Short communication

Assessing the impact of environmental factors influencing the spatio-temporal distribution of *Johnius belangerii* (Cuvier, 1830) Belanger's croaker along Mumbai, Northwest Coast of India

K K Ramteke[a], L Shenoy[*,a], B B Nayak[a], G Deshmukhe[a], A B Inamdar[b] & V V Singh[c]

[a]ICAR-Central Institute of Fisheries Education, Mumbai – 400 061, India

[b]Centre of Studies in Resource Engineering (CSRE), IIT Bombay, Powai, Mumbai – 400 076, India

[c]ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi – 682 018, India

*[E-mail: lathashenoy@cife.edu.in]

The aim of this study was to assess the impact of environmental factors influencing the spatio-temporal distribution of *Johnius belangerii*. Fishery independent fortnightly resource surveys were conducted in Mumbai waters from September, 2017 to May, 2018 to determine the effect of environmental variables on spatio-temporal distribution. A Generalized Additive Modelling (GAM) approach showed that distribution and abundance of *J. belangerii* varied spatio-temporally, and environmental factors were found to be influential. GAM models demonstrated that higher catch was located in waters of Sea Surface Temperature (SST) from 25.1 - 31.1 °C with Sea Bottom Temperature (SBT) values ranging from 26-31 °C and salinity of more than 34 $^0/_{00}$. Correlation of environment variables with Catch per Unit Effort (CPUE) suggests significant relationship with SST (0.81), SBT (0.85) and Sea Bottom Chlorophyll-*a* (0.73). The result of this study will be helpful for clearly understanding the intricacies of spatial distributions of fish in relation to changing habitat condition which will be useful in the sustainable management of aquatic resources.

Introduction

The Belanger's croaker *Johnius belangerii* (Cuvier, 1830) belongs to family Sciaenidae, also known as jew fish, croakers or grunters and has wide geographical distribution in Indo-West Pacific, west of the Persian Gulf, east of southern China and Indonesia. *J. belangerii* inhabits shallow coastal waters upto 40 m depth and is known for its carnivorous feeding habit which mainly consists of invertebrates particularly stomatopods, molluscs and isopods. Majority landing of sciaenid fishes comes as by-catch from shrimp trawler in Maharashtra. Quantity-wise landing of sciaenid occupies third position after prawn and mackerel in Maharashtra. Total marine fish landing of India is estimated at 3.63 mt[1]; Sciaenids contribute 6 % to the total marine fish landing and 20 % to demersal landing. Majority of marine landing is contributed by modern mechanized craft (99.2 %) and remaining from motorized (0.45 %) and artisanal craft (0.35 %).

Many studies are available on food and feeding, reproductive biology, growth and mortality aspects of sciaenid fishes. However, the change in spatiotemporal distribution in relation to environmental factors has not been examined. In a situation where increasing fishing pressure due to capital intensive fishing shows declining pattern in rate of fish catch from known fishing ground, prediction based on environmental variables becomes important because of its accuracy and reliability. Environmental variables control the spatio-temporal distribution of fish population and therefore, it is crucial to find out relationship between the environment and catch rate[2]. Environmental variables vary according to location and in turn are responsible for formation of meso-scale events (for instance ocean circulation, temperature and chlorophyll front which, in turn determines the food availability). Many fisheries independent and dependent surveys on this complex pattern of environment and aquatic organism have revealed that distribution change is influenced by the combined activities of abiotic and biotic variables[3]. Change in distribution is the initial response received by species from their surrounding[4,5].

Understanding of adaptive behavior in response to short and long term changes in environment aids to resolve the complexity in spatio-temporal distribution, which is critical of successful stock assessment, lack

of understanding may result in complete collapse of overexploited fish resources[6]. Ecosytem approach to fisheries management is based on understanding the effects of environment variables on spatio-temporal distribution of fishes. In this context, an attempt was made to study spatio-temporal distribution of *J. belangerii* in relation to environmental variables.

Material and Methods

Fishery independent fortnightly trawl surveys were conducted on M.F.V NARMADA (IV), Training cum research vessel of ICAR-Central Institute of Fisheries Education, Mumbai from September, 2017 to May, 2018 to collect fish catch data from coastal waters off Mumbai (Fig. 1). Identical net setting and hauling procedure was followed, 46 m bottom trawl of 35 mm mesh size cod end was used during survey and sorted samples were analyzed in the laboratory and identified up to species level.

