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Stock status indicators for Cobia *Rachycentron canadum* in the Indian EEZ

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Abstract

Regional fisheries for cobia (*Rachycentron canadum*) along the Indian coast was assessed using length-based stock status indicators. Drift gill nets-cum-hook and line fisheries landed bigger sized cobia as bycatch while multi-day mid-water trawls landed juveniles. Dominant size groups in the landings along the west coast were 40–160 cm and 60-120 cm on the east coast. Gear selectivity operating at regional levels because of the multi-gear fisheries and fishing grounds of the Indian EEZ affects the size distribution of fish caught. Compared to drift gill net-cum-hooks and line units targeting large pelagics in deeper waters, smaller size groups of cobia dominated as bycatch in trawls. The length at first capture (Lc_{50}) being smaller than the estimated length at first maturity of about 60 cm, implementing size-based output controls such as Minimum Legal Size (MLS) is suggested. The indicators for fishing mortality rates (F_{max}) on the cobia stocks were on the higher side in certain locations only, but being part of the multi-species bycatch mix, there is little scope to introduce fishing gear regulations solely for cobia. However, the option of short-term, targeted spatio-temporal effort regulations with fishers' participation can be explored, based on the stock assessments made at local or regional levels.

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Introduction

Cobia (*Rachycentron canadum*) is a minor bycatch in the artisanal and small scale fisheries in India. However, it is a premium priced food fish and because of its excellent husbandry potential, has become a preferred candidate species for open sea cage culture in India. Genetic population studies of cobia sampled from various locations along the Indian coastline have indicated 3 populations, one along the north-west coast (north-eastern Arabian Sea), one along the south-west coast (south-eastern Arabian Sea) and one in the Bay of Bengal along the entire east coast (Divya *et al*., 2017). The species is much favoured for open sea cage culture in India and breeding programmes for farming activities are in place (Gopakumar *et al.*, 2011; Loka *et al*., 2016). As part of the assessment of large pelagic fisheries along the Indian coast which are mostly by drift gill nets, long lines and similar gears, cobia landings were assessed at various landing centres during 2014-2019. Cobia landed either as bycatch in trawl nets or drift gill nets and occasionally in targeted fisheries with hooks and line, were sampled. The length frequency and biology data collected were explored with stock assessment tools like ELEFAN and Length-based Spawning Potential Ratio (LBSPR) index to arrive at the stock status and management advisories.

Materials and methods

Monthly sampling of cobia landed by the trawlers (15-22 mm cod-end mesh size), large mesh (120-140 mm) drift gill nets and hooks and line units operating from Cochin, Mangalore, Veraval, Chennai and

Visakhapatnam fisheries harbours covering the east and west coasts of India was done during the period 2014-2019. Sampling covered region-specific multi-gear fisheries landing cobia as bycatch at each centre. Individual cobia caught in specific gears were measured for fork length (FL) or total length (TL) and the gear-wise cobia length frequency data was routinely estimated. The monthly estimated marine fish landings database created through stratified, multi-stage random sampling programme of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) for all major fishery resources of each region was used to arrive at a gear aggregated, catch weighted, region-specific length composition for cobia. The von Bertalanffy growth parameters L_∞ and K (annual) were estimated using ELEFAN GA routine (Mildenberger *et al.*, 2017) using the best fit (R_n) criteria. Natural mortality (M) was estimated following Then *et al.* (2015) as $M = 4.118K^{0.73}L_\infty^{-0.33}$. Total mortality (Z), fishing mortality (F) and gear selectivity parameters SL_{50} and SL_{75} (Hordyk *et al*., 2015a) were estimated with the Linearised Length Converted Catch Curve method available in TropFishR package (Mildenberger *et al*., 2017). The spawning potential ratio (SPR) expressed as the ratio of total egg production in the fished and unfished conditions is a function of fishing pressure and was used as an indicator. SPR of >0.4 indicating 'underexploited' and <0.2 indicating 'overexploited' with intermediate as 'moderately/ optimally exploited' (Legault and Brooks, 2013) were used. The relative fishing mortality (F/M), considered a proxy for sustainability, Fishery Reference Points (F_{max}, $F_{0.1}$ and $F_{0.5}$) and Spawning Potential based biological reference points (F_{30}, F_{35} and F_{40}) following Hordyk *et al.* (2015b) were estimated for the cobia stocks on a regional basis and used to evaluate the stock status.

