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Catch-effort relationship and projection scenarios for the dual-fleet trawl fishery of Mangalore and Malpe, southwest coast of India

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Non-equilibrium surplus production models were fitted to derive the empirical production maxima for the single-day (SDF) and multi-day fleet (MDF) trawlers operating from Mangalore-Malpe bases. The Pella-Tomlinson model fitted for SDF showed that the fishery is presently stabilized at an effort level close to the empirical production maximum (11429 tonnes). While using the Schaefer model, the yield from MDF was found to be in excess of the ideal (32406 tonnes). Projection scenarios using different effort levels for MDF indicate that a 15% /annum decrease in effort from the present can bring back the population to a healthy level by the year 1999. The biological interaction among the different component species of the two fleets are also provided.

Mangalore and Malpe are the major fishing ports in Karnataka state producing more than 40% of the state's average annual marine fish catch. Contributing as much as 56% of the production, bottom trawling is the principal method employed from these ports for exploiting demersal resources. The trawl fishery along this coast, which is multispecies in character, has developed gradually since 1959, fuelled by the demand for exportable penaeid prawns, and more recently for cephalopods and finfishes. The status of the fishery, with particular reference to individual demersal finfish and shellfish resources, has been studied from time to time[1-3].

The trawl fishery at Mangalore and Malpe bases is primarily composed of two different fleets[4] with the older Single Day Fleet (SDF) consisting of small trawlers (29-36 feet OAL) and the relatively new Multi Day Fleet (MDF) comprising of larger trawlers (36-56 feet OAL). The SDF operations are confined to within 10-15 km from the shore at depths ranging from very shallow to a maximum of 25 m. The trawling grounds of MDF are different from SDF and encompass a very wide area covering a little more than the entire Karnataka coastline. Their depth of operation is mainly confined to 25-100 m. The MDF fishery is by and large a successful one and this can be gauged from the fact that during 1982-83, it contributed only 36% of the total trawl landings at Mangalore[5] while presently their average contribution amounts to a significant 68%. A study on the comparative economic performance of the two fleets showed that MDF is by far the most profitable of trawl operations, but, profits have been decreasing due to declining catch rates caused by a rapid increase in MDF strength[4].

Therefore, to find the optimum yield that can be obtained without affecting the long-term productivity of the stock (Maximum Sustainable Yield), surplus production models were applied to the above two fisheries. Generally, surplus production models are applied to single stocks, but it has also been applied to multispecies fishery with and without prey-predator interaction[6-8], inspite of many inherent drawbacks[9,10]. Though MSY values are obtained they cannot be considered as biologically optimum yields because of the multispecies nature of the fisheries. Rather they can be considered as empirical maxima of production figures. Therefore, in the absence of any other estimates of sustainable yields of these two fisheries, the non-equilibrium version of Schaefer, Fox and Pella-Tomlinson models[14-16]

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have been employed in this study to derive the empirical production maxima.

Materials and Methods

The period covered for the study was seven fishing seasons (from 1988-89 to 1994-95). Each fishing season commences by September and lasts till May (9 months). June to August (3 months) is usually the closed season due to monsoon and associated rough weather conditions. In some years, fishing has commenced in August itself.

Data on catch and effort were collected based on weekly observations of trawl landings at Mangalore and Malpe fishing ports using a multistage random sampling design[11]. The 95% confidence limits did not exceed 12% of these estimates[12]. This basic data was used to compute annual and seasonal catch and catch rate (kg/h) estimates for each species/group.

Fitting production models—The catch effort data analysis (CEDA, ver 1.1) package developed by Holden & Bravington[13] was used to fit the surplus production models of Schaefer[14], Fox[15] and Pella & Tomlinson[16] to the data. For fitting the models the multispecies catch from each fleet was treated as from a single stock. In CEDA, starting values are obtained by regression, using Schnute's method[17] for the production models. Models were fitted using three different observation-only error models for the distribution of catch conditional on abundance and effort: Normal, Gamma and log-Normal. The catch rate is assumed to be directly proportional to population size, with a constant catchability coefficient. Equilibrium methods were not used for the production models. Confidence intervals for the estimates were determined by a bootstrapping method provided in the software.

