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Research Article

GIS-based mapping of the spatio-temporal distribution of Reeve's croaker, *Chrysochir aurea* (Richardson, 1846), along the coast of West Bengal, India

S Jana[a], T S Nagesh*[,a], D Bhakta[c], T J Abraham[b] & M Bhor[c]

[a]Department of Fisheries Resource Management, Faculty of Fishery Sciences,
West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal – 700 094, India
[b]Department of Aquatic Animal Health, Faculty of Fishery Sciences,
West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal – 700 094, India
[c]ICAR-Central Inland Fisheries Research Institute, Kolkata, West Bengal – 700 120, India
*[E-mail: tsnagesh2@gmail.com]

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The current study used GIS mapping to identify potential fishing areas for *Chrysochir aurea* (Richardson, 1846), a commercially important sciaenid species, along the coast of West Bengal, India, by analysing its spatio-temporal distribution and abundance. Data were collected from two purposively selected trawlers operating along the coast of West Bengal from October 2021 to September 2022. *Chrysochir aurea* was found to be distributed at depths ranging from 10 m to 67 m, with the largest catch per hour value (19.07 kg h^{-1}) occurring at depths ranging between 10 m and 30 m. The maximum catch was recorded in the southeast, which is regarded as a potential fishing zone along the coast. The predictive maps inferred that the species is more prevalent in the southeast region during pre-monsoon and both southeast and southwest regions during post-monsoon and winter seasons. Spatio-temporal distribution of *C. aurea*, recorded in the present study, will not only help in identifying the potential fishing grounds but also in framing management strategies for sustainable fisheries along the West Bengal coast.

[**Keywords**: *Chrysochir aurea*, GIS mapping, India, Potential fishing zone, Spatio-temporal distribution]

Introduction

Sciaenid fishery forms a substantial commercial fishery accounting for approximately 2.93 % and 7.73 % of total marine landings in India and West Bengal, respectively in 2023(ref. 1). *Chrysochir aurea* (Richardson, 1846), commonly known as Reeve's croaker, is one of the commercially important and widely distributed sciaenid species in the Indo-West Pacific region mostly inhabiting coastal marine muddy bottom and brackishwaters[2]. It is reported to be dominantly occurring from Sri Lanka, through the Bay of Bengal, to southern China (including Taiwan) and the southern parts of Indonesia and Malaysia[3].

Despite its relevance, research inputs on *C. aurea* were restricted to the biological information like feeding biology[3,4], length-weight relationship, growth[5-7] and population dynamics[8], while an attempt has not been put forth to the spatio-temporal distribution of the species. Understanding the fluctuations on a spatio-temporal scale has ecological and management implications because the distribution and abundance of fish vary throughout the geographical scale. Lack of such information may hinder the understanding of ecological processes and have an impact on management strategies for conservation[9]. A potentially effective tool for managing fisheries and ecosystems is reported to be a Geographic Information System (GIS) through which the distribution of species can be analysed and mapped. Extensive research has been conducted on the GIS-based spatio-temporal distribution of marine fishes across various countries[10-14]. However, there is a significant paucity of such studies in Indian waters.

Although the principal risks to this species are unknown, overfishing is likely to be a major concern in the Bay of Bengal and Gulf of Thailand[2]. This species may also be impacted by anthropogenic habitat loss and degradation[2]. However, there is no detailed data on the distribution of the species to suggest proper management strategies. Therefore, a study was conducted along the West Bengal coast, India, to assess the abundance and spatio-temporal distribution of *C. aurea* using GIS mapping.

Materials and Methods

Study area

The present study was conducted off the Digha coast of West Bengal between 20°51'47.46" N and

21°59'41.94" N latitude, and 87°01'50.1" E and 89°58'48.06" E longitude during the period from October 2021 to September 2022. Trawl fishing operation was carried out at 123 locations between the above-mentioned latitudes and longitudes at a depth range from 10.6 m to 85.9 m.

Onboard data collection

Geographical coordinates of fishing and allied information like date of fishing, time and depth of shooting and hauling, total catch of *C. aurea* (kg) and total fish catch in the haul (kg) from two purposively selected trawlers (16 m and 11 m Overall length; 320 HP and 106 HP engines, respectively and with cod-end mesh size of 18-35 mm) operating in two directions (southeast and southwest) were collected using a structured schedule.

The shooting points and hauling points were recorded from the Geographical Position System (GPS) onboard (GARMIN), and the depth (m) of the fishing area was measured using the fish finder fitted onboard.

Input data for mapping

Geo-location of fishing and allied information in the form of .xlsx files was converted to CSV (Comma-Separated Values) format for GIS software in Microsoft Excel. The spatio-temporal data, thus obtained, were used as input for the GIS study[15-17].

