A FRAMEWORK FOR ANALYSING FLEET DYNAMICS IN A PRAWN FISHERY

Elkana Ngwenya

Faculty of Fisheries and the Marine Environment
Australian Maritime College
P.O. Box 21, Beaconsfield
Tasmania 7270, Australia.

Abstract:

In this paper data on fishing locations of individual vessels are used to obtain a spatial and temporal series of transition probabilities for describing and forecasting group behaviour.The transitions used in the paper give the likelihood of effort allocation to selected fishing grounds, over two consecutive time periods. The real transitions probabilities indicate the likelihood of relocating to an alternative fishing ground, and virtual transitions indicate the likelihood of remaining on the current fishing ground. The model assumes that the endogenous allocation of fishing effort is conditioned by the rational learning of fishers, the extent of search and reduction of uncertainty in fisheries production, and fishers' adaptive decision making. The framework draws extensively from the theory of and literature on rational expectations, search and uncertainty in production, and decision making. The results for annual transitions show strong neighbourhood effects; a tendency to make more virtual transitions than real transitions; and, that annual transition probabilities are not equilibrium transition probabilities.

1. INTRODUCTION

A framework that enables describing and forecasting likely movement of vessels in a prawn fishery is presented and illustrated. The technique used requires data on the initial distribution of vessels and transitions that reflect movement of vessels.The framework is based on time-invariant, and time-varying transition probabilities. The paper is organised as follows. The literature on fleet dynamics is summarised in Section 2. A framework for representing ground choices is presented in Section 3. The rationale for the choice of model is developed in Section 4. The nature of the data used is detailed in Section 5. This is followed, in Section 6, by a brief description of the technique used for simulating transition probabilities and destination vectors. Preliminary results that illustrate the use of the framework are reported in Section 7, and conclusions are drawn in Section 8.

2. LITERATURE REVIEW

Fisheries production is a joint production process involving endogenous allocation of effort, producing fish products as well as information on size, age, abundance, and temporal and temporal distribution of fish. The joint production process relies heavily on search. The choice of fishing sites will depend on the attractiveness of fishing grounds, Allen and McGlade [1986], the number of renewals possible, Mangel [1982], and information sharing among searchers, Mangel and Clark [1983] and Campbell et al. [1993]. The searcher attempts to maximise profits subject to economic and noneconomic constraints, Watson, et al. [1993]. Fleet dynamics are due to search in order to reduce uncertainty. In this paper a stochastic modelling of fisheries production and its implications for Markov modelling of site choices in fishing[1] is presented.

3. A MARKOV FRAMEWORK

Fleet dynamics are modelled using a two-state and an m-state transition model[2]. The two-state transition model focuses on the decision: *to fish or not to fish.* These two states are defined as m_0 (no fishing state), m_1 (fishing in any ground).

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[1] Note that the term fishing as used in this paper refers to the composite of events that include searching and harvesting.

[2] The m-state transition model focuses on fishing in m-1 distinct fishing grounds and the 'not fishing' state.

Four types of transitions are therefore possible. These transitions are (i) m_0m_0, no fishing in two consecutive days; (ii) m_0m_1, fishing in the second day of the two consecutive days; (iii) m_1m_1, continued fishing over two consecutive days; and, (iv) m_1m_0, not fishing on the last day of the two consecutive days.

The two-state transition model focuses on the decision to fish, and not the decision regarding where to fish. It is clear that this decision problem is trivial when fleet participation is very high. It is reasonable therefore to argue that fishers' main decision problem regards where to fish. This decision problem is defined by the m-state transition model. The two- and m-state transition model assumes adaptive expectations. The transition models are driven by past fishing behaviour or the history of the fishing fleet, and any transition in the state space reflects economic rationality in fishers' fishing behaviour. These transition probabilities are influenced by rational learning in search and economic behaviour in harvesting.

The transition probabilities obtained in the two- and m-state transition models are used as follows. The transition probabilities give a descriptive account of the fishers' participation choice, and express the likelihood of particular ground choices being made by fishers. The initial starting vector shows the position of the vessels at the start of each fishing day. The destination vector is constructed that shows the proportion of vessels in different fishing grounds at the end of the fishing day. The destination vector is calculated by premultiplying the transition probability matrix by the starting or initial vector.

The Markov model of fleet dynamics requires, therefore, (i) a starting vector, (ii) a transition probability matrix, and (iii) a destination vector. The vectors and transition probability matrices are computed for each fishing day,[3] fishing season and fishing period. The magnitude of elements of the starting vector and transition probability matrix depend, among other factors, on physical, biological, economic and noneconomic factors. Such factors include, for example, the number of vessels operating in the fishery, the number of alternative high-yielding fishing grounds distant[4] to or in the neighbourhood of the current fishing ground, management requirements[5], off-season activities of skippers, ownership of vessels, classes of vessels, and routine maintenance work on vessels, and the traditional vantage starting positions which are conditional on catch and weather conditions. All these factors lead to a considerable variation in ground and port choices of fishers.

