Indian J. Fish., 43(2) : 115-120, Apr.-Jun., 1996

Markov chain application to the dynamics of the pelagic fishery along the Kerala coast, India

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ABSTRACT

The changing pattern of the composition of the pelagic fish assemblage in Kerala in the context of the introduction of the ring-seine gear has been modelled with the help of Markov chain model. The transition probabilities of the species dominance with respect to four dominant groups, namely, oilsardine, muckerel, whitebait and carangids before and after the introduction of the ring-seine have been estimated. The long term transition probabilities have also been computed with a view to predicting the status of the dominance of the major pelagic groups.

Introduction

The dynamics of the exploited fish populations are studied with the help of suitable population models. Conventional models in fish stock assessment mainly investigate the response of the fish stocks to ths varying regimes of exploitation through single species based modelling. Only v<ary few attempts have been made towards multispecies stock assessment and their applicability in general is debatable. The data demands for these methods are quite extensive and the collection of the relevant data is time consuming and expensive. Knowledge of the dynamics of species dominance over a period of time under varying exploitation patterns is critical for the proper aissessment of the exploited stocks. None of the conventional stock assessment approaches address this problem. However, the classical multivariate statistical techniques, the related distribution theory and descriptive techniques for exploring patterns were applied to the data sets. Saila and Erzini (1987) presented a review of the methods and the models used in the fisheries context to study fish assemblage with special reference to Markov process application. Formacion and Saila (1994) studied the dynamics of the dominance order of pelagic fish stocks in the purse seine fishery in the Phillippines based on a simple Markov chain model. In this paper the change in the dominance of the major pelagic fish assemblage along the Kerala coast in the context of the introduction of ring-seine has been investigated. The pre- and post ring-seine scenario has been analysed with respect to change in the composition of pelagic fish catch through the transition probability approach.

Database and methodology

The quarterly landings of marine fish landings from 1981-'94 in Kerala obtained through a multi-stage stratified sampling developed by the Central Marine Fisheries Research Institute, Cochin form the database for this study. Although ring-seine operations commenced from the third quarter of 1986, the period 1988-'94 has been considered as the post ring-seine period since the actual effect began to manifest only from 1988 onwards (Alagaraja *et al.* 1994). The partitioning of the total fish landings into pelagic and demersal groups was done as per the classification followed by the Central Marine Fisheries Research Institute (CMFRI, 1982). For this study the four dominant pelagic groups considered were oilsardine (A), whitebait (B), carangids (C) and mackerel (D). The estimation of transition probabilities and the related theory of Markovian process are given in Formacion and Saila (1994).

A brief review of the fishery

Kerala has been the major contributor to the marine fish landings in India (CMFRI, 1995). Over the years the fishing practices along the Kerala coast had undergone tremendous changes and the region in the depth range of 0 — 50m had been thoroughly exploited both vertically and horizontally. Dominance of pelagic fish stocks such as the oilsardine and mackerel have been the main feature of fish landings in the state. Earlier to the eighties, these small pelagic fish stocks were exploited mainly by employing the traditional gears such as the boat seine, shore seine, small gillnets and other smaller gears. Early eighties witnessed the introduction of purse seines whose impact on the pelagic stocks such as oilsardine and mackerel could not be assessed clearly. Though there was an increase in the landings of some of the pelagic stocks it was, however, not clear, whether it was actually the effect of purse seiners or due to natural fluctuations (Jacob *et al.* 1982). Large scale motorisation of the indigenous fishing crafts also began during the eighties. In the second half of the eighties an indigenous gear namely ring-seine was introduced and became the favourite gear of the traditional fishermen using the motorised craft. The real impact of ring-seine was felt from 1987 onwards with increase in effort and the resultant catch (Alagaraja *et al.*, 1994). Since 1988, the ring-seine dominated the fishery and caused a major set back to the traditional boat seine operations. By and large, there has been perceptible change in the species dominance. The period under study, 1981-'94 has witnessed large variations in the major pelagic groups such as oilsardine, whitebaits, carangids and mackerel. With this in background this study attempts to estimate the short term and long term transitions in species dominance in the exploited pelagic fish assemblage with respect to pre- and post ring-seine operation period and predict the future scenario.