For mapping, geographic coordinates were converted from Degree Decimal Minute to Decimal Degree with the help of Microsoft Excel. The latitude and longitude points were converted into decimal degrees using the formula as given below.

$$\text{Decimal degree} = Degree + \frac{Minutes}{60}$$

Coastline and bathymetry maps were digitised from available nautical maps and saved in shape file format (.shp). All the queries and bathymetric maps were integrated into GIS and mapped by interpolating the data. Season-wise (pre-monsoon, post-monsoon and winter) GIS-based predictive maps of spatio-temporal distribution of *C. aurea* were prepared using Inverse Distance Weighted (IDW) models in Geostatistical Analysis ArcGIS 10.1 software[18].

To study the abundance of the species, Catch Per Unit Effort (CPUE) was estimated in terms of Catch Per Hour (CPH) using the following formula:

$$\text{Catch Per Hour (CPH)} = \frac{Total\ catch\ (kg)}{Total\ fishing\ hours\ (hour)}$$

Independent samples Kruskal-Wallis test was performed to determine significant differences among the three seasons (pre-monsoon, post-monsoon and winter). Season-wise cluster analysis was performed employing the Bray-Curtis similarity index[19] to describe the similarity in CPH in different seasons using the software PAST ver. 4.0.

Results

The current investigation indicated the distribution of *C. aurea* at depths ranging from 10 m to 67 m with Catch Per Hour (CPH) ranging between 0.13 and 19.07 kg h^{-1}, and the largest CPH occurred at depths between 10 and 30 m. The average CPH in the southeast region of Digha landing centre was higher (3.16 kg h^{-1}) than in the southwest region (2.44 kg h^{-1}). The GIS based predictive maps of spatio-temporal distribution of *C. aurea* in pre-monsoon (January to March), post-monsoon (July to September) and winter (October to December) are presented in Figure 1 (a – c). The average CPH was maximum in post-monsoon (3.63 kg h^{-1}), followed by winter (3.45 kg h^{-1}) and pre-monsoon (3.35 kg h^{-1}) seasons. The predictive maps showed more abundance towards the southeast region during pre-monsoon and in both the southeast and southwest regions during post-monsoon and winter seasons.

The species was distributed at a depth ranging between 10.6 and 32.9 m in the pre-monsoon (January to March) season. The maximum CPH (9.74 kg h^{-1}) was recorded between 21°11'26.64" N and 21°19'04.50" N latitude; and 89°02'46.92" E and 88°55'01.50" E longitude in the southeast at a depth range of 11.3 m to 12.4 m (Fig. 1a). The species was more concentrated in the depth range of 10.8 to 23.7 m in the pre-monsoon period. The CPH was found to be lowest (0.35 kg h^{-1}) between 21°10'16.02" N and 21°10'46.56" N latitude; and 89°02'53.34" E and 89°04'42.36" E longitude in the southeast at a depth range from 16.5 to 20.1 m.

In the post-monsoon (July to September), *C. aurea* was found in the depth range between 18.3 and 69.5 m. The area between 21°08"35.70" N and 21°05'46.14" N latitude; and 89°10' 20.70" E and 89°06"57.42" E longitude in the southeast at a depth range of 43.9 – 47.5 m exhibited the highest aggregation (19.07 kg h^{-1}) (Fig. 1b). The higher CPH (5 to 15 kg h^{-1}) was also found in the depth range from 18.2 to 67.6 m. The lowest CPH (0.17 kg h^{-1}) was reported between 21°04'45.84" N and 21°00'06.90" N latitude; and 89°08'11.22" E and 89°01'36.54" E longitude in the southeast at a depth range between 65.8 and 69.5 m.

The species was caught in the depth ranging between 10.1 and 36.2 m in the winter (October to December) season. The higher CPH (5 to 12 kg h^{-1}) was recorded in the depth range of 11.5 to 22.5 m (Fig. 1c). The maximum CPH (12.01 kg h^{-1}) was reported from 21°15'19.2" N to 21°15'42.36" N latitude; and 89°04'30.00" E to 89°04'44.22" E longitude in the southeast at a depth ranging between 11.5 and 13.7 m. The CPH of 0.13 kg h^{-1} was found to be the lowest from 21°24'53.28" N to 21°19'35.64" N latitude and 88°02'15.90" E to 89°06'08.52" E longitude in the southeast at the depth range of 32 – 36.2 m.

