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Combining surplus production and spectral models to define fishery management advisory - a case study using the threadfinbream fishery along Kerala coast

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ABSTRACT

Threadfinbreams have emerged as a very important resource along the west coast of India both as food fish and as raw material for export oriented surimi production. The state of Kerala contributes 30-40% of the total threadfinbream production in the country landed mainly by multiday trawlers. The analysis of the catch and effort of threadfinbreams during 1985-2012 along Kerala revealed that the landing recently showed decline despite increased fishing effort. A simulation study was conducted to examine the effects of restrictions imposed on the total hours of operation of multiday trawlers on the threadfinbream fishery of Kerala. A genetic algorithm was used for simulation of threadfinbream fishery along Kerala coast using surplus production model and spectral time series methods. Numerical simulations were made for selected seven levels of exploitation and the average biomass and average yield were calculated and compared with the maximum sustainable yield (MSY). The results indicated that the optimum level of exploitation is at 85.1% of the current level of exploitation to keep the average annual yields during 2013-2020 just below MSY.

Keywords: Kerala, Maximum sustainable yield, Spectral model, Surplus production model, Threadfinbreams

Introduction

Tropical fisheries resource management is focused towards sustaining the resources for their continuous availability in future. The possible options for fisheries resource management to sustain resources would be to restrict fishing effort by regulating the number and operation of fishing vessels. The extent of restriction under this management strategy can be planned only after the assessment of impact posed by fishing on the fisheries resources. Up to a certain extent, simulation models generated from the updated fishery information can be used to render a numerical solution by estimating the impact of different management scenarios. Researchers and fishery managers have used simulation models for projecting the behaviour of fishery under different management scenarios and to address the specific issues related to environmental fluctuations, bycatch and fishery of economically important species (Paulik, 1969; Grant *et al.,* 1981; George and Grant, 1983; Ackley, 1995; Prager, 2002; Pelletier and Mahévas, 2005; Needle, 2014). In India, an ideal simulation model was developed for fleets like trawl and ring seine fishery in Kerala using surplus production and spectral time series models (Sathianandan and Jayasankar, 2009). However, there are no reports available on numerical projection of a fishery group using simulation models along Indian waters.

The threadfinbreams or Nemipterids under the family *Nemipteridae* is an important demersal group which contributes to 17.4% of the total demersal fish landings and 4.6% of the total marine fish landings (TML) along Indian coast (CMFRI, 2012). The total threadfinbreams landings along Kerala coast during 1985-2011 grew from 24,150 t to 66,513 t while the all India landing of threadfinbreams increased from 38,571 t to 1, 74,079 t. Kerala state contributed an average share of 42% during 2001-2011 in total national landings of threadfinbreams. The exploitation rate is reported to be above the optimum level for *Nemipterus randalli* and *Nemipterus japonicus,* with the spawning stock biomass estimated in both the species to be more than 30% of the stock at its unexploited level (CMFRI, 2010).

Multiday trawlers are the major fleet which significantly land threadfinbreams along Kerala coast.

The analysis of the effort (in actual hours of operation) and catch data revealed that there are three phases in the development of fishery (Fig. 1). The effort and catch were increasing in the initial phase (1985-1997) followed by a reduction in both catch and effort (1998-2005) in the second phase. The third phase (2009-2012) showed an increase in effort as well as catch for the group. During this phase, the effort was continuously increasing whereas the landings showed a decline in 2012 after a peak in 2011. The catch per unit effort (CPUE) also showed a declining trend during 1985-2012 (Fig. 2).