Results and discussion

Region-wise trend of cobia landings indicated that the west coast of India accounted for 80% of the species landed in the country, mostly as bycatch in hooks and lines, drift gill nets and mid-water trawls. The landings at Chennai, Mangalore and Veraval fisheries Harbours comprised mostly of smaller sized cobia occurring as bycatch from mid-water trawl net operations within depths of 30 m. Larger sized cobia were landed by hooks and line and gill nets, which were mostly operated in deeper, offshore waters, at Cochin and Visakhapatnam fisheries harbours (Fig.1 a-e).

Best-fitting growth curves with the highest Rn values indicated annual growth coefficient (K) in the range of 0.1 to 0.6 and reflected regional ecological factors as well as gear-influenced selectivity patterns (Table 1). Annual growth rates (K= 0.09 to 0.63) have been reported globally for wild-caught cobia (Franks *et al*., 1999; Somvanshi *et al.,* 2000; Fry and Griffiths, 2010; Ganga *et al.,* 2012). The size ranges of the fishes used in the analysis obviously influence the estimates reported. In Karnataka, considerable numbers of small-sized cobia were landed by trawlers and probably because juveniles grow faster, higher growth rates were estimated based on the modal progression analysis of the length frequency

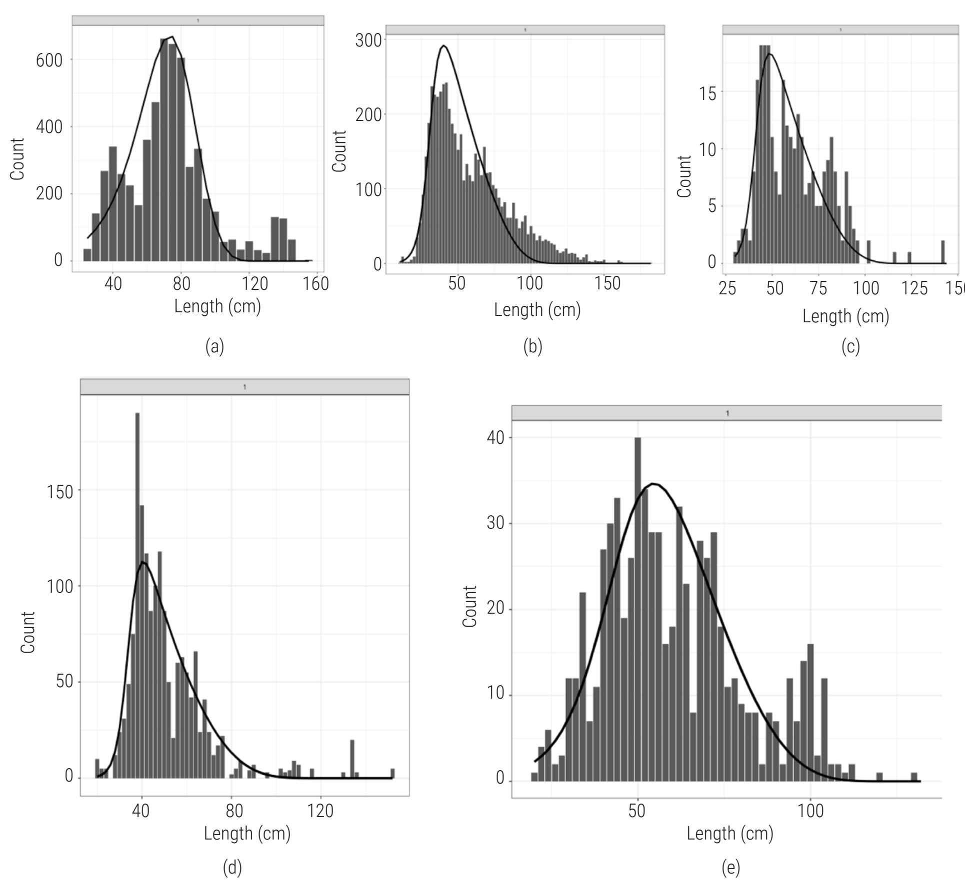

Fig. 1. Length frequency of cobia landings along west coast (a-Cochin; b-Mangalore, c-Veraval), east coast (d-Chennai, e-Visakhapatnam) of India

