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Fishery, reproductive biology and stock status of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817), landed along the north-east coast of India

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ABSTRACT

The fishery, biology and stock status of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1817), landed along the north-east coast was studied during 2011-2014. The average annual catch was 52,206 t. Catch was more or less equally contributed by trawlers, gillnetters and seiners with average catch rates of 3.05 kg h^{-1}, 22.74 kg $unit^{-1}$ and 140.09 kg $unit^{-1}$ respectively. Catch was positively influenced by wind speed and negatively by sea surface temperature and precipitation. Growth in males was isometric, while it was allometric in females and indeterminates. Females outnumbered males in the commercial catches. Length at first maturity varied between 18.32 and 18.86 cm. Peak spawning season was during July - October and February - April. Relative fecundity was 567.51 ova per gram body weight. von Bertalanffy growth equation obtained was: $L_t = 27.72\ [1\text{-}e^{-1.2\ (t\ +\ 0.023)}]$. Length at first capture and life span estimated were 12.78 cm and 2.48 years respectively. Natural mortality, fishing mortality and total mortality were 2.06, 3.69 and 5.75, respectively with an exploitation rate of 0.64. Peak recruitment was found to be during September-October. Maximum sustainable yield and yield per recruit were 40,675 t and 14.74 g respectively which were obtained by increasing the present fishing effort by 20%, but at the increased fishing effort, the increase in yield was a meager 0.53%, which indicates that the present level of fishing can be continued.

Keywords: Biology, Fishery, North-east coast, *Rastrelliger kanagurta*, Stock status

Introduction

Fishery for mackerel along north-east coast of India comprising the coasts of West Bengal, Odisha and Andhra Pradesh, is contributed chiefly by the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817), with occasional occurrence of stray numbers of *Rastrelliger faughni*. *R. kanagurta*, a commercially important pelagic resource nationally, has emerged in recent decades as a dominant fishery along the north-east coast of the country. During the decade 2001-2010, the annual average landings of mackerel along the north-east coast was 22,709 t, an increase from 16,476 t during 1991-2000 and 11,645 t during 1985-1990 (Maheswarudu *et al*., 2013). Environmental parameters are known to influence the fishery of mackerel, often leading to wide seasonal and annual fluctuations in landings (Krishnakumar *et al*., 2008). Climate change induced progressive increase in sea surface temperature (SST) could have resulted in the northward extension of the distributional range of mackerel, leading to increased catches in the region. Mackerel is exploited by a variety of gears *viz*., trawlnets, gillnets and seines. The fish, being a planktivore, plays a pivotal role in the marine food chain by converting the primary and secondary production and by forming links to higher carnivores in coastal waters. Demand for mackerel as table-fish has been on the rise in this region and hence, the fishery forms an important source of livelihood for the vast majority of the fisherfolk. There have been exhaustive studies on the fishery and biology of mackerel from the west coast (Yohannan, 1979; 1982; Noble, 1986; Noble *et al*., 1992; Devaraj *et al*., 1994, Rohit *et al*., 1998). Studies from the east coast are mostly limited to the south-eastern region (Abdussamad *et al*., 2006; 2010), with a sole study by Luther (1995) on the fishery and resource characteristics of mackerel from Visakhapatnam. The present study was therefore undertaken, to assess the fishery, reproductive biology and stock status of Indian mackerel landed along the north-east coast.

Materials and methods

Data on catch of *R. kanagurta* and effort expended in all gears at various fish landing centres along the north-east coast for the period from January 2011 to December 2014 were obtained from Fishery Resource Assessment Division of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI), India. Mean values of SST, precipitation, wind speed and salinity for the region from 2011 to 2014 were obtained from International Comprehensive Ocean Atmospheric data Sets (ICOADS; http://www.esrl.noaa.gov/psd); of chlorophyll a, particulate organic carbon (POC) and particulate inorganic carbon (PIC) from GIOVANNI online data system of Goddard Earth Sciences Data and Information Services Center (GES DISC) of National Aeronautics and Space Administration (NASA; http://giovanni.gsfc.nasa.gov/giovanni) and of El-Nino Southern Oscillation (ENSO) from National Oceanic and Atmospheric Administration (NOAA http://www.esrl.noaa.gov/psd/enso/mei/table). Multiple stepwise regression analyses (linear fit) were performed to identify the oceanographic parameters that were significantly ($p<0.05$) correlated with mackerel catch rates. Only significant parameters were retained in the final model. Statistical analyses were carried out using SPSS ver. 16.0 software (SPSS Inc., Chicago.).