4. RATIONALE FOR THE FRAMEWORK

The Markovian framework used in this paper presupposes that the fisher's decision making process regarding participating in the fishery, fishing in particular grounds, and participating in exploratory activity is aimed, in part, at reducing production uncertainty. Demand and stock uncertainty affect the dynamics of production regardless of the cost of harvesting. Search is therefore a means of reducing uncertainty about the biomass available for harvesting commercially. In fisheries search, stock uncertainty is likely to have an effect on search patterns of fishers. The fisher is considered to influence the catch rate and the level of search activity in order to maximise expected profits subject to biological, technical and related constraints.

The motivation for the numerical technique used here is therefore that: fishers make transitions to alternative fishing grounds in order to maximise expected profits. The fishers' economic decision is to relocate to a fishing ground in which production is such that marginal revenue exceeds marginal cost, and to remain in the selected fishing ground until marginal revenue equals marginal cost. The fishers transitions are therefore in response to the need to both maximise expected profit and reduce production uncertainty through exploration. Their economic behaviour therefore underpins the Markov model proposed.

The framework is focussed on analysing group behaviour of fishers using data on individual fishers data[6]. Individual relocation choices are modelled using a multinomial logit and/or multinomial probit model. Both the multinomial logit and probit models of individual fisher behaviour and the Markov model of group behaviour assume the following. Fishers' expectation of catch influence their relocation decision making. Each fisher exploits information available on fishing conditions, spatial abundance and competition, without making systematic errors. It is assumed that rational

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[3] It is assumed that fishers can only visit one fishing ground in a day. The nature of the data used in the illustration supports this assumption.

[4] The expectation of high catch in the neighbourhoods of the distant alternative fishing grounds is also important.

[5] Management may propose closure of selected fishing grounds that serve as nursery areas or areas of recruitment.

[6] This is in contrast to studies on group behaviour that use aggregate data and draw implications for individual behaviour, for example, Lee et al. [1970] and Bartholomew [1976].

learning in fisheries search and harvesting is possible[7]. Each skipper is assumed to believe that their fishing locations will converge to the true or most ideal location, given the circumstances of each fishing firm. Fishers are expected to change their search patterns and/or tactics when they expect a management policy change, within the constraints of fishing time and competition in production. The direct result that rational learning produces may be difficult to show empirically, however. For example, in a Markovian model with rewards it is often difficult to model the effects of catch (the reward) and the fishing path (relocation transitions) separately. Nonetheless, the transition that the fisher makes may be considered a proxy of that result of rational learning in fishing.

5. DATA

Confidential prawn trawling data on vessel location and catch are used. Four prawn fishing periods, 1991 through 1994, are considered. Forecasts are made for each of these fishing seasons as a check for model consistency. Forecasts are then provided for subsequent fishing periods. The data are organised as follows. First, a transition number matrix for a group of vessels is constructed. The transition number matrices give the history of fishing during the selected time period. Second, a transition probability matrix is constructed. The transition probability matrix shows the proportion of vessels making any of the possible types of transitions over a specified time period.

6 SIMULATING FLEET MOVEMENT

The likely movements of vessels in the prawn fishery are simulated using historical transition probabilities and starting vectors. A simulation of the transition probabilities and the destination probability predicts likely vessel movement conditional on knowledge on (i) the current location of vessel, and (ii) past transition probabilities. Two random numbers, i and j, that are between 0 and 1, are generated. The first random number, i, places the vessel according to the starting vector and the second random number is used to represent that vessel's destination, based on previous day transition probabilities. Statistical inference from simulation are drawn using simple goodness of fit test between the elements of simulated and observed the destination vectors[8]. The χ^2 values obtained are a subset of all possible χ^2 values from one simulation. The reliability of the goodness of fit is tested by computing the mean and standard deviation of the χ^2 value. Reliability statistics for the estimated destination vector and estimated goodness of fit values by running the simulation a selected number of times. The simulation is repeated several times to compute the average proportion and the standard error of the proportion of significant χ^2 values. The results are tested for sensitivity to (i) choice of transition probability matrix, and (ii) choice of starting values.

7. RESULTS

The results shown in Table 1 show a concentration of relocations on virtual transitions. Real transitions to few fishing grounds in the neighbourhood of the current fishing ground are fairly strong. These results suggest that the current location choices of the fleet are related strongly to previous location of vessels, and the accessibility and catch rates in the fishing grounds in the neighbourhood of the current fishing ground. The preference ranking of fishing grounds is similar for the periods 1991 through 1994. The results shown in Table 2 suggest that the intensity of allocation of effort is not significantly different between any two sample periods.