Independent samples Kruskal-Wallis test indicated insignificant differences ($p > 0.05$) in the distribution of CPH among the three seasons (pre-monsoon, post-monsoon and winter). Season-wise cluster analysis depicted 82 % similarity in CPH between winter and pre-monsoon seasons, while post-monsoon showed 81 % similarity with winter and pre-monsoon seasons (Fig. 2).

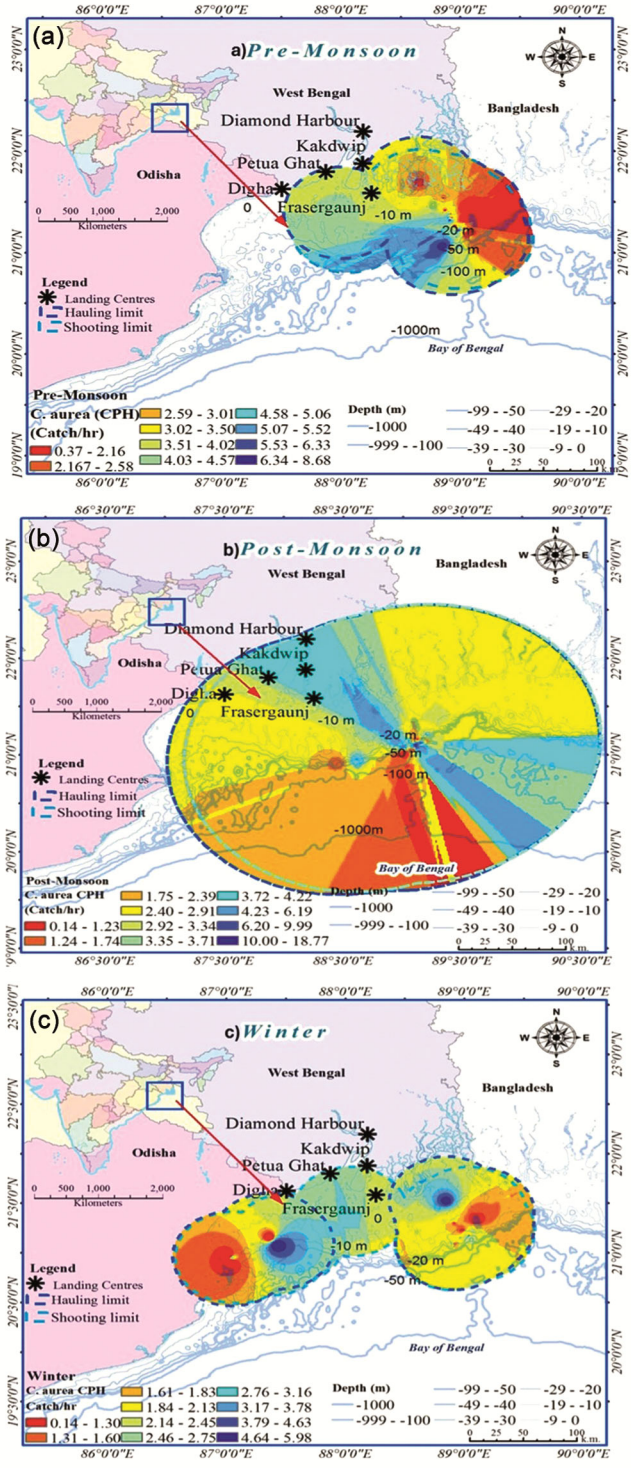

Fig. 1 — GIS based predictive map illustrating spatio-temporal distribution of *C. aurea*: a) Pre-monsoon (January to March), b) Post-monsoon (July to September), and c) Winter (October to December), along the West Bengal coast

Discussion

Chrysochir aurea is a common species found in brackish and marine coastal habitats ranging from Sri Lanka to Southern China, Indonesia and Malaysia[3,20]. The species can be found at depths ranging from 11 to 64 m[(ref. 3)]. In the present study, regardless of season, the maximum catch was found in the southeast direction of the West Bengal coast owing to rich fishing grounds. The southeast region off Digha

