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Note

Stock assessment of Bombayduck *Harpadon nehereus* (Hamilton, 1822) from Gujarat coast using non-equilibrium production model

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ABSTRACT

Bombayduck *Harpadon nehereus*, harvested mainly by *dol* nets (stationary bag nets), has been a prolific fishery in the northern region of Arabian Sea and Bay of Bengal. Biomass and maximum sustainable yield (MSY) estimates for the Bombayduck stock in the Saurashtra region were obtained from a non-equilibrium surplus production model approach utilising catch per unit effort (CPUE) time series derived from fish landing data. Fox model was found to be the most appropriate defining model and the results demonstrated that the stock is currently being overexploited.

Keywords: Bombayduck, 'Dol' net, Gujarat, Maximum sustainable yield (MSY), Non-equilibrium surplus production model

Bombayduck *Harpadon nehereus* (Hamilton, 1822), forms an important commercial fishery along north-west coast of India. During 2011, its production contributed 7.8% to the total marine landings of Gujarat in terms of quantity forming the second major pelagic resource landed in the state. Fishery of Bombayduck is typical in nature as its abundance is concentrated in a narrow belt, above 80°F isotherm (Raj, 1954) and is mainly caught by fixed bag nets locally known as '*dol*' nets. In Gujarat, bulk of the fishery is concentrated within the belt 20-21°N; 71-72° E at a depth range of 20-45 m and is landed chiefly at three fishing harbours *viz*., Nawabunder, Jafrabad and Rajpara. The Saurashtra stock of Bombayduck has been identified as unique by several workers (Bapat, 1970; Khan, 1983). Bombayduck forms the major constituent of '*dol*' net catch and hence the '*dol*' nets fishery has become synonymous with Bombayduck fishery. *Dol* nets are fixed bag nets operated in the sea against the tidal current. The mouth of the net is kept stationary with the help of galvanised iron pipes of 3-4 inches dia. The net range in length from 70 to 100 m and in mouth size from 30 to 35 m, kept open using buoys and chain sinkers.

The fishery and biology of the Bombayduck from the Saurashtra coast was extensively studied (Bapat, 1970; Khan, 1985, 1986a, 1987; Ghosh *et al*., 2009). Stock assessment and population dynamics were also carried out using analytical methods (Khan, 1986b, 1989; Ghosh, 2009) utilising length frequency data collected for a maximum of three years. Unlike these studies, the current study attempted to describe the Bombayduck fishery based on catch and effort data for a period of 15 years, collected from all the three major fishing harbours, which has *dol* net landings along the Saurashtra coast, using non-equilibrium production models.

Monthly catch and effort, *f* in fishing hours of Bombayduck fishery were collected from the three landing centres, following stratified multistage random sampling survey method (Srinath *et al.*, 2005). Catch data from *dol* net were aggregated to get a time series of annual landings for the period from 1997 to 2011. Different non-equilibrium production models *viz*., Schaefer (1954), Fox (1975), Pella and Tomlinson (1969) were used to analyse the catch and effort data for the best fit using the Catch and Effort Data Analysis software, CEDA ver. 3.0 (Kirkwood, 2001). The effect of varying the model assumptions (three error models *viz.*, least squares, log-transform and gamma); were investigated to find the sensitivity of the model. Initial proportion of stock was assumed to be at an intermediate level. Best fitting model was selected by examining the residual plots, co-efficient of determination and a comparison of confidence intervals of MSY values obtained from each combinations.

The intermediate parameters obtained *viz.*, intrinsic rate of population growth (r), catchability coefficient (q)

and the carrying capacity of the stock or unexploited stock size (K) were used for the estimation of different limit reference points, performance indicators and precautionary target like $f_{0.1}$. Reference points, maximum sustainable yield (MSY = rK/e); effort at MSY (f_{msy} = r/q); sustainable biomass (B_{msy} = K/e) and $f_{0.1}$ = 0.9f_{msy} were derived. Current biomass (B_{now}), catch (C_{now}) and fishing effort (f_{now}) were estimated to further evaluate performance indicators like B_{msy}/B_{now} and f_{msy}/f_{now}.

The trend of catch and catch rate (CPUE) of Bombayduck during the study period are shown in Fig. 1 and 2. Catch varied from a highest 78000 t in 1998 to 25000 t in 2009. CPUE also varied from 45 kg h^{-1} in 1997 to 12 kg h^{-1} in 2009. A gradual decrease in the trends was apparent both in the case of catch as well as catch rate and therefore, the data were found suitable for surplus production model. Fox model with a logarithmic fit was found to give the best fit (r^2 = 0.856). Residual plots are shown in Fig. 3 and 4 which give uniform distribution of coordinates without any outliers and influential points. Residual plots against time and catch were plotted to understand the fitness of the model to the catch data.

