Assessment of changes in the cephalopod species composition in landings off Visakhapatnam coast, Andhra Pradesh

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Cephalopods are landed by the large trawlers (12-14 OAL (Overall Length), 98/110 hp), known as sona boats and the smaller trawlers (9.5-10 OAL, 68/90 hp). Time series data with respect to catch, catch rate and species composition of cephalopods (cuttlefish and squids) off Visakhapatnam coast for the period 1998-2010 were analysed. The Markov chain model was used to assess the species dominance to understand the changes and predict the dominance order of different species of cephalopods.Monthly and annual data on the effort and total cephalopod landings by the trawlers based at Visakhapatnam Fisheries Harbour collected by ICAR -CMFRI through a stratified multi-stage random sampling method was used. For estimation of species composition, weekly samples collected during the period were analyzed and appropriately weighted to arrive at monthly and annual landings. The three dominant species/groups *Uroteuthis (Photololigo) duvaucelii* (A), *Sepia aculeata* (B) and *S. pharaonis* (C) were employed to assess the resource dominance pattern over the period. The basis of the simple Markov model applied to fish dynamics is that at any particular period, the fishery can be classified into discrete number of states, and that the probability of change from one state to another over a particular time interval depends on the present state. The sequence of states occurring at a particular point is called a Markov chain and is essentially stochastic or random in nature with transitions occurring with given probabilities. The controlling factor in a Markov chain is the transition probability; which is the probability for the system to go to a new state, given the current state of the system. Transitions are then recognized as occurring when dominance at a point changes from one species or species group to another.The process of dynamic change in the fishery with respect to most abundant species in the fishery can be studied over long periods of change through higher order transition probabilities Limiting probabilities are used to find whether the fishery will ever reach a stable state or equilibrium if the conditions affecting the fishery remain the same over time.

During the period 1998-2010 estimated landings of cephalopod in Visakhapatnam Fisheries Harbour was 12113.6 t with an average annual production of 931.8 t. The cephalopod landing during 1998-2003 was less than 1000 t; which increased subsequently and recorded a steep increase to 2193 t (in 2010). The effort also increased over the period from a 139462 in 1998 to 2461167 in 2010. The average catch per unit effort was 1.03 Kg. The CPUE was very low during the 2002 to 2006 although effort was high. Cephalopods were landed by the large trawlers (sona boats) and small mechanized boats (SMBs). While the SMBs mainly contributed to the cephalopod landings during 1998 -2003, the contribution of the larger trawlers increased tremendously. The small mechanized trawlers had contributed 58.3 % during 1998 to 2001 while sona boats contributed 63.4 % of the cephalopod landings during 2002-2010. Fishery for cephalopods begins by June and peak landings occur during June to September.

During the period squids contributed 20.5% and cuttlefish 79.8% to the total cephalopod landings. Octopus landings were negligible. Among cuttlefish, *Sepia pharaonis*, *S. aculeata*, *Sepiella inermis* and occasionally *S. elliptica, S. brevimana* and *S. prashadi* were landed. *S. aculeata* contributed 34.22% followed by *S. pharaonis* (29.6 %), *S. inermis* (9.6%), *U. duvaucelii* (20.54 %) and the

Table 1. Dominance of major species/species groups

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1998	C	C	C	A	A	A	A	A	A	A	A	A
1999	A	A	A	A	-	A	A	A	B	B	C	C
2000	A	A	A	A	-	A	A	A	A	A	A	B
2001	A	A	A	B	-	B	A	B	A	B	B	B
2002	B	B	B	B	-	B	C	B	B	C	B	B
2003	B	B	C	B	-	B	B	B	B	B	B	B
2004	B	B	B	B	-	B	B	B	B	B	B	B
2005	B	B	B	B	-	B	B	B	B	B	B	B
2006	C	C	B	B	-	C	C	B	B	B	B	B
2007	B	B	B	C	-	B	B	B	B	B	C	C
2008	A	A	A	A	-	C	C	C	A	C	A	B

A –. *Uroteuthis (Photololigo) duvaucelii* B – *Sepia aculeata* C – *Sepia pharaonis*

Table 2. Transition probabilities of major cephalopod species landed

Species	*U. duvaucelii*	*S. aculeata*	*S. pharaonis*
U. duvaucelii	0.750000	0.166667	0.083333
S. aculeata	0.075758	0.818182	0.106061
S. pharaonis	0.192308	0.307692	0.500000

Table 3. Higher order transition probabilities

Species	*U. duvaucelii*	*S. aculeata*	*S. pharaonis*
U. duvaucelii	0.591152	0.287005	0.121843
S. aculeata	0.139199	0.714682	0.146121
S. pharaonis	0.263695	0.437645	0.29866

rest (6.23%) to the total cephalopod landings. Among squids, *Uroteuthis (Photololigo) duvaucelii* contributed entirely to the squid landings. Stray numbers of *L. uyii* and *Sepioteuthis lessoniana* were observed. During 1998-2010 periods, *U. duvaucelii* was the dominant species. During 2002 to 2007, *S. aculeata* was the dominant species contributing to the fishery while 2008 to 2010 *S. pharaonis* landings were the highest.Over the decade, price per kilogram for *S. pharaonis* was ₹220 to ₹230, *S. aculeata* ₹220, *S. inermis* ₹80-100 and *U. duvaucelii* at ₹50-60.

The higher order transition probabilities can be used to predict the fishery at various time periods (Table 3). The limiting probabilities of the various states indicated for *U. duvaucelii, S.pharaonis* was 0.291286 and 0.164078 respectively and highest in *S.aculeata* (0.544647). The transition probabilities of the dominant species estimated using the maximum likelihood estimator are given in Table 2.

The Markov chain model a probabilistic model to produce estimates of unobservable, yet meaningful parameters indicated that the probability that *U. duvaucelii* is dominating the fishery in a month, given that the same was dominating in the fishery in the previous month (p_{00}) is 0.75. From the higher order transition probabilities it is clear that, if *U. duvaucelii* is dominant in the fishery now, the probability that it continues to be the dominant group in the next year ($p_{00}^{(1)}$) is 0.5911. In case of *S. aculeata*, p_{22}, which gives the probability of dominance in two successive months, is 0.7147. The limiting probability that *S.aculeata* will dominate in the cephalopod fishery of Vishakhapatnam is 0.5446 while it is only 0.29 and 0.16 for *U.duvaucelii* and *S.pharaonis* respectively. The analysis indicates that in the long run the cephalopod fishery of Vishakhapatnam coast is more likely to be dominated by *S.aculeata*