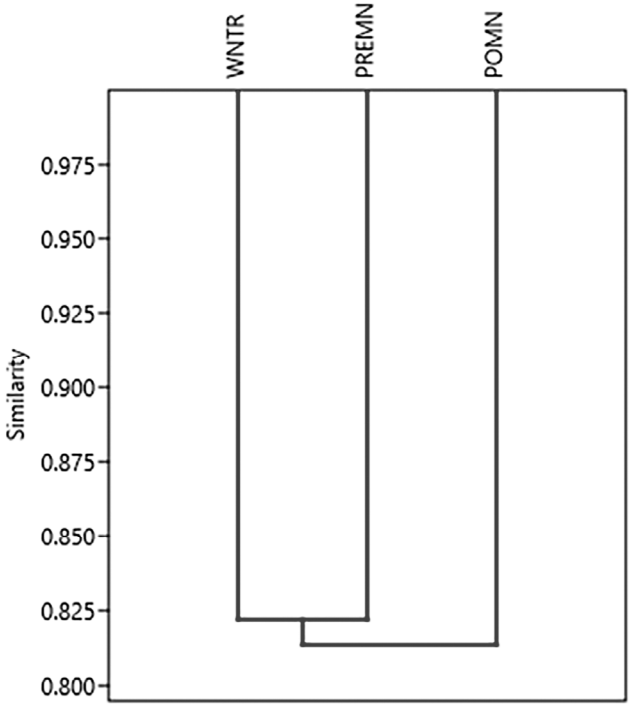

Fig. 2 — Season-wise hierarchical clustering of CPH using Bray-Curtis similarity index

landing centre is regarded as a Potential Fishing Zone (PFZ) of the West Bengal coast (as per PFZ advisories, ESSO-Indian National Centre for Ocean Information Services (INCOIS)), indicating that this region is more productive.

Sciaenids can be found from shallow inshore areas to depths of more than 300 m in tropical and subtropical waters all over the world[21]. On the other hand, some species, including *C. aurea*, reach estuaries and even freshwater, but most species are restricted to continental shelves and slopes and live on or near the bottom[21]. Adults of *C. aurea* are generally found in large schools over muddy bottoms in murky waters, where small crustaceans are available as the main food source for *C. aurea*[22]. It occurs abundantly in deeper waters off the West Bengal coast during the post-monsoon season, which could be related to a variety of causes, including biotic and abiotic factors[13]. The influx of nutrients from the Ganga River and Hooghly-Matlah estuary during the monsoon gets settled into the post-monsoon period and provides a nutrient-rich area, which might increase the abundance of the species during the post-monsoon period. *Chrysochir aurea*'s distribution throughout the West Bengal coast was irregular, determined mostly by depth of water and to a lesser extent by season, which was highly connected with food availability and movement due to spawning[14]. The current study found that the species was more common in the southeast half of the inshore area (50 m depth) during all seasons, indicating a good fishing ground off the coast of West Bengal. The area of southeast region of the West Bengal coast is highly productive due to the Hooghly-Matlah estuary and the Ganga River, which are detritus-rich zones that provide preferred feeding habitat for *Acetes* sp., which in turn, is the most favoured food item for *C. aurea*, resulting in their greater abundance[23].

According to Chanda *et al.*[4], *C. aurea* is a carnivorous species, and crustaceans formed the primary food in its diet throughout the year. *Acetes* sp. and *Squilla* sp. are the most dominant among them. *Acetes* sp. can be found up to 50 m deep[24], whereas the *Squilla* sp. is commonly found between 60 and 120 m deep[25]. The most important fish food items of *C. aurea* include *Secutor* sp., *Bregmaceros* sp., *Stolephorus* sp., *Coilia* sp., and ribbon fish[4]. *Secutor* sp. usually found in the depth range of 3 – 60 m[(ref. 26)]; and the *Coilia* sp. and *Stolephorus* sp. are found up to 50 m depth[27-28]. *Chrysochir aurea* is generally found at a depth range of 10 – 67 m, with maximum catch at depths of 10 to 30 m. So, it can be deduced that the abundance of *C. aurea* coincides with the occurrence of its preferred food items.

The oceanic environmental parameters may also influence fish distribution and their abundance. The migration pattern for spawning or improved feeding conditions a the major driver for the spatial and temporal distribution of fish species, which are by and large influenced by environmental changes[29]. *Chrysochir aurea* is a commercially important species and is landed throughout the year along the West Bengal coast. According to Nguyen Van *et al.*[2], the species may be vulnerable to fishing pressure in the Bay of Bengal. This species may also be impacted by habitat loss and degradation due to anthropogenic activities[30]. Restrictions on bottom trawling and moratorium between May and August are being followed in China and Taiwan to conserve the species[2]. For sustainable fisheries, the current study suggests a combination of mesh size control and fishing effort reduction.

Conclusion

The present study on *C. aurea* is the first attempt of its kind to analyse the season-wise spatio-temporal distribution and abundance of the resource along the West Bengal coast. The results of the study will help the fishers in locating the potential fishing ground and the stakeholders in framing management strategies for sustainable fisheries of the species along the coast.

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Conflict of Interest

The authors declare that there is no conflict of interest in this paper.

Author Contributions

SJ: Data collection, analysis, GIS mapping, and manuscript writing; TSN: Conceptualisation, review and editing; TJA: Review & editing; DB: Visualization & review; and MB: GIS mapping.

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