The theory

Let p_{ij} be the transition probability assuming the system is at state j now given that the system was at state i in the immediately preceding period. Let there be s states in the system. Here we consider the dominance of a particular group as a state. (Thus, if group 'A' is dominant, the system is said to be in State A). The transition probability matrix is given by:

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1s} \\ p_{21} & p_{22} & \cdots & p_{2s} \\ \vdots & & & \vdots \\ p_{s1} & p_{s2} & \cdots & p_{ss} \end{pmatrix}$$

where p_{ii} is the probability that the group remains dominant in the fishery in two consecutive periods and p_{ij} is the probability the dominant group changes from i to j in one period.

The limiting probabilities are:

$$\lim \; SP.J^{(t)}$$

The maximum likelihood estimate of the transition p_{ij}

$$p = n_{ij}/n_{i.} \qquad \text{—(1)}$$

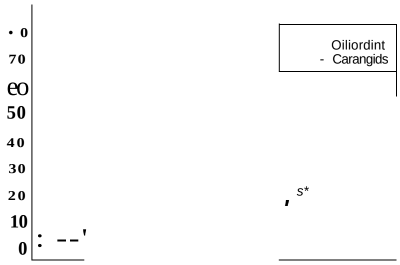
where n_{ij} is the number of observed direct transitions from state i to state j in one step and $n_{i.} = \Sigma n_{ij}$ number of observations in state i.

Results and discussions

The estimated landings of the major pelgic groups and the total marine fish are presented in Table 1. All the 4 major components exhibited wide variations during 1981-'94. The per cent contribution of exploited pelagic fish to the total marine fish landings in the state decreased from about 73% in 1981 to 51% in 1994. There has been drastic fall in the contribution of the oilsardine to the total pelagic landings falling from about 72% in 1981 to 1% in 1994. However, during the same period the contribution of the carangids and the mackerel has increased (Fig. 1 and 2). The average marine fish landings during the pre-ring-seine period (1981-'87) was about 342 thousand tonnes which increased to about 585 thousand tonnes in the post ring-seine period. The average contribution of the oilsardine to the exploited pelagic fish landings decreased from about 49% in the pre ring-seine phase

TABLE 1. *Estimated landings of the major pelagic groups and the total pelagics in Kerala during 1981-'94 (Figures in thousand tonnes)*

year	Oil sardine	White bait	Carangids	Mackerel	Total pelagics	Total landings
1981	147	4	5	16	203	279
1982	143	14	13	11	225	326
1983	155	55	16	13	274	386
1984	147	41	14	12	253	393
1985	79	36	13	18	205	325
1986	41	27	72	22	218	383
1987	45	17	23	10	153	303
1988	61	46	47	44	266	469
1989	185	45	50	85	440	647
1990	179	27	69	78	433	663
1991	106	45	79	54	357	564
1992	54	48	85	38	320	607
1993	50	49	72	59	315	575
1994	2	32	60	72	290	568



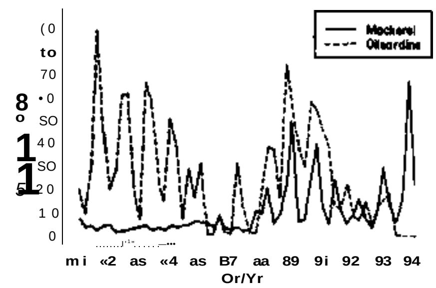
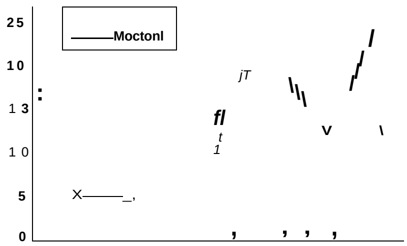


Fig. 1. Percentage of oilsardine and carangids in the pelagic landings of Kerala (1981-'94).

Fig. 3. Quarterly landings of oilsardine and mackerel in Kerala (1981-'94).



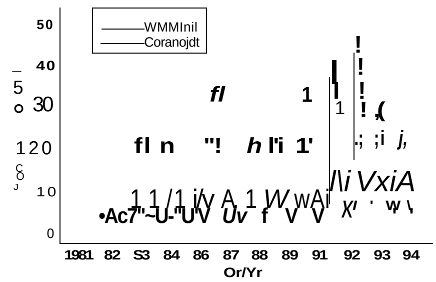


Fig. 2. Percentage of whitebait and mackerel in the pelagic landings of Kerala (1981-'94).

