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Sardines of the Gulf of Mannar ecosystem - fishery and resource characteristics of major species

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ABSTRACT

Fishery, species diversity and resource characteristics of exploited sardine resources of the genera S*ardinella* were studied during 2000-2008. Sardines were exploited by sardine gillnets, trawls and shore seine. Annual average production for the period was 20,249 t. They formed about one fourth of the total marine fish production (77,443 t) of the region. Fishery was supported by eight species dominated by *Sardinella gibbosa,* followed by *S. sirm, S. albella* and *S. longiceps*. Fishery fluctuated widely with declining trend over the years mainly due to reduction in the fishing effort following destruction of traditional crafts and gears during the Tsunami in 2004. Oilsardine in the fishery registered an increasing trend with wide annual fluctuation during the period. Stock assessment studies show that the exploitation rate of major species ranged between 0.45 and 0.62, against the E_{MSY} value of 0.72 and 0.86. This indicated that sardine resource as a whole is under-exploited, offering considerable scope for enhancing their yield. Despite contributing a higher share to marine fish production, sardines, along with other small pelagics, play a vital ecological role in sustaining the stock and fishery of other predatory groups especially large pelagics by providing them a major share of their forage. They support 46 to 87% of the total food of pelagic predators and 14 to 29% of demersal predators.

Keywords: Fishery, Gulf of Mannar coast, Resource characteristics, Sardines, *Sardinella*

Introduction

Sardines from the largest fishery resource of Indian coastal waters in terms of biomass. Owing to the lowest position in the food web, they play a vital role in the ecosystem. They occupy a position just above the primary producers and graze on them for their energy needs and support a variety of predatory resource by offering themselves as forage. Any fluctuation in their abundance may have its direct reflection in the ecosystem. Any fishery management program of a sardine dominant ecosystem needs to take care of the ecological interactions existing in the ecosystem. For this, thorough knowledge on the dynamics of component species is an essential pre-requisite.

Considerable scientific work has been carried out and database has been developed on the fishery and biology of oilsardines from the west coast of India. But contribution to the oilsardine database from the east coast is limited. Compared to oilsardine, work in the same line for lesser sardines is mainly from the east coast (Annigeri, 1987; 1989; Lazarus, 1980, 1987; 1990; Sam Bennet *et. al.*, 1992; Sekharan, 1971a,b,c). However, recent contributions from the region to the sardine database are very limited. In order to fill this vacuum, fishery and biology of all dominant species were studied during 2000-2008.

Materials and methods

Regular weekly observations were made at four landing centres *viz.*, Threspuram (Tuticorin North) and Punnakkayal landing centre for gillnet fishery, Tuticorin Fishing Harbour for trawls and Major Harbour landing centre for shore seines during 2000-2008. Magnitude of exploitation was assessed by field observation and from the data collected by the Fishery Resource Assessment Division (FRAD) of the Central Marine Fisheries Research Institute. Species diversity of the resource was monitored and biology of four dominant species (which form 98.4% of the catch) was studied. Biology of *Sardinella gibbosa* was studied during 2000-2008 and other species during 2004 and 2008. Reproductive and feeding biology of 4,223 specimens of *Sardinella gibbosa,* 408 of *S. sirm,* 912 of *S. albella* and 624 of S. *longiceps* were studied. Growth and mortality parameters were estimated from monthly length frequency data following Ford-Walford plot (Ford, 1933; Walford, 1946) and by ICLARM's FiSAT software (Gayanilo *et al.,* 1997). Length measurements of 25,086 specimens of *S. gibbosa,* 14,136 *S. sirm,* 3,841 *S. albella* and 6,612 *S. longiceps* were used for length frequency estimates. Age at zero length (t_o) was estimated as in Bertalanffy (1934) and size at first capture (Lc) as in Pauly (1984). Natural mortality (M) was estimated using Pauly's empirical formula (Pauly, 1980), using 29 °C as the mean sea surface temperature. Total mortality (Z) and exploitation rate (E) were estimated from the catch curve as in Pauly (1983).

Total stock (P) during different years were computed from the relation; P = Y/U; where, Y is the yield in tonnes and U the exploitation rate. Stock and biomass were computed using length cohort analysis. E_{MSY} and maximum sustainable yield (MSY) was estimated folloing graphical method as per Corten (1974). A study was also carried out during 2005-2008 to assess the ecological interactions of different biotic and abiotic components in the ecosystem.