To predict the influence of environmental conditions on the catch rate of *J. belangerii*, Generalized Additive Models (GAMs) were used. Models considered for study were fitted using 'mgcv' package[7] in the R version 3.5.1 environment. Spatial data collected during independent survey overlay on the India geo referenced base map with World Geodetic System (WGS) coordinate reference system was used for generation of theme map. After confirming dates and location for remotely sensed data extraction, maps were generated in ArcGIS. Parameters included in the study were surface chlorophyll-*a* (chl-*a*), Sea Surface Temperature (SST), Bottom Temperature (SBT), Sea Surface Height (SSH), Sea Bottom Chlorophyll-*a* (SBC), Ocean Mixed Layer (OML) and Salinity (Table 1). These variables were selected based on the coverage and importance.

Results and Discussion

The spatio-temporal distribution map from surveyed catch data was prepared and processed in GIS Software (Fig. 2). For each pair of column matrix function pair drawn by scatter plots showed clear relationship between catch rate and environmental variables. Upper diagonal panel of the plot shows correlation coefficient while lower diagonal panel shows smoothing line. Preliminary correlation for environment variables with Catch per unit effort (CPUE) was performed. Analysis suggests collinearity (Fig. 3) for Surface chlorophyll-*a* (0.68), SST (0.81), SBT (0.85) and SBC (0.73). Inference test
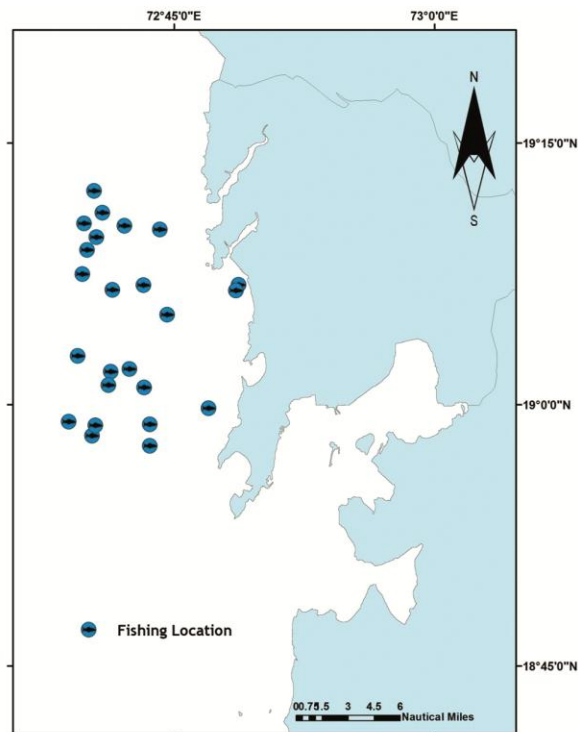

Fig. 1 — Sampling locations map, off Mumbai coast, India

Table 1 — Environmental data sources for assessment

Parameter	Deviance explained %	GCV
s(Chla)	46.6	0.012433
s(Chla)+s(sst)	69.4	0.016478
s(Chla)+s(sst)+s(Salinity)	72.5	0.017709
s(Chla)+s(sst)+s(Salinity)+s(bottomT)	76.7	0.0152
s(Chla)+s(sst)+s(Salinity)+s(bottomT)+s(OMixedLayer)	78	0.0152
s(Chla)+s(sst)+s(Salinity)+s(bottomT)+s(OMixedLayer)+ s(SeaSurfaceHeight)	90	0.014586
s(Chla)+s(sst)+s(Salinity)+s(bottomT)+s(OMixedLayer)+s(SeaSurfaceHeight)+s(DO)	94.3	0.010744
s(Chla)+s(sst)+s(Salinity)+s(bottomT)+s(OMixedLayer)+s(SeaSurfaceHeight)+s(DO)+s(bottom_chla)	94.8	0.012433
Total variation % explained	94.8	

for fitting the variable in GAM model was similar for all regression model mainly, the Chi-square ($\chi2$) tests[8,9]. The $\chi2$ –test used for estimation of significant

Fig. 2 — Spatial distribution of Catch per unit effort (CPUE) during study period

level for added predictor for that level of significance was set at 95 %. Cross validation was used to estimate optimal degrees of freedom. Best fit model CPUE for *J. belangerii* was selected on the basis of deviance level (94.8 %).The best GAM with the lowest Akaike's Information Criteria (AIC) was of the following form (Table 2):

CPUE ~ α + S1(Chl-*a*) + S2(SST) + S3(SBS) + S4(SBT) + S5(OML) + S6(SSH) + S7(DO) + S8(SBC)