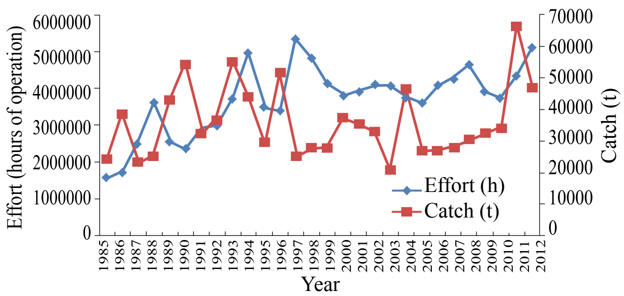

Fig. 1. Catch and effort in the threadfinbream fishery along Kerala coast during 1985-2012

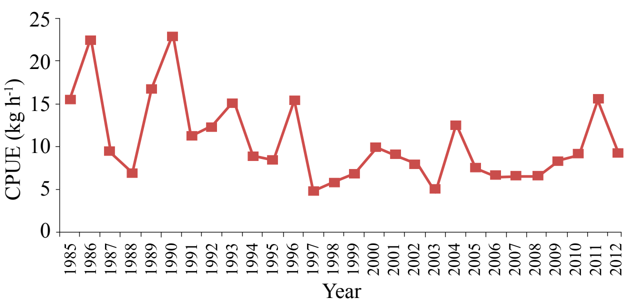

Fig. 2. Catch per unit effort (kg h^{-1}) of threadfinbreams along Kerala coast during 1985-2012

In this context, a study was conducted to examine the effects of various management scenarios in terms of restriction of the total hours of operation of multiday trawlers on the threadfinbream fishery of Kerala. It was assumed that the pattern of change in effort would have an impact on the landings of threadfinbreams along the coast. The study was aimed to generate possible effects of changes in effort on the landings of threadfinbreams and for identifying best solution to keep the harvest in the neighbourhood of maximum sustainable yield (MSY).

Materials and methods

The threadfinbream resource off Kerala includes mainly two species namely Japanese threadfinbream, *Nemipterus japonicus* and Randall's threadfinbream, *Nemipterus randalli* (Murty *et al.,* 2003). This tropical demersal fishery resource lives in schools, generally close to bottom around depth zones of 50-100 m. The distribution is within a range of 34°N - 12°S, 31°E - 133°E (Russell, 1990). Both species are distributed in Indo-Pacific region with the maximum abundance in Eastern and Western Indian Ocean (Russell, 1990). The threadfinbream resources along the Kerala coast are caught using multiday trawlers at about 35 - 70 m depth zones. Japanese threadfinbream is caught from depth zones of about 40-60 m while the Randall's threadfinbream from 30-50 m zones. The fishing season for threadfinbreams starts in September along the Kerala coast and continues till April with peak season from September to January.

Time series data on catch and effort (in actual fishing hours) of threadin breams landed by multiday trawlers along Kerala coast during 1985-2012, collected by Central Marine Fisheries Research Institute (CMFRI) Kochi was used for the study. The simulation methods using spectral time series model, surplus production model (Schaefer, 1954) and genetic algortithm developed by Sathianandan and Jayasankar (2009) were found ideal and applicable for our analysis. The computer software developed in C++ and validated by CMFRI, Kochi (Sathianandan and Jayasankar, 2009) was used for executing the spectral time series models and genetic algorithm for simulation of fishing effort, biomass, fishing mortality and yield for the former study. This method was used in the current study to project the impacts of different management scenarios on the threadfinbream fishery along Kerala coast. The parameters or constants used in this model were : Initial biomass 'B_0', Carrying capacity, '*K*', Intrinsic growth rate, '*r*' and Catchability coefficient '*q*'.

The parameters were estimated using a genetic algorithm developed at CMFRI, Kochi using the time series data on threadfinbream catch and trawling effort during 1985-2012. Further, these parameters were used to calculate maximum sustainable yield (MSY), biomass at MSY (B_{MSY}), fishing mortality at MSY (F_{MSY}) and the fishing effort corresponding to MSY (f_{MSY}) (Sathianandan and Jayasankar, 2009). The time series simulation of trawling effort was executed using the spectral time series (Sathianandan and Jayasankar, 2009) model with the estimation of model parameters and residual variance. We have used a total of 1000 simulations of effort series using the fitted spectral model. Further, the biomass, fishing mortality and yield were calculated for each simulated effort using the estimated surplus production model. In this situation, the regulation of fishing effort in terms of fishing hours for trawlers were introduced by manipulating the simulated effort in different scales (increasing and decreasing). The calculation of biomass, fishing mortality and yield were followed under different fishing scenarios. Then, these fishery indicators were compared for optimising the fishery management scenarios to a single solution.

