6.8
Decapterus	14.6	0.0	0.0	0.0	0.0	0.0
Selar	3.4	0.0	0.0	0.0	0.0	0.0
Nemipterus	0.3	0.0	0.0	0.0	0.0	0.0
Fish Juvenile	0.8	0.0	0.0	0.0	0.0	0.0
Megalopa	5.4	0.0	0.0	0.0	0.0	18.9
Sea Horse	0.2	0.0	0.0	0.0	0.0	0.0

The total marine fish production of A.P. for 2013 was 2.66 lakh t. Pelagic resources accounted for 1.47 lakh t forming 55.4% of the total landings for the state. The dominant groups landed were clupeids (0.46 lakh t and 31.1%), mackerels (0.34 lakh t and 22.9%), carangids (0.21 lakh t and 14.0%), ribbon fishes (0.19 lakh t and 12.8%), tunas and billfishes (0.16 lakh t and 11.0%) and seer fishes (0.05 lakh t and 3.4%).

Among clupeids, the major contributors were lesser sardines contributing 0.11 lakh t, oil sardine contributing 0.07 lakh t and *Stolephorus* contributing 0.07 lakh t. Carangids landed were contributed by horse mackerel (31.6%), scads (30.1%), leatherjackets (4.4%) and other carangids (33.9%). *Rastrelliger kanagurta* formed almost the entire of the mackerel landings, the rest being formed by *Rastrelliger faughni*. Seer fish catch was dominated by *Scomberomorus commerson* (72.8%) and *Scomberomorus guttatus* (27.2%). Among tuna, the dominant species landed were *Thunnus albacares* (48.0%), followed by *Euthynnus affinis* (26.9%), *Katsuwonus pelamis* (19.1%) and *Auxis thazard* (6.0%). The landings of billfishes and barracudas for the year were 0.03 lakh t and 0.04 lakh t, respectively.

Half of the ribbonfish, horse mackerel and other carangids catches were by trawlers, whereas for scads, *Stolephorus* and barracudas, three-fourth of the catches were by trawlers. One-fourth of the lesser sardine and mackerel landings were contributed by trawl nets. The catch rate of mackerel in trawlers was 1.05 kg/h. The catch rate of lesser sardines and *Stolephorus* in trawlers were 0.23 kg/h and 0.93 kg/h. The catch rate of ribbon fishes in trawlers was 2.14 kg/h. The catch rate of horse

mackerel, scads and other carangids in trawl nets were 0.51 kg/h, 0.85 kg/h and 0.55 kg/h. The catch rate of barracudas in trawlers was 0.53 kg/h.

More than half of the tuna catches and half of the *Scomberomorus commerson* catches were in gill nets. Catch rates in gill nets of *Rastrelliger kanagurta*, *Thunnus albacares*, *Scomberomorus commerson*, *Katsuwonus pelamis* and *Euthynnus affinis* were 10.89 kg/unit, 9.67 kg/unit, 5.60 kg/unit, 4.69 kg/unit and 2.75 kg/unit. The catch rate of oil sardine, lesser sardine and ribbonfish in gill nets was 1.51 kg/unit, 3.47 kg/unit and 5.63 kg/unit.

More than half of the billfish and one third of the yellowfin tuna catches were by hooks and lines. Their catch rates were 15.36 kg/unit and 19.97 kg/unit.

Visakhapatnam:

Sardine and mackerel landed in silk (gill) nets amounted to 242 t and 875 t at catch rates of 126.24 kg/unit and 65.7 kg/unit. The landing of sardine and seerfish in small trawlers and sona boats was meager to the tune of 100 t and 170 t. Mackerel landing in small trawlers and sona boats were 2330 t and 1982 t at catch rates of 1.61 kg/h and 1.33 kg/h. Landing of ribbonfish in small trawlers and sona boats were 1565 t and 1172 t at catch rates of 1.08 kg/h and 0.79 kg/h. In small trawlers, 3252 t of carangids and 1116 t of barracuda was landed at catch rates of 2.25 kg/h and 0.77 kg/h. whereas in sona boats, 2916 t of carangids and 839 t of barracuda was landed at catch rates of 1.96 kg/h and 0.56 kg/h. Tuna landing from the non-motorized and motorized boats was 1256 t and 1241 t at catch rate of 976 kg/unit and 306 kg/unit, of which yellowfin tuna formed 64.1% and 43.4 %.

Kakinada:

Tuna catches at Dummulapeta and Bhairavapalem was 1684 t and 839 t at catch rates of 528.7 kg/unit and 920.6 kg/unit. Yellowfin tuna contributed 42.3% of the tuna catches at Dummulapeta and 38.6 % of the tuna catches at Bhairavapalem.

Sardine

The length of oil sardine, *Sardinella longiceps* at Visakhapatnam ranged from 60 mm to 219 mm with an annual mean of 126.24 mm. The highest mean length of 199.20 mm was recorded in the month of January and the lowest mean length of 85.01 mm was recorded in October. The annual sex ratio was 1.04. Males dominated the catch in December while females dominated the catch in May and July. Juvenile fishes were only caught during August – November. May - July is the peak breeding season of oil sardine. This is substantiated by the presence of high proportion of spawners and by high gonadosomatic index (5.92) in these months. Their average fecundity was 31200 with

ova diameter varying from 0.38 mm to 0.54 mm. Food component analysis in gut revealed an abundance of planktonic matter. Empty or trace amounts of food in stomach was encountered in most fishes. Feeding intensity was highest in January. The length of *Sardinella fimbriata* ranged from 55 mm to 199 mm with all juveniles recorded during September – December. There was a preponderance of males in the catch in all months with annual sex ratio of 0.5.

Mackerel

The length of Indian mackerel, *Rastrelliger kanagurta* at Visakhapatnam ranged from 110 mm to 269 mm with an annual mean of 189.86 mm. Maximum mean length of 227.69 mm was recorded in January and minimum mean length of 136.16 mm was recorded in June. Annual sex ratio was 2.38. Males dominated the catch in January - February and August-September while females dominated the catch in rest of the months. August appears to be the peak breeding month with all the females in mature condition and high gonadosomatic index value of 6.85. Their fecundity ranged from 81346 to 270500 with ova diameter varying from 0.28 mm to 1.02 mm. The analysis of food components revealed an abundance of copepods, decapods, ostracods, *Coscinodiscus*, Foraminifera along with minute quantities of cladocerans, fish eggs and larvae, zoea, tintinnids and nematods. Feeding intensity revealed most of the individuals to have stomachs quarter – half filled. For, *Rastrelliger faughni*, the length varied from 190 mm to 279 mm. Females dominated the catches in most months with sex ratio of 1.75. April appears to be their peak spawning month with high proportion of gravid females.

Ribbonfish

Trichiurus lepturus was the sole species with size ranging from 380 to 1059 mm and having mean length of 582.28 mm. There was a preponderance of females in the catch in all months except December. Mature females were encountered in high numbers in January and again in July – August. Highest GSI % of 5.46 was observed in August. Fecundity varied from 24636 to 260834 with ova diameter ranging from 0.31 mm to 0.74 mm. The high IRI values of nonpenaeids, cephalopods, penaeids, clupeids, juveniles of ribbon fishes, scombrids and carangids and other teleosts and digested fish imply that they were the principal food constituents of *Trichiurus lepturus*. More than half of the fishes had their stomachs either empty or had trace amounts of food material in it. Feeding intensity was highest in December.

Tuna

The length of skipjack tuna, *Katsuwonus pelamis* at Visakhapatnam ranged from 360 mm to 679

mm with an annual mean of 511.7 mm. The highest mean length of 578.4 mm was recorded in the month of October and the lowest mean length of 475.8 mm was recorded in August. Annual sex ratio was 1 with male domination in December and female domination in August, September and November. Mature females were encountered in September and December. Average gonadosomatic index was 1.15. Feeding intensity was highest in September and lowest in December. The high IRI values of cephalopod, penaeid prawn, carangid, mackerel, little tuna, sardine and anchovy along with digested food imply them to be the principal food constituents. The length of yellow fin tuna, *Thunnus albacares* at Visakhapatnam ranged from 320 mm to 1659 mm with an annual mean of 681.54 mm. Maximum mean length of 1056.1 mm was recorded in November and minimum mean length of 471.12 mm was recorded in July. Cephalopods are their preferred prey, followed by mackerel, crab, squilla, coastal tunas, carangids and other scombrids. For, *Euthynnus affinis*, the length ranged from 360 mm to 579 mm with an annual of 443.57 mm.

Seer fish

The length of *Scomberomorus guttatus* at Visakhapatnam ranged from 200 mm to 379 mm with an annual mean of 304.22 mm. Significant dominance of females in catch was recorded in all the months. Feeding intensity was high in November – December and low during October. Mackerel, sardine, anchovies, nonpenaeid prawns and squid were the principal food components encountered in their gut. For, *Scomberomorus commerson*, the length varied between 560 mm to 1459 mm with annual mean of 862.56 mm. Highest mean length of 966.22 mm was recorded in December and lowest mean length of 823.75 mm in September.

Barracuda

The length of *Sphyraena jello* at Visakhapatnam ranged from 180 mm to 599 mm with an annual mean of 335.31 mm. Annual sex ratio was 0.84. Females dominated the catches in July while males dominated in rest of the months. Average GSI % was 2.55 with mature females mostly encountered during June – July. Average fecundity was 270606 with ova diameter ranging from 0.20 – 0.50 mm. Feeding intensity was higher during January and August – September. The high IRI values of squid, mackerel, carangid and clupeid along with digested food imply them to be the principal food constituents. The mean length of *Sphyraena obtusata* was 238.79 mm with length ranging from 210 mm to 299 mm. There was significant domination by females in the catch. Most females encountered in catch were in mature state with average gonadosomatic index value of 4.22. Feeding intensity was very low in most months. Carangids were their preferred prey items.

Dolphin fish

The length of *Coryphaena hippurus* ranged from 460 to 1279 mm with mean of 724.96 mm. Highest mean length of 790 mm was recorded in August and lowest mean length of 701.5 mm was recorded in December. Carangids, frigate tuna and sucker fishes were the principal food items encountered in their gut.

Cobia

The mean length recorded for *Rachycentron canadum* was 565.67 mm with length varying from 330 mm to 1139 mm. The highest mean length of 594.64 mm was recorded in November and the lowest mean length of 521.4 mm was recorded in September.

Group	Catch (t) in 2013	Catch (t) in 2012	Increase (+) / Decrease (-) %
Clupeids	45839	68108	-32.7
Mackerel	33718	25377	32.9
Ribbon fish	18800	19193	-2.0
Carangids	20691	19732	4.9
Tunas	13243	17945	-26.2
Seer fishes	4961	5824	-14.8
Barracudas	3752	3954	5.1
Bill fishes	2999	3590	-16.5

Contribution of demersal resources to total landings of Andhra Pradesh remained the same at 28.5% and 28.4% during 2012 and 2013 respectively. The major groups that contributed to demersal landings were perches, pomfrets, sciaenids, elasmobranchs, silverbellies, goatfish and catfish. Relative abundance of threadfin breams and sciaenids in trawls decreased by 10% and 23% respectively from 2012 to 2013. The main threadfin bream species landed were *Nemipterus japonicus, N. randalli, N. bipunctatus, N. peronii* and *N. nematophorus*. The major species of sciaenids were *Otolithes ruber, Nibea maculata, Johnius carutta* and *Pennahia anea*.

The relative abundance of flatfish in trawls remained the same at 0.3 kg/hr for the state during 2012 and 2013. The major groups that contributed to flatfish landings were soles, halibut and flounders. The relative abundance of catfish in trawls increased by 33% from 2012 to 2013. The main species

landed were *Netuma thalassina* and *Plicofollis tenuispinis.* Studies were made on the variation of seawater temperature, salinity, dissolved oxygen, hydrogen-ion concentration and nutrients in the surface-waters of the Visakhapatnam coast. Seawater temperature shows a double oscillation in a year showing a major peak during summer month at May and a minor peak in September. There was a fall in water temperature in July and second one in December. The salinity of coastal waters showed marked seasonal fluctuations, registering low values during the north-east monsoon period and increasing gradually from Nov - Dec onwards to record the maximum values during the summer months. The coastal waters are influenced by the southerly and northerly currents alternately. During the north-east monsoon period, there is an influx of freshwater from local rivers and land runoffs which bring marked lowering in salinity of the coastal waters. The nutrient salts also showed seasonal variations. During the north-east monsoon period the concentration of the nutrients went up due to the discharge of fresh and polluted waters from the rivers and land runoffs. After the cessation of the north-east monsoon their concentration decreased. The dissolved oxygen content of the coastal waters also showed some variation. The value was high during the winter months, (when salinity is low) and north east monsoon period and was low during May to June. The hydrogen-ion concentration showed similar trends of temperature.

The estimated penaeid prawn catch was 29570 t and it contributed 10.4% to total marine fish landings in 2012. Mechanized trawlers contributed high (81.7%) with 4.9 kg cph, followed by driftnets and others operated by in built motorised boats (10.3%) with 27.8 kg cpue, non motorized gill nets (2.6%) with 19.41kg cpue, and motorized gill nets (2.4%) with 22.82 kg cpue. The estimated crab catch was 5946 t. Mechanized trawlers contributed maximum (73.9%) with 0.896 kg cph, followed by motorized gill nets (10.0%) with 0.7 kg cpue, drift nets and others operated by in built motorised boats (8.3%) with 4.56 kg cpue and non motorised gill nets (5.7%) with 0.65 kg cpue

Penaeid shrimp catch has increased by 12.4% (3202 t). The catch by trawlers has increased by 7.47% due to increase in effort by 1.1% as well as increase in cph by 6.29%. The catch of driftnets and others operated by in built motorised boats has increased by 580% due to increase in effort by 220% as well as increase in cpue by 112%. The catch of non-motorized gill nets has increased by 75.7% due to increase in in cpue by 36.87%. Despite increase in effort by 117% the catch of motorized gill nets has decreased by 66.38% due to decrease cpue by 84.5%.

Crab catch has increased by 4.26% (243t). Despite increase in effort by 1.1%, the catch of mechanized trawlers has decreased by 50% due to decrease in cph by 50.55 %.The catch of motorized

gill nets has increased by 116.85% due to increase in effort by 117%. Catch of non motorized gill nets has increased by 60.09% due to increase in effort by 36.62%.

The catch of small mechanized trawlers was represented by 25 species of penaeid prawns, dominated by *M. monoceros* (29.52 %), followed by S. *crassicornis* (15.41 %), *T. curvirostris* (8.99%), *M. dobsoni* (6.93 %), *P. stylifera* (5.47%) and *P.semisulcatus* (3.23%). The catch landed by sona boats was constituted of 15 genera/ species of penaeid prawns, dominated by *M. monoceros* (38.44%), followed by *Solenocera spp* (13.91 %), *Metapenaeiopsis spp* (10.89%), *M. dobsoni* (10.18%) and *Parapenaeopsis spp.* The crab catch by trawlers was constituted with commercial crabs (49.38%) and other crabs (50.62%). The catch of commercial crabs was supported by *P. sanguinolentus* (83.61%), *P. pelagicus* (10.35%) and *Charybdis sp* (6.02%).

