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Assessment of changes in the threadfin bream species composition using Markov chain

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ABSTRACT

The threadfin bream landings in the Chennai Fisheries Harbour consistently declined from 5450 t in 1994 to 2406 t in '98. The catch rate also declined from 22.6 kg/trawl hour in '90 to 2.3 kg/h in '98. Markovian model is employed to assess the changes in species dominance over the 15 year period. Transition probabilities as well as the steady state probabilities are worked out separately for four species of threadfin breams. It was found that the probability of dominance of *Nemipterus japonicus* has decreased, indicating a major shift in the species composition of the threadfin breams. The possibility of short term prediction on the species dominance pattern by employing Markovian model is demonstrated.

Introduction

The fishery of trawlers based at Chennai has undergone considerable changes during the past decade. The size, efficiency of the trawlers have increased and the main area of operation has shifted to south Andhra Pradesh coast (Vivekanandan and Meiyappan, 1999). The annual trawl effort has increased substantially resulting in consistent decline in the catch per hour of trawl effort (Vivekanandan, 1996). There are growing evidences to suggest that several demersal fish stocks along the coast are undergoing changes. In the present study, time series data on the changes in the catch, catch rate and species composition of threadfin breams, which constitute a major trawl fishery along the north Tamil Nadu - south Andhra Pradesh coast, have been analyzed for the period 1984-1998.

Although temporal changes in the catch composition have been often reported, explicit methods are rarely used for analyzing the dynamics of multispecies fish stocks. Formacion and Saila (1994) introduced a Markov chain model for analyzing assemblage of organisms, which was followed by Srinath (1996) for understanding the dominance order of pelagic fish assemblage along the Kerala coast. In the present analysis, Markov chain model is employed for interpreting the observed changes and predicting the dominance order of different species of threadfin breams.

Materials and methods

Monthly and annual data on the effort and total threadfin bream landings by the trawlers based at Chennai Fisheries Harbour are being collected by CMFRI, 18 days in a month by following

stratified multistage, random sampling method. In the present study, the available data for the period '84-'98 have been analyzed and interpreted. For estimation of species composition, weekly samples were collected during the same period, analyzed in the laboratory and weighed to arrive at monthly and annual landings of each species. To assess the species dominance pattern over the years, the Markovian model was employed on the time series data of species composition. The principle of Markov chain is described below.

Define a state i at time t of a fishery to denote that group i is the dominant group present in the fishery at time t and let there be k such states in the fishery. Define by Pii, the one-step transition probability, that the fishery is at state j now, given that the fishery was at state i during the immediately preceding period. The one-step transition probability matrix is given as :

$$P = \begin{bmatrix} P_{ii} & P_{iz} & \dots & P_{ik} \\ P_{zi} & P_{zz} & \dots & P_{zk} \\ . & . & . & . \\ . & . & . & . \\ P_{ki} & P_{kz} & \dots & P_{kk} \end{bmatrix} \quad \text{.....(1)}$$

Where P_{ii} and P_{ij} denote respectively the probabilities that the group i is dominant during two successive periods and the dominance changes from i in one period to group j in next period, where i = j. The maximum likelihood estimator (MLE) of the transition probability is given by

$$P = n_{ij} / n_j, \quad \text{.....(2)}$$

Where n_{ij} is the number of observed direct transitions from state i to state j in one step, and $n_i = \sum_{j \equiv i}^{k} n_{ij}$ is the total number of observed transition from state i to the other states in one step.

Similar higher step transition probabilities $P_{jk}^{(n)}$ are computed using the recursive equation given below :

$$P_{jk}^{n+1} = \sum_{r} P_{jr}^{(n)} \; P_{rk}^{(i)}$$

Here, $\overline{P_{jk}^{(n)}}$ denotes that if the system is presently in state j, the conditional probability will pass on to state r and finally to state k in the next step. The limiting probabilities are given as

$$\Psi_k = \lim_{n \to \infty} P_{ij}^{(n)}$$

The limiting probabilities are obtained by computing higher order transition probabilities further and noting down the steady state distributional values of each of them. The above theory is applied to the monthly landing data on four species of threadfin breams with a view to study their changes in dominance pattern.

Results and discussion

Decline in catch and catch rate

The estimated annual effort of trawlers based at Chennai Fisheries Harbour increased from 1,75,000 fishing hours (h) during 1984 to 13,40,944 h during '98 (Fig. 1a). The annual landings of threadfin breams, which increased from 459 t in 1984 to 5450 t in '94, declined since then and was only 2406 t in '98 (Fig. 1b). Consequently, the catch rate increased from 2.6 kg/h in 1984 to 22.6 kg/h in 1990 but consistently declined since then to 1.8 kg/h in '98 (Fig. 1c).