A total of 2,684 specimens of *R. kanagurta* in the size range of 7.5 to 26.0 cm were collected randomly from Digha and Paradeep in the northern region and Visakhapatnam and Kakinada in the southern region. Fork length (mm) and wet body weight (in grams to 0.01 g precision) were measured. Length - weight relationship was calculated as $W = aL^b$ (Le Cren, 1951) separately for both sexes and indeterminates and significant differences in the slopes of the regression lines for males, females and indeterminates were ascertained by ANACOVA (Snedecor and Cochran, 1967). Monthwise sex ratio was estimated and Chi-square test was performed to test the homogeneity of male and female distribution. Size at first maturity (L_{50}) was determined logistically by fitting the fraction of mature fish (stage III and above) against length interval using the procedure of King (1995). Spawning season was determined from the proportion of gravid and ripe females (V and VI) over months. Gonadosomatic index (GSI) for females was calculated using the formula: GSI = (weight of gonad x 100)/weight of fish. Ovary subsamples were obtained from the anterior, middle and the posterior regions of mature and ripe ovary (V and VI) and fecundity was estimated by raising the number of ova in all subsamples to the total ovary weight. Ova diameter distribution was studied under a microscope using calibrated ocular micrometer.

For estimating von Bertalanffy growth parameters L_∞ and K, the monthwise length composition data from the landings at Digha, Paradeep, Visakhapatnam and Kakinada for four years (2011-2014) were pooled and grouped with 1.0 cm class interval and analysed using the ELEFAN I module of FiSAT software version 1.2.0 (Gayanilo *et al*., 1995). Growth performance index (φ) and probability and size at first capture (L_c) were estimated as in Pauly and Munro (1984) and Pauly (1984). Age at zero length (t_0) was calculated from Pauly's (1979) empirical equation and growth and age were determined using the von Bertalanffy growth equation, $Lt = L_\infty (1 - e^{-k(t-t_0)})$. Length at recruitment (L_r) was taken as the midpoint of the smallest length group in the catch. Lifespan (t_{max}) was estimated at $3/K + t_0$ (Pauly, 1983a). Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980) and total mortality (Z) was calculated from length converted catch curve (Pauly, 1983b) using FiSAT software. Fishing mortality (F) was estimated as Z - M. Length structured virtual population analysis (VPA) of FiSAT was used to obtain fishing mortalities per length class. Exploitation rate (E) and exploitation ratio (U) were estimated as F/Z and F/Z $(1-e^{-z})$, respectively. Total stock (P) and biomass (B) were estimated from the ratios Y/U and Y/F respectively; where Y is the annual average yield in tonnes. Maximum sustainable yield (MSY) was calculated as in Gulland (1979) for exploited fish stocks. The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F was estimated from Beverton and Holt Yield per Recruit model using excel worksheet (Sparre, 1987).

Results

Fishery

The average annual catch of mackerel along north-east coast during 2011-2014 was 52,206 t. Annual catch exhibited a steady increase from an average of 41,842 t during 2011-2012 to 62,570 t during 2013-2014. Highest catch of 69,115 t was recorded in 2014. The catch was more or less equally shared by trawlers, gillnetters and seiners. Average catch rates in trawlers, gillnetters and seiners were 3.05 kg h^{-1}, 22.74 kg $unit^{-1}$ and 140.09 kg $unit^{-1}$ respectively. Catch rate in trawlers increased during the study period from 2.46 to 4.29 kg h^{-1}, in gillnetters from 13.11 to 26.11 kg $unit^{-1}$ and in seiners from 34.05 to 217.32 kg $unit^{-1}$. Two-third of the catch was contributed by the southern region (Andhra Pradesh) and the rest by the northern region (West Bengal and Odisha). Catch along the northern region was highly variable, with an annual average of 17,131 t. Spectacular increase in catches were observed in the southern region, wherein the catch has leaped from 22,379 t in 2011 to 55,813 t in 2014. Trawl was the dominant gear in the northern region, contributing 42% of the catch, whereas in the southern region, seines (37%) dominated followed by gillnets (34%) and trawls (28%). Catch rates in all gears were higher in the southern region (1.0 kg h^{-1} for trawls, 10.9 kg $unit^{-1}$ for gillnets and 17.7 kg $unit^{-1}$ for seines) as compared to the northern region (2.0 kg h^{-1} for trawls, 11.9 kg $unit^{-1}$ for gillnets and 122.4 kg $unit^{-1}$ for seines) (Table 1). Highest average catch of 6,369 t was recorded in February along the north-east coast. In general, catches were good during August-March. Higher catch rates in trawls were observed during December-January (4.7 kg h^{-1}), in gillnets during September (50 kg $unit^{-1}$) and in seines during June - July (320.8 kg $unit^{-1}$) (Table 2).

