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Fishery of flatfishes with observations on the biology and stock assessment of the Malabar sole, *Cynoglossus macrostomus* Norman, 1928 exploited off Kerala coast

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ABSTRACT

The flatfishes form one of the important demersal fishery resources exploited along Kerala coast. Annual average production of flatfishes was 16938 t during 1985-2012, of this *Cynoglossus macrostomus* formed 85.4%. Peak landings were recorded from September onwards after south-west monsoon. The von Bertlanffy's growth parameters estimated for *C. macrostomus* were L_{∞} = 186 mm and K = 0.70 y^{-1}. The fish attained 94, 141,169, 175 and 183 mm at the end of 1, 2, 3, 4 and 5 years. The age determination based on the length frequency data showed that life span was five years. Total mortality observed was 2.34 y^{-1}, and natural mortality 1.10 y^{-1}. The length-weight relationship showed no significant variation between sexes. The spawning is prolonged with two peaks. The size at first maturity is estimated as 102 mm for females and 95 mm for males. Females dominated the fishery. The resource at present is being exploited at the optimum level in Kerala. The total and standing stock of this species along the Kerala coast is 20,400 t and 9,052 t respectively. The exploitation rate (E) was estimated as 0.63. The relative yield per recruit and biomass per recruit analysis also showed that the stock of *C. macrostomus* in Kerala is exploited optimally.

Introduction

Flatfishes inhabit marine environments ranging from the southern Arctic Ocean to continental seas off Antarctica, but the largest quantities are caught in the temperate and boreal zones of the Northern Hemisphere (Munroe, 2005). Flatfishes are an important demersal fishery resource exploited along the Kerala coast. Trawl nets and ring seines are the important gears used for exploitation of this resource. Although flatfishes belong to seven families, the flatfishes of the families Cynoglossidae and Psettodidae alone support the commercial fishery in Kerala. The Malabar sole, *Cynoglossus macrostomus*, is an important demersal finfish resource of Kerala constituting over 92% of the flatfish catch. Neendakara, Cochin, Munambam, Ponnani, Puthiappa, Beypore and Azheekal are the major fishing harbours, which account for more than 80% of the flatfish landings.

The studies on flatfish along the west coast of India are limited to the work of Seshappa and Bhimachar (1951), Feroz Khan and Nandakumaran (1993), Jayaprakash and Inasu (1998), Jayaprakash (1999, 2001 and 2002), Vivekanandan *et al.* (2003) and Manojkumar (2006). The present account gives details of flatfish fishery and some aspects on the biology, growth and stock assessment of the Malabar sole exploited along the Kerala landlings.

Materials and methods

The data on landing of flatfishes in different gears in Kerala collected by Central Marine Fisheries Research Institute for the period from 1985-2012 were used for this study. The data on length frequency distribution collected from trawl landings from different landing centres during 2005 to 2012 formed the material for the study**.** A total of 18115 specimens of *C. macrostomus* in the size range

of 38-164 mm were used for biological studies and stock assessment. The length-weight relationship was studied following Le Cren (1951). Length frequencies were raised to correspond to the weight of the catch assessed for the day and subsequently for the month, following Sekharan (1962). The maturity stages of gonads were determined on the basis of physical appearance and by observing under microscope, following the standards laid down by I.C.E.S (Lovern and Wood, 1937). The size at first maturity of *C. macrostomus* was estimated from the percentage composition of different maturity stages for 10 mm length class intervals for female fish using pooled data of 2005-2012. The size at which 50% of the fish were mature (stage IV and above) was considered as the size at first maturity. The monthly sex ratio was estimated and the values were tested for significance using chi-square test. The growth and mortality parameters, recruitment pattern and yield per recruitment parameters were estimated using FiSAT (Gayanilo Jr., *et al*., 1996). For estimation of the natural mortality, the t_o was considered as '0' (Sparre *et al*., 1989) and the surface seawater temperature was taken as 28^0C. The exploitation ratio 'U' was estimated using the formula $U = F (1-e^{-Z})/ Z$. The annual stock and standing stock were estimated by Y/U and Y/F respectively, where 'Y' is the annual average catch of this species. Rapid classification of the stock was done following Mohamed *et al*. (2010).