Additional model presumptions used were the initial proportion of the population at the start of the study, which was assumed to be low for SDF and high for MDF. These assumptions were based on the fact that SDF grounds are heavily exploited, whereas, the MDF grounds are being expanded to deeper areas every year.

The software provides values of **K** (carrying capacity); **r** (intrinsic rate of growth); **q** (catchability coefficient) and **Z** (shape parameter of Pella-Tomlinson production function). Empirical maxima were obtained by using $rK/4$ (for Schaefer); rKe^{-1} (for Fox) and $rK\ (1+Z)^{-1/Z}\ (1-(1+Z)^{-1/Z}$ (for Pella-Tomlinson).

Projections—Projection scenarios with different effort projections were applied to both the trawl fleets using the best fitting production model. For MDF, the first scenario was a 15% per annum increase and decrease in effort from 1994-95 level up to year 2001 and the second scenario was a 30% increase and decrease in effort. For SDF, the scenario chosen was a 8% increase and decrease in effort from 1994-95 level.

Results and Discussion

Catch, effort and catch rate relationship

During the study period, the production from MDF showed a decline in 1989-90 and thereafter an increasing trend was observed (Table 1). The

Table 1—Year-wise catch, effort and catch rates of single-day (SDF) and multiday (MDF) fleets at Mangalore-Malpe.

Year	Catch (tonnes)		Effort (× 10^6 h)		Catch rate (kg/h)	
	SDF	MDF	SDF	MDF	SDF	MDF
1988-89	8868	22981	1.78	6.37	49.84	36.04
1989-90	7634	13759	1.73	4.32	44.22	31.87
1990-91	7753	18934	1.71	5.75	45.40	32.94
1991-92	10429	18629	2.27	6.61	45.92	28.16
1992-93	16449	17209	2.63	7.41	62.61	23.22
1993-94	9049	26396	2.16	9.47	41.85	27.86
1994-95	11497	34073	1.94	12.68	59.13	26.87
Average	10240	21712	2.03	7.52	49.85	29.57

increase was particularly steep after 1992-93 mainly because of a precipitous increase in effort brought about by a rapid escalation in the strength of MDF (Fig.1). The SDF production was more or less stable during the period except for the spurt in catch during 1992-93 season (Table 1).

The catch-effort relationship was positive for both MDF and SDF (Fig.2). In the case of SDF, catch and effort were maximum in 1992-93 and the 1994-95 levels were considerably lower than these. In the case of MDF the curve shows a continued upward trend and would probably come to an end at some high effort level (Fig.2B). In the Gulf of Thailand a similar steady increase in effort did not produce a drop in total yield of all species combined[8]. One reason is the continual expansion of the trawling grounds and another is the multispecies nature of the catch, with year to year variation in individual species production. The catch rate showed a slight increasing trend with increased effort in the case of SDF (Fig.3A), however, the relationship was not a good fit (r = 0.33). For MDF (Fig.3B), a negative correlation was seen with the catch rate showing a clear declining trend with increased effort (r = -0.5). The SDF fishery, with decrease in effort shows signs of recovery from overcapitalization in 1994-95 (Table 1), whereas, for MDF, catch rates are decreasing. A previous study[18] (using data from 1978-79 to 1988-89) on MDF at Mangalore revealed that the fleet strength of MDF should be maintained at 175 boats. However, the fleet

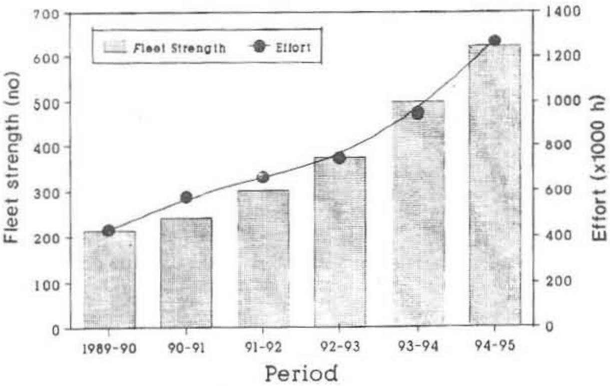

Fig.1—Steep increase in MDF size and proportional increase in fishing effort.