Results and discusssion

Initial and final estimates of parameters of the surplus production model obtained for the threadfinbream fishery are given in Table 1 and Table 2. The MSY, B_{MSY} and F_{MSY} were estimated to be 34,251 t, 20,674 t and 1.656 for threadfinbream fishery from the surplus production model. The average catch of threadfinbreams during 2006-2012 was 30,371 t which is below the estimated MSY.

Table 1. Initial and final estimates obtained through Wang's method and genetic algorithm respectively for the parameters of Schaefer's surplus production model for threadfinbream fishery in Kerala

Parameter	Description	Threadfin breams
	Initial estimates	
B_0	Initial biomass (t)	46726.3
K	Carrying capacity (t)	108596
r	Intrinsic rate of growth	2.9022
q	Catchability coefficient	0.00000042
	Final estimates	
B0	Initial biomass (t)	51797.15
K	Carrying capacity (t)	41348.17
r	Intrinsic rate of growth	3.31338
q	Catchability coefficient	0.000000477

Table 2. Estimates of parameters for the spectral model using effort series of threadfinbream fishery in Kerala

a_0	3699723		
No (*i*)	*f*	a_i	b_i
1	0.03571429	-433569	-560571
2	0.21428571	-621081	-133890
3	0.07142857	-574525	10087
4	0.28571429	-302789	-313467
5	0.3214857	-263005	88843
6	0.17857143	-107664	-192400
7	0.5	-9155407	-296942
8	0.46428571	-136308	-188956

The average annual yield during the seven year period of 2006-2012 was 33,678 t and the average of the yield during 2013-2020 obtained through simulation at current level of exploitation is 31,365 t (Tabel 3). Thus, there is a 7% reduction in the estimated yield in comparison with the average yield during 2006-2012. The average simulated yield was below MSY. However, the average simulated biomass was 53% higher than the average biomass during 2006-2012. The average simulated biomass was always higher than the biomass at MSY level (Fig. 3). Under the fishing scenario where effort was reduced to 75% of the current level, two major observations seen were the reduction of average simulated yield by 19% in comparison with the average annual yield during 2006-2012 and the yield was found to be below the estimated MSY (Fig. 4). In this fishing scenario, there

Table 3. Fishing mortality (F); average biomass (B) and average yield (Y) in tonnes for different levels of exploitation, for threadfinbream fishery in Kerala

MS	Year	F	B	Y		F	B	Y		F	B	Y
EC	2013	1.222	27057	32364	EC 85.1(opt)	1.099	28518	30759	EC125	1.527	23351	34776
	2014	0.721	26218	21595		0.649	27723	20220		0.901	22464	24180
	2015	1.445	31792	38522		1.12	32793	34113		1.806	29208	42038
	2016	1.579	24319	36088		1.379	25932	33425		1.974	20421	36728
	2017	1.179	22070	28993		1.061	23934	27937		1.474	17548	29772
	2018	1.019	25999	28079		0.917	27600	26595		1.274	21885	30354
	2019	1.412	28342	36202		1.25	29678	33967		1.765	24924	38633
	2020	1.113	24318	29078		1.002	25964	27723		1.392	20291	30928
EC50	2013	0.671	34271	20710	EC75	0.916	30691	27670	EC150	1.832	19558	34869
	2014	0.361	33761	12915		0.541	29984	17812		1.082	18717	25451
	2015	0.722	36673	24413		1.084	34269	32692		2.167	26462	43367
	2016	0.789	32623	25188		1.184	28400	32339		2.369	16750	34690
	2017	0.589	31582	19534		0.884	26773	25563		1.769	13322	27949
	2018	0.51	33822	17626		0.764	29964	23788		1.529	17599	30385
	2019	0.706	34917	23550		1.059	31658	31198		2.118	21323	38519
	2020	0.557	32702	18821		0.835	28465	25035		1.67	16408	30583
EC200	2013	2.443	11615	27739								
	2014	1.442	11164	23194								
	2015	2.889	19991	39553								
	2016	3.16	10198	24962								
	2017	2.358	6321	18070								
	2018	2.038	8890	22698								
	2019	2.824	13037	30076								
	2020	2.226	9058	23291								