Results

Catch and effort

Flatfish landlings in Kerala has increased consistently from 11,331 t in 1985 to 28,445 in 1992 and declined to 12,385 t in 1995 and then rose to 25,433 t in 1999. Subsequently the catch fluctuated between 16,747 t and 21,790 t. The average contribution of flatfish catch to the total catch in Kerala was 16,938 t (2.92%). The fishing fleet that landed flatfish were mainly trawlers (73.4%) and motorised fishing vessels (23.4%) with more than 96% of the catch being from these two sectors. The increase in the catch was due to intensification of trawling, which is the most effective method of exploiting this resource. Introduction of ring seine also helped to increase the production of flatfish catch in Kerala. Towards the end of the study period, the fishery had increased considerably, but the contribution of this resource to the total landing remained around 3% during this period (Fig.1). The best season for the fishery is immediately after the south-west monsoon, September always being the month of peak commercial catches.

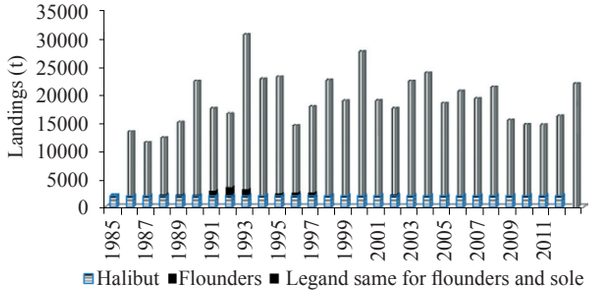

Fig. 1. Annual landing (t) of flatfishes in Kerala during 1985-2012

The flatfishes were represented by soles, flounders and halibuts and formed 16,685 t (98.5%), 136 t (0.8%) and 116 t (0.7%) respectively of flatfish landings in Kerala. Highest landing of halibut was recorded in 1996 at 567 t, thereafter the fishery has shown a declining trend and collapsed. Most of the flatfish species except Malabar sole occur in small quantities in the catch by different fishing gears, which supports an important fishery from Quilon to north Kerala with highest landings along the Malabar coast.

There was an increase in the effort expended by mechanised units from 2.1 million fishing hours in 1985 to 6.5 million fishing hours in 2012 with an average of 4.1 million fishing hours. In the case of motorised units, the effort has shown increase from 2.1 million fishing hours in 1985 to 7.2 million fishing hours in 1998. Hereafter the effort declined to 3.8 million fishing hours in 2012 with an average of 4.5 million fishing hours. In non-mechanised units, estimated fishing effort has shown a declining trend from 5.6 million fishing hours in 1985 to 0.86 million fishing hour in 2012 (Fig. 2).

Catch rate and seasonal abundance

The catch rate of flatfishes in mechanised units ranged between 1.9 kg h^{-1} (1986) and 4.9 kg h^{-1} (1999) with an average of 2.9 kg h^{-1}. The catch rate has shown a declining trend upto 2011, but showed improvement in 2012. In motorised units the catch rate fluctuated between 0.18 kg h^{-1} (1985) and 2.93 kg h^{-1} (1992) with an average

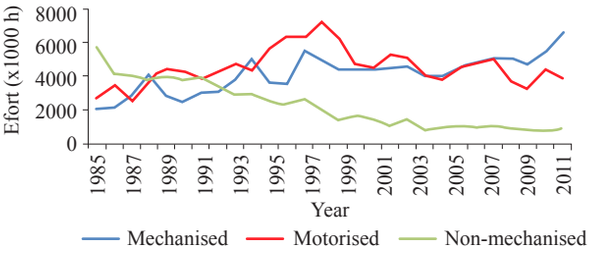

Fig. 2. Sectorwise annual fishing effort in Kerala during 1985-2012

of 0.9 kg h^{-1}, while in non-mechanised units the catch rate was less than 1 kg h^{-1}. The catch rate has shown a declining trend continuously in motorised and non-mechanised units (Fig. 3).

Species composition

Among all the species of flatfishes occurring along the Kerala coast, it is only the Malabar sole, *C. macrostomus* that formed a major fishery especially along the Malabar coast. The area between Quilon to north of Kerala is the important zone for Malabar sole landings. There is a distinct demarcation in the areas of high landings of different species of flatfishes. Malabar sole dominates the catch forming more than 85.4% of the flatfish landings, but its intensity is reduced in the central part of Kerala, where *Cynoglossus bilineatus* dominated the fishery. Other species, such as *Cynoglossus dubius* (2.64%), *Cynoglossus arel* (0.34), *Psettodes erumei* (0.61%) and others (2.81%) occur in the state but their landings are too meagre to contribute to the sole fishery (Fig. 4).