Results and discussion

Fishery

Sardines are targeted along the coast by sardine gillnet (mesh size: 20 to 35 mm) and shore seine. In trawls, they were caught as by-catch. About 87.4 % of the catch was by gillnets and the rest by shore seines (5.2%) and trawls (7.4%). Fishery showed wide inter-annual fluctuation during the period, with marginal declining trend. Sardine catch varied between 16,941 t (2004-'05) and 24,025 t (2007-'08) during the period (Table 1) and formed 25.8% of the total marine fish production. Fishery occurred round the year with main peak during December-March and a small peak during July-August. Catch rate in different gears also varied widely. It was 43.5 kg unit^{-1} effort in sardine gillnets, 175.2 kg in shore seines and 3.7 kg in trawls.

Fishery was supported by eight species and dominated by *S. gibbosa* (35.9%), *S. sirm* (25.8%), *S. albella* (18.8%) and *S. longiceps* (17.9%). Other species in the catch were *S. dayii, S. clupeoides, S. fimbriata* and *S. melanura,* which together formed 1.6%. Catch in gillnet was dominated by *S. gibbosa* and *S. sirm;* in shoreseine by *S. albella* and *S. longiceps* and in trawls by *S. gibbosa.* Production of oilsardine tends to increase during this period with wide annual fluctuation. Catch increased from 500 t in 2000 to 1,850 t in 2006. Since there was no demand for oilsardines along the region till early nineties, fishermen used to avoid oilsardine shoals whenever they came across. But the trend changed during the period under study and the demand for oilsardine aroused from different quarters, which resulted in their increased harvest.

Size composition of species and growth

Shoreseines which operate in nearshore waters within 5 m depth zone exploit mainly juveniles of all species. Size composition of sardines in gillnets which operate beyond 10 m and trawls that operate beyond 25 m depth zone showed no significant variation. *S. gibbosa* in the fishery was supported by 65-195 mm with modes at 120-125, 140-145 and 160-165 mm and mean at 138 mm. Major share of the catch was by 115-150 mm fishes. Multi-modal population of 60-180 mm size with 134.7 mm as mean and 130-135 mm as the major mode supported *S. albella* fishery. Major share of the catch was by 125-150 mm fishes. Fishery of *S. sirm* was also constituted by multi-modal population of 100-235 mm size with 169 mm as mean and 165-170 mm as major modes. Major share of the species catch was by 160-190 mm fishes. Fishery of *S. longiceps* was by uni-modal population of 105-225 mm size with 130-135 mm as mode and 140 mm as mean. Major share of the catch comprised small fishes of 125-155 mm size.

Size at capture of sardines (at 50% level) in gillnet estimated were 11.1 cm for *S. gibbosa,* 12.1 cm for *S. longiceps,* 14 cm for *S. sirm* and 12.1 cm for *S. albella.*

Juvenile component of sardine in the catch was only in lower proportion for all species. Catch of *S. longiceps* and *S. albella* in shore seine was constituted mainly by juvenile and sub-adults. Juveniles of *S. gibbosa* and *S. sirm* formed part of the catch in gillnets and trawls. On an average for the region, juveniles of *S. gibbosa* form 5.6% in number and 2.4% in weight of the species catch. It was respectively

Table 1. Gear-wise sardine and total fish production from the Gulf of Mannar coast (in kg) during 2000-2008.

Period	Sardine gillnet	Shore seine	Trawl	Total sardine	Total fish
2000-01	18169037	729690	1503616	20402343	70473296
2001-02	21982552	858609	999821	23840982	77524667
2002-03	18129837	1432690	956044	20518571	70030181
2003-04	17088954	1680696	1453767	20223418	90986718
2004-05	13180266	1156092	2604830	16941188	75393861
2005-06	16100000	893000	1035000	18028000	71467000
2006-07	16321000	941000	750000	18012000	69798000
2007-08	20673000	627000	2725000	24025000	93867000
Mean	17705581	1039847	1503510	20248938	77442590

12.6 and 6.2% of the catch of *S. longiceps,* 8.3 and 3.4% of *S.sirm* and 17.4 and 6.9% of *S. albella.* Though juveniles occur in the catch round the year, major share (84 to 96 %) was landed during February-June by shoreseines and during April –June/July by sardine gillnets and trawls.

Growth parameters of the species were estimated from the pooled length frequency data and it can be depicted using the von-Bertalanffy growth equation:

$L_t = L_\alpha [1- e^{-k(t-t_o)}]$.

The growth equations for different species were as follows:

S. gibbosa : $Lt = 19.37 [1- e^{-1.82(t-0.0012)}]$.
S. longiceps : $Lt = 23.16 [1- e^{-1.55(t-0.09)}]$.
S. sirm : $Lt = 24.31 [1- e^{-2.1(t-0.093)}]$.
S. albella : $Lt = 20.8 [1- e^{-1.1(t-0.0072)}]$.