In the model, all smoothing functions S1, S2, S3, S4, S5, S6, S7 and S8 are penalized cubic regression splines. The spline of GAM plot showed significant relationship between the environmental variables and catch rate of *J. belangerii*. GAM plot of Chlorophyll-a indicated its impact on locations where catch rate was 2.4 - 4 kg and bottom Chlorophyll as significant for catch abundance (Fig. 4). The concentration of Chlorophyll-*a* had been used to identify the degree of primary productivity and support good fisheries[10]. SST and SBT showed positive relationship at 25.1 - 31.1 $^\circ$C and 26 - 31 $^\circ$C respectively, similar to findings by other researchers[11]. They also observed that tropical sciaenid fishes prefer warmer temperature. Similarly, distribution pattern of fish depends on changes in environmental temperature[12,13]. Ocean Mixed Layer Response plots showed high CPUE at 9-12 m which affect distribution by determining the average level of light seen. SSH
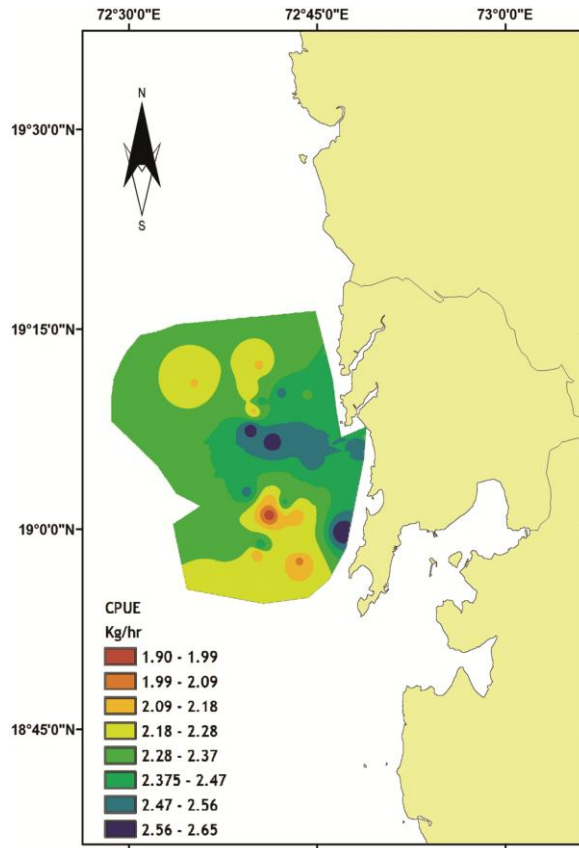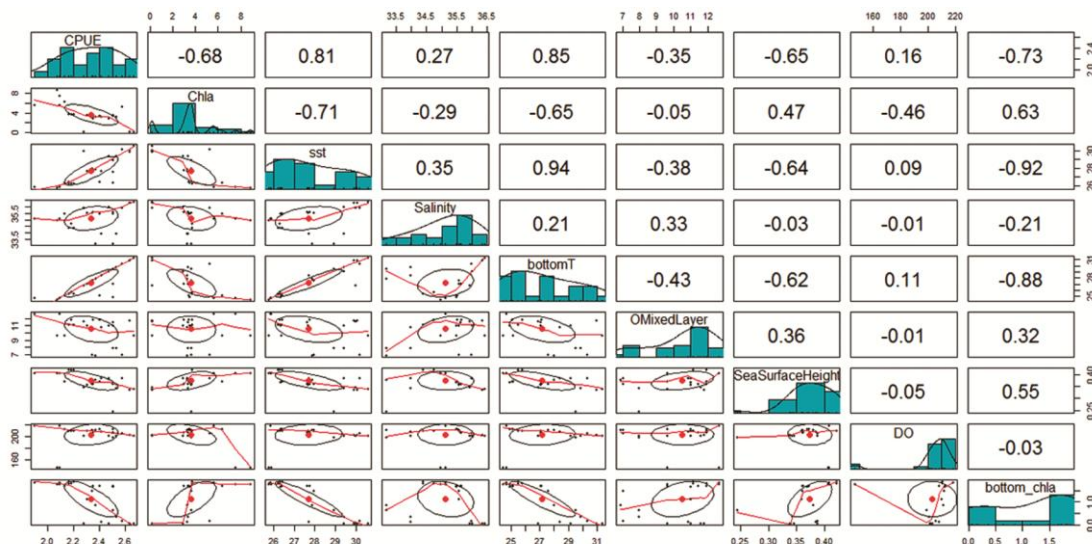

Fig. 3 — Pairplot of *Johnius belangerii* and selected explanatory variables. In the pair plot, the upper diagonal panel shows the (absolute) correlations coefficient and the lower diagonal part the pair-wise scatterplots with a smoothing line.