The estimated penaeid prawn catch was 28744 t and it contributed 10.8% with 3 kg cph to total marine fish landings in 2013. Mechanized trawlers contributed high 83.4% (23966 t) with 4.6 (4.9) kg cph, followed by other units operated by outboard motorised boats 13.84% (3932t) with 3.53 kg cph, non motorized gill nets 1.2 % with 0.3 kg (430 t) cph and motorized gill nets 1.13 % (324 t) with 0.23 kg cph, others operated by in built motorised boats 0.2 % with 0.1 kg cph. The estimated crab catch was 4999 t and it contributed 2 % with 0.5 kg cph. Mechanized trawlers contributed 76% with 0.73kg cph, followed by other units operated by outboard motorised boats 14.3% with 0.63 kg cph, motorized gill nets 5.3% (266 t) with 0.2 kg cph and non motorised gill nets 4.5% with 0.14 kg cph.

The catch of small mechanized trawlers was represented by 20 species of penaeid prawns, dominated by *M. monoceros* (27.6%), followed by *M. barbata* (12%), *S. crassicornis* (11%), *Solenocera melantho* (9.4%), *M. dobsoni* (5.4%), *T. curvirostris* (4.8%) *P. indicus* (4.7%) and *P. uncta* (4.1%). The catch landed by sona boats was constituted of 12 species of penaeid prawns, dominated by *M. monoceros* (29%), followed by *S. crassicornis* (25%), *Metapenaeopsis stridulans* (20.3%), *Parapenaeopsis stylifera* (10%), *P. indicus* (4%), *P. monodon* (3%) and *M. dobsoni* (3%). The crab catch by trawlers was constituted with commercial crabs 3321 t (66%) and other crabs 1678 t (34%). The catch of commercial crabs was supported by *P. sanguinolentus* (70.5%), *P. pelagicus* (19.3%) and *Charybdis sp* (10%).

The total landing of cephalopods in Andhra Pradesh was estimated at 4222 t, forming 1.4% of the total fish landings in 2012. Cuttlefish landings were estimated at 2670 t (63.2 %), and squid 1552 t (36.8 %). The mechanized trawlers (MDSOTN + MDTN + MSOTN +MTN) contributed almost entirely (99.1 %) to the cephalopod landings. The estimated landing of cephalopods at the

Visakhapatnam was 2098.5 t. Cuttlefish landings was estimated at 1646.8 t and squid at 1051.4 t. During the period *Sepia pharaonis, S aculeata* and *Sepiella inermis* (cuttlefish), *Loligo duvauceli*, (squids), were observed in the fishery. Octopus was not landed at all. *S pharaonis (450.22 t) 21.5 %*. *Sepia aculeata* landed (476.9 t) 22.73 % and *Sepiella inermis* (73.5 t) 3.5 %. Among squids *Loligo duvauceli* was the only species landed. Maximum landings of cephalopods occurred during July-August. The total catch of cephalopods in Andhra Pradesh increased by 1414 t (33.5 %) over the previous year 2011 (2808 t). The cuttlefish landings increased by 934 t (35 %) as against the previous year (1734 t). The squid landings increased by 478 t as against 1074 t in 2011 by 30.8 %. Juveniles of *Sepia pharaonis* occurred throughout the year. 19.6 % of the total landings were juveniles. Maximum percentage of juveniles occurred during April (45.9 %) and March (32.6 %). Juveniles of *S aculeata* occurred throughout the year. 49.7 % of the total landings were juveniles. Maximum percentage of juveniles occurred during March (75.9 %), February (75 %), April (71.1 %). Juveniles of *Loligo duvauceli* occurred throughout the year. 49.9 % of the total landings were juveniles. Maximum percentage of juveniles occurred during February (64.7%), October (58.7%), December (57.9 %), and July (57.7 %). Juveniles of *Sepia pharaonis* occurred throughout the year. 19.6 % of the total landings were juveniles. Maximum percentage of juveniles occurred during April (45.9 %) and March (32.6 %). Juveniles of *S aculeata* occurred throughout the year. 49.7 % of the total landings were juveniles. Maximum percentage of juveniles occurred during March (75.9 %), February (75 %), April (71.1 %). Juveniles of *Loligo duvauceli* occurred throughout the year. 49.9 % of the total landings were juveniles. Maximum percentage of juveniles occurred during February (64.7%), October (58.7%), December (57.9 %), and July (57.7 %).

The total landing of cephalopods in Andhra Pradesh in 2013 was estimated at 3325 t, forming 1.25% of the total fish landings. Cuttlefish landings were estimated at 1970 t (59%), and squid 1355 t (41%).The estimated landing of cephalopods at the Visakhapatnam was 1407 t. Cuttlefish landings was estimated at 627 t and squid at 779 t. Maximum landings of cephalopods occurred during July. The total catch of cephalopods in Andhra Pradesh decreased by 897 t (21%) over the previous year 2012 (4222 t). The cuttlefish landings decreased by 1020t (62%) as against the previous year 2012 (1647 t). The squid landings decreased by 272 t as against 1051t in 2012 by 26 %.The mechanized trawlers contributed 100 % to the cephalopod landings. During the period *Sepia pharaonis, S aculeata* and *Sepiella inermis* (cuttlefish), *Loligo duvauceli*, (squids), and other species were observed in the fishery. Octopus was not landed at all. The *S. pharaonis* landed (280 t) 45 %, *S.*

aculeata (286t) 45.6 % and *Sepiella inermis* (33t) 5 %. Among squids, *L. duvauceli* was the only species landed. Juveniles of *S. pharaonis, S aculeata, L. duvauceli* was observed throughout the year. Juveniles of S. *pharaonis* were 6.3 % of the total landings. Juveniles of *S. aculeata* were 41 % of the total landings. Juveniles of *L. duvauceli* were 21 % of the total landings.

Pollution and litter in the coastal and marine ecosystem and their impact

Among the three sites monitored, water quality was found to be affected in the sewage outfall area where carbon dioxide level was high and dissolved oxygen low. Though the environmental parameters showed seasonal variations, the water quality at sewage outfall site (Lawson's bay) was in hypoxic condition.

One significant observation was the low level of dissolved oxygen and moderately high Biological Oxygen Demand (BOD) in both fishing harbour and Lawsons bay locations. The impact of urbanization on the near shore regions is evident in the water quality as indicated by the low oxygen levels. However, high levels of nutrients were also observed in fishing harbour as well as Lawson's bay samples compared to Mangamaripeta samples.

Monthly samples of Non biodegradeable wastes dumped along the beaches revealed that the quantity of NBW were highest in Rushikonda (192.30 g/m^2) closely followed by Bhimili (174.74 g/m^2) and comparatively lower in RK Beach (139.54 g/m^2). Bhimili had more Glass wastes (91.67 g/m^2) whereas Rushikonda had more of Plastics (127.90 g/m^2) and RK Beach had more of Glass as well as Plastics (48.71 g/m^2, 44.97 g/m^2) respectively.

A survey on status of marine litter and beach sanitation along north Andhra coast revealed higher litter accumulation recorded in Visakhapatnam beaches. Probably, the intense use of beaches for recreation, tourism, and religious activities has increased the potential for litter contamination in the urban beaches of Visakhapatnam. Visakhapatnam is followed by East Godavari and Srikakulam in the total amount of litter accumulation. Vizianagaram district recorded comparatively the lowest among all the districts.

Ecosystem process of critical marine habitats and development of protocols for restoration

Three sites viz., fishing harbour (Surface and Bottom), Lawsons Bay and Mangamaripeta were monitored for environmental degradation. They were graded as per USEPA, 2004 as Good, Fair and

Poor. These grades are clearly depicting that fishing harbor surface and bottom waters are Fair and Lawson's bay samples are poor when compared with the reference site Mangamaripeta which is having a good grade among the different sites studied. Cluster analysis or Bray-Curtis similarity and dendogram of water quality parameters of different stations revealed that there is distinct grouping of stations that apparently reflected differences in the physiochemical parameters of the water samples. There is high similarity between the fishing harbor samples and Mangamaripeta samples. Lawson's bay is distinct from these two stations, confirming the high levels of pollution due to domestic wastes. However fishing harbor samples may contain some polluted materials but some in-depth study involving different parameters may reveal in detail.

Many species of coastal birds were identified and photographed from the surveys conducted in these coastal regions of Visakhapatnam. Terns, Black Terns flock consisting of more than 100 birds were observed at Munagapakkam. The fishes in the catch corresponding to the tern sighting mainly comprised of oil sardine. Brown headed gull (Larus brunnicephalus) flock consisiting of more than 200 birds visited bhimili during October – December and they were also observed coinciding with high catches of oil sardine.

GIS based resource mapping of distribution and abundance of fin fishes and shellfishes off Indian coast for suggesting operational based strategies for fisheries management

Mapping of yellowfin tuna fishing grounds accessed by Pudimadaka fishermen was carried out.

Multiday fishing from Visakhapatnam was mainly conducted north of Visakhapatnam up to Chilika Lake in Odisha at a distance of 317 km from Visakhapatnam. Total catch ranged from 20 kg to 450 kg/haul of the trawler with the trash component ranging from 10% to 70% Catch rate ranged from a low of 10.6 kg/hr to a high of 126.32 kg/hr. The main species landed were ribbonfish, goatfish, squid, threadfin bream, lizardfish and penaeid prawns.

The catch rate in single day trawling trips ranged from a low of 1.6 kg/hr to a high of 21.8 kg/hr. Percentage of discards ranged from 25% to 66.7%. The farthest trip was 12 km away from Visakhapatnam and shortest was at a distance of 4 km from Visakhapatnam

Trawl samples were collected from trawlers operating from Paradeep in Orissa and Digha in West Bengal and the data was analyzed with respect to diversity indices, dominance plot, Bray–Curtis

similarity and abundance and biomass comparison plot. In line with the higher number of species, Shannon diversity {H'(log 2)} was more in Paradeep (4.82) as compared to Digha (2.82) reflecting the diverse nature of this centre. The Simpson species richness index for Paradeep (0.95) was also found to be more than that of Digha (0.74). The species dominance plot indicates that Paradeep samples are more diverse than Digha with respect to number of species. In the dominance plot, the curve for Paradeep, which lies on the lower side, extends further and rises slowly due to presence of more number of species. This plot indicates the rich diversity of trawl catches in Paradeep as compared to Digha. The similarity in species composition and abundance between Digha and Paradeep using Bray–Curtis similarity was 16.67%. The abundance/biomass comparison (ABC) plot for Paradeep showed the K dominance curve for biomass to be above the curve for abundance. W statistics value was highest in Paradeep (0.063). These indicate higher degree of evenness and lower degree of disturbance at Paradeep. The ABC plot for Digha showed the K dominance curve for abundance to be above the curve for biomass. W statistics value for Digha was -0.193. These indicate lower degree of evenness with higher disturbance level at Digha.

Inventorization of fish landing centres of Andhra Pradesh (115 in six coastal districts), Odisha (67 in six coastal districts) and West Bengal (55 in two coastal districts) was completed with information collected on spatial coordinates, fishing operations, fishing seasons and fishing gears.

Diversity indices of trawl catches in trawl landing centers of Visakhapatnam, Digha and Paradeep

Stations	Species (S)	Total no. of Individuals (N)	Species richness (d)	Pielou's evenness (J')	Shannon H'(loge)	Simpsons 1-Lambda'
Digha	54	8219	5.87	0.72	2.87	0.91
Paradeep	78	5274	8.98	0.46	2.02	0.73
Visakhapatnam	115	7145	12.84	0.62	2.98	0.88

Bray–Curtis similarity for trawl catches in trawl landing centers of Visakhapatnam, Digha and Paradeep

	Visakhapatnam	Paradeep	Digha
Visakhapatnam	0	0	0
Paradeep	41.11	0	0
Digha	25.30	30.07	0

Bio inventorying and biodiversity valuation of marine organisms in selected marine ecosystems along the Indian coast

A systematic list of 453 species of marine fauna distributed along Visakhapatnam coast was prepared.

A systematic list of 155 species of elasmobranch distributed along Indian coast was prepared.

One fin fish species was identified and reported as first record along east coast of India and eight fin fish species were identified as first record along Visakhapatnam coast.

Consolidated list of 555 species of marine fauna were prepared for the valuation purpose which are distributed along Visakhapatnam coast.

A total of twenty two species which are new to Visakhapatnam and east coast of India were identified and lists of species were prepared.

Four fin fish species (*Roa jayakari, Acanthurus bariene, Stegastes fasciolatus* and *Tripterodon orbis)* were deposited in national biodiversity repository of CMFRI and accession no. were obtained.

Investigations on vulnerable coral reef ecosystems of Indian waters with special emphasis on formulation of management measures for conservation

A survey was undertaken along Puri, Paradeep and Gahirmatha for coral associated fauna of Odisha coast. The abundances of jelly fishes were located along Gahirmatha of Odisha coast. No other coral associated fauna were located in this area.

Two different soft coral *(Pteroeides sp.* & *Stylatula sp.*) were collected from trawl discards from Visakhapatnam fishing harbour.

Spiny sea urchin and zooanthid were located at Lawson's bay of Visakhapatnam coast.

Marine ornamental fish samples were collected from fish landing at Visakhapatnam fishing harbor. The fish samples were identified based on standard references. Altogether ninety one species belonging 33 families and five orders were identified. Order perciformes contributes more in terms number of species (85%).

A survey on coral and coral associated fauna were undertaken by Line intercept transect (LIT) method at Amini and Kadamat Island of Lakshadweep from 30.01.14 to 11.02.14. During survey different species of hard corals, soft coral, sponges, Echinoderms, mollusks, coelenterates, seaweed,

seagrass and marine ornamental fishes were located at specific latitude and longitude from two Islands.

During survey some specimen of soft corals were taken from intertidal areas from Amini Island. The collected specimen were preserved in 10% alcohol and brought to the laboratory for further examination. Some sections of specimens were taken and kept in test tube and sodium hypochlorite solutions were added to it for digestion of organic matters and separations of spicules. The silicious spicules were taken for microscopic observations. Different shapes of spicules were observed under microscopes and photographs were taken for species identifications.

The galloping sea star, *Stellaster equestris* (Retzius, 1805) was collected from trawl discards from Visakhapatnam fishing harbour. The abundances of jelly fishes were located along Kakinada and Visakhapatnam coast of Andhra Pradesh.