Length -weight relationship

A total of 188 females in the length range of 48-164 mm (2-30 g) and 242 males in the range of 54-158 mm (2-32 g) were used for determining length-weight relationship of *C. macrostomus*. The relationship was determined by least square method and regression equation derived for both the sexes are :

Female : $W = 0.00009623L^{2.4734}$ (r=0.9253)

Male : $W = 0.00002093\ L^{2.7614}$ (r=0.9748)

The analysis of covariance showed that there was no significant difference at 5% level between sexes and the equation obtained for sexes pooled is:

$W = 0.00005858L^{2.6174}$ (r=0.9853)

Maturity and spawning

Monthly variation in the percentage composition of different stages of maturity in *C. macrostomus* showed that gonads in all stages of development were present in the fishery during most of the months. Ripe fishes were available in the fishery throughout the year with higher availability during September-November and February-March. Immature fishes dominated the commercial catches followed by maturing and spent fish (Fig. 5). The spawning season extended from August to May with peak during September-November and February-April. Month-wise sex ratio showed that females dominated the catch during most of the months. The annual sex ratio (male:female) was found to be 1:1.86. The chi-square test indicated that the difference is not significant at 5% level (Fig. 6).

Size at first maturity

Female fish up to 70 mm were immature. The length of the smallest mature female fish was 71 mm. The

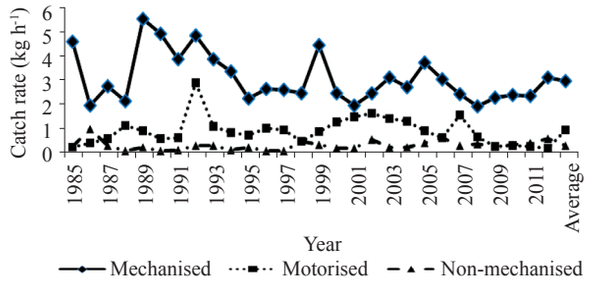

Fig. 3. Sectorwise catch rate of flatfishes in Kerala during 1985-2012

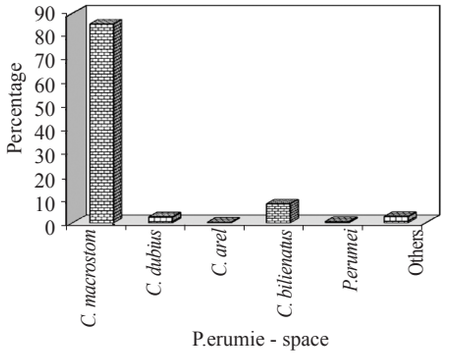

Fig. 4. Average annual percentage composition of different species of flatfishes in Kerala

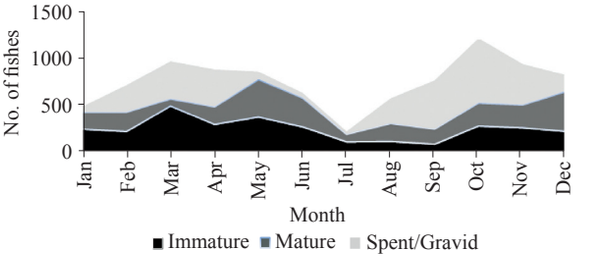

Fig. 5. Month-wise occurrence of different stages of maturity in C. *mactostomus* along the Kerala coast

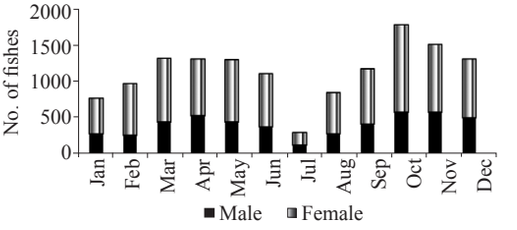

Fig. 6. Monthly sex ratio in *C. macrostomus* in Kerala

maturing females started to appear in the fishery from 71 mm onwards and 50% of them were mature at 102 mm size and this was estimated as the size at first maturity of females of *C. macrostomus* along the Kerala coast (Fig.7). In the case of males, mature fishes started to appear in the fishery from 68 mm onwards and 50% of them mature at 95 mm.