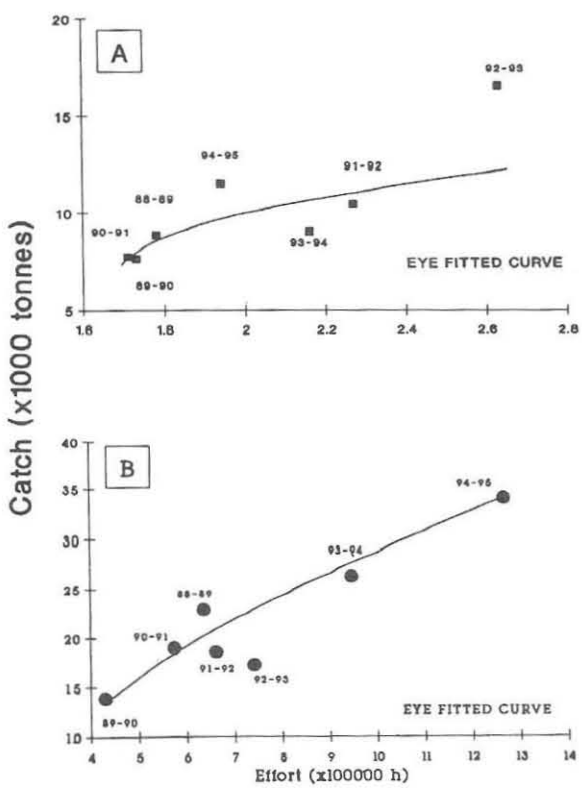

Fig.2—Catch and effort relationship of SDF fishery (A) and MDF fishery (B).

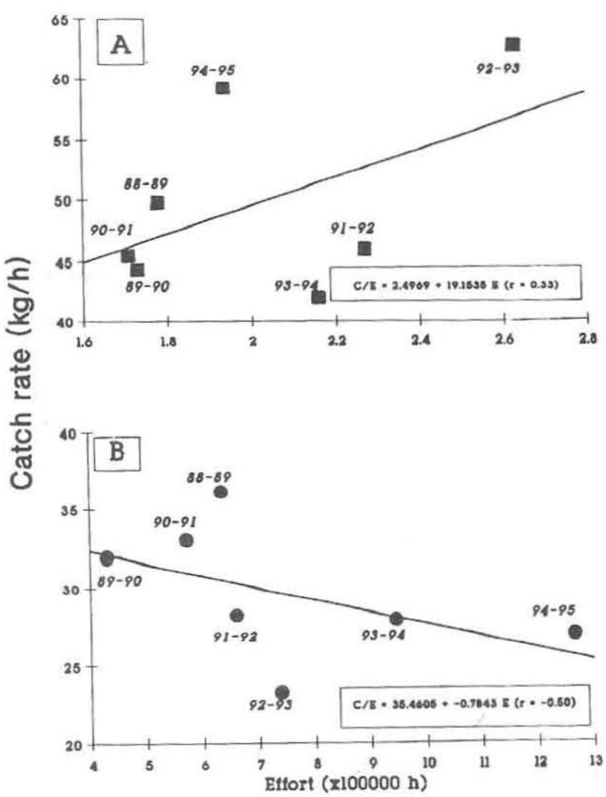

Fig.3—Relationship between effort and catch-rate of SDF (A) and MDF (B).

strength at Mangalore has more than doubled[4] since then to reach 398 boats in 1995.

Predator/prey relationships and catch trends

Biological interactions among species in a fishery is a key factor in understanding the dynamics of a tropical multispecies fishery. In the SDF landings about 12 species of crustaceans, 2 species of cephalopods and 58 species of fishes co-occur of which 17 are abundant, 28 less abundant and 27 occur rarely in the landings[4]. A list of key species groups, together with their average production, production trends and food-chain status is given in Table 2. All these species together constituted 92% of the SDF trawl catch. Most of the co-occurring species in SDF are preys for larger predators. The two major predators present in the SDF trawling grounds are ribbonfishes and sciaenids, and the production of the latter shows an increasing trend. In the MDF landings there were about 15 species of crustaceans, 6 species of cephalopods and as many as 113 species of finfishes which occurred in the landings during one period or the other. Out of this, 53 species occurred abundantly, 46 in less abundance and 35 rarely[4]. Finfishes formed 62%, crustaceans constituted 26% and cephalopods 13% of catches by MDF. Among these, the dominant species groups were (Table 3) stomatopods (18.3%) followed by cephalopods (12.8%), threadfin breams (10.1%), larger carangids (8.1%), larger prawns (6.3%), lizardfish (4.5%) and anchovies (4.5%). A majority of the co-occurring species are predators and some of them like lizardfishes and flatheads show a declining trend, while some of the previously insignificant species like squids are increasing. This can be explained by the removal of predators and food competitors. The major demersal prey species in MDF are the stomatopods whose production trends are not reflective of the abundance because of widespread discards into the sea.