Fig. 4. Quarterly landings of whitebait and carangids in Kerala (1981-'94).

to about 26% in the next phase whereas the contribution of carangids increased from about 10% to about 19%, the other major contributor being the mackerel. The quarterly landings of the four major groups from 1981-'94 are depicted in Fig. 3 and 4. The majority of the landings of these 4 groups take place during October - March. Dominance of the groups in the quarterly pelagic landings is summarised in Table 2. It is clear from the table that there is a shift in the dominance pattern. Oilsardine which was the most dominant component of the pelagic fish assemblage was replaced by the carangids. The change commenced from the third quarter of 1986 from which period the ring-seine operations started and the clear change in dominance was manifested from 1988 onwards except for the year 1990. During the 28 time periods in the pre ring-seine phase the oilsardine dominated the pelagic fish assemblage in 19

TABLE 2. *Dominance of major groups in the quarterly pelagic landings of Kerala during 1981-'94*

Quarter	Year													
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Jan-Mar (Qr I)	A	A	A	A	A	A	C	C	A	A	A	A	C	C
Apr-Jun(Qr II)	A	A	A	A	B	D	C	D	B	A	A	C	B	C
Jul-Sep (Qr III)	A	A	B	B	A	C	A	B	A	A	C	C	C	D
Oct-Dec (Qr IV)	A	A	A	A	B	C	A	A	A	A	C	C	A	D

cases, whereas it dominated only 12 times during the later phase.

The transition probabilities of the states (dominant groups) are computed using the maximum likelihood estimator given in equation 1 and presented in Table 3. The four step transition probabilities are presented in Table 4 for both the phases. If the pre ring-seine scenario was to continue and if the oilsardine (A) is dominant in the fishery the probability thai; in the next year the dominant group will still be the oilsardine (0.699). The probability that the oilsardine will dominate the fishery from the dominance of whitebait in the fishery now will be 0.711. There is shift in the transition probabilities in the post ring-seine phase in which the probability of dominance of the oilsardine had decreased.

The limiting probabilities of these four states (dominant groups) is given in the last column of Table 3. If the probabihtic nature of the process of change undergone by the fishery remains as in the pre ring-seine phase, in the long run the oilsardine has the maximum likelihood of dominating the pelagic fish assemblage with the limiting probability of 0.662. However, in the post ring-seine phase its likelihood of being the most dominant group has considerably decreased and it is likely that in the long run the small carangids will contribute significantly to the pelagic fish assemblage. Thus, in the long run, the chances of oilsardine dominating the landings and sustaining the fishery are remote if the ring-seine effort is left unregulated.

The major aim of fishery models is to contribute to a better understanding of the dynamics of fisheries. This model type uses the Markov chain to compress data into a few predictive quantities. As per applicability of this type of model it may be mentioned here that the per-

Table 3. *Transition probability matrix and the limiting probabilities*

	A	B	C	D	Limiting probability
Pre-ring-seine phase:					
A	0.722	0.222	0.000	0.056	0.662
B	1.000	0.000	0.000	0.000	0.148
C	0.250	0.000	0750	0.000	0.148
D	0.000	0.000	1000	0.000	0.037
Post-ring-seine phase :					
A	0.667	0.083	0 250	0.000	0.442
B	0.667	0.000	0 333	0.000	0.129
C	0.200	0.100	0 500	0.200	0.307
D	0.500	0.000	0 000	0.500	0.123

(A : Oilsardine, B : Whitebait, C : Carangids, D: Mackerel).

TABLE 4. *Four step transition probabilities*

	A	B	C	D
Pre-ring-seine phase:				
A	0.699	0.158	0.103	0.040
B	0.711	0.165	0.082	0.042
C	0.524	0.103	0.348	0.026
D	0.462	0.082	0.436	0.021
Post-ring-seine phase:				
A	0.501	0.075	0.315	0.109
B	0.499	0.074	0.312	0.115
C	0.504	0.069	0.286	0.141
D	0.538	0.069	0.273	0.119

(A : Oilsardine, B : Whitebait, C : Carangids, D: Mackerel).

formance of the model as a predictor of the system depends largely on the assumptions around which it is built. Here it can reasonably be stated that the Markov chain model has produced predictive results which seem to be tenable from an ecological and fishery management point of view.

Acknowledgement

The author wishes to express his deep sense of gratitude to Dr. M. Devaraj, Director, CMFRI, for kindly going through the manuscript and giving valuable suggestions for improvement.

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