Suffix of EC represent the percentage change for the simulated effort, 'F'- Fishing mortality per year, 'B'- Average biomass (t), 'Y'- Average yield (t), 'MS'- Management strategy

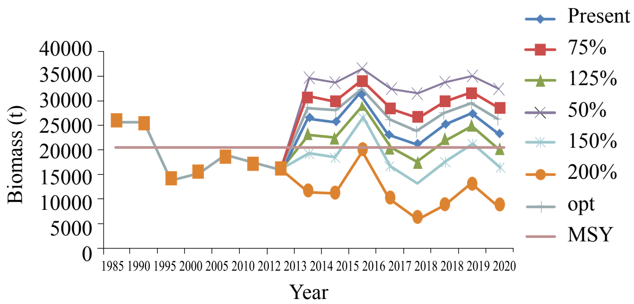

Fig. 3. Simulated biomass for threadfinbream fishery in Kerala up to 2020 at different levels of exploitation namely, present level, reduced to 75% and 50% of the present level and increased by 25%, 50% and 100% of the present level along with biomass at MSY.

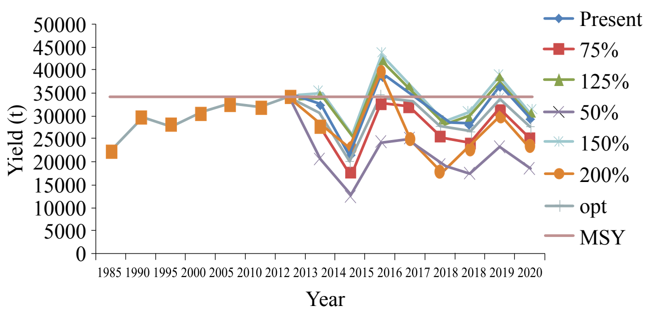

Fig. 4. Simulated yield for threadfinbream fishery in Kerala up to 2020 at different levels of exploitation namely, present level, reduced to 75% and 50% of the present level and increased by 25%, 50% and 100% of the present level along with the MSY.

was a significant improvement in biomass by 75% in comparison with the average biomass during 2006-2012. Moreover, the simulated biomass for all the years was found to be above B_{MSY}.

These results indicate that there can be a reduction of effort below the current level of fishing. At the same time, it should be more than 75% of the current level. With this fact in mind, various finer levels of fishing (reduction of effort from 100% to 75%) were tested to optimise the effort which would provide the highest average yields just below MSY without compromising biomass. As a result of this simulation experiment, it is observed that the reduction of effort to 85.1% of the current level will maintain the annual average yields in the neighbourhood of MSY during 2013-2020. The average annual yield and biomass were observed to be 29,342 t and 27,767 t respectively at this level of exploitation. The maximum and minimum simulated yields were found to be 34,113 t and 20,220 t respectively.

Earlier, the threadfinbream resources were landed as bycatch in shrimp trawls along the Kerala coast (Murty *et al.,* 2003). However, in the recent past, they are observed as a major resource caught in trawls during September to January (CMFRI, 2012). Thus, the resource cannot be considered as a bycatch in the present fishery context. Resource based simulation models will provide insights into direct mortality on target group and an indirect idea on the incidental mortality on other biota (Hollowed *et al.,* 2000). The resource based estimates always provide the baseline for developing the ecosystem based multispecies models (Kinzey and Punt, 2008). The baseline data for the multispecies ecosystem models comes from species specific and group specific assessments (Pauly *et al.,* 2000). Thus our present study will be a baseline for the future assessment of the species in single and multi-dimensional platforms.

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