Of the different environmental parameters assumed to impact the fishery; wind speed, SST and precipitation were found to significantly ($p<0.05$) influence the mackerel catch rates. Catch rate in trawls and gillnets were positively influenced ($p<0.05$) by wind speed. Further, the catch rates in trawls were negatively influenced ($p<0.05$) by SST and in gillnets were negatively influenced ($p<0.05$) by precipitation (Table 3). Oceanographic parameter did not significantly influence ($p>0.05$) the catch rate in seines.

Length composition

There has been a gradual decrease in mean length of mackerel over the years along the north-east coast. Mean length of 194.2±4.8 mm observed in the southern region in 2011 decreased to 180.6±6.0 mm in 2014, and in northern region it decreased from 203.1±3.4 mm to 193.2±1.7 mm. Mean length, in general, was higher in the northern region ($p>0.05$). Highest mean length recorded was 213.7±8.1 mm during February in the southern region and 219.7±0.0 mm

Table 1. Annual mackerel landings along with catch rates in different gears along the north-east coast

Year	Northern region				Southern region			
	Total catch (t)	Trawl catch rate (kg h^{-1})	Gillnet catch rate (kg $unit^{-1}$)	Seine catch rate (kg $unit^{-1}$)	Total catch (t)	Trawl catch rate (kg h^{-1})	Gillnet catch rate (kg $unit^{-1}$)	Seine catch rate (kg $unit^{-1}$)
2011	20,729	0.2	5.3	9.8	22,379	2.27	7.8	24.2
2012	12,182	1.3	3.5	13.2	28,393	1.97	10.1	129.1
2013	22,311	1.0	26.6	20.2	33,713	1.23	11.6	146.4
2014	13,302	1.7	8.3	27.4	55,813	2.58	17.9	189.9
Average	17,131	1.0	10.9	17.7	35,074	2.01	11.9	122.4

Table 2. Average seasonal mackerel landings along with catch rates in gears along the north-east coast

Year	Northern region				Southern region			
	Avg. catch (t)	Trawl catch rate (kg h^{-1})	Gillnet catch rate (kg $unit^{-1}$)	Seine catch rate (kg $unit^{-1}$)	Avg. catch (t)	Trawl catch rate (kg h^{-1})	Gillnet catch rate (kg $unit^{-1}$)	Seine catch rate (kg $unit^{-1}$)
January	2735	2.4	8.4	10.9	2908	1.96	14.7	67.4
February	2116	0.8	11.0	11.8	4254	2.36	21.6	96.3
March	917	1.1	9.3	10.4	4604	2.14	17.7	131.9
April	570	1.7	5.9	7.6	1045	1.32	12.1	84.1
May	44		2.0	2.0	1031		8.1	179.8
June	352	1.2	5.6	6.8	3736	0.95	10.4	352.7
July	223	0.6	2.0	2.6	2673	1.52	6.3	279.6
August	719	0.7	4.5	5.2	4332	2.55	9.8	182.7
September	3235	1.2	37.2	38.4	2720	1.31	12.8	141.2
October	2214	2.6	15.5	18.1	1999	1.66	8.9	102.7
November	1637	1.3	9.8	11.2	2343	2.06	9.2	49.8
December	2370	1.9	4.8	6.6	3428	3.14	9.6	63.2

Table 3. Environmental parameters significantly impacting mackerel catch rates in gillnets and trawlnets

Model	Dependent variable	Parameters	Coefficients	p value	r^2
G1	Mackerel catch rate in gillnets	Wind Speed	0.070	0.038	0.090
G2		Wind Speed	0.107	0.002	0.267
		Precipitation	-0.159	0.002	
T1	Mackerel catch rate in trawlnets	Wind Speed	0.016	0.008	0.148
T 2		Wind Speed	0.019	0.001	0.321
		SST	-0.447	0.002	

during May in the northern region. In October, mean length observed in the southern region was significantly ($p<0.05$) lower, when compared to the northern region (Fig. 1).