Age and growth

For estimation of growth and mortality parameters of *C. macrostomus*, the raised length frequency corresponding to each month pooled over the years from 2005-12 was used. The restructured length frequency distribution and the growth curve obtained using the FiSAT programme is given in Fig. 8. The values of growth parameters L_∞ and K were estimated as 186 mm and 0.70 y^{-1} respectively**.** The age at zero length (t_0) was estimated as -0.002 years. The fish attained a size of 94, 141, 164, 175 and 183 mm at the end of 1, 2, 3, 4 and 5 years respectively. The total life span is 5 years

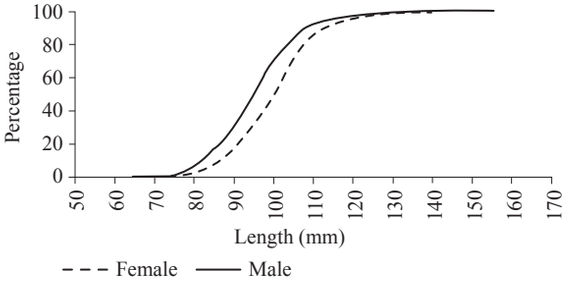

Fig. 7. Size at first maturity in *C. macrostoumus*

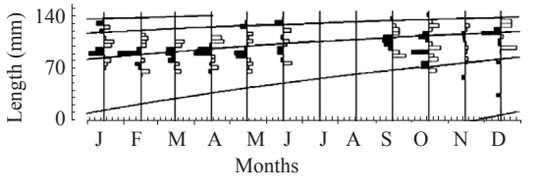

Fig. 8. Plot of FiSAT analysis of C. *macrostomus* (Pooled data exploited off Kerala

with predominant age group of '0' and '1' year class in the fishery. Majority of the fishes were in the range of 80-122 mm indicating that major share of the landings of this species is juveniles and subadults. The age was determined based on the von Bertalanffy's growth equation as follows:

$L_t = 186\ (1\text{-}e^{-0.70\ (t\text{-}(-0.002)}$)

Mortality parameters

The estimated Z using the growth parameters for the period 2005-2012 ranged between 1.89 y^{-1} (2006) and 3.22 y^{-1} (2012) and with an average of 2.34y^{-1}. The instantaneous natural mortality (M) estimated using Pauly's empirical formula (Pauly, 1980) for an average temperature of 28°C was 1.10 y^{-1} (Table.1). The estimate of fishing mortality ranged from 1.02 y^{-1} (2010) to 2.19 y^{-1} (2012), with an average of 1.60 y^{-1}. The fishing mortality was 1.5 times more than natural mortality and can be attributed to the presence of large number of smaller fishes in the landings.

Recruitment pattern

The recruitment pattern of *C. macrostomus* showed a distinct peak with maximum recruitment during April-August contributing to 75.2% of total recruitment (Fig. 9). Highest recruitment took place in May (19.8%) and lowest in January (0.52%).

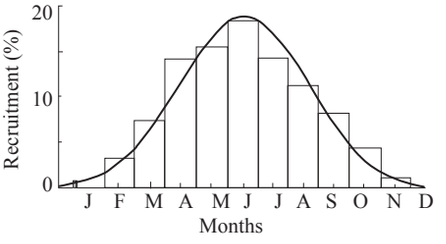

Fig. 9. Recruitment pattern of *C. macrostomus* exploited along the Kerala coast

Table. 1. Estimates of mortality and stock parameters of *C. macrostomus*

Year	Z	F	M	E	SSB (t)	St.SB (t)	Rec. Nos	Yield (t)
2005	2.73	2.19	1.10	0.54	6298	10827	5809244	17263
2006	1.89	1.35	1.10	0.54	7542	12789	6946938	16950
2007	2.05	1.51	1.10	0.74	7764	10658	5200027	11974
2008	2.18	1.64	1.10	0.75	4578	9165	3810484	10348
2009	2.24	1.14	1.10	0.51	4156	8284	4035191	9163
2010	2.12	1.02	1.10	0.48	8069	8069	2094494	10771
2011	2.31	1.77	1.10	0.77	4886	9279	3565796	12598
2012	3.22	2.18	1.10	0.68	9505	16546	5645161	15378
Average	2.34	1.60	1.10	0.63	6599.75	10702.00	4638417	10971

Z - Total mortality, F - Fishing mortality, M - Natural mortality, E - Exploitation rate, SSB – Spawning stock biomass, St.SB – Standing stock biomass

Length at first capture (Lc) and length at recruitment (Lr)

The smallest fish in the sample was 38 mm, which is taken as the size at recruitment and the corresponding age at recruitment was 0.2 years. The length at first capture (Lc) of *C. macrostomus* was estimated as 95 mm and corresponding age was 1 year (Fig. 10). The optimum size of exploitation was estimated as 102 mm at 1.1 years, which is very close to the length at first maturity and at this size, more than 50% of the recruits get a chance to mature before they are caught.