Table 2 — Analysis of deviance for GAM covariates and their interactions of the best GAM fitted

| Parameter	Data Source	Resolution
Surface chlorophyll	MODIS-Aqua 4km Satellite –NASA	4km
Sea surface temperature	MODIS-Aqua 4km Satellite –NASA	4km
Bottom temperature	E.U. Copernicus Marine Service Information	0.083^0x 0.083^0
Dissolved oxygen	E.U. Copernicus Marine Service Information	0.5^0 x 0.5^0
Sea surface height	E.U. Copernicus Marine Service Information	0.083^0x 0.083^0
Bottom Chlorophyll	E.U. Copernicus Marine Service Information	0.5^0 x 0.5^0
Ocean Mixed Layer	E.U. Copernicus Marine Service Information	0.083^0x 0.083^0
Salinity	E.U. Copernicus Marine Service Information	0.083^0x 0.083^0
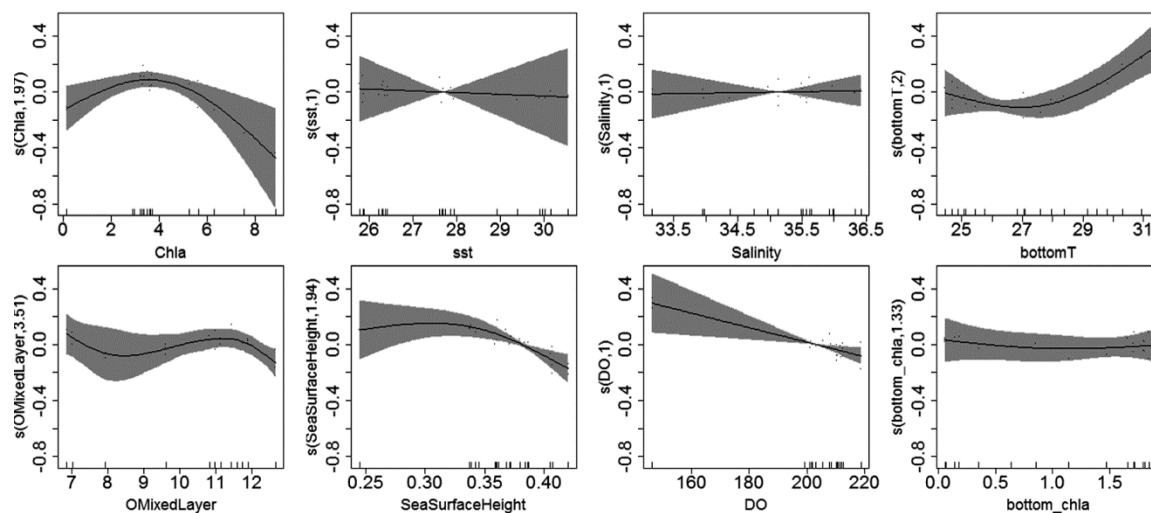
Fig. 4 — Coefficients of the Generalized Additive Model (GAM) for *Johnius belangerii* against additive terms. Dashed lines indicate the value of GAM coefficient, Shaded area are the 95 % confidence intervals at P < 0.05.

controls the mass movement of water and nutrient flow which is basic for productivity of marine environment. Sea Surface Height plot indicated high catch at 0.35 - 0.41 m. SSH used to delineate current patterns and mesoscale eddies formed by warm cold rings[14-16]. In addition, salinity and dissolved oxygen has shown influence on catch rate at 34 - 36.5 $^0/_{00}$ and 200-215 mmol/L, respectively. Salinity is crucial in alteration of species composition and spatiotemporal distribution[17,18].

Fisheries-independent data along with environmental parameters are valuable for assessing spatio-temporal distribution. Results of the study clearly demonstrate that environmental features impact the distribution fish, and it is strongly linked to physicochemical variables of the habitat in which they live.

Conclusion

The findings of the present study are based on the fishery independent fortnightly resource surveys and remotely-sensed environmental variables from Mumbai waters, India. Analysis of environmental variables showed that they were influential in the spatio-temporal distribution and abundance of *J. belangerii.*

Conflict of Interest

There is no conflict of interest in relation to this work.

Author Contributions

KKR and LS: Conceived and designed the experiments and wrote the manuscript; KKR and BBN: Performed the experiments; KKR, GD and ABI: Analyzed the data; and KKR, VVS and LS: Contributed to reagents/materials/analysis tools.

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