Stock assessment of mackerel in the Indian seas. Length-weight relationship calculated separately for the two sexes and indeterminates were:

Male :	$\log W = \log 0.0080 + 3.0616 \log L$ ($r^2 = 0.74$)
Female :	$\log W = \log 0.0048 + 3.2278 \log L$ ($r^2 = 0.80$)
Indeterminate :	$\log W = \log 0.0043 + 3.3834 \log L$ ($r^2 = 0.86$)

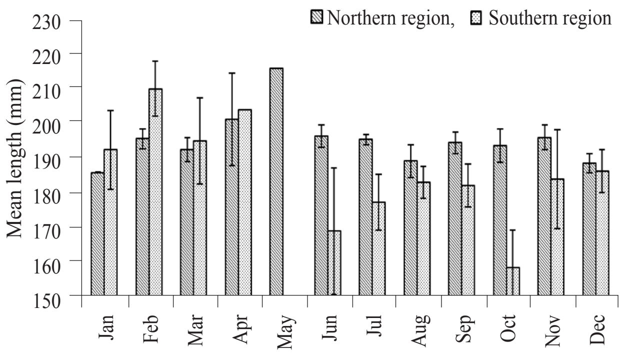


Fig. 1. Mean lengths (Mean±SE) of *R. kanagurta* landed in different months along north-east coast

The slope (b) of the regression relation for females ($t_{cal} = 2.486$; $t_{crit\ 0.05} = 1.967$; df = 1130) and indeterminates ($t_{cal} = 3.214$; $t_{crit\ 0.05} = 1.967$; df = 467) were significantly different from the isometric value of 3 indicating allometric growth. For males ($t_{cal} = 0.586$; $t_{crit\ 0.05} = 1.967$; df = 1084), the slope did not vary from 3, indicating isometric growth. The slope of the regression line for males was significantly different ($p<0.05$) from indeterminates ($F_{cal}= 4.11$; $F_{crit} = 3.86$). However between females and males and females and indeterminates, there was no significant difference ($p>0.05$) in the slope of the regression line ($F_{cal}= 1.41$ and 1.18; $F_{crit} = 3.85$ and 3.86). The pooled length weight relationship for males and females was:

$\log W = \log 0.0059 + 3.1646 \log L$ ($r^2 = 0.77$)

Size at first maturity

R. kanagurta attained sexual maturity at a size of 18.86 cm along northern region (Fig. 2) and 18.32 cm along southern region (Fig. 3). Females dominated the commercial catches in most years. Overall sex ratio was 1:1.65 in the southern region and 1:1.04 in the northern region. Significant ($p<0.05$) dominance of females was observed in 2012, 2013 and 2014 in the southern region and in 2014 in the northern region and of males in 2011 in the northern region. In the northern region, significant dominance ($p<0.05$) of males was recorded during April-May and of females was recorded during August. Along the southern region, females dominated significantly ($p<0.05$) during July-August and October-December (Table 4).

Spawning season

Gravid and ripe females were encountered round the year along the north-east coast. Peak spawning along northern region was in April and during July - October and

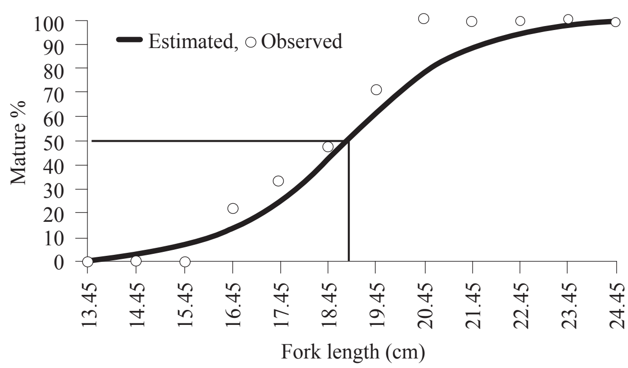


Fig. 2. Size at first maturity of females of *R. kanagurta* in northern region

Table 4. Monthly sex ratio in the mackerel landings along the northern and southern region of north-east coast

Months	Northern region		Southern region	
	Sex ratio (F/M)	Chi square value	Sex ratio (F/M)	Chi square value
January	0.85	0.61	0.93	0.13
February	1.42	3.64	0.78	1.36
March	1.01	0.00	1.04	0.04
April	0.25	22.50	1.28	1.72
May	0.15	31.41		
June	1.16	0.59	2.28	24.98
July	0.85	0.61	2.13	20.40
August	1.48	4.65	0.91	0.21
September	0.94	0.09	1.33	2.34
October	0.85	0.61	2.19	22.20
November	1.40	3.33	1.54	5.74
December	1.02	0.01	2.92	47.02