Table 1. Regional growth parameter estimates for cobia

Centre/Stock	Years	L_∞ (cm)	K (Annual)	R_n
Veraval (North-west coast)	2015 -2019	167 (TL)	0.12	0.6
Mangalore (South-west coast)	2015 -2020	195 (FL)	0.52	0.4
Cochin (South-west coast)	2017-2019	166 (FL)	0.6	0.6
Chennai (South-east coast)	2017- 2019	150 (TL)	0.1	0.7
Visakhapatnam (South-east coast)	2016-2017	84 (FL)	0.53	0.6

data. The possibility of reduced numbers of larger fish due to sustained impacts of fishing by lowering the mean size of the catch is mentioned in literature, but it appears more likely that the current fishing grounds of trawl which is the main gear contributing to the landings are dominated by juveniles. It was reported that among the several undersized but commercially important species occurring as bycatch in the trawl nets, cobia with an estimated volume of 7 t caused significant economic loss to fishermen through lower prices for juvenile fishes (Dineshbabu and Radhakrishnan*,* 2009). Fishermen target fishing grounds with good catches based on their experience and the seasonal abundance of juveniles of cobia along with other fishes in such fishing grounds are probably reflected in the landings. Cobia has been reported to show strong migration and homing behaviour with a tendency to aggregate in certain areas like reefs as well as surface floats and oil platforms (Shaffer and Nakamura, 1989; Williams, 2001).

The overlying assumptions were that the fishing gears neither excluded large-sized fish nor specifically targeted juvenile fishes and the entire fish population was represented in the samples collected from multiple gears appropriately aggregated for the monthly length composition data. The stock on the north-west coast showed lower growth increments (length) compared to the south-west coast. The average length at one year of age as inferred from the inverse von Bertalanffy growth function (VBGF) was 77 cm for the south-west coast (south-eastern Arabian Sea) as compared to 19 cm for the north-west coast (north-eastern Arabian Sea). On the east coast (Bay of Bengal) of India, the average length of 1 year old cobia was 25 cm. Studies with microsatellite and mitochondrial markers have indicated the presence of three populations of cobia along the Indian coast with their genetic distinctiveness attributed to the reported barrier in productivity (Divya *et al*., 2017) caused by the Findlater jet and other ocean current patterns (Prasannakumar *et al*., 2001; Gauns *et al*., 2005; Satya Prakash and Ramesh, 2007). Growth parameters estimated in this study as characteristic of each regional fished stock agree with these observations. It also indicates that even for widely distributed species such as cobia, stock assessment using local fisheries and biology data is justified.

The exploitation rate indicated moderate (E<0.6) and low (E<0.5) fishing pressure (Gulland, 1983; Fischer *et al*., 2022) at Cochin and Visakhapatnam respectively compared to other centres monitored (Table 2). The length at which 50% of fishes of the particular size group become vulnerable to the fishery (SL_{50}) indicated sizes of -0-41 cm in all the centres except Cochin (Table 3). Length at first maturity (when 50% of the fish in the particular size group are capable of spawning) or L_m has an important use in fisheries management, mainly as an indicator to prevent growth overfishing. The L_m of cobia was taken as 60 cm based on expert opinion, as a reasonable estimate to reconcile with results from various studies on reproductive aspects of cobia in the Indian EEZ, including broodstock development experiments for hatchery purposes and the MLS recommended to prevent growth overfishing impacts on identified marine fish stocks along the Kerala coast (Mohamed *et al.,* 2014). The results indicate that with SL_{50} < L_m, growth overfishing risks have to be addressed with appropriate controls such as MLS on sizes of fish landed.

The relative fishing mortality (F/M) has been used as a proxy for sustainability, with ideal values <1 (Prince *et al.,* 2015). In this study, estimated values of relative fishing mortality ranged from 0.2 (Chennai) to 4.1 (Mangalore). The spawning potential ratio (SPR) indicator is considered more useful than relative fishing mortality since it incorporates the effects of fishing pressure (F/M) as well as the gear selectivity effects. If fish caught are smaller than the size at which they mature, then even low F/M (<1) can cause overfishing. With these criteria, it is evident that trawl-based cobia bycatch fishery at Veraval and Mangalore require fisheries management interventions, while fisheries based in Chennai, Visakhapatnam and Cochin have fewer issues of sustainability.