Assessment of fishing impacts on biodiversity loss, with special reference to the threatened species, to formulate management options for their protection

Technical characteristics details of destructive fishing gears mostly trawl were collected and documented. Bycatch sample from commercial trawler were taken and analysis were carried out to find the species compositions. Informations regarding the number and quantity of protected species mostly turtle were collected for evaluation of threatened species.

Altogether 11 different groups were found, of which finfishes are most dominant in terms of biomass (84%) whereas shrimps in terms of abundances (75%).

Quantification of juveniles of commercially important species was done to estimate the economic loss due to juvenile fishing by commercial trawler.

Analyses of discard samples were carried out and 130 species were identified from discard samples. Ninety five species of finfishes, 4 species of gastropods, 1 species of bivalves, 6 species of cephalopods, 13 species of shrimps, 2 species of stomatopods, 8 species of crabs, 1 species of lobsters and juveniles of unidentified sharks and rays.

Informations regarding the number and quantity of protected species mostly turtle were collected for evaluation of threatened species Landings of protected species such as juvenile of tiger shark, bowmouth guiter fish and turtles (Olive Ridley and green turtle) were observed along Visakhapatnam coast

Genetics, genomics and biotechnological applications in mariculture and fishery resources management

In this project, DNA bar-coding of grouper was done to resolve the ambiguity in the morphological based species identification of the fish selected for breeding. For the comparative analysis, a total of five different individuals were collected, and the details of five individuals are follows: 1. Brood stock maintained in the cage; 2.Juvenile fish produced in the hatchery and 3. Three different sizes (Small, medium and large size fish) of fishes collected from the landing centres. Tissue samples of five individuals were collected and DNA Bar-coding was carried out with cox-1 gene. After DNA bar-coding, the sequence information was used in BOLD search, and after the analysis the fish specimens were identified as *Epinephelus coides*.

Development of strategies to sustain the stock and fishery of large pelagics in Indian waters

The annual catch of tuna recorded by hooks and lines at Visakhapatnam during 2012 was 2714 t with the catch rate of 42.3 kg/unit. 43.4% of the hooks and lines catches at Visakhapatnam was contributed by tunas alone. The dominant species landed in hooks and lines were *Thunnus albacares* (53%), *Katsuwonus pelamis* (31%) and *Euthynnus affinis* (16%). In gill netters at Visakhapatnam, the annual catch was 675 t, at a catch rate of 35 kg/unit forming a quarter of the total gill net catches. One third of the gill net catches was constituted by *Thunnus albacares*.

The annual catch of tuna by hooks and lines at Pudimadaka was 397 t with a catch rate of 14.2 kg/unit forming 46% of the total hook and line catches. The dominant tuna species was *Thunnus albacares* contributing 59% to the total tuna catch.

The annual hook and line catches of tuna at Kakinada (Dummulapeta and Bhairavapalem) amounted to 3363 t at a catch rate of 126.1 kg/unit. Tunas formed 35.4% of the total hook and line catches at Kakinada. The major contributor to the tuna fishery at Kakinada was *Thunnus albacares* contributing 37.2% to the total tuna catch.

The length of skipjack tuna, *Katsuwonus pelamis* at Visakhapatnam ranged from 300 mm to 650 mm with an annual mean of 504.7 mm. The highest mean length of 572.2 mm was recorded in the month of March and the lowest mean length of 443.8 mm was recorded in November. Annual sex ratio was 1.73 with significant dominance by males in February and March and by females in rest of

the months. Only mature females were recorded in February and March indicating it to be the peak breeding season. The average gonadosomatic index was 1.5 with a maximum of 2.1 recorded in February. Their fecundity ranged from 61516 to 606966 with ova diameter varying from 0.23 mm to 0.7 mm. The high IRI values of cephalopod, penaeid prawn, frigate tuna, carangids and flying fish along with digested food imply them to be the principal food constituents.

The length of yellowfin tuna, *Thunnus albacares* at Visakhapatnam ranged from 330 mm to 1980 mm with an annual mean of 944.5 mm. Maximum mean length of 1411 mm was recorded in December and minimum mean length of 470.6 mm was recorded in September. Annual sex ratio was 0.61. Males dominated the catch from March – August and from October - December while females dominated the catch in January, February and September. Mature females were encountered in most months with peak occurrence during April – August (70.8% - 100%). The gonadosomatic index varied from 0.5 to 1.9 with an average of 1.1. Their fecundity ranged from 398705 to 11130000 with ova diameter varying from 0.18 mm to 0.83 mm. Cephalopods are their preferred prey, followed by mackerel, crab, squilla, balistids, carangids and flying fish.

Growth parameters of pelagic resources landed at Visakhapatnam

	Linf	k	Z	M	F	E	Lc	Recruitment	Peak pulse
Katsuwonus pelamis	68.2 cm	0.34	1.26	0.69	0.57	0.45	50.58 cm	Bimodal in March – June and Aug - Oct	
Thunnus albacares	208.9 cm	0.08	0.48	0.2	0.28	0.59	109.8 cm	Unimodal May – Oct with peak in July	84.4%

Stock Assessment of pelagic resources landed at Visakhapatnam

	Stock (t)	Biomass (t)	Biomass per recruit (g)	MSY(t)	Annual average yield (t)	Yield per recruit (g)
Katsuwonus pelamis (hooks and lines)	11800	6709	506.9	4227	3824	288.94
Thunnus albacares (hooks and lines)	50284	39936	16063.16	9585	11182	4497.68

Index of Relative Importance (%) of food items encountered in the gut of *Katsuwonus pelamis*

	Digested fish	*Loligo*	Penaeid prawns	Frigate tuna	Carangids	*Decapterus*	Flying fish	Others
March	3	97						

April		26	74					
June	74			26				
July	95				5			
October	70					20	11	
November	33	31				34		2
January	99							1

Index of Relative Importance (%) of food items encountered in the gut of *Thunnus albacares*

	Loligo	Mackerel	Crab	Digested fish	Flying fish	*Squilla*	Balistid	Scad	Frigate tuna	Purple back squid	Others
February	53	37	1	4							5
March	74	7		2							17
April	52			48							
June	3		2	73	18						4
July	2			26	4	19		45	4		
August	16			25	1	15	36		1		6
September				93		6					1
October	81			9							10
November	89			4				2	1		4
December	10		20	17				9		41	3
January	5	1	1	55				18		13	7

Seer fish catch was dominated by *Scomberomorus commerson* (66.9%) and *Scomberomorus guttatus* (33.1%). More than 40 % of the seer fishes were landed by hooks and lines. Tunas were exploited mainly by gill netters and hooks and lines. Their catch rate in hooks and lines was 49.54 kg/unit. Among tuna, the dominant species landed were *Thunnus albacares* (45.5%), followed by *Euthynnus affinis* (27.5%), *Katsuwonus pelamis* (23.2%) and *Auxis thazard* (3.8%). The landings of billfishes and barracudas for the year were 0.025 lakh t and 0.04 lakh t, respectively. The catch rate of

barracudas in trawlers was 0.55 kg/h. Around two third of the bill fishes were landed by the non mechanized sector alone.

The seerfish landing by trawlers at Visakhapatnam was 414.85 t with catch rate of 0.15 kg/h. *Scomberomorus guttatus* dominated the gillnet landings while the trawl fishery was supported by both *Scomberomorus guttatus* and *Scomberomorus commerson*. The catch in gill nets was 119 t at a catch rate of 8.38 kg/unit forming 6.3% of the gill net landings. The length of *Scomberomorus guttatus* at Visakhapatnam ranged from 280 mm to 479 mm with an annual mean of 369.09 mm. Significant dominance of females in catch was recorded in all the months. Mackerel, sardine, anchovies and squid were the principal food components encountered in their gut.

The annual catch of tuna recorded by hooks and lines at Visakhapatnam during 2013 was 611.1 t with the catch rate of 18.4 kg/unit. 30.94% of the hooks and lines catches at Visakhapatnam was contributed by tunas alone. The dominant species landed in hooks and lines were *Thunnus albacares* (53.4%), *Euthynnus affinis* (24.56%) and *Katsuwonus pelamis* (22.03%). The length of skipjack tuna, *Katsuwonus pelamis* at Visakhapatnam ranged from 380 mm to 679 mm with an annual mean of 519.5 mm. The highest mean length of 600.16 mm was recorded in the month of October and the lowest mean length of 489.2 mm was recorded in March. Annual sex ratio was 1.35 with significant dominance by males in September and by females in February – March and November - December. More than 80% of the females were mature in March indicating it to be the peak breeding season. Average gonadosomatic index was 1.47. Their fecundity ranged from 205947 to 1758204 with ova diameter varying from 0.18 mm to 0.7 mm. The high IRI values of cephalopod, penaeid prawn, carangids, sardines and anchovies along with digested food imply them to be the principal food constituents. The length of yellow fin tuna, *Thunnus albacares* at Visakhapatnam ranged from 120 mm to 1719 mm with an annual mean of 783.05 mm. Maximum mean length of 1182.4 mm was recorded in April and minimum mean length of 434.62 mm was recorded in December. Annual sex ratio was 2.82. Males dominated the catch in January and October while females dominated the catch in January, September and December. High percentage (83.33%) of mature females was observed in October. Their fecundity ranged from 2306062 to 3815101 with ova diameter varying from 0.2 mm to 0.56 mm. Cephalopods are their preferred prey, followed by mackerel, crab, squilla, coastal tunas, carangids and other scombrids.

The length of *Sphyraena jello* at Visakhapatnam ranged from 280 mm to 679 mm with an annual mean of 408.88 mm. Annual sex ratio was 1.33. The high IRI values of mackerel, carangids and

whiting along with digested food imply them to be the principal food constituents. The mean length of *Sphyraena obtusata* was 265.5 mm. There was significant domination by females in the catch. Most females encountered in catch were in mature state with average gonadosomatic index value of 3.37. Their fecundity varied from 45838 to 105964 with ova diameter ranging from 0.35 mm to 0.48 mm. Carangids were their preferred prey items.

The length of *Coryphaena hippurus* ranged from 260 to 1099 mm with mean of 690.83 mm. Fecundity ranged from 329540 to 1357007 with ova diameter varying from 0.68 mm to 1.27 mm. Carangids, frigate tuna and sucker fishes were the principal food items encountered in their gut.

The mean length recorded for *Euthynnus affinis*, *Rachycentron canadum*, *Istiophorus platypterus*, *Makaira indica* and *Xyphius gladius* were 382 mm, 499.17 mm, 1983.33 mm, 1850 mm and 1266 mm, respectively at Visakhapatnam.

Development of regional Fishery Management Plans (FMPs) for the clam fisheries of Southern India

The bivalve fishery of the Bhimili estuary**:** The total bivalve production exploited from this estuary was estimated at 49.2 t in 2012. The total effort was 1167 units. The average catch per unit effort was 38.6 Kg. The average monthly catch was 4.1 t and average effort 97.3 units. Three species of clams (*Meretrix meretrix, M casta, Anadara* sp) and the oyster *Crassostrea madrasensis* are exploited from this estuary. *Meretrix casta* landed 6.59 t, M *meretrix* landed 2.8 t, *Anadara* sp 0.22 t and *Crassostrea madrasensis* landed 39.6 t.

The bivalve fishery declined significantly compared to previous year 2011 (88.7 t). The total bivalve catch declined by 44.5 % (39.46 t). The effort also declined by 668 units (36.4 %). The catch per unit effort declined during this year at 38.6 Kg as against 48.3 Kg in 2011. The catch of Meretrix *casta* declined by 56.1 %, *M meretrix* by 79.8 %, *Anadara* sp. by 74.1 %. Landings of *C madrasensis* also decreased by 32.8 % from 58.93 t in 2011.

The bivalve fishery of the Kakinada Bay: The bivalve fishery of Kakinada Bay of Andhra Pradesh was monitored from two major landing centres, viz; Chollangi and Peddavalsala during the year. The estimated total bivalves landed from Kakinada Bay were 914.1 t, with an average monthly landing of 47 t. The total effort was 5565 units and the average catch per unit affort was 99.5 Kg. The species landed were *Anadara* sp. (250.6 t), *M meretrix* (120.3 t), *Paphia malabarica* (28.9 t), *Katelysia opima* (20.8 t), *Meretrix casta* (3.1 t), t. *Geloina* sp. (0.75 t), and others (26.1 t). The total clam production

was 424.4 t. Oysters landed were Windowpane oyster, *Placuna placuna* (447.4 t), edible oyster *Crassostrea madrasensis* (42.2 t) and other oysters (14.5 t.) The total oyster production was 504.1 t. The price of the bivalves ranged from Rs. 8 to 12 per Kg.

The clam production in Kakinada bay increased by 22.6 t (5.6%) in 2012 compared to the previous year. The landings of *M meretrix* increased by 47.5 t (39.5%), *P malabarica* by 14.9 t (51.6%), *K opima* 16.3 t (78.4%). However, the landings of *Anadara sp* declined by 26.1 t (9.4%), *M casta* by 21.6 t (87.5 %), *Geloina sp* by 8.5 t (91.9 %).

Evaluation of ornamental gastropod fisheries in India and assessment of shell craft industry

Gastropod fishery of the Kakinada Bay: The estimated total gastropod landing from Kakinada Bay during 2012 was estimated at 216.9 t with average monthly landings of 18.1 t. The total effort was 5565 units and the average catch per unit effort was 37.9 Kg. The species landed were *Cerithidium* sp. (99.5 t), *Telescopium* sp (26.3 t), *Thais* sp. (15.2 t), *Murex* sp (20.8 t) *Hemifusus* sp (20.7 t), *Umbonium* sp (14.24 t), and other gastropods (20.2 t). Maximum landings were during March and August- October. The price of gastropods ranged from Rs. 6 to 12 per Kg.

The total gastropod landings declined by 96 t (31 %) as against the previous year. The effort declined by 555 (10%); however the catch per unit effort increased by 10.2 Kg (21%). The landings of Cerethidium sp registered an increase of 141.4 t (58.7 %); all other species recorded a decline in landings viz., *Umbonium* sp 11.1 t (78.2 %), *Hemifusus* sp 10.9 t (52.7%), *Murex* sp 10.5 t (50.5%), *Telescopium* sp 3.3 t (12.5%) and *Thais* sp. 1.3 t (8.6%).

Sustainable molluscan mariculture practices

Green Mussel (Perna viridis) Spat production: Brood stock of green mussels was collected from the Kakinada fishing harbor. Spawning of the green mussel *P viridis* occurred on 11 September 2012 (10^{th} successful spawning in the Mariculture hatchery of Visakhapatnam Regional Centre of Central Marine Fisheries Research Institute). 10.3 million larvae were reared and over 2.5 lakh spat were settled after 21 days. The spat were reared and further used for nursery rearing experiment.