The model has predicted MSY of 43,784.05 t of Bombayduck stock along Saurashtra coast (Table 1). The catches exceeded MSY levels during the period 1997 to 2005 with an average catch of 56000 t. Later, total annual catches dropped below MSY level from the year 2006. The corresponding f_{msy} value estimated was 74,884 fishing hours. Though 2011 catch lingers around MSY, the current effort f_{now} is 22,29,840 h which is 51.2% higher than the optimum effort required for retaining a sustainable fishery. The values of B_{now}/B_{msy} and f_{now}/f_{msy}, 0.69 and 1.51, respectively indicates overexploitation. A reduction of 40.5% of effort is estimated to reach the precautionary reference effort limit $f_{0.1}$ (13,27,396 h) which is widely considered to ensure relatively stable and efficient harvest by the fishery managers.

Khan (1989), analysing the data for 1979 to 1984, suggested adopting management measures including effort reduction to maintain the stock at sustainable levels. Ghosh *et al.* (2009), advised a reduction in effort level by 40% to sustain the fisheries based on the data from 2003 to 2006 following Gulland (1979). Hence it is evident that the fishing pressure on the Bombayduck stock along the '*dol*' net fishing grounds off Gujarat is high requiring management measures such as effort reduction for the long-term sustenance of the resource in addition to following mesh size enhancement and closure of fishing during the summer months (February to May) during which the juvenile catch is rampant as suggested by Khan *et. al*. (1992). Effort reduction can be through buy-back schemes of the nets by the State Government and redeployment of the crafts for deep sea fishing. Periodic

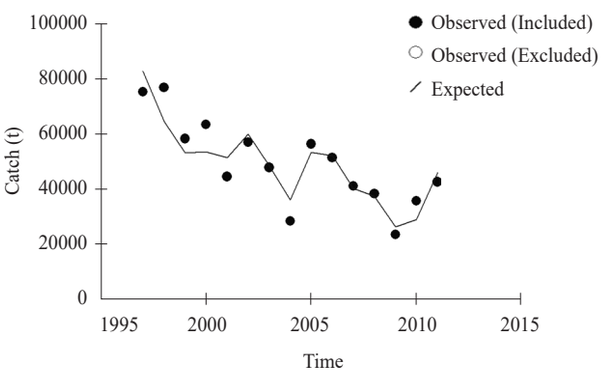

Fig. 1. Expected catch and observed catch against time

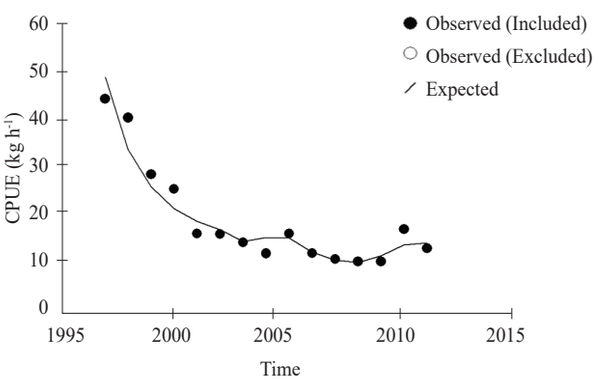

Fig. 2. Expected CPUE and observed CPUE against time

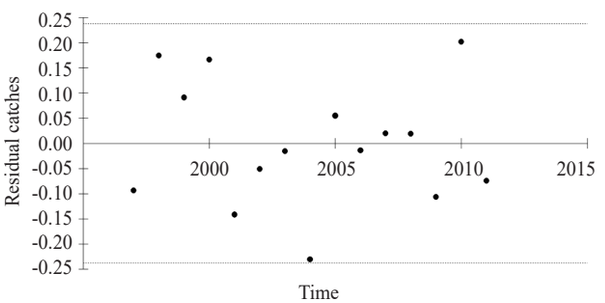

Fig. 3. Residual catch against time

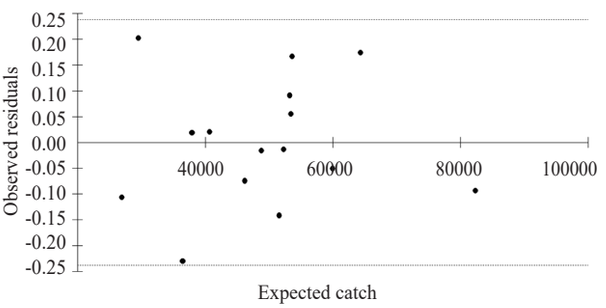

Fig. 4. Residual catch against expected catch

Table 1. Parameter estimates of Bombayduck catch from Sourashtra region

Parameter	Estimate
Model	Fox
Fit	Log transformed
r^2	0.856
K(t)	237288.5
q	2.45 x 10^{-4}
r (per year)	0.5013614
MSY	43784.05 (ranges from 41388.56 to 48013.93 at 95% confidence interval)
B_{msy}	87293.46
B_{now}	60351.1
f_{msy} (hours)	1474884
$f_{0.1}$	1327396
f_{now}	2229840
Average Bombay duck catch 1997-2011 (range)	49559 t (24193-76573 t)
B_{now}/B_{msy}	0.69
f_{now}/f_{msy}	1.51

review of stock status also needs to be carried out to check for stock revival.

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