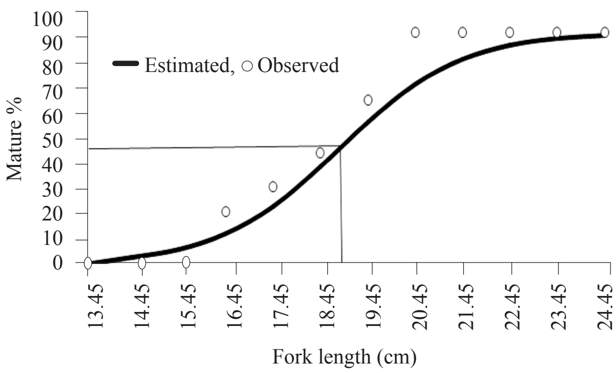


Fig. 3. Size at first maturity of females of *R. kanagurta* in southern region

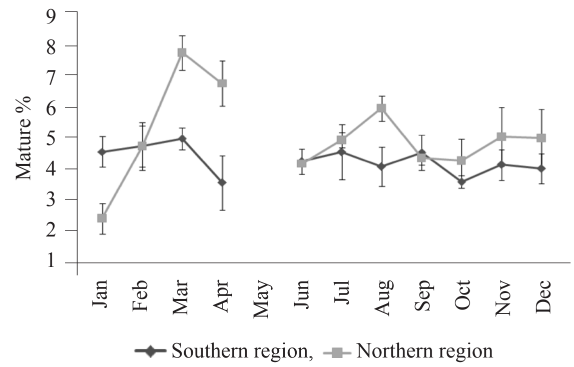


Fig. 5. Gonadosomatic index (Mean±SE) of females of *R. kanagurta* during different months

in southern region during February-April and in August (Fig. 4). In September, significant difference ($p<0.05$) was observed between the regions in the proportion of mature females. Gonadosomatic index for females peaked during March-April and August in the northern region and February-March in the southern region, which is in agreement with the peak spawning season observed in the species (Fig. 5). The mature ovaries contained both maturing and mature ova. The mature ova measured from 0.6 to 0.7 mm in diameter whereas the maturing ova measured from 0.3 to 0.6 mm. The presence of yolked ova of different sizes in mature ovary indicated prolonged spawning during the peak spawning period. Largest sizes of yolked ova encountered coincided with the peak spawning months of *R. kanagurta.*

Fecundity

Number of eggs released increased with the weight and size of the fish. The number of ova per gram body weight ranged from 151 to 1313, the average being 568. Total fecundity ranged from 13,800 to 2,52,000. Relationship between body length and fecundity and body weight and fecundity was:

$\log F = \log -3.3623 + 6.2088 \log L$ ($r^2 = 0.83$)
$\log F = \log -0.5186 + 2.5127 \log W$ ($r^2 = 0.83$)

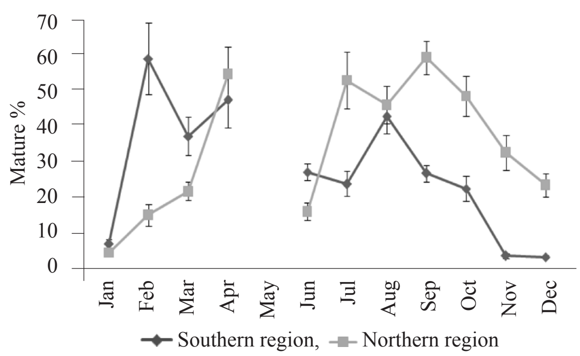


Fig. 4. Month-wise occurrence (Mean±SE) of mature females of *R. kanagurta* during different months

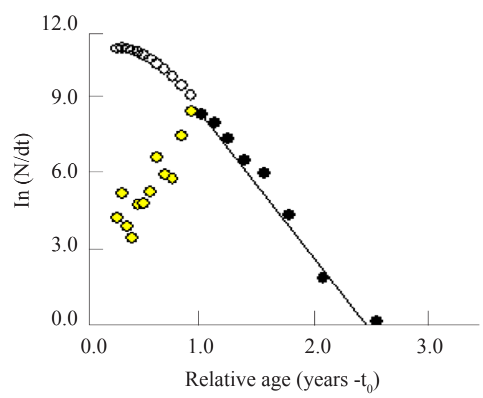
Growth

Growth parameters, L_∞ and K (annual) estimated were 27.72 cm and 1.2 year^{-1} respectively. Growth performance index (φ) was found to be 2.96 and t_0 was calculated at -0.023 years. von Bertalanffy growth equation derived was: $L_t = 27.72\,[1 - e^{-1.2\,(t + 0.023)}]$

Lifespan was estimated as 2.48 years. Accordingly, the fish attained a size of 19.6 and 25.27 cm at the end of 1 and 2 years. The fishery was dominated by fishes of 0 year and 1 year old classes. The length at first capture (L_c) was 12.78 cm which corresponds to an age (t_c) of 0.49 year.