Nursery rearing: An upwelling system was set up for rearing the green mussel spat to develop a nursery technique for faster growth of spat to the seeding size for further farming in the estuaries and sea. The spat of initial average shell length of 6.8 mm and average weight of 0.04 g were stocked in

the PVC tubes set in the upwelling tank, provided with continuous aeration and feed (I*sochrysis galbana* and *Chaetoceros calcitrans*). The spat attained an average shell length of 12.15 mm, average width of 6.8 mm and average weight of 0.34 g in 50 days. Preliminary results indicate faster growth in the upwelling system compared to growth in tanks. This will shorten the nursery rearing phase and produce seed for stocking in the farm in a much shorter period. The experiment is in progress.

Spawning and production of hatchlings of *Hemifusus pugilinus:* The sea snail, *Hemifusus pugilinus* collected from the Kakinada Bay of Andhra Pradesh spawned in the Mariculture hatchery of Visakhapatnam Regional Centre of Central Marine Fisheries Research Institute. Female of 80.13 mm shell height, 41.39 mm shell width and total weight 53.04.g, laid a string of 40 egg capsules on 16 October 2012. The capsules were held together by a common holdfast. Development was inside the capsule and the hatchlings were released from the capsules on the 28^{th} to 30^{th} day of incubation. A total number of 3000 hatchlings hatched out from 40 capsules. The hatchlings were fed bivalves such as *Perna viridis, Meretrix casta* and also meat paste of squids and attained a size of 6-8 mm in 35 days. Hatchlings of *Hemifusus* sp. have been produced in the hatchery for the first time and given their fast growth under captive conditions; it is a suitable candidate for mariculture. Hatchery produced hatchlings can be sea ranched for wild stock replenishment since they are highly targeted for their ornamental shells and operculum which is used in Unani medicine.

Sponsored Projects

Strengthening of database and GIS for the Fisheries Sector-Marine Fisheries Census-2010

All India Marine Fisheries Census 2010 was conducted by Visakhapatnam Regional centre in three Maritime states of India namely Andhra Pradesh, Orissa and West Bengal where 27 supervisors and 743 enumerators were involved in census of approximately 4,54,200 households belonging to 2,313 villages. During second phase, in two districts of West Bengal, census was conducted for about 50,000 households involving 106 enumerators and 3 supervisors.

Open Sea floating cage demonstration farm for R&D in marine finfish & shellfish production

Open sea floating cage culture demonstration project, sponsored by the National Fisheries Development Board, was operated by the Central Marine Fisheries Research Institute at Balasore, Orissa. The project started in February and harvest was carried out in November 2009. The HDPE open sea circular floating cage (net dimensions; 6 m dia and 6 m height) was stocked with 4,500 fingerlings of sea bass, *Lates calcarifer* (44.68 g. mean average wt.). Stocked population was fed with trash fish available from the local landing centres at an appropriate feeding rate (7.0-15.0 % of biomass). The harvest was done in November, 2009, after 8 months of culture period, in the presence of Dr. S. Ayyappan, DDG (Fy.), ICAR, Dr. G. Syda Rao, Director, CMFRI, Dr. C. Vasudevappa, Chief Executive, NFDB, Dr. Anil Kumar, TIFAC, DST, New Delhi, Prof. C. K. Mukherjee and Prof. P. Srinivas Rao, IIT, Kharagpur, Dr. B. Dandapat, ADF (Marine) Balasore, Orissa and other extension officials from Orissa State Fisheries Department. About 3.1 t of fish was harvested (Wt. range 0.55- 1.1 kg). Around 5000 nos. of sea bass fingerlings which were reared in the seed cages (2 m dia and 4.5 m deep) for a culture period of 3 months were also handed over to the Fishermen society by the DDG (Fy.), ICAR and the Chief Executive NFDB for the next crop.

Cage was installed in Bay of Bengal (N 18^{o} 52' 284" E 84^{o} 36' 156") off Baruva-Kothuru, Srikakulam, Andhra Pradesh. *Lates calcarifer* (Seabass) fry, procured from CIBA, Chennai were reared upto fingerling size (30.83 g) with 60 % survival and stocked in cage.

Cage culture of Asian seabass was demonstrated to the Marine Fishermen Co-operative Society, Baruva-Kothuru. Demonstration of open sea cage culture of Sea bass to the Burma repatriates Marine fishermen multipurpose co- operative society Ltd., Uppada, Andhra Pradesh was conducted. After 7.5 months culture harvest was done with 53.0% survival. Total harvested production was 1.3 t. Size range was from 0.25 -1.45 kg.

An experiment to find out the suitability of Tiger shrimp (*Penaeus monodon*) culture in open sea cage was carried out. A good yield with survival of 31.0 % and FCR of 4.26 in 99 days period was achieved.

An experiment to develop proper nursery rearing system for Asian seabass, *Lates calcarifer* in open sea floating cage was carried out. Around 10,000 no. of sea bass fingerlings (55 ± 0.46 mm) were stocked in two hapa (5000 no. in each) fixed in the cage. Mixed feeding was followed with live Artemia, shrimp feed, Artemia flakes and Acetes during different stages of nursery rearing. Stocked fishes attained 198 ± 32.02 mm with survival of 81% after 145 days.

National Initiative on Climate Resilient Agriculture (NICRA)

Modeled the effect of climatic and oceanographic parameters on oil sardine, Indian mackerel and silver pomfrets catch rates in gillnets of Andhra Pradesh. Survey of fishermen revealed that they believed in climate change. Wind was the parameter that had changed the most in the last two decades. Sea status was ranked as the most problematic to fishermen. Avenue for safe exit from villages in case of natural calamities was the highest scoring adaptation measure. Wind was the most critical parameter affecting the marine fishery and overfishing was the biggest problem facing fisheries. Mapping of PFZ areas along north coastal Andhra Pradesh was carried out and two areas of consistent high PFZ hits were identified. Phytoplankton (*Nannochloropsis oculata*) was cultured at temperature range of 28 to 32 ^{0}C with the temperature difference of 1^{o}C for 7 days and a significantly higher growth and multiplication of phytoplankton was found in the culture which was maintained at 29^{o}C. Experiments on influence of environmental parameters for production of small rotifers for feeding fish larvae were carried out. Digitising of old data on water quality parameters is under progress. This data may be used for correlating with the fishery data. Rainfall, wind velocity and wind direction data were collected from IMD, Chennai through Cyclone warning centre in Visakhapatnam. Data collection on real time water parameters from ICOADS and SeaWIFFS were done and collected data will be used for further analysis with fishery data. Correlation between quarter wise data of catch and water analysis revealed that there is a direct relationship between temperature and fish catch of oilsardine while DO was having an inverse relationship with fish catch. Skip jack is also having inverse relationship with temperature and fish catch.

Climate change

Features of the ocean environment off the north-east coast of India (Andhra Pradesh, Orissa and West Bengal)

Clear evidence of warming of the ocean off Andhra Pradesh and Orissa as seen from SST anomaly plots for SST data from 1960-2010. (Source of SST data: ICOADS)

Evidence of warming of the ocean off West Bengal is seen though intensity is less, possibly, a consequence of the influx of freshwater from the Ganges-Brahmaputra river systems.

Weak linear association of SST anomalies for the region with El Nino or La Nina for data from 1960-2010.

SST plots show a 0.87 ^{O}C (from 28.14 ^{O}C to 29.01 ^{O}C) rise in temperature for Andhra Pradesh, 0.78 ^{O}C (from 27.6 ^{O}C to 28.37 ^{O}C) for Orissa and 1.7 ^{O}C (from 27.34 ^{O}C to 29.04 ^{O}C) for West Bengal from 1960-2010.

Positive linear association of average decadal SST for the region with the decadal average intensity of the Indian Ocean Dipole (IOD) was observed for data from 1960-2010. The IOD was measured as Dipole Mode Index (DMI), wherein positive DMI reflected a positive IOD year (Source of DMI data: www.jamstec.go.jp).

Positive linear association was detected between DMI and Chlorophyll-a for the region from 1997-2010. Correlation coefficient was 0.42 for Andhra Pradesh, 0.43 for Orissa and 0.30 for West Bengal.

Peak chlorophyll-a values were recorded from July-September for Andhra Pradesh, July-November for Orissa and August-December for West Bengal during 1997-2010.

Average annual chlorophyll-a values were the highest for West Bengal with an average value of 4.04 mg/m^3, followed by Orissa with 1.27 mg/m^3 and Andhra Pradesh with 0.47 mg/m^3.

Positive linear association (correlation coefficient of 0.52) was detected between SST and Chlorophyll-a values for Andhra Pradesh during 1997-2010.

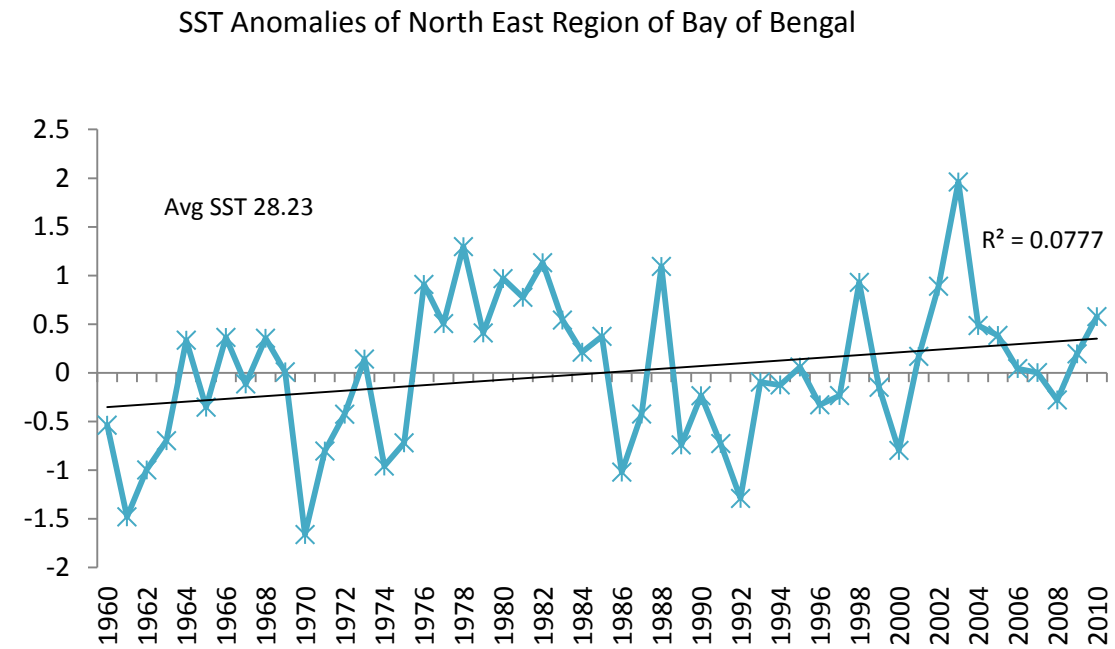
North to South meridional winds dominated during the last quarter (October-December) over Andhra Pradesh coast (Source of wind data: ICOADS). Published literature reported that the winds change direction in September every year.

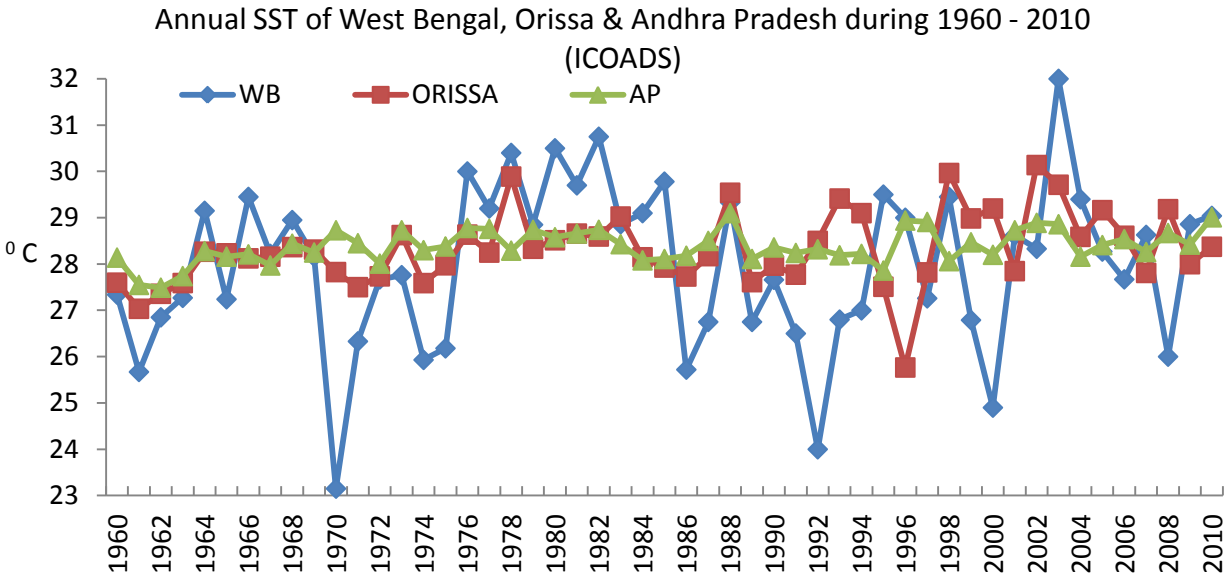
Positive linear association between quarterly wind intensity and direction with Chlorophyll-values for Andhra Pradesh was observed for second half of the year during 1998-2010. The correlation coefficients for wind and Chlorophyll-a values for the third quarter from 1998-2010 was 0.32 and for the fourth quarter was 0.30.

Increased incidence of cyclones during the last decade. http://disastermanagement.ap.gov.in/website/history.htm.