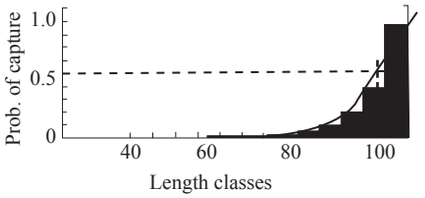

Fig. 10. Length at first capture of C. *macrostomus* along the Kerala coast

Yield per recruit

Using Beverton and Holt's yield per recruitment model, the maximum relative yield per recruit (Y/R) is estimated at the exploitation rate (E) of 0.79 (Fig. 11). The exploitation rate ranged between 0.54 (2005) and 0.77 (2011) with an average of 0.62, which is less than the optimum exploitation rate estimated by the Beverton and Holt's method. This means that the current level of exploitation is below the MSY level, but since the exploitation rate is very close to the optimum level, further increase in the effort will be detrimental to the resource.

Stock estimates

The average annual yield of *C. macrostomus* along the Kerala coast was 14484 t at an exploitation rate (E) and exploitation ratio (U) of 0.63 and 0.62 respectively.

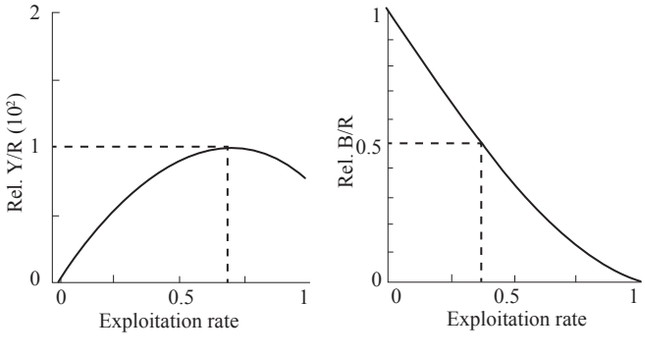

Fig. 11. Relative yield per recruit for *C. macrostomus* exploited off Kerala

The average annual total stock and standing stock was estimated as 20,400 t and 9,052 t respectively.

Status of the stock

Rapid classification of the stock based on the landings for the period 1985-2012 indicated that soles are in the less abundant category, with recent average catch forming 61.1% of the historical maximum catch of 27,301 t. The recent average landings of flounders formed 9.6% of the historical maximum, which indicates depleted stock status. In the case of halibut, the recent average catch was only 2.4% of the historical maximum, indicating collapsed state of the stock.

The spawning stock biomass (SSB) of *C. macrostomus* ranged from 4,156 t (2009) to 9,505 t (2009) with an average of 6,599 t. The standing stock biomass ranged between 8,068 t (2010) and 12,789 t (2006) and the average for the period was 10,702 t. The SSB formed more than 30% of the standing stock at the unexploited level indicating that the species has high regeneration capacity.

Discussion

Flatfish fishery of Kerala has traditionally played an important socio-economic role in the fisheries sector of the state. Fishing is an important activity in Kerala, dominated by mechanised and motorised vessels operating trawl net and ring seines and flatfishes are caught as a bycatch in these gears. The flatfish fishery of Kerala is characterised by abundance of the Malabar sole, *C. macrostomus*. Trawl operations are known to transform the sea bottom, which has proved to be ideal habitat for flatfishes. In the intense trawling grounds, the flatfishes thrive well and the landings of the flatfishes have increased despite decline in the landings of other demersal fishes (Gracia and Staple, 2000). Fluctuation in the catch and catch rate is inherent feature of the fishery and like any other tropical fishery resource, flatfishes also exhibited seasonal and annual fluctuation in the landings. Jayaprakash (2002) while studying the fluctuation in abundance of Malabar sole in the Malabar upwelling ecosystem observed a clear decadal trend comparable to such trends existing in rainfall, sea level and solar periodicity.