Mortality, exploitation and virtual population analysis (VPA)

The mortality rates M, F and Z computed were 2.06, 3.69 and 5.75 respectively. Length converted catch curve utilised in the estimation of Z is shown in Fig. 6. The exploitation rate (E) obtained was 0.64. VPA (Fig. 7.) indicated that main loss in the stock up to 16.4 cm size was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually out numbered the natural losses



(for Z=5.75; M (at 28.0°C) = 2.06; F = 3 .69; E = 0.64)

Fig. 6. Length converted catch curve of *R. kanagurta* landed along north-east coast

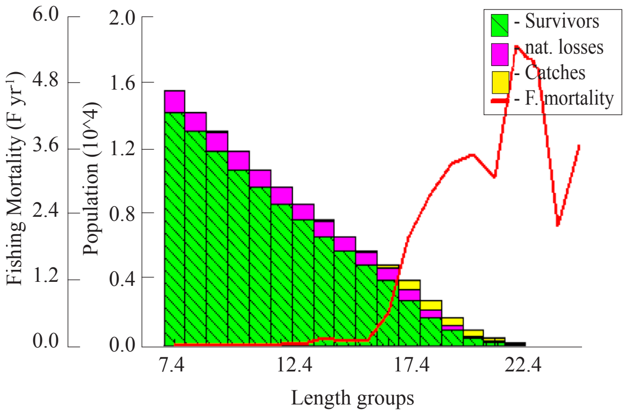


Fig. 7. Length structured virtual population analysis of *R. kanagurta*

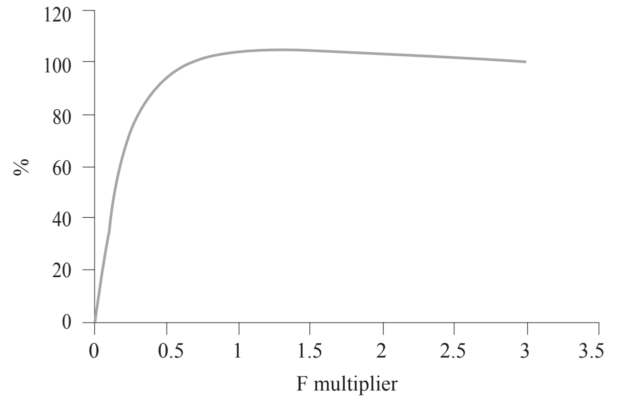


Fig. 9. Yield relative to present yield of *R. kanagurta* for different multiples of F

from 19.4 cm onwards. Maximum fishing mortality of 5.51 was recorded at size of 23.4 cm.

Recruitments

Smallest length at recruitment was 7.4 cm. Average annual recruit into the fishery was 3,541 million numbers. A unimodal recruitment pattern was observed with 79.20% of the recruits occurring between July and November. Highest recruitment with 19.70 and 19.67% of recruits was recorded in the months of October and September.

Stock and maximum sustainable yield (MSY)

The annual total stock, biomass and MSY were estimated at 81,611, 14,148 and 40,675 t, respectively.

Yield / Recruit

Yield and biomass curves showed that yield and yield/recruit could marginally be increased by increasing the present level of fishing by 20% (Fig. 8). Maximum yield and yield per recruit obtained by increasing the present fishing effort by 20% are 52,481.3 t and 14.82 g, whereas at the present level of fishing, it is 52,206 t and 14.74 g respectively. Increase in relative yield at the increased effort is a trivial 0.53% (Fig. 9).