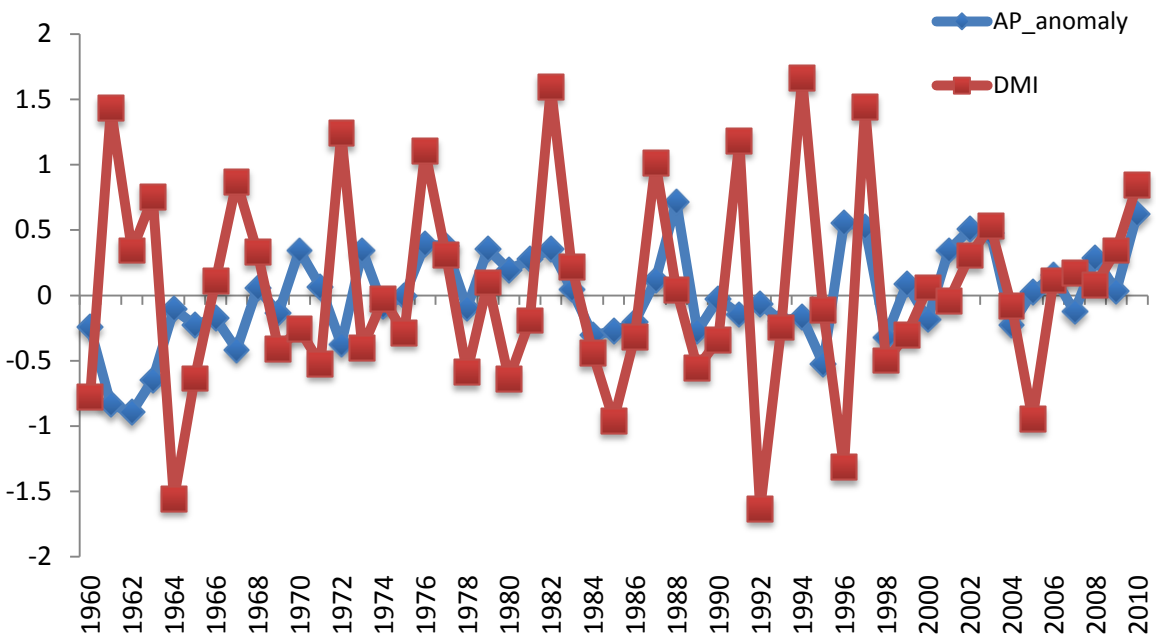
The Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere phenomenon in the Indian Ocean. It is normally characterized by anomalous cooling of SST in the south eastern equatorial Indian Ocean ($0^0 – 10^0$S and 90^0E – 110^0E) and anomalous warming of SST in the western equatorial Indian Ocean (10^0N – 10^0S & 50^0E -70^0E). Several authors have identified the influence of the Indian Ocean Dipole (IOD) on the interannual variability of the Indian summer monsoon rainfall (ISMR). The IOD and the ENSO have complementarily affected the ISMR during the last four decades. Whenever the ENSO-ISMR correlation is low (high), the IOD-ISMR correlation is high (low). The IOD plays an

important role as a modulator of the Indian monsoon rainfall and influences the correlation between the ISMR and ENSO.

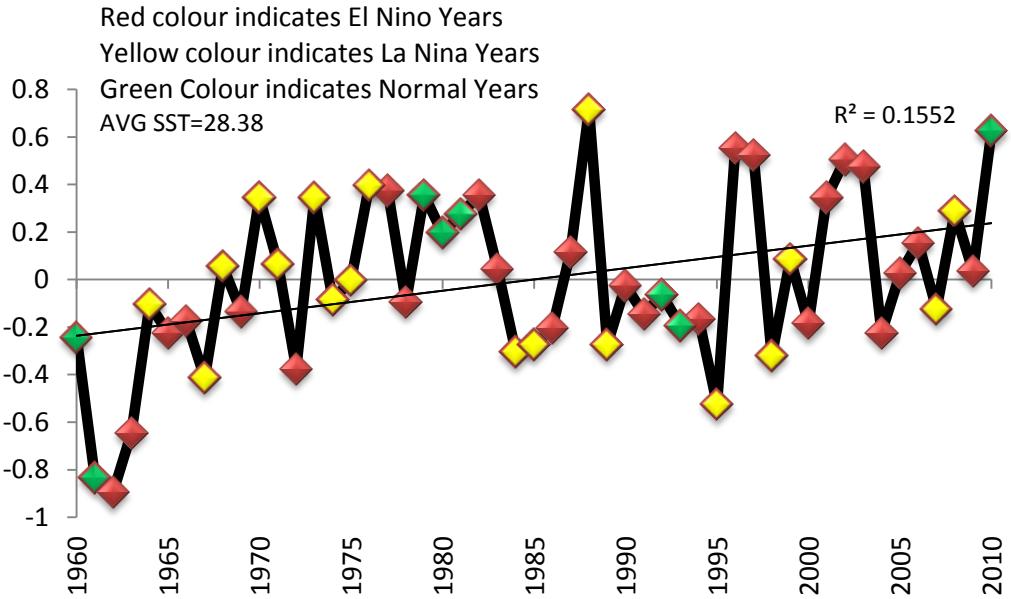




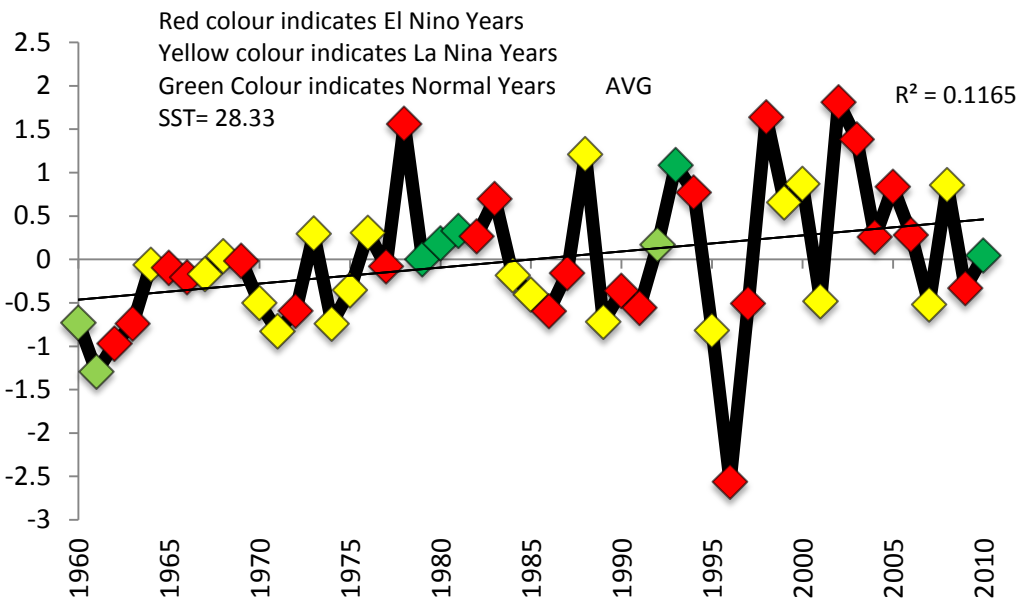
Trend of Andhra Pradesh SST Anomalies & Dipole Mode Index of Indian Ocean during 1960-2010



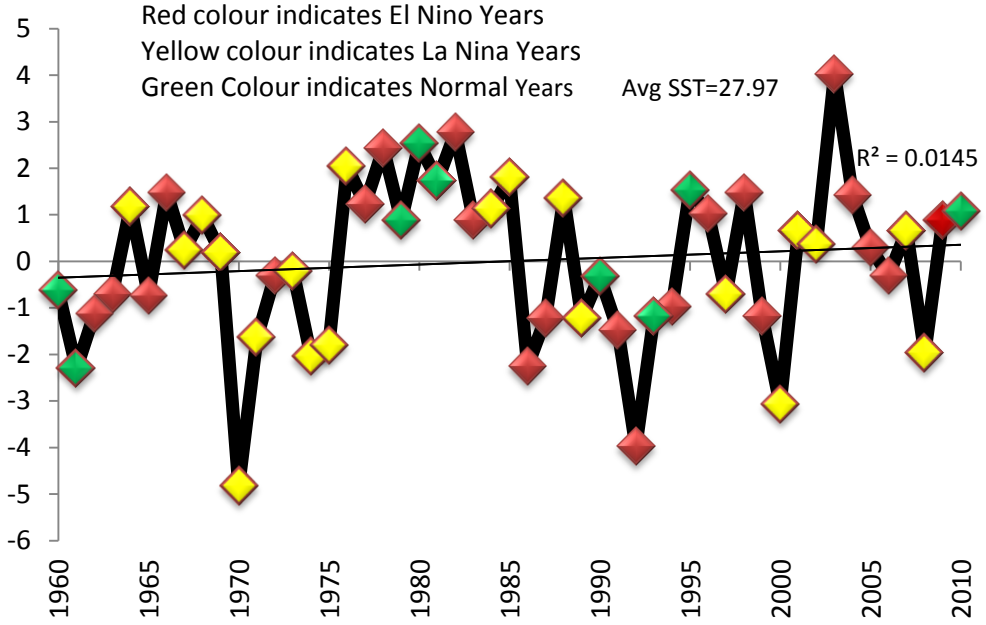
SST Anomalies of Andhra Pradesh during 1960 - 2010 (ICOADS) indicating El Nino & La Nina Years

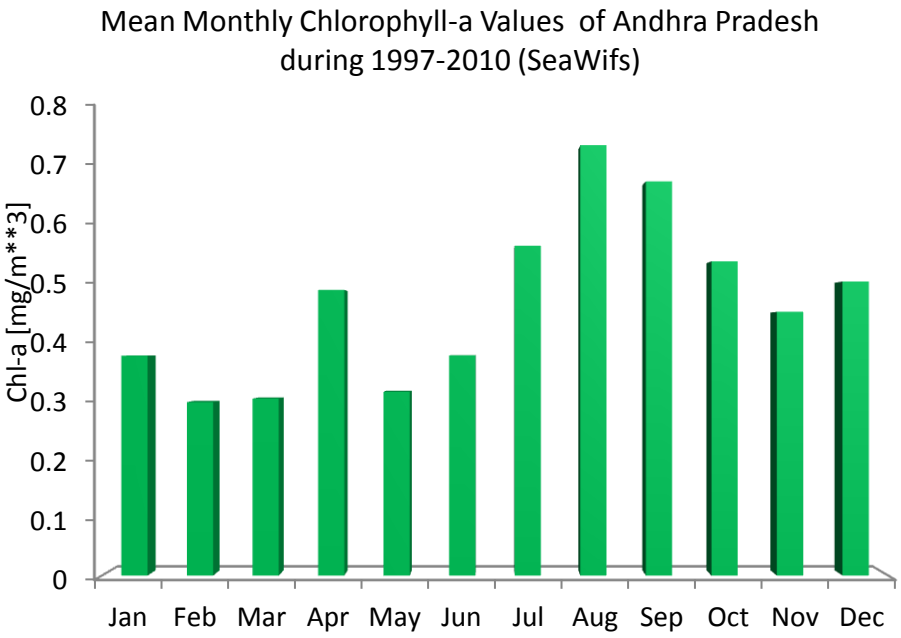


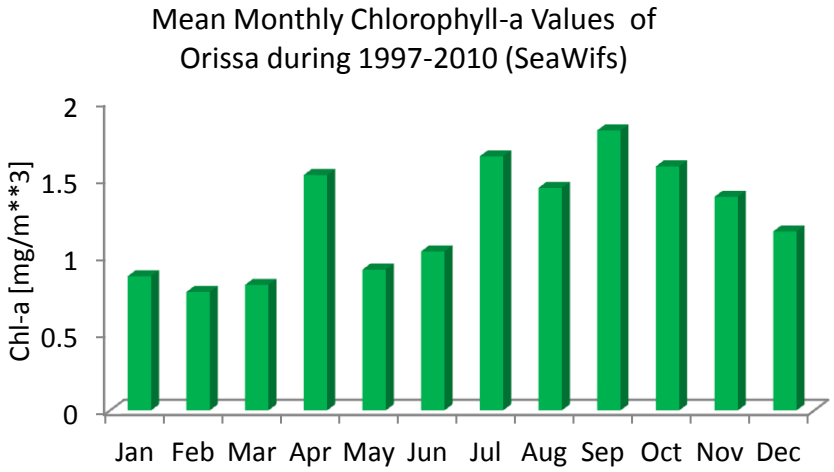
SST Anomalies of Orissa during 1960 - 2010 (ICOADS)
indicating El Nino & La Nina Years

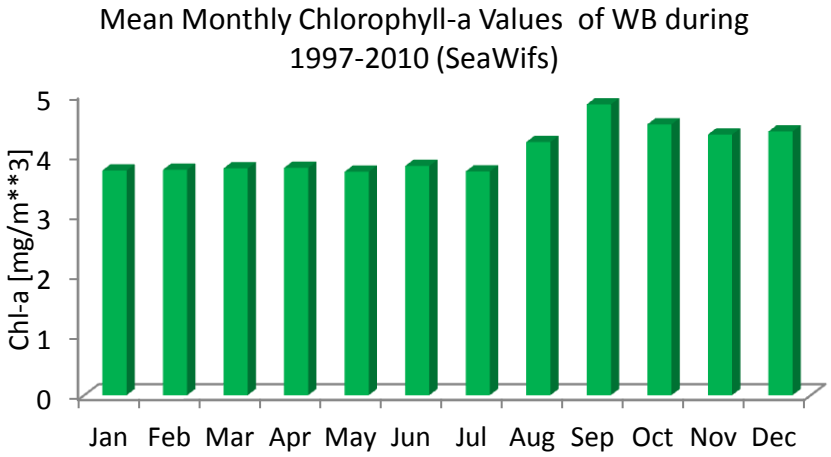


SST Anomalies of West Bengal during 1960 - 2010 (ICOADS)
indicating El Nino & La Nina Years




Mean Monthly Chlorophyll-a Values of Andhra Pradesh during 1997-2010 (SeaWifs)
Chl-a [mg/m**3]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Mean Monthly Chlorophyll-a Values of Orissa during 1997-2010 (SeaWifs)
Chl-a [mg/m**3]
2
1.5
1
0.5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



Cyclone occurrence (annually and seasonally) in Andhra Pradesh

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1977												
1978												
1979												
1980												
1981												
1982												
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1984												
1985												
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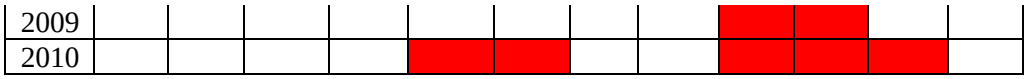
2007												
2008												



Impact of climate change on marine fish catch

Both SST and marine fish landings for the region showed an increasing trend during 1985-2010.

Negative linear association was recorded between rainfall rates and fish landings for Orissa & Andhra Pradesh.

Negative linear association was observed between Particulate Inorganic Carbon and fish landings of West Bengal.

Positive linear association was observed between Coloured Dissolved Organic Material and fish landings of Orissa and between Particulate Organic Carbon and fish landings of Andhra Pradesh.