Empirical catch maxima and projections

The empirical maxima levels obtained by using CEDA for SDF and MDF are given in Table 4. Although the Fox, Schaefer and Pella-Tomlinson (P-T) models gave reasonable estimates of empirical maxima for MDF, the Schaefer model was chosen as the best because it gave values with narrowest confidence intervals. Because of lack of good contrast in the SDF data, the r^2 values obtained for all error models were poor. For SDF, the Pella-Tomlinson model using the Gamma error function gave reasonable maximum values. The Fox and Schaefer model did not appear to fit the SDF data well. The empirical maximum for MDF (32406 tonnes) was far in excess of the period's average catch (21712 tonnes) but lower than the 1994-95 catch (34073 tonnes). In the case of SDF, the estimate (11429 tonnes) by P-T model was close to the 1994-95 catch and a little in excess of the period's average catch (10240 tonnes). The expected and observed catch for SDF and MDF (Fig. 4) using the selected models indicate that for MDF the Schaefer model fits the data closely

Table 2— Production trends and food chain status of key resources exploited by SDF at Mangalore-Malpe. Key species groups comprise 92% of the total SDF production.

Key Species	Average catch (tonnes)	Average %	Catch trend	Food-chain status
Stomatopods	3380	33.0	Increasing	Prey
Flatfishes	2574	25.1	Increasing	Prey
Shrimps	1144	11.2	Increasing	Scavenger
Ribbonfishes	1013	10.0	Fluctuating	Predator
Small carangids	434	4.2	Decreasing	Prey
Clupeids	304	3.0	Stable	Prey
Crabs	288	2.8	Stable	Scavenger
Sciaenids	278	2.7	Increasing	Predator

inspite of the broad generalizations made. For SDF, the P-T model gave reasonable parameter estimates but with relatively wide confidence intervals.

The MDF projection scenarios (Fig.5A) show that at 15% /annum increase in effort, which is the current rate of annual increase, the population would be considerably reduced by the year 2001. At 30% increase, the population would almost be decimated. On the other hand, if the effort is reduced at the rate of 15% /annum, the population can be brought back to the 1988-89 level by the year 1999 which means having a fleet strength not exceeding 200 boats. At 30% /annum decrease, the population biomass can be improved further. The SDF population level which is more or less stable would decrease if the effort is increased by 8%/annum (Fig.5B) and it could be increased if a similar effort reduction is applied.

The study shows that non-equilibrium production models as employed in CEDA package can be applied to multi-species fishery. The P-T model fitted for SDF indicates that the fishery has stabilized during the last two seasons near the empirical production maximum figure. This is mainly because the effort level has come down considerably from the peak of 2.63 x 10^5 h. The effort projections for SDF demonstrates that either the effort can be maintained at the same level or decreased to maximize catches. For the multi-day fleet, the Schaefer model gave a very good fit and viable production maxima estimates. The model implies that there is no further scope to increase the effort level of MDF as the fishery has reached

Table 3— Production trends and food chain status of key resources exploited by MDF at Mangalore-Malpe. Key species groups comprise 73.4% of the total MDF production

Key Species	Average catch (tonnes)	Average %	Catch trend	Food-chain status
Stomatopods	3972	18.3	Stable	Prey
Cephalopods	2780	12.8	Increasing	Predator
Nemipterids	2195	10.1	Increasing	Predator
Large carangids	1758	8.1	Increasing	Predator
Large prawns	1360	6.3	Increasing	Scavenger
Synodontids	975	4.5	Decreasing	Predator
Anchovies	975	4.5	Increasing	Prey
Clupeids	750	3.5	Decreasing	Prey
Flatheads	632	2.9	Decreasing	Predator
Pricanthids	527	2.4	Increasing	Predator

Table 4— Estimated values of empirical production maxima of SDF and MDF using different models at Mangalore-Malpe.