8. CONCLUSION

The paucity and magnitude of real transitions have the following policy implications. First, closing grounds with zero or near zero virtual and/or real transitions to fishing is unlikely to alter fishing patterns. Closed fishing grounds may be still be used as transit routes to other open fishing grounds. Second, research may be conducted to establish the availability of commercial-sized prawns in fishing grounds currently registering zero or near zero transitions. Such search activity may not be viable if conducted by commercial fishers since it would take a considerable time off their fishing schedule. Any evidence suggesting commercial-sized prawn distributions in these zero or near zero transition grounds could be used to recommend relocation of effort to the current zero or near zero transition grounds. Third, zero or near zero transition grounds and/or other grounds may be closed permanently to serve as nursery areas.

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[7] Game theory presents learning issues similar to issues of expectation formation in economies with a sequence of incomplete markets and/or markets with differentially informed traders.

[8] The χ^2 test with m-1 degrees of freedom is preferred for the m-state model because of the relative large number of states, compared to the distribution for the two-state case. Other goodness of fit tests can be used.

TABLE 1: Real and Virtual Transitions for the fishing period 1991 to 1994

		To Zone 0	To Zone 1	To Zone 2	To Zone 3	To Zone 4	To Zone 5
From State 0	**1991**	0.9366	0.0148	0.0073	0.0130	0.0090	0.0194
	1992	0.9402	0.0119	0.0049	0.0135	0.0111	0.0184
	1993	0.9280	0.0126	0.0065	0.0137	0.0138	0.0254
	1994	0.9336	0.0113	0.0053	0.0145	0.0127	0.0227
	mean	0.9346	0.0127	0.0060	0.0137	0.0117	0.0215
	std dev	0.0052	0.0015	0.0011	0.0006	0.0021	0.0032
From State 1	**1991**	0.0886	0.8363	0.0489	0.0076	0.0185	0.0000
	1992	0.0674	0.8289	0.0465	0.0070	0.0503	0.0000
	1993	0.0688	0.8348	0.0512	0.0122	0.0330	0.0000
	1994	0.0492	0.8839	0.0229	0.0051	0.0387	0.0002
	mean	0.0685	0.8460	0.0424	0.0080	0.0351	0.0001
	std dev	0.0161	0.0255	0.0131	0.0030	0.0132	0.0001
From State 2	**1991**	0.0338	0.0674	0.7387	0.0787	0.0814	0.0000
	1992	0.0304	0.0787	0.7036	0.0912	0.0961	0.0000
	1993	0.0330	0.0568	0.6840	0.1320	0.0942	0.0000
	1994	0.0261	0.0542	0.7697	0.0481	0.1018	0.0000
	mean	0.0308	0.0643	0.7240	0.0875	0.0934	0.0000
	std dev	0.0035	0.0112	0.0380	0.0348	0.0086	0.0000
From State 3	**1991**	0.0470	0.0026	0.0179	0.8984	0.0341	0.0000
	1992	0.0392	0.0013	0.0127	0.9048	0.0419	0.0001
	1993	0.0326	0.0019	0.0155	0.9121	0.0379	0.0000
	1994	0.0229	0.0004	0.0088	0.9264	0.0415	0.0000
	mean	0.0354	0.0016	0.0137	0.9104	0.0389	0.0000
	std dev	0.0102	0.0009	0.0039	0.0120	0.0036	0.0000
From State 4	**1991**	0.0664	0.0283	0.0707	0.0755	0.7268	0.0323
	1992	0.0549	0.0444	0.0327	0.0737	0.7757	0.0186
	1993	0.0530	0.0284	0.0402	0.0821	0.7753	0.0210
	1994	0.0566	0.0342	0.0403	0.0780	0.7790	0.0118
	mean	0.0577	0.0338	0.0460	0.0773	0.7642	0.0209
	std dev	0.0059	0.0076	0.0168	0.0037	0.0250	0.0085
From State 5	**1991**	0.1256	0.0000	0.0000	0.0000	0.0120	0.8624
	1992	0.1264	0.0000	0.0000	0.0003	0.0207	0.8526
	1993	0.1212	0.0000	0.0000	0.0000	0.0142	0.8646
	1994	0.1167	0.0000	0.0000	0.0000	0.0196	0.8636
	mean	0.1225	0.0000	0.0000	0.0001	0.0166	0.8608
	std dev	0.0045	0.0000	0.0000	0.0001	0.0042	0.0055

TABLE 2: Chi-square Values for Goodness of Fit Tests using Annual Destinations Vectors in Six States

FROM STATE	91/92	91/93	91/94	92/93	92/94	93/94
0	0.0019	0.0050	0.0037	0.0040	0.0014	0.0008
1	0.0597	0.0187	0.0576	0.0141	0.0239	0.0293
2	0.0086	0.0439	0.0226	0.0252	0.0351	0.0663
3	0.0053	0.0055	0.0212	0.0026	0.0091	0.0075
4	0.0407	0.0236	0.0325	0.0089	0.0069	0.0056
5	0.7109	0.0005	0.0055	0.0027	0.0012	0.0022

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