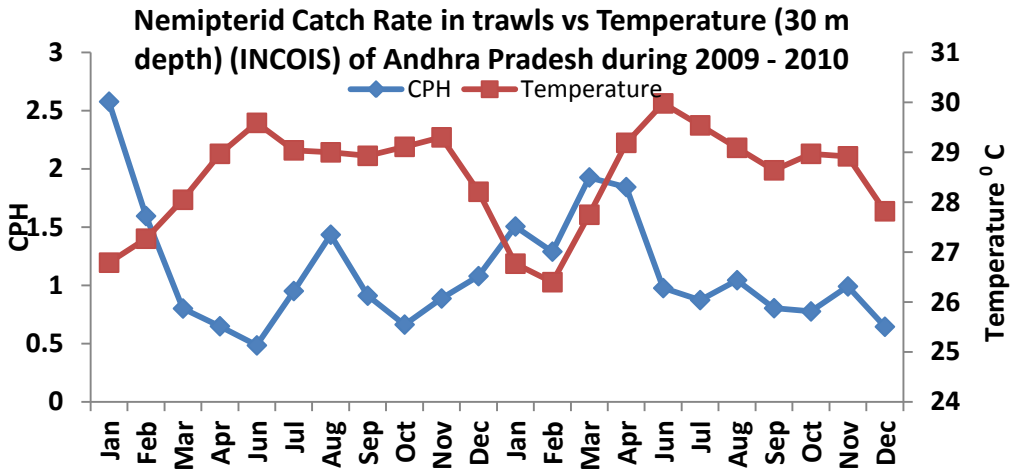
Positive linear association was recorded between Chlorophyll-a levels and pelagic fish landings for Andhra Pradesh. Both sardine landings and Chlorophyll-a values peaked in the third quarter. Mackerel landings peaked during the first quarter of the year.

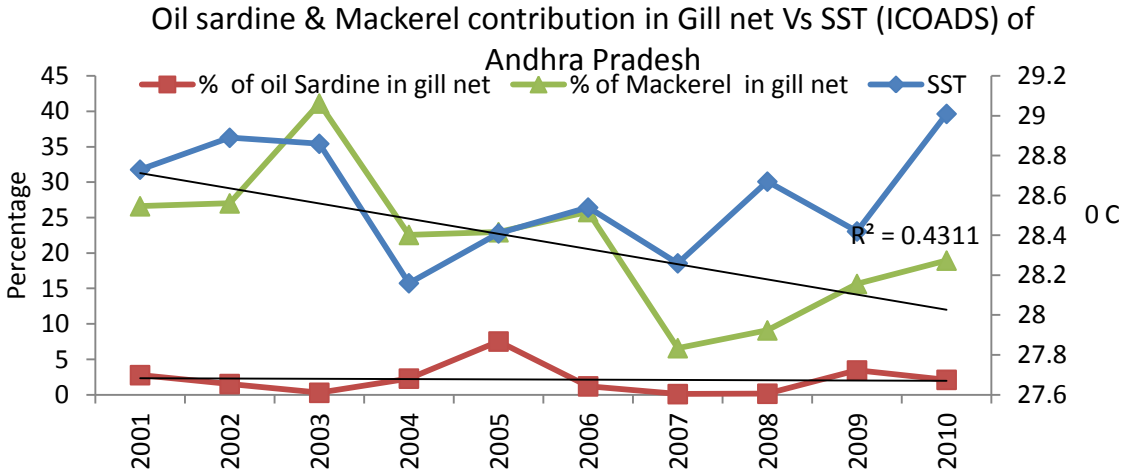
Highest mean landings of yellowfin tuna in the fourth quarter was observed when wind direction was from north to south. The north to south winds during October - January is favorable for tuna fishery with tuna moving along with wind and current from offshore deeper waters to near shore shallower waters.

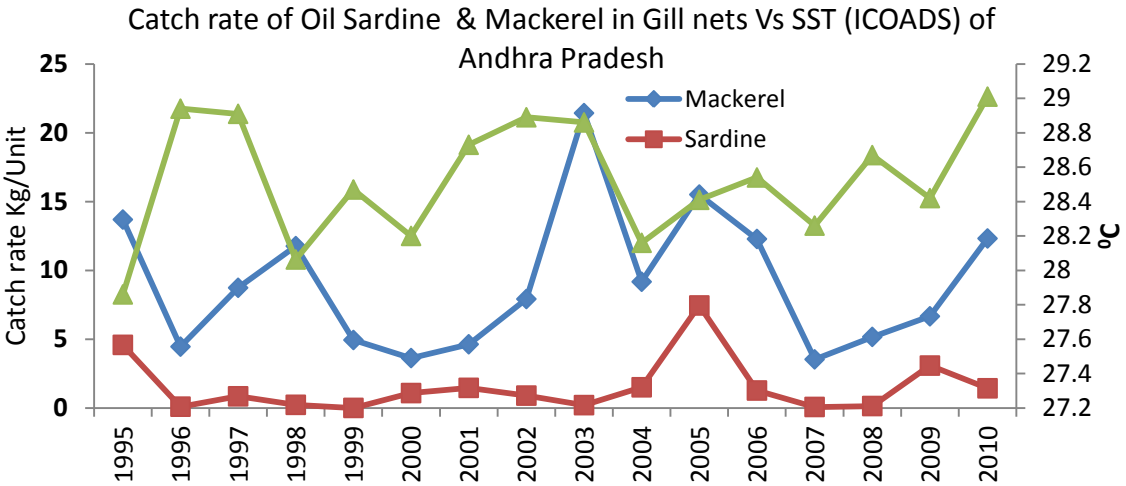
Impact of climate change on fish catch rates

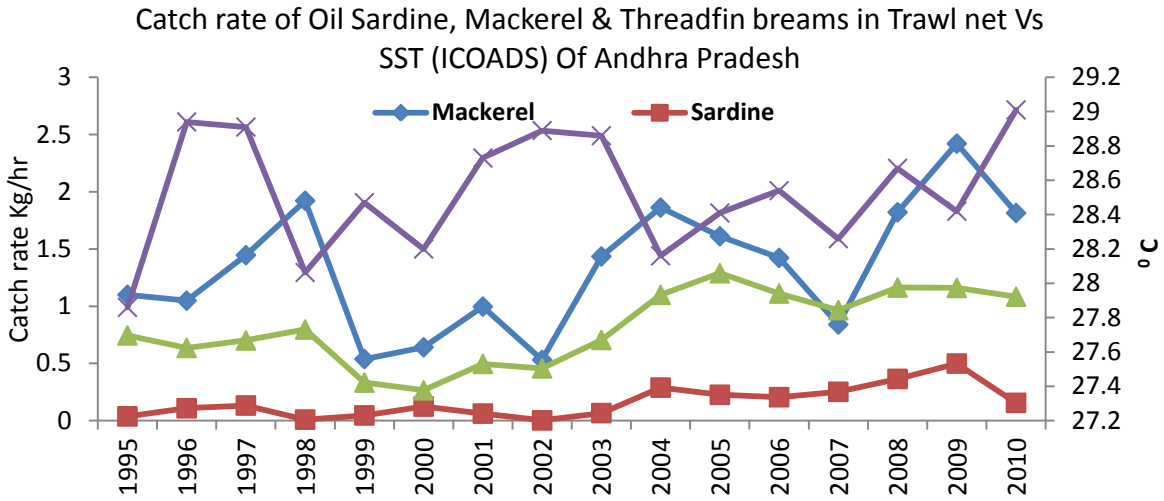
Negative association between water temperature at 30 m and threadfin bream catch rates possibly as a result of vertical migration of fish.

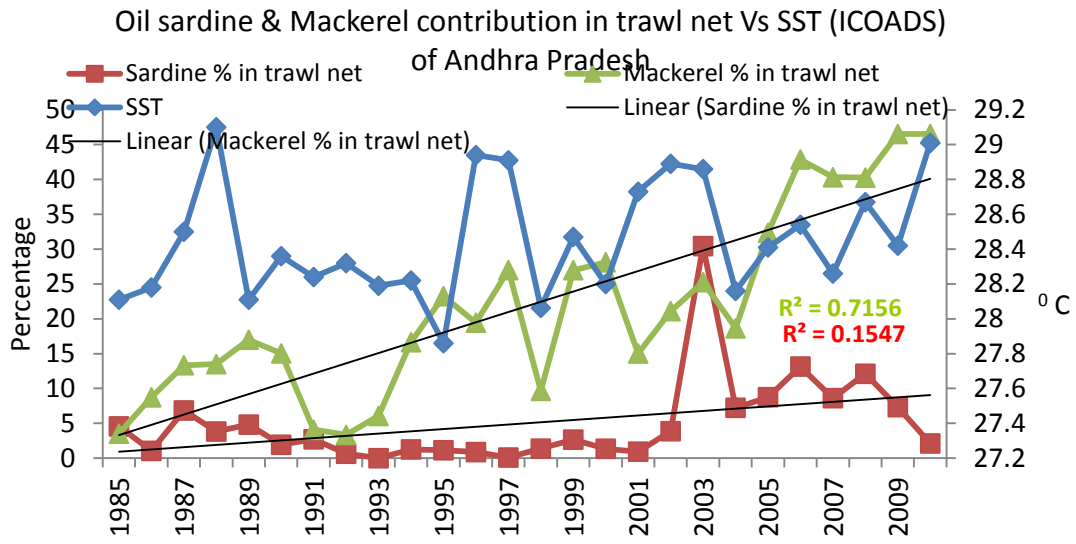
Increased catch rates and contribution in trawler landings by small pelagic fish viz., sardine and mackerel and decreased catch rates and contribution to gillnet landings possibly indicating a vertical migration of the resource with increasing SST.


Nemipterid Catch Rate in trawls vs Temperature (30 m depth) (INCOIS) of Andhra Pradesh during 2009 - 2010
CPH
Temperature
CPH
Temperature ⁰ C
3
2.5
2
1.5
1
0.5
0
31
30
29
28
27
26
25
24
Jan Feb Mar Apr Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr Jun Jul Aug Sep Oct Nov Dec

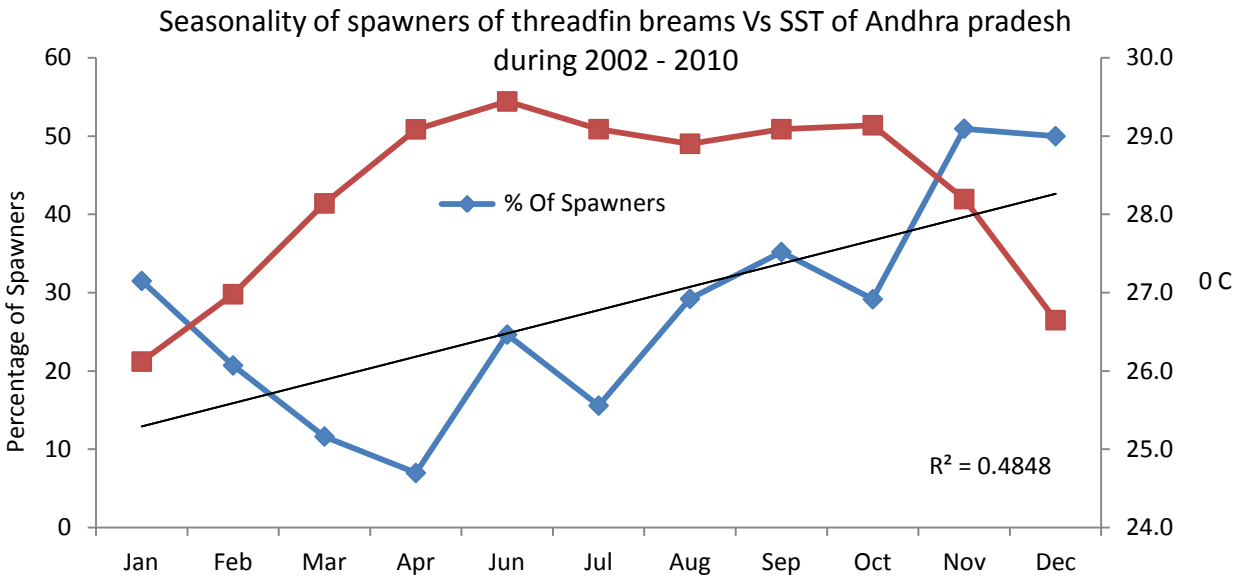

Oil sardine & Mackerel contribution in Gill net Vs SST (ICOADS) of Andhra Pradesh
% of oil Sardine in gill net
% of Mackerel in gill net
SST
Percentage
0 C
R² = 0.4311
45
40
35
30
25
20
15
10
5
0
29.2
29
28.8
28.6
28.4
28.2
28
27.8
27.6
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


Catch rate of Oil Sardine & Mackerel in Gill nets Vs SST (ICOADS) of Andhra Pradesh
Mackerel
Sardine
Catch rate Kg/Unit
⁰C
25
20
15
10
5
0
29.2
29
28.8
28.6
28.4
28.2
28
27.8
27.6
27.4
27.2
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