The contribution of threadfin breams in the total trawl landings declined from 22.7% in 1990 to 8.0% in '98. In the late '80's and early '90's, the small trawlers (OAL : 9 to 11 m) based at Chennai were gradually replaced by larger trawlers (OAL : 13 to 15 m), which enabled the fleet to undertake voyages up to 7 days along the south Andhra Pradesh coast

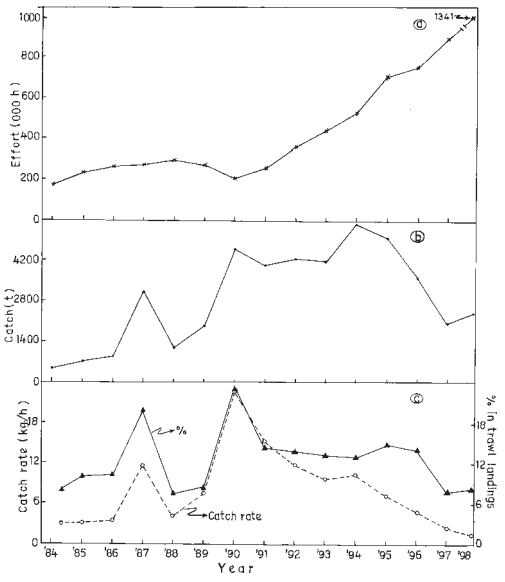

Fig.1 Estimated trawl effort (1a) threadfin bream catch (1b), catch rate and contribution (%) of threadfin breams to total trawl landings (1c) in Chennai Fisheries Harbour

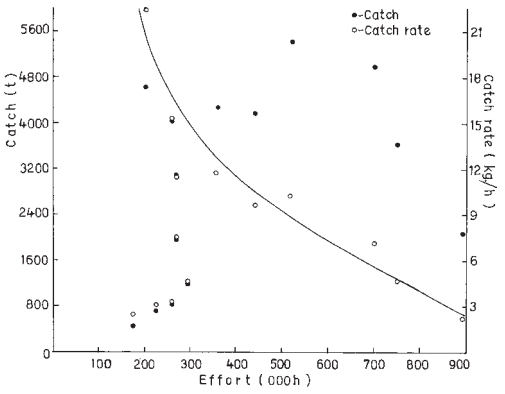

Fig.2 Relationship between trawl effort and catch and catch rate of threadfin breams at Chennai Fisheries Harbour during 1984-1997

(Vivekanandan and Meiyappan, 1999). The increase in fishing efficiency coupled with fishing in highly productive areas (off Nizampatnam, south Andhra Pradesh) resulted in very high catch and catch rate of the fish during the late '80's and early '90s. However, the sustained increase in the fishing effort during the '90's has proved to be detrimental to the fishery. The catch rate which was 22.6 kg/h at the trawl effort of 205,000 hours (1990), declined to 2.8 kh/h at 8,95,000 h (1997) (Fig. 2), and further to 2.3 kg/h at 13,40,944 h (1998).

Changes in species composition

The threadfin bream fishery along the north Tamil Nadu-south Andhra Pradesh coast is contributed by 6 species, viz., *N. japonicus*, *N mesoprion*, *N. delagoae*, *N. tolu*, *N. luteus* and *N. metopias*, the first 4 species being the dominant and the last 2 occur rarely. Despite the annual fluctuations in percentage contribution of each species in the threadfin bream landings, the following salient features of the fishery emerged (Table 1) : (i) The contribution of *N. japonicus* to the threadfin bream landings came down from 52.4% in 1984 to 28.0% in '98. (ii) The contribution of *N. delagoae* share which ranged from 6.9% to 19.5% during 1984- '93, increased and ranged from 21.6% to 29.5% during 1994-'98. (iii) *N. luteus* and *N. metopias*, which together contributed 1.8 to 13.0% during 1984-'92, did not form a fishery during 1993-1998.