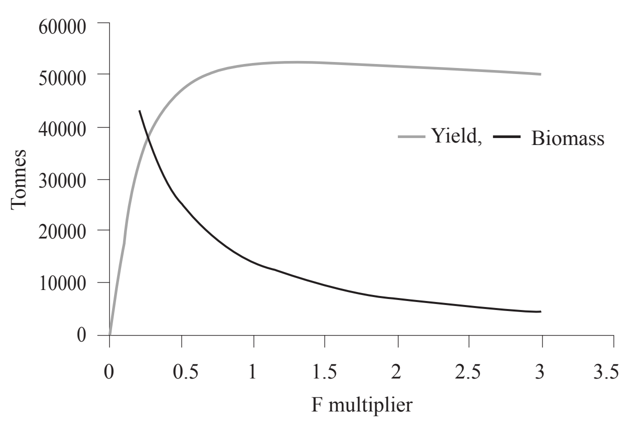


Fig. 8. Yield and biomass of *R. kanagurta* for different multiples of F

Discussion

Annual average catch of mackerel along north-east coast increased from 22,709 t during 2001-2010 (Maheswarudu *et al*., 2013) to 52,206 t during 2011-2014. In 2014, the catch reached an all time high of 69,115 t. Bulk of the mackerel catch was contributed from the southern region of the north-east coast. Catch rates in trawlers, gillnetters and seiners increased during the period. During 1985-2000, catch rate of mackerel in trawls was 1.08 kg h^{-1} (Abdussamad *et al*., 2006), which increased to 3.05 kg h^{-1} presently. This increase in catch and catch rate in recent years is attributed to the extension of fishing into deeper waters by multiday trawlers and gillnetters, where abundance of the resource is relatively high. Sudarsan *et al*. (1988) reported abundance of mackerel resource in deeper waters with abundance increasing from 20-150 m depths. The improvement in operating efficiency of different gears would have further enhanced mackerel catch and catch rates. Variations observed in catch and catch rates among various gears and various months are due to the differences in their fishing grounds and their depth of operation coupled with changes in the vertical distribution of mackerel tuned to the prevailing environmental conditions. Movement of mackerel shoals between nearshore and deeper waters were observed in an earlier study from Visakhapatnam by Luther (1995), which according to him, was the reason for the seasonal differences in catch and catch rates of various gears.

Catch rates of mackerel was impacted by wind speed, SST and precipitation. Wind speed and SST are known to influence the nutrient levels and productivity in the coastal waters (Krishnakumar and Bhat, 2008). Higher productivity results in an abundant supply of food leading to higher probability of larval survival and recruitment, ultimately leading to an increase in fish abundance and catch. Similar observations from west coast on higher catches of mackerel coinciding with low SST was reported by Krishnakumar and Bhat (2008), indicative of upwelling of bottom cooler waters to the surface. Minor upwelling of subsurface waters occurs during March-May (pre-south-west monsoon) in the southern region of the north-east coast (LaFond, 1954; 1955), but no upwelling is reported from the northern region. However, marked changes in SST are observed between various seasons all along the north-east coast with a steep fall during winter. Contrary to earlier findings by Krishnakumar *et al*. (2008), on rainfall and ENSO not significantly correlating with mackerel catches, negative correlation between precipitation and catch rate in gillnets were observed in the present study. This is probably because with increase in precipitations mackerel shoals migrate to deeper waters in search of plankton and are not caught in surface operated, nearshore gillnets. Moreover, fishing efficiency of gillnets are impacted by turbulence caused in the sea due to precipitation.

Mean length of mackerel exhibited declining trend along the north-east coast. However, present mean lengths were higher than those recorded earlier by Yohannan and Sivadas (2003) and Abdussamad *et al*. (2006). Higher mean lengths in the northern region is probably because of its nutrient and plankton rich waters resulting from the large volumes of river discharge, which forms a congenial environment for the fish to feed sumptuously, grow and proliferate. Males exhibited isometric growth, whereas females and indeterminates exhibited allometric growth. Length-weight relation was similar to that reported earlier from the same waters by Rao (1962), Luther (1995) and Abdussamad *et al*. (2006). Similar relation was also calculated from west coast by Noble *et al*. (1992), Rohit *et al*. (1998), Abdurahiman *et al*. (2004) and Rohit and Gupta (2004).

Fish attained sexual maturity and spawned at the end of first year. Size at first maturity was more or less similar to that reported earlier from the same waters by Luther (1995) and Abdussamad *et al*. (2006) and from Tuticorin by Abdussamad *et al*. (2010). However along the west coast, size at sexual maturity (17-180 mm) was lower (Rohit and Gupta, 2004; Sivadas *et al*., 2006). Differences observed in maturity sizes between east and west coasts are probably because of the influence of ocean environment on the biology of the fish. Females dominated the catches in most months of the year along the north - east coast. In contrary, earlier workers from Visakhapatnam (Luther, 1995) have reported no annual difference in the sex ratios of adult population. In west coast (Rohit *et al*., 1998; Sivadas *et al*., 2006), males outnumbered females. Differential migration pattern of males and females to and from the fishing grounds would have resulted in exploitation/fishing of either the males or females at any particular time, leading to varied sex ratios.