The hierarchical analysis showed that soles, flounder, and halibut occur near the shores, typically in sandy and muddy grounds in the continental shelf, from 10 to 200 m depth and were landed together with target species (Vivekanandan *et al*., 2003). The variability observed in catch rate of the flatfish groups considered in this study suggests that resource abundance may also be extremely variable both seasonally and inter-annually.

Although Norman (1927, 1928) described 91 species of flatfishes from Indian waters, only a few species contribute to the fishery. The bulk of the catch was constituted by C. *macrostomus,* particularly in Malabar region. A few other species such as *Cynoglossus dubius, Cynoglossus macrolepidotus, Cynoglossus lingua, Pseudorhombus* spp. and *Psettodes erumei* also occurred occasionally in the fishery. Not all of them are of commercial importance due to small sizes or low abundance. Only the pleuronectids and paralichthyids are economically important because of their good taste. The bothids, soleids as well as some species of cynoglossids constitute fishery resources of relative commercial importance in the area. *C. macrostomus* which is a shoaling species is the only species forming an independent and full-fledged fishery, though other species of flatfishes are landed in small quantities. Major portion of the catch is obtained within a short period immediately after the commencement of the fishing season. The Malabar sole dominates the south Karnataka-north Kerala coast, but its intensity is reduced in the central part of Kerala; and it ceases to be a fishery off the southern part of the state (Vivekanandan *et al*., 2003).

Length at first maturity is very important to determine the minimum legal size that may be required to maintain the sustainable spawning stock. The length at first maturity of *C. macrostomus* was 102 mm for females and 95 mm for males. This was similar to the observation made by Jayaprakash (1999). Seshappa and Bhimachar (1951) observed that the spawning season of Malabar sole starts by September–October and ceases by June. Only one batch of eggs was present in the ovary. Jayaprakash (1999) reported two spawning seasons with peak spawning once a year, during a definite short period. As revealed in the present study, spawning in this species is prolonged with peaks during February-April and September- November when more gravid and spent fishes were present in the fishery.

Jayaprakash (1999) while studying the sex ratio of Malabar sole observed that males dominated the catches during most of the period. In contrast to the above, in the present study, females dominated the catches during most of the months. The length-weight relationship between male and female showed no significant difference as reported by Feroz Khan and Nandakumaran (1993), Victor (1978) and Jayaprakash (2001).

The longevity of *C. macrostomus* was estimated to be about 5 years, however the maximum number of fishes caught was recorded in the age group of 0-1 years, which indicated that they are caught before they grow large enough to add significantly to the stock biomass. Seshappa and Bhimachar (1951) using the growth checks on scales and by length frequency methods indicated that *C. macrostomus* attained a length of 100-129 mm, 140-149 mm and 170-180 mm in the first, second and third years respectively. Studies made by Feroz Khan and Nandakumaran (1993) indicated that this species attained 106 mm in the first year and 131 mm in the second year. Jayaprakash and Inasu (1998) using the same method reported that Malabar sole grows fast in early part of its life, which attained 114 mm at the end of the first year and 136.5 mm at the end of the second year of its life. The present study showed that the growth was fast in the first two years of life. Bulk of the annual landings recorded consist of 0-1 year class with a length range of 80-120 mm.

'M' value of 1.10 y^{-1} indicated moderate natural mortality for *C. macrostomus*. The fishing mortality ($F=1.60y^{-1}$) is an indication of moderate fishing of this species as also revealed by exploitation rate of 0.63. The present study indicated that *Cynoglossus* spp. is a less abundant resource in Kerala, while halibuts and flounders are depleted stocks as reported by Mohamed *et al*. (2010) However, the spawning stock biomass estimated for *C. macrostomus* is quite high indicating potential for revival of the stock.

The current exploitation rate estimated for *C. macrostomus* was less than that required to yield maximum yield per recruit ($E_{max}= 0.79$). However, the exploitation rate is close to the optimum rate estimated. Thus for the benefit of the stock, it is better if the efforts are confined at the present level. For the management of flatfish fishery, the monsoon ban on trawling needs to be continued and additionally implementation of spatial and temporal closures in estuarine systems as well as in shallow coastal areas which are used as nursery grounds by soles and flounders, would be extremely important to the recovery of depleted stocks of flatfishes.

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