The above estimates of growth parameters are well within the range of earlier estimates from the same and other areas for different species (Sekharan, 1971c; Lazarus, 1987; Annigeri, 1989 and Sam Bennet *et.al.,* 1992).

Length-weight relationship

Length-weight relationship of the species were estimated and is depicted below in the format as:

Log W = Log a + b Log L

S. gibbosa : Log W = Log 0.0075 + 2.899 Log L
S. longiceps : Log W = Log 0.0126 + 2.903 Log L
S. sirm : Log W = Log 0.0038 + 3.207 Log L
S. albella : Log W = Log 0.0094 + 2.868 Log L

Present estimates are comparable and show no significant difference from the earlier estimates of Sekharan (1971c) for the respective species from different regions.

Maturity, spawning and recruitment

Maturity processes in four species were studied and size at first maturity was estimated using probability curves. Sardines attained sexual maturity and spawned along the coast during the first year itself. *S. gibbosa* attain sexual maturity at 13.3 cm size (TL), *S. longiceps* at 15.0 cm, *S. sirm* at 16 cm and *S. albella* at 10.5 cm. Presence of mature and spent fishes indicated that all four species spawn round the year with peak during December-March (Table 2). A second small peak in spawning occurs during June-July for *S.gibbosa* and *S. sirm,* during August for *S. albella* and July-August for *S. longiceps*. Both peaks in spawning coincide with the peak fishing season of species, indicating that they were being caught in the spawning grounds during spawning congregation.

Fecundity estimates show relatively high fecundity for the species studied. Average fecundity of *S. gibbosa* was 8,535 eggs per fish of 16.8 cm average size. It was 58,950 per fish of 18.8 cm for *S. longiceps*, 48,427 per fish of 20.4 cm for *S. sirm* and 12,329 per fish of 14.2 cm for *S. albella.*

Juveniles are recruited to the fishery one to two months after spawning. *S. longiceps* and *S. albella* enter shoreseine fishery in large numbers by February and *S. gibbosa* and *S. sirm* in gillnet and trawl fishery by April. The size at recruitment was 60 mm for *S. gibbosa,* 65 mm for *S. albella,* 100 mm for *S. sirm* and 105 mm for *S. longiceps.*

Mortality and exploitation rate

Removal or mortality of the stock from the ecosystem is through fishing and natural causes. Mortality rate due to different causes are depicted in Table 3. Major loss of stock is due to fishing in *S. gibbosa, S. albella* and *S. longiceps* and it was due to natural causes in *S. sirm*. These estimates

Table 2. Average occurrence (%) of sardines with gravid and spent ovary during different months.

Species / Months	*S. gibbosa*		*S. sirm*		*S. albella*		*S. longiceps*	
	Gravid	Spent	Gravid	Spent	Gravid	Spent	Gravid	Spent
January	50.2	39.7	24.2	56.7	50.1	45.3	49.5	29.8
February	64.4	34.0	23.4	73.6	46.8	34.5	38.6	33.4
March	66.7	7.3	48.6	33.3	52.3	22.6	-	-
April	41.5	12.5	37.2	20.5	-	-	16.4	9.8
May	25.7	3.8	27.8	0.0	28.4	12.5	22.2	7.3
June	38.4	22.2	48.4	17.6	27.6	3.8	-	-
July	36.5	14.6	-	-	-	-	36.7	12.4
August	79.5	1.6	68.4	6.8	36.8	42.6	42.7	36.4
September	67.3	2.8	58.6	10.4	42.4	6.4	38.6	2.5
October	83.7	11.2	63.2	8.6	58.6	5.6	51.0	11.3
November	62.3	21.9	68.7	18.2	50.4	18.3	52.6	7.6
December	49.8	46.2	50.9	49.1	49.6	29.8	42.3	21.4

Table 3. Estimates of mortality and exploitation parameters (mean) of sardines during 2000-2008

Species	Fishing mortality (F)	Natural mortality (M)	Total mortality (Z)	Exploitation rate (E)	Exploitation max (E_{MSY})
S.gibbosa	4.91	3.06	7.97	0.62	0.86
S. longiceps	5.01	2.64	7.65	0.65	0.78
S. sirm	2.6	3.23	5.83	0.45	0.72
S. albella	3.06	2.19	5.25	0.58	0.79

show that the resources are subjected to considerable fishing pressure. But exploitation rates remain lower than E_{MSY} in all species indicating that they remain under exploited from the present fishing grounds and still have scope for increasing the production. Relatively high values of E_{MSY} close to '1' indicate the possibility that resource can sustain heavy fishing pressure.

Mortality and other stock parameters differed considerably from the earlier estimates (Annigeri, 1989 and Sam Bennet *et al*., 1992). This can be attributed to the present pattern and rate of exploitation of the resource, as compared to the earlier situation.