Using the maximum likelihood estimator given in equation 2, the transition probabilities of the dominant species are determined (Table 2). Using this matrix, the 12-step transition probabilities are obtained separately for the data sets pertaining to the periods 1984-'89 and 1990-'98 (Table 3). If the fishery situation of 1980's had continued, and given that *N. japonicus* is dominant now, the probability is that 12 months from now the dominance of *N. mesoprion* would be 0.351 only. Furthermore, the probability that *N. japonicus* will dominate the fishery from *N. mesoprion* now will be 0.526. However, due to changes in the fishery of '90's, the probability of the dominance of *N.japonicus* has decreased, i.e., the probability that *N. japonicus* will domi-

TABLE 1. *Percentage contribution of different species to the threadfin breams landings during 1984-1998*

Year	*N.japonicus*	*N.mesoprion*	*N.delagoae*	*N.tolu*	*Others*
1984	52.40	10.92	16.75	11.47	8.50
1985	51.83	18.64	11.10	8.50	9.90
1986	38.59	27.45	8.40	16.46	9.10
1987	37.48	28.22	6.94	14.34	13.00
1988	30.10	31.52	16.14	13.40	8.90
1989	30.10	37.81	19.45	10.13	2.50
1990	29.18	42.63	18.19	8.21	1.80
1991	21.47	49.79	17.68	7.36	3.70
1992	31.17	37.46	19.39	5.17	6.80
1993	36.41	41.48	14.23	7.88	0.00
1994	32.26	28.64	29.49	9.61	0.00
1995	26.59	35.23	22.11	16.08	0.00
1996	32.83	31.80	21.56	13.82	0.00
1997	27.69	38.03	24.04	10.25	0.00
1998	28.00	38.00	22.70	11.30	0.00

TABLE 2. *Dominance of threadfin breams in the monthly catches along Chennai coast during the period January 1984 - December 1998*

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1984	A	A	A	D	A	A	A	B	A	A	A	A
1985	B	A	A	B	D	B	C	A	A	B	C	B
1986	A	A	B	A	A	B	B	A	A	A	A	A
1987	A	A	A	A	B	A	A	B	B	A	B	A
1988	A	A	A	B	A	B	A	A	B	B	A	C
1989	A	C	A	B	B	B	B	B	B	B	B	B
1990	A	B	B	C	B	A	B	B	A	B	A	B
1991	B	B	B	B	B	C	B	C	A	B	A	A
1992	B	B	B	B	A	B	A	B	C	A	A	A
1993	B	B	B	B	A	B	A	B	B	A	A	A
1994	A	A	A	A	A	B	C	B	C	C	B	A
1995	D	B	D	B	A	B	C	B	C	D	A	A
1996	A	A	B	A	B	C	A	A	B	B	B	C
1997	A	C	A	A	C	A	B	B	A	B	A	C
1998	A	B	B	B	B	A	A	A	A	B	A	A

A: *N.japonicus*, B: *N.mesoprion*, C: *N.delagoae*, D: *N.tolu*

nate the fishery for 12 months from now will be only 0.381. Similar higher step transition probabilities are computed to know the steady state distribution probabilities. Accordingly, the limiting probabilities for each of the four species of threadfin breams are computed (Table 4). Thus, if the probabilistic nature of the process of change undergone by the fishery remains the same as in the period prior to 1990, the probability that *N.japonicus* will be denominating the threadfin bream assemblage is 0.510m, and *N.mesoprion* dominating, is 0.350. However, the same was not the situation during the 1990s, in which the limiting probability value for the dominance of *N.japonicus* has reduced drastically to 0.381; on the otherhand the dominance pattern of other species especially *N.*

TABLE 3. *Twelve-step transition probabilities*

Before 1990	A	B	C	D
A	0.520	0.351	0.059	0.000
B	0.526	0.356	0.059	0.000
C	0.524	0.354	0.058	0.000
D	0.000	0.000	0.000	0.000
1990 onwards				
A	0.381	0.455	0.126	0.038
B	0.381	0.455	0.126	0.380
C	0.381	0.455	0.126	0.038
D	0.381	0.455	0.126	0.038

A: *N.japonicus,* B: *N.mesoprion,* C: *N.delagoae,* D: *N.tolu*

TABLE 4. *Transition probability matrix and the limiting probabilities*

	A	B	C	D	Limiting probability
Before 1990					
A	0.620	0.320	0.050	0.000	0.51
B	0.430	0.480	0.090	0.000	0.35
C	0.750	0.250	0.000	0.000	0.05
D	0.500	0.500	0.000	0.000	0.00
1990 onwards					
A	0.400	0.500	0.080	0.020	0.381
B	0.350	0.400	0.210	0.040	0.455
C	0.450	0.450	0.000	0.100	0.126
D	0.330	0.670	0.000	0.000	0.038

A: *N.japonicus,* B: *N.mesoprion,* C: *N.delagoae,* D: *N.tolu*

mesoprion and *N. delagoae* have increased substantially. This is perhaps due to the extension of trawl fishing to areas off Nizampatnam and to depths 40m during the 1990s.

The drastic decline in the catch and catch rate of the threadfin bream is a matter of concern. It appears that the fishery is experiencing severe fishing pressure due to sustained increase in the trawl effort.

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