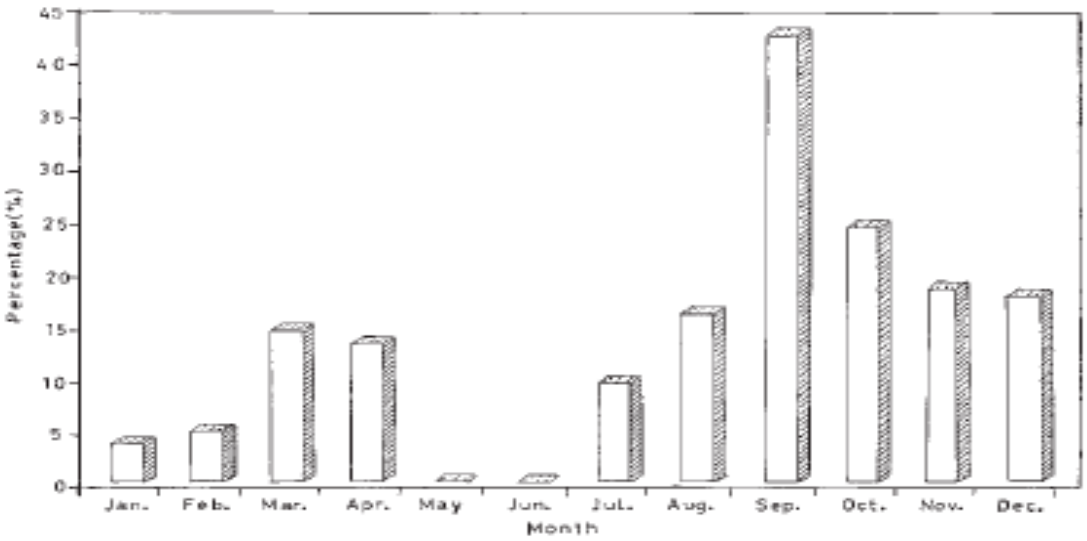


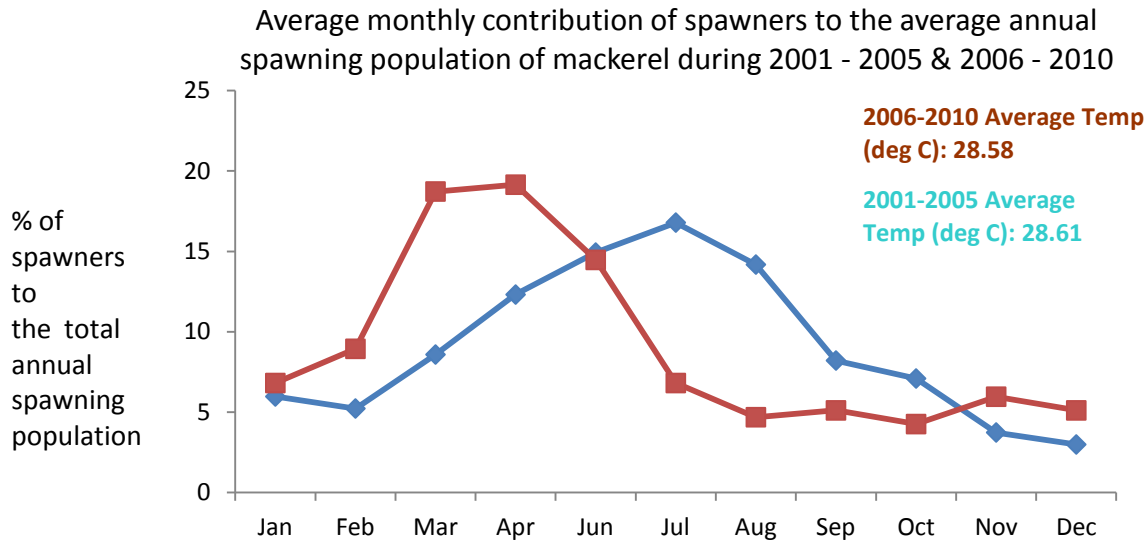


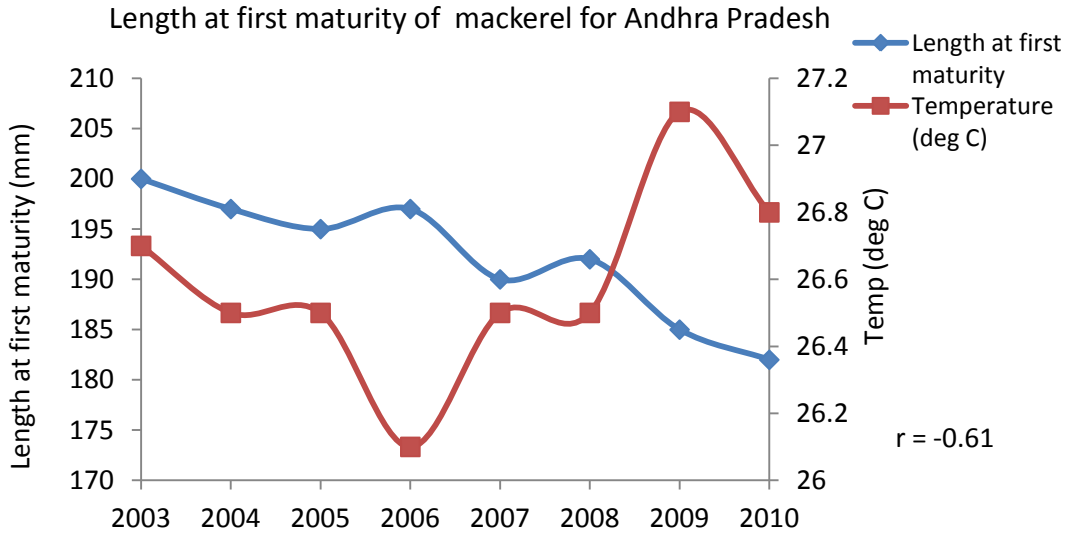
Impact of climate change on reproductive biology of fishes



Seasonality of spawners of threadfin breams of Andhra Pradesh during 1990 – 1999 (Rajkumar *et. al.*, 2003)







Resourcewise fishery, reproductive biology and trophodynamics

Salient findings from three states which can be related to environmental parameters

Length

Mean length for most of the species with the exception of yellowfin tuna and tiger shrimp were lower at Visakhapatnam and higher at Digha and Paradeep.

Mean length for oil sardine and white shrimp was highest at Digha during October – January.

Mean length for oil sardine was lowest at Visakhapatnam during October – January.

Mean length for mackerel at Paradeep and Visakhapatnam was higher during the premonsoon months.

Mean length for *Liza macrolepis* and *Nemipterus japonicus* was lower at Digha during the warmer months.

Mean length at Visakhapatnam for yellowfin tuna, tiger shrimp and white shrimp was higher during October – March, December – April and January – April, respectively.

Reproductive biology

Preponderance of females in the catch of oil sardine at Paradeep and Digha from September – December. Peak breeding season of oil sardine at Digha was from April – July and at Visakhapatnam from May – September.

Dominance of males in the catch of mackerel for all the three states. Prolonged peak breeding season of mackerel at Visakhapatnam was from February – October and at Digha was from June – November.

Abundance of females in the catch of *Liza macrolepis* at Visakhapatnam and Digha from March – September. Breeding season for *Liza macrolepis* was throughout the year at Visakhapatnam but from August - December at Paradeep and from October – January at Digha.

Significant dominance of females in the catch of *Nemipterus japonicus* and *Loligo duvaucelli* at Visakhapatnam and Digha. Mature females of *Nemipterus japonicus* and *Loligo duvaucelli* were observed throughout the year at Visakhapatnam in high numbers but only during monsoon in low numbers at Digha.

Domination by females in the catch of skipjack tuna and by males in the catch of yellowfin tuna at Visakhapatnam. Peak breeding season at Visakhapatnam for skipjack tuna was in February and March and for yellowfin tuna from April – August.

Significant dominance by males of tiger shrimp at Visakhapatnam and Paradeep was during January – June and by females of tiger shrimp at Digha and Paradeep was during July - December. Peak breeding season of tiger shrimp at Visakhapatnam was from March – June and at Digha from June - July.

Significant domination by females of white shrimp at Visakhapatnam was during January – July and at Digha was throughout the year except December. Peak breeding season for white shrimp at Visakhapatnam was from February – June and at Digha from March - August.

Trophodynamics

Fishes with considerable amount of food in stomach was higher at Visakhapatnam than that of Paradeep and Digha for oil sardine, mackerel, *Liza macrolepis*, tiger shrimp, white shrimp and tuna.

No empty or trace amount of food in stomachs were observed in tiger shrimp at Visakhapatnam during April – June.

The incidence of squids with empty or trace amount of food in stomachs was very high in all the three states.

Indigenous Traditional Knowledge

Andhra Pradesh: Traditional sector (Number of respondents: 122):

Name of the ITKs' (title) and description of the ITK with respect to the parameter of climate change with which it is linked:

a) Diverse catch of small pelagics with decreasing salinity/increasing rainfall
b) Wind blowing from north-east direction favors tuna catch
c) Change in water color coupled with decreasing transparency caused by upwelling results in more catch of small and large pelagics
d) Unidirectional flow of surface currents and wind leads to good pelagic catch

Table: Climate change parameters ranked as 1st, 2nd, 3rd and 4th by majority of respondents in the traditional sector.

Parameter/Rank	Temperature (%)	Sea Level rise (%)	Wind Direction/Speed (%)	Rainfall (%)	Others (%)
1st	37.7	0.8	39.3	22.1	0.1
2nd	18.9	3.3	44.3	32	1.5
3rd	33.6	11.5	13.9	36.1	4.9
4th	9	57.4	2.5	9.8	21.3

Motorised sector (Number of respondents: 86):

Name of the ITKs' (title) and description of the ITK with respect to the parameter of climate change with which it is linked:

a) Decreasing temperature, moderate sea state and north-east wind favors tuna catch in the months from October - February

b) Change in water color coupled with decreasing transparency caused by upwelling results in more catch of small and large pelagics
c) Unidirectional flow of surface currents and wind leads to good pelagic catch

Table: Climate change parameters ranked as 1st, 2nd, 3rd and 4th by majority of respondents in the motorised sector.

Parameter/Rank	Temperature (%)	Sea Level rise (%)	Wind Direction/Speed (%)	Rainfall (%)	Others (%)
1st	23.3	2.3	47.7	26.7	
2nd	31.4	7	32.6	29.1	
3rd	32.6	18.6	15.1	30.2	3.5
4th	11.6	59.3	4.7	12.8	11.6

Mechanised sector (Number of respondents: 93):

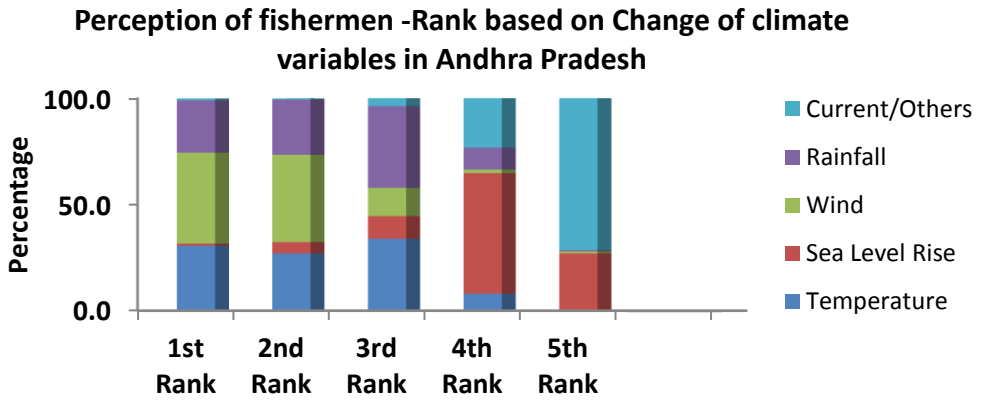
Name of the ITKs' (title) and description of the ITK with respect to the parameter of climate change with which it is linked:

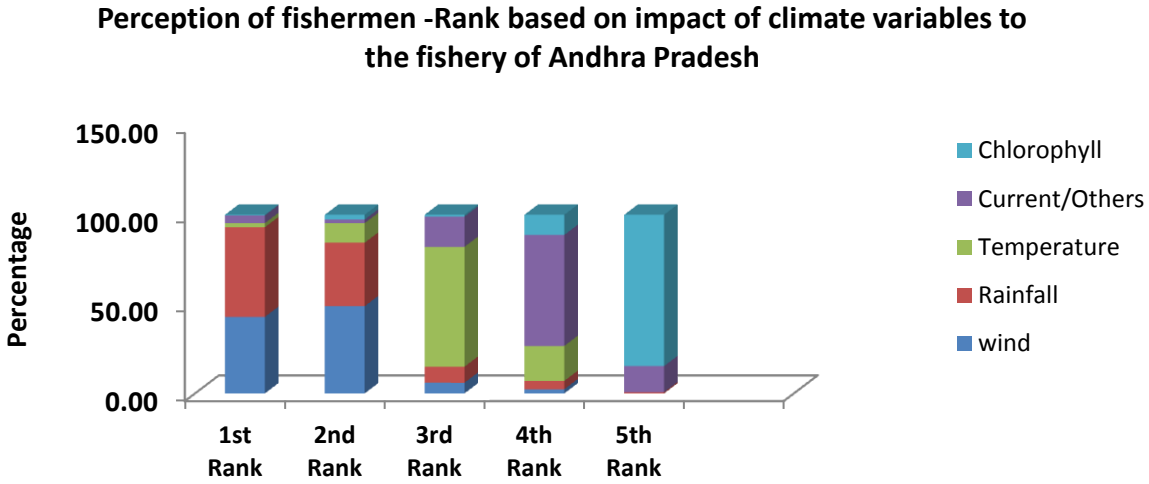
a) Increase in catch of crustacean and cephalopod resources with increase in temperature
b) Qualitative and quantitative increase in catch of demersal resources with increasing rainfall/decreasing salinity
c) Inadvertent intrusion of jelly fishes into the coastal waters during summer months resulting in reduced catch rates of commercially important marine fin and shell fishes
d) High current flow in postmonsoon months reduces the operational efficiency of trawlnets

Table: Climate change parameters ranked as 1st, 2nd, 3rd and 4th by majority of respondents in the mechanised sector.

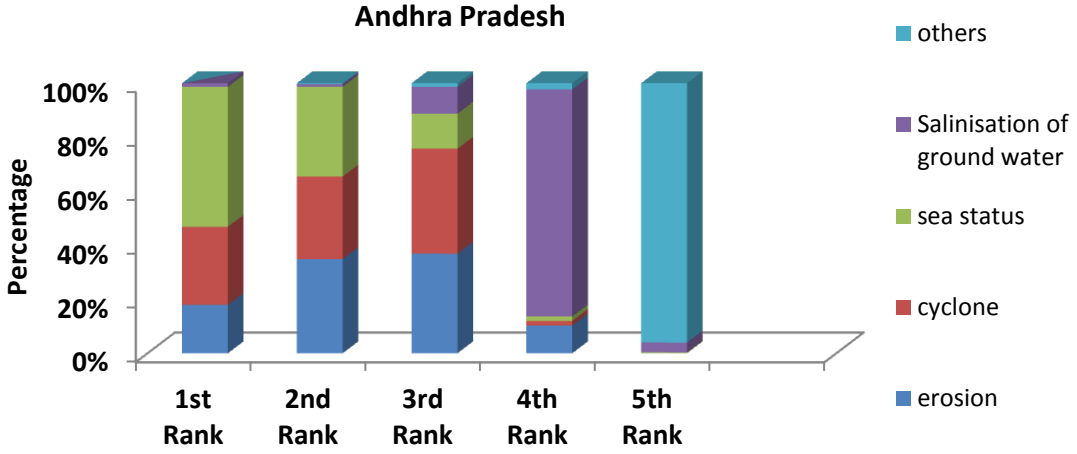
Parameter/Rank	Temperature (%)	Sea Level rise (%)	Wind Direction/Speed (%)	Rainfall (%)	Others (%)

1st	28		43	25.8	3.2
2nd	33.3	6.5	45.2	15.1	
3rd	35.5	2.2	10.8	49.5	2
4th	3.2	53.8	1.1	7.5	34.4