The F_{max} or fishing mortality which produces maximum yield per recruit indicated current fishing mortality rates on the cobia stocks were higher than desirable (Table 4). F_{30}, F_{35} and F_{40} which correspond to fishing mortality that leads to spawning stock biomass levels of 30, 35 and 45% respectively indicated a need to reduce present fishing mortality rates which were close to the F_{max} through appropriate effort controls (Table 5). Several species which occur as bycatch have been observed to experience high F (Alverson *et al.,* 1994).

Table 3. Stock status indicators for gear selectivity (SL_{50}) and SPR

Centre	SL_{50}	SP Ratio	F/M
Veraval (North-west coast)	39 (37-41)	1	2.9
Mangalore (South-west coast)	27 (26-27)	1	4.1
Cochin (South-west coast)	62 (62-64)	1	1.2
Chennai (South-east coast)	34 (33-35)	0.23	0.2
Visakhapatnam (South-east coast)	36 (34 -38)	1	0.5

Table 2. Mortality rates and selectivity parameters of cobia in different regions along Indian coast

Centre	Z	M	F	E	SL_{50}	F/M
Veraval (North-west coast)	0.63	0.16	0.47	0.74	41	2.9
Mangalore (South-west coast)	2.31	0.45	1.86	0.81	30	4.1
Cochin (South-west coast)	1.20	0.55	0.68	0.56	62	1.2
Chennai (South-east coast)	0.35	0.12	0.23	0.66	32	0.2
Visakhapatnam (South-east coast)	0.92	0.6	0.32	0.35	40	0.5

Table 4. Fishery-based Reference Points

Centre	F_{max}	$F_{0.1}$	$F_{0.5}$
Veraval (North-west coast)	0.15	0.09	0.07
Mangalore (South-west coast)	0.39	0.26	0.19
Cochin (South-west coast)	0.48	0.31	0.23
Chennai (South-east coast)	0.09	0.05	0.04
Visakhapatnam (South-east coast)	1.03	0.51	0.4

Table 5. Spawning stock-based Reference Points

Centre	F_{30}	F_{35}	F_{40}
Veraval (North-west coast)	0.12	0.1	0.09
Mangalore (South-west coast)	0.36	0.31	0.26
Cochin (South-west coast)	0.43	0.37	0.31
Chennai (South-east coast)	0.07	0.06	0.05
Visakhapatnam (South-east coast)	0.5	0.4	0.3

However, regulation of fishing mortality through the input (mesh/ hook size regulations) or output controls (catch limits), is difficult as landings are bycatch in the multi-species fishery. Hence the option of MLS which has been more widely accepted as a fisheries management tool by fishers can be used for managing the fishery. Implementation of MLS for those gears that have relatively high numbers of juveniles landed through controls on the size and quantity landed could ensure sustainability.

A study by Dineshbabu *et al.* (2012) on trawl fisheries during 2008-2009 estimated that around 0.2 million juveniles of *R. canadum* having an average weight of 29 g were discarded as trawl bycatch in Mangalore Fisheries Harbour. Management based on spatio-temporal restrictions by avoiding fishing areas with high and seasonal juvenile abundance was suggested by Dineshbabu *et al.* (2009). Gear input and output controls are relatively more difficult to implement in a multi-gear, multi-species context of the Indian marine fisheries sector. Hence, short and specific spatial closures of fishing areas in known spawning or nursery grounds, especially in regions off Chennai and Mangalore by employing a participatory approach with fishers, with suitable incentives to compensate for the loss of fishing opportunities may be a better option.

In conclusion, cobia is a low volume, high value resource, mostly occurring as a seasonal bycatch in various regions of the Indian EEZ. The study highlights need to develop generic fisheries management measures such as MLS, as well as region-specific closed fishing areas or seasons and strengthening of ecosystem-based fisheries assessments using indicators, for ecologically significant but data-limited fishery resources such as cobia which mostly occur as bycatch.

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