Stock, biomass and sustainable yield

Estimates of stock, biomass and potential yield of the species were estimated and results are given in Table 4. Potential yield (MSY) estimates were much higher and is very close to total stock. Present yield is much lower than the potential yield indicating possibility for further increase in production. Resource supports a large biomass comprising of small fishes with relatively short life span. All major species mature and spawn during the first year itself with year round spawning activity. These together with high fecundity of the member species ensure continuous recruitment to replace the stock which succumb to fishing and natural causes. These biological characteristics of the resource further justify the high values obtained for E_{MSY} and as well as potential yield.

Table 4. Estimates of yield, stock, biomass and potential yield (MSY) (mean) of sardines during 2000-2008.

Species	Present yield (t)	Total stock(t)	Standing stock biomass (t)	Spawning stock biomass (t)	MSY (t)	Level of exploitation
S. gibbosa	7,269	11,724	7,964	4,030	10,082	Under-exploited
S. longiceps	3,624	5,575	2,821	1,562	4,348	Under-exploited
S. sirm	5,224	11,608	2,030	870	8,357	Under-exploited
S. albella	3,806	7,055	3,097	2,947	5,573	Under-exploited

Sardines in the food web of Gulf of Mannar

Sardines are omnivores in feeding habit, with diatoms as the major food item. Other components of their food are detritus, copepods as well as eggs and larvae of a variety of marine organisms. Though some differences were observed in the food component of species, statistical tests show no significant variation between species. Food and feeding of lesser sardines were provided by earlier workers from south-east (Sekharan, 1971a) and south-west coast (Lazarus, 1980). Feeding habits and basic gut content of lesser sardine shows no significant variations from earlier reports. However the diatom, *Fragillaria oceanica,* which form major food of *S. longiceps,* along the south-west coast is totally absent in the gut of specimens collected from the present study area.

Being the lower most nektonic component of food pyramid positioned just above the primary producers, sardines mainly convert the primary production into animal protein. Hence, sardines are considered as an important component of food web particularly as forage for other species at different levels of food pyramid (Table 5). A tropho-dynamic study show that sardines alone form 20.5% of the food of large pelagic carnivores, 12.1% of medium pelagic carnivores, 3% of small pelagic carnivores and 6.9 % of large benthic carnivores.

Catch and catch rate of sardines from the Gulf of Mannar ecosystem registered marginal declining trend during the post-tsunami period and is attributed to reduction in effort owing to the destruction of a large proportion of traditional crafts and gears in tsunami. Revival of fishery with the re-introduction of lost crafts and gears to the pre-tsunami level, production reached a level above pre-tsunami yield (24,025 t) in 2007-'08.

Fishery was supported mainly by zero year groups with their size at first capture much smaller than the size at maturity. However, since species attain sexual maturity during the first year itself and spawn round the year, part of the stock caught might have spawned before being caught. Present study on spawning biology further indicates

Table 5. Major ecological groups and their relative dependence on sardines and other forage groups in the Gulf of Mannar ecosystem

Forage group \ Ecological group	LPC	MPC	LBC	MBC	SBC	SPC	PH
Sardines	20.5	12.1	6.9	1.0	0.8	3.0	0.0
Other clupeids	33.7	64.9	9.3	10.0	13.3	39.4	1.0
Other pelagics	16.8	10.0	13.1	3.5	0.0	4.1	0.0
Other fishes	6.5	3.9	20.1	12.9	14.4	9.1	0.0
Crustaceans	15.1	5.3	31.6	68.8	68.8	30.1	42.1
Molluscs	6.3	3.8	19.0	3.8	1.6	1.4	0.5
Detritus and others	0.0	0.0	0.0	0.0	1.1	12.9	56.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

LPC- large pelagic carnivores, MPC- medium pelagic carnivores, SPC- small pelagic carnivores
LBC- large benthic carnivores, MBC- medium benthic carnivores, SBC- small benthic carnivores, PH - pelagic herbivores

that an individual fish may spawn more than once in a year. Exploitation rate indicates that about 35 to 55% of the stock of different species escapes fishing. Successful spawning by the escaped stock alone is sufficient to maintain the stock at the sustainable level. Present findings suggested no stress on the spawning stock and recruitment.

Exploitation rate over the years indicated that the resource remain under exploited during the period. As indicated by the $E_{MSY,}$ the production can be increased by increasing the effort input with constant monitoring of the stock and fishery. Sardine gillnet was found to be most ideal for exploitation of sardines as they exploit mainly adults. Therefore, increased effort input by this gear may be encouraged. Though trawls also exploit mainly adults, further increase in trawl effort may not be healthy for other co-existing resources.

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