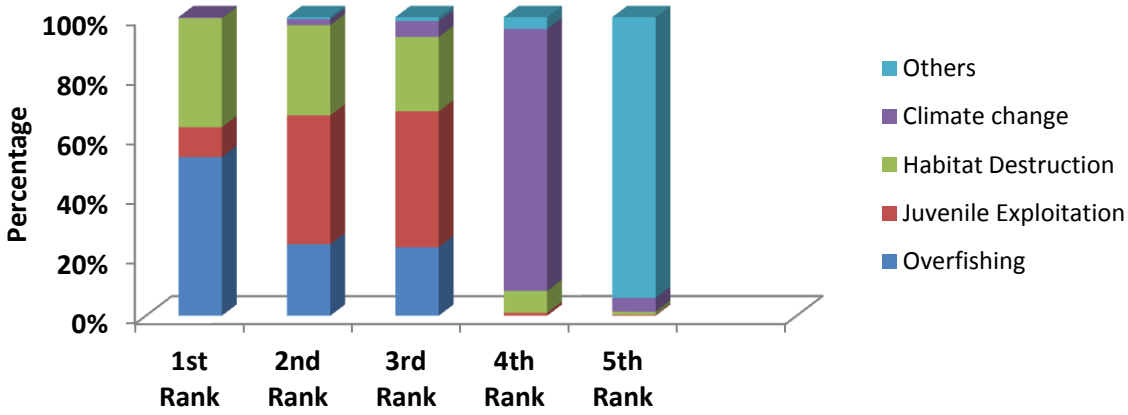




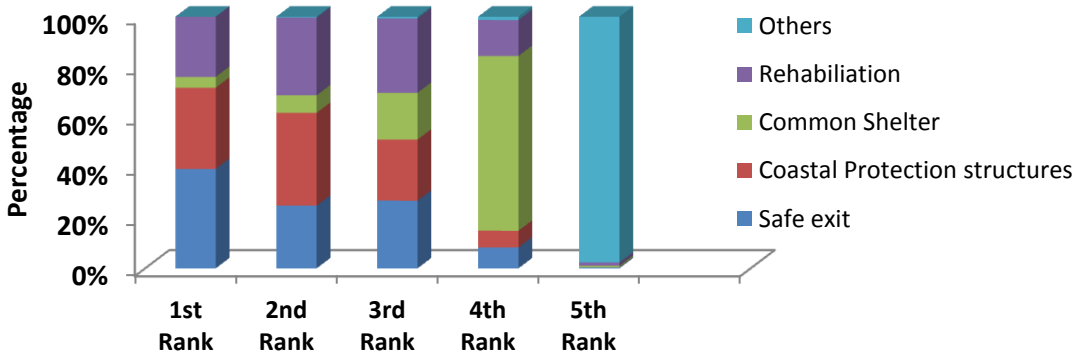
Ranks based on Problems faced by fishermen in the last 20 years in Andhra Pradesh

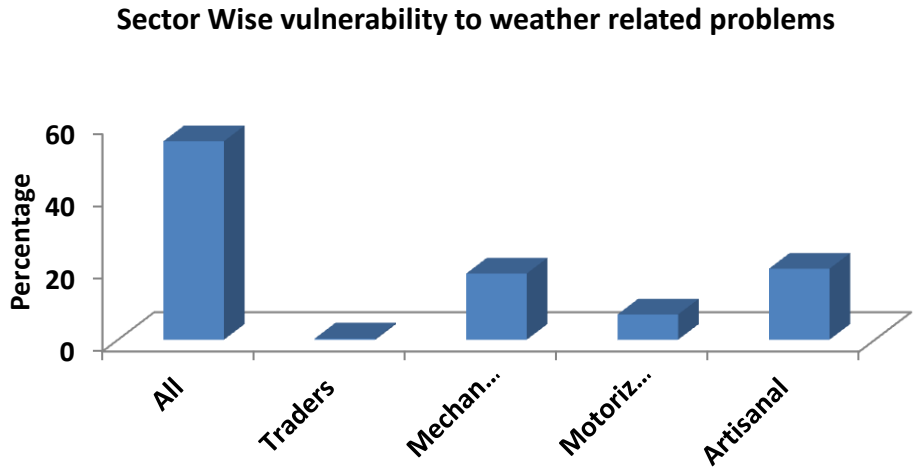


Ranks based on Problems faced in fisheries sector of Andhra Pradesh



Ranks given on Adaptation options suggestions by the fishermen





7.6% of the respondents are prepared to take weather related insurance without external support.

98% of the respondents read or watch newspapers, radio, TV and other bulletins.

69.8% of the respondents are of the opinion that there is increase/change in disease occurrence among fishermen in the last 20 years.

73.8% of the respondents are of the opinion that there is change in the type and quantity of fish availability in recent years.

62.1% of the respondents are able to predict weather from climatic/oceanographic conditions.

60.5% of the respondents are able to predict fish catch from climatic/oceanographic conditions.

West Bengal: Mechanised sector (Number of respondents: 137):

Name of the ITKs' (title) and description of the ITK with respect to the parameter of climate change with which it is linked:

a) Increase in catch of clupeids and mackerel with increase in temperature
b) Diverse catch of clupeids with decreasing salinity/increasing rainfall

Table: Climate change parameters ranked as 1st, 2nd, 3rd and 4th by majority of respondents in the mechanised sector.

Parameter/ Rank	Temperature (%)	Salinity (%)	Sea Level Rise (%)	Coastal upwelling (%)	Wind Direction /Speed (%)	Rainfall (%)
1st	97.1			2.9		

2nd			19.7	9.5	48.9	21.9
3rd			8.8	62.7	24.1	4.4
4th	0.7	3.7	2.9	13.1	26.3	53.3

Frequent cyclonic storm (99%) is the other major problem affecting the fisherfolk of west Bengal.

There are of the opinion that coastal protection structures are a must to counter the effect of cyclones.

Orissa: Mechanised sector (Number of respondents: 183):

Name of the ITKs' (title) and description of the ITK with respect to the parameter of climate change with which it is linked:

a) Increase in catch of clupeids and mackerel with increase in temperature
b) Diverse catch of clupeids with decreasing salinity/increasing rainfall
c) Qualitative and quantitative increase in catch of demersal and crustacean resources with increasing rainfall/decreasing salinity and with extremities of temperature

Table: Climate change parameters ranked as 1st, 2nd, 3rd and 4th by majority of respondents in the mechanised sector.

Parameter/Rank	Temperature (%)	Sea Level rise (%)	Wind Direction/Speed (%)	Rainfall (%)	Others (%)
1st	47.5	19.1	23	10.4	
2nd	25.1	7.1	19.1	48.7	
3rd	13.1	34.4	23.5	27.3	1.7
4th	14.2	12.6	29	13.6	30.6

Unlike in West Bengal where cyclone is a major problem, in Orissa sea state (53%) appears to be other major problem.

49% were of the opinion that marine ecosystem is seriously threatened by habitat destruction.

Mariculture

An experiment was conducted to assess the growth and multiplication of marine phytoplankton *Nannochloropsis sp*. in relation to different temperatures. Since the average temperature in the hatchery tank was 28^{o}C, the experiments were conducted in the temperature range of 28 to 32 ^{0}C. The

temperature difference between the treatments was 1^{o}C. The experiment was carried out in 20 liter pet jars. Pet jars were washed with salt and dried before use. After drying, pet jars were filled with 18 liter filtered and UV treated water. A thermo stable heater with auto cut was fixed in the jar to control the required temperature. F/2 medium was added at required quantity before adding the inoculums (*Nannochloropsis sp*.). *Nannochloropsis sp* was added in the jars as inoculums at concentration of approximately 0.85 million per ml. The initial stocking density of algae was counted from all the treatment jars. The algal density in each jar was counted daily at morning 10.00 hrs.

The algal count was significantly similar on the first day of culture at all the cultured temperatures, since the inoculums were added from the same stock of algae. A significant difference at 5% level in growth and density of algae occurred from fourth day onwards. On day four of culture, the highest algal count was found at 29^{o}C and the lowest at 32^{o}C. The algal biomass crashed on the fifth day in culture tank which was maintained at 32^{o}C. During the culture period of seven days, a significantly higher growth and multiplication of phytoplankton was found in the culture which was maintained on 29^{o}C.

Temperature (°C)	*Nannochloropsis* sp. count (million/ml)						
	Day1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
28	0.85 ± 0.005	1.27 ± 0.23	1.60 ± 0.25	1.99^{ab} ± 0.09	2.77 ± 0.37	2.85^{b} ± 0.05	3.49^{b} ± 0.04
29	0.85 ± 0.00	1.40 ± 0.01	1.60 ± 0.25	2.07^{a} ± 0.13	3.15 ± 0.05	3.67^{a} ± 0.17	5.47^{a} ± 0.27
30	0.85 ± 0.005	1.55 ± 0.25	1.55 ± 0.07	1.70^{bc} ± 0.05	2.43 ± 0.07	3.00^{b} ± 0.05	4.27^{b} ± 0.32
31	0.85 ± 0.001	1.71 ± 0.14	1.41 ± 0.06	1.90^{ab} ± 0.01	2.70 ± 0.01	2.89^{b} ± 0.01	4.35^{b} ± 0.21
32	0.86 ± 0.001	1.60 ± 0.01	1.60 ± 0.05	1.60^{c} ± 0.05	crashed	----	---

a, b, c - Values with different superscripts in each column are significantly different at 5% level

In situ monitoring of marine environment

Sea water samples were collected twice a month for assessing water quality from the surface and bottom of 5 m, 10 m, 20 m and 30 m depth. Sampling dates were fixed in accordance to the lunar cycles.

The mean sea surface temperature values recorded for the four stations from which water samples are collected was 28.32°C.

Water temperatures were higher during Quarter 2 (April – June) for the surface waters, which are the summer months and during quarter 3 (July – Sept) for the bottom waters.

Minimum water temperatures were recorded during Quarter 4(Oct – Dec) for the surface waters, which are the winter months and during quarter 1(Jan – March) for the bottom waters.

The mean value of salinity for surface waters was 30.42 ppt.

The salinity values were higher during Quarter 2 and lower during quarter 4 for both the surface and bottom waters. This corroborates with the increase in the mean sea surface temperatures during summer months. Maximum salinity of 34.50 ppt was recorded during quarter 2, which decreased to a minimum of 23 – 25 ppt during quarter 4.

Chlorophyll values collected from all the four stations were plotted and compared with data from 2007 – 2010. The peak values were found during the 3rd quarter of 2011, which are in full agreement with previous years. Chlorophyll values were higher for the surface waters than for bottom waters. In surface waters, it was higher for near shore waters than for deep waters. This can be attributed to the influx of nutrients from land runoff.

Life Cycle Assessment

Carbon emitted per kg of fish caught at Visakhapatnam was 0.39 kg. Carbon dioxide emitted per kg of fish caught at Visakhapatnam was 1.43 kg.

The contribution of marine fisheries at Visakhapatnam, Nizamapatnam and Machilipatnam at all stages of its life cycle to climate change was studied by determining their carbon footprints. Pre-harvest phase consisted of vessel construction and maintenance and provision of fishing gear, harvest phase included harvest from mechanized and motorized crafts and post-harvest phase involved fish transportation and fish processing. The functional unit selected was 1 kg of marine fish to the consumer.

Visakhapatnam: Fuel and electricity consumption was 0.48 l / kg and 0.255 kWh/ kg of marine fish. The C and CO_2 emitted were 0.382 kg C / kg and 1.404 kg CO_2 / kg.

Nizamapatnam: Fuel and electricity consumption was 0.52 l / kg and 0.26 kWh/ kg of marine fish. The C and CO_2 emitted per kg were 0.408 kg C and 1.501 kg.

Machilipatnam: Fuel and electricity consumption was 0.48 l / kg and 0.21 kWh/ kg of marine fish. The C and CO_2 emitted per kg were 0.374 kg C and 1.374 kg CO_2.

The highest consumption and the highest emissions were observed from the harvest phase. The fuel and electricity consumption and C and CO_2 emissions were high for mechanized landings and low for motorized landings.

Under National Initiative on Climate Resilient Agriculture (NICRA) project Integrated District Level Adaptations and Mitigations (IDLAM) survey was conducted for 1500 households from 15 villages of Krishna District of Andhra Pradesh by interviewing fishermen to determine their perception on climate change.

Satellite Telemetry studies on migration patterns of tunas in the Indian seas

Initially targeted cruise were made to find out the suitability of Catamaran for tagging purpose and to find the survival status of tuna when kept onboard for longer time. Frequent meetings with fishermen

for finding out the regular status of tuna fishery along Visakhapatnam coast.Seawater collected from the tuna tagging sites was analyzed.

Successful Tagging of Yellow fin Tuna was done in the first year at Visakhapatnam and Lakshadweep coast. Yellowfin tunas were tagged in the second year using pop-up satellite tags off Visakhapatnam, Lakshadweep and Mangalore. Preliminary results emanating out suggests that the species movement is restricted to Indian waters but they undergo huge vertical dives frequently.

Development of library of putative probionts of the genus *Bacillus, Pseudomonas* and *Micrococcus* for use in mariculture systems

Twenty eight strains isolated from sediment, seaweeds and fish gut samples exhibited clear zone of inhibition > 10 mm diameter against *Vibrio alginolyticus* in the double layer method and against *Vibrio alginolyticus* and *Vibrio anguillarum* in the cross streak method. The biochemical tests were performed and these strains were found to belong to genera *Bacillus*, *Vibrio*, *Aeromonas*, *Pseudomonas* and *Micrococcus*.

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Stock Characterization, Captive Breeding, Seed Production and Culture of Hilsa (*Tenualosa ilisha*)

Two cages of 6 m diameter and 4 m depth were fabricated and launched at Sagar Island and Barrackpore to study grow-out of hilsa.

Two small cages (2 m dia) was installed, one at Barrackpore and other at Sagar Island and stocked with 6-7 mm fingerlings to examine the survivability of hilsa in cages.

Two cages of 6 m diameter and 4 m depth were launched at Sagar Island and Barrackpore to study grow-out of hilsa in different salinity regimes. The cage launched at Sagar Island used single-point mooring system, wherein the cage was allowed to rotate around the mooring system. The cage launched at Barrackpore used fix mooring system, wherein the cage was fixed at both the ends with

chains and concrete blocks. Two small cages (2 m dia) was installed at Barrackpore and Sagar Island and stocked with 6-7 mm fingerlings to examine the survivability of hilsa in cages. However stocked hilsa did not survived for more than 24 hrs.

Consultancy Projects

Study on the use of fly ash for the manufacture of artificial reefs (Reel Balls)

Miniature models of artificial reefs were designed and constructed with inclusion of different levels of replacement of Cement with Fly Ash. Three different designs of artificial reef modules were constructed using different concentrations of fly ash and their suitability tested under laboratory conditions. Designed Reefs were kept in one t tanks with vigorously aerated seawater to study the leaching of minerals and metals under lab condition and attachment of microflora and algae will also be studied. All water quality parameters were analyzed. Minerals and metals leaching was studied by collecting water and analyzed by outsourcing the samples. Leaching of Zinc, Sulphur and Magnesium into sea water occurred. The fly ash modules were found to be stable to immersion in sea water. Detailed final report was prepared and submitted to NTPC.

Installation of artificial reef at a selected site off Visakhapatnam, Andhra Pradesh Client: NTPC – Simhadri Thermal Power plant, Visakhapatnam, Andhra Pradesh and Dist Admn (Dept of Fisheries)

Site selection was performed along the near shore waters off the coast of Visakhapatnam.

Sensitization of fishermen of the selected site (Muthyalmmapalem) was done regarding artificial reef and its benefits.

Collection of baseline data on socio-economic status of the fishermen community of the selected fishing village was achieved through bench mark survey.