Fleet	Model used	Empirical maxima (tonnes)	Fit	r^2 value	Confidence interval (70%)	1994-95 catch (tonnes)	Av. catch (tonnes) 1988/89-1994/95
MDF	Fox	25528	Log	0.97	(21937,30231)	34073	21712
	Schaefer	32406	Normal	0.98	(29448,33547)		
	Pella-Tomlinson	24036	Log	0.96	(20326,28379)		
SDF	Fox	8775	Gamma	0.71	(4367,18822)	11497	10240
	Schaefer	12562	Log	0.75	(4388,37885)		
	Pella-Tomlinson	11429	Gamma	0.73	(7709,19115)		

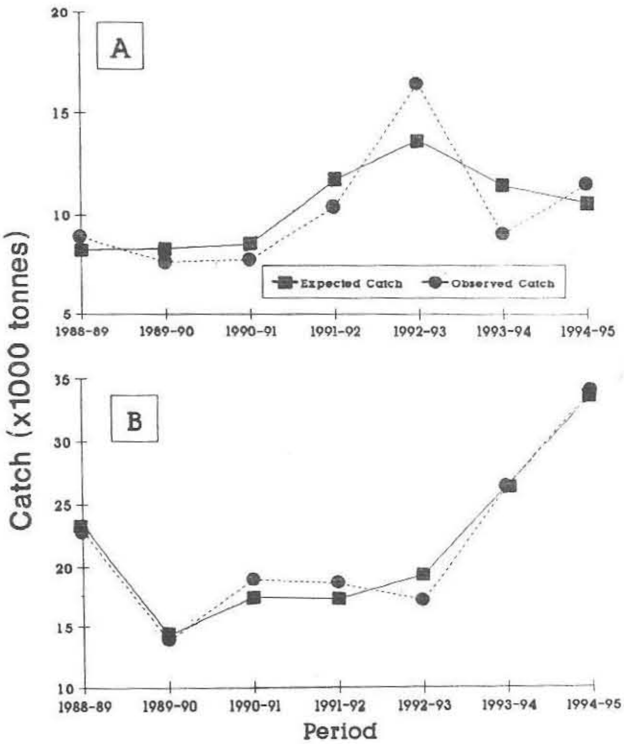

Fig.4—Expected and observed catch for SDF using the fitted P-T model (A) and for MDF using the fitted Schaefer model (B).

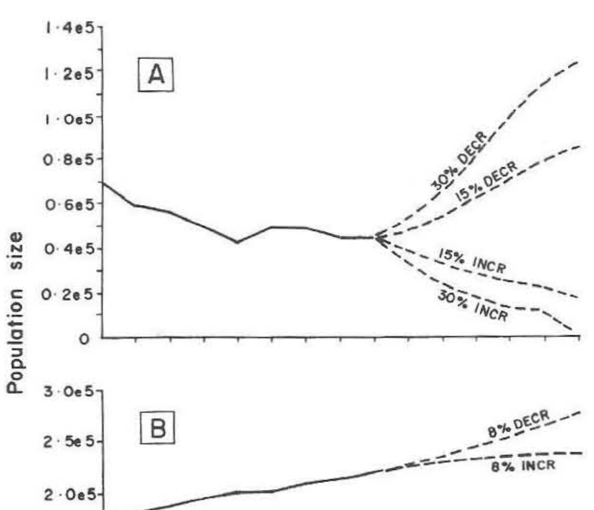

Fig.5—Projections up to year 2001 using A) Schaefer model depicting change in population size (catch) of MDF with different effort scenarios and, B) using P-T model depicting change in population size (catch) of SDF with different effort scenarios.

very high effort levels and is already experiencing declining catch rates. Moreover, this fishery is expanding its grounds every year and it probably can expand further up to 200 m depth, beyond which the fleet will face technological limitations. Therefore 15% /annum decrease in effort would help the fishery to recoup itself.

The results from this study could be used prudently in formulating management options until such time when appropriate multispecies models for the tropics are developed.

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