Mature females were observed round the year with two peaks in spawning, between July-October and February-April. Peak spawning season was more prolonged in the northern region than that of the southern region. The extended peak spawning recorded is attributed to the wider geographic area covered during the present study, in contrast to earlier studies which reported peak spawning from specific locations. Higher values of gonadosomatic index coincided with peak periods of spawning. Mackerel breeds during or after the north-east monsoon when abundant food availability favours larval survival (Rao, 1962). Luther (1995) reported on major spawning peak in February-June and minor peak in August-September from Visakhapatnam, while Abdussamad *et al*. (2006) observed peak spawning activity during December-January at Kakinada. Presence of spawners throughout the year but low, when compared to peak spawning period, is indicative of lack of population synchrony in terms of gonad development (Ganga, 2010). Observations on the spawning season are supported by the size progression of yolked ova during different months. In the present study, ripe ovaries contained two batches of ova, one maturing and the other mature. Similarly, Rao (1962) and Ganga (2010) showed the existence of two distinct groups of mature ova released in two batches, indicating fractional spawning. Fecundity estimated in the present study was higher than 476±163 eggs per gram body weight reported by Ganga (2010) from south-west coast and 198 to 515 eggs per gram body weight reported by Gopakumar *et al*. (1991) from south-east coast. This is because fish tends to produce large batches of eggs in waters with marked variations in annual temperature (Ghosh *et al*., 2014). Relationship between fecundity and body length and body weight indicated that the increase in fecundity in relation to the weight of fish is much lower when compared to the length of fish.

Present estimate of L_∞ (27.72 cm) and growth coefficient (1.2) is marginally lower than 29.95 cm and 1.2, 28.35 cm and 1.7 and 28.63 cm and 1.89 respectively reported by Luther (1995), Yohannan *et al*. (2002) and Abdussamad *et al*. (2006) from the region. Differences in environmental parameters, food availability, predation, exploitation and type of fishing gears used, influences the growth parameters. Higher lengths, close to 24 cm, attained after one year were reported by Rao (1962) and Abdussamad *et al*. (2006) from Visakhapatnam and Kakinada. Mackerel has longevity of two and half years. Similar views were expressed by Luther (1995). The fishery is dominated by 0 and 1 year old classes, as also observed earlier (Luther, 1995; Abdussamad *et al*., 2006) from the region. Recruitment length has increased recently from 5.5 (Yohannan *et al*., 2002) to 7.5 cm. Length at first capture (12.78 cm) is lower than length at first maturity indicating that majority of them were caught before they could mature and spawn at least once in their life. This indicated stress on spawning stock and could be addressed by increasing their size and age at exploitation, which is only possible by increasing the mesh size of gears employed. Unimodal recruitment pattern with peak recruitment during September-October was observed presently. According to Beverton and Holt (1956), natural mortality coefficient of a fish is directly related to the growth coefficient (K) and inversely related to the asymptotic length (L_∞) and life span. *R. kanagurta* with higher growth coefficient of 1.20 $year^{-1}$ and shorter lifespan of 2.48 years was found to have relatively higher natural mortality coefficient of 2.06 per year. M/K ratio of 1.72 was within the normal range of 1 - 2.5, as suggested by Beverton and Holt (1959). Natural mortality coefficient in the present study was lower when compared to 2.21 - 2.64 reported earlier by various authors (Devaraj, 1983; Yohannan *et al*., 2002; Yohannan and Sivadas, 2003; Rohit and Gupta, 2004; Abdussamad *et al*., 2006; Abdussamad *et al*., 2010). However, similar exploitation rates were suggested by most of them (Yohannan *et al*., 2002; Rohit and Gupta, 2004; Abdussamad *et al*., 2006; Abdussamad *et al*., 2010). Yield per recruit was lower than 18.0 to 21.6 g reported by Abdussamad *et al*. (2006) from Kakinada waters.

Slight increase in yield, to the tune of 0.53%, is possible by increasing the present fishing effort by 20%. However, as MSY is lower than the present annual average yield, and as virtually no increase in yield is possible, the present fishing effort is optimum and has to be maintained without further increase. Further increase in fishing pressure would lead to growth overfishing. Moreover in a multispecies multigear fishery, as existing presently, changes in effort will have to take into consideration other target species as well.

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