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Cephalopod fishery at Kakinada along the east coast of India : Resource characteristics and stock assessment of *Loligo duvauceli*

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Abstract
At Kakinada along the east coast of India, cephalopods were exploited by trawls. Fishery occurred round the year with peak during August-October. Peak abundance and fishery of cuttlefishes coincides with this period, whereas for squids it is during March-May. Cephalopod production continued to increase initially with fishing effort, until 1995, but declined thereafter despite increased fishing effort and expansion of fishing to deeper waters. Fishery, growth, mortality, recruitment pattern and exploitation rates of *Loligo duvauceli* were studied. Nearly 97% of their catch was by zero year groups. They attain sexual maturity and spawn during the first year itself. Spawning occurred round the year with peak during December-February. Exploitation rate of the species is large, 0.741 compared to E_{max} (0.44). This indicated that their stock is under heavy fishing pressure and subjected to over-exploitation. Stock also exhibited declining trend over the years during 1995-'99. These necessitate immediate attention to avoid collapse of the stock and fishery.

Key words : Cephalopods, *Loligo duvauceli,* Stock assessment

Introduction

Cephalopods are the highly developed group of invertebrates and occupy a leading place among the exploited marine fishery resource of the world because of their abundance and high nutritional quality. They constitute 4-5% of the total marine fish production from Indian waters (Meiyappan *et al.* 2000). Their report suggested that the resource in general is either under exploited or optimally exploited from Indian waters. Cephalopods, though share common environment with other marine fishes, they often adopt different life history strategies. In recent years several studies were conducted aimed at understanding the biology and behaviour of commercially important species and their response to exploitation. However, knowledge on many crucial aspects of several species remains limited.

Cephalopod fishery at Kakinada was supported by squids (Order: Teuthoidea) and cuttlefishes (Order: Sepioidea). Increased fishing effort and introduction of large deep going multi-day trawlers along the coast though initially improved the catch, it started declining after 1994-'95. These necessitated proper understanding on the population characteristics of species supporting fishery for developing management strategies. Present study was aimed to update such information on *Loligo duvauceli* along the east coast.

Materials and methods

Fishing effort, catch and catch composition of cephalopods in fishery were monitored at weekly intervals during 1995-1999. Biology of *Loligo duvauceli* was also studied simultaneously. Random samples of the species were collected and analyzed for sex ratio, gonadal maturity *etc.* Catch and effort data documented by the institute for the period 1985-'95 were also used to analyse behaviour of the fishery to increasing fishing pressure over the years.

Monthly length frequency data of the species in the catch was used to estimate growth parameters, mortality rates, exploitation rates and recruitment pattern. Growth parameters, L_∞ and K were estimated through surface response analysis of restructured length frequency histogram by ICLARM's FiSAT software (Gayanilo *et. al.* 1995). Size at first capture (L_{c50}) was estimated following Pauly (1984) and age at zero length (t_0) from von Bertalanffy plot (Bertalanffy 1934)

Natural mortality (M) was estimated from the empirical formula proposed by Pauly (1980), by taking mean sea surface temperature as 29°C and total mortality (Z) and exploitation ratios from catch curve as per Pauly (1983). Exploitation rate (E) was estimated from the equation; $E = F/Z$; where, $F = Z-M$ is the fishing mortality rate. Total stock (P) was computed from the relation; $P = Y/U$; where, Y is the yield and U exploitation ratio $U=F/Z \times (1- e^{-z})$. Maximum sustainable yield (MSY) was estimated graphically as per Corten (1974).

Results

Fishery

Cephalopods were exploited almost exclusively by trawls. Annual effort increased gradually and steadily from 45,002 units during 1985-'86 to 63,989 units by 1998-'99. During the same period, duration of active fishing also increased from 317,284 hours to 990,110 hours. Active fishing time was increased sharply during nineties after the introduction of voyage fishing. With increase in effort, fishing activity was further extended to far deep seas.

Cephalopod landings increased during this period, with wide annual fluctuation (Fig. 1). Catch increased from 289 tons during 1985-'86 to 1,029 tons during 1994-'95. It declined steadily thereafter to 515 tons by 1997-'98. Catch was the lowest during 1990-'91. Catch rate also registered similar fluctuation between 3.6 kg/unit effort during 1990-'91 and 20.1 kg during 1994-'95 (Fig. 2). Catch/hour of trawling fluctuated between 0.4 kg during 1990-'91 and 1.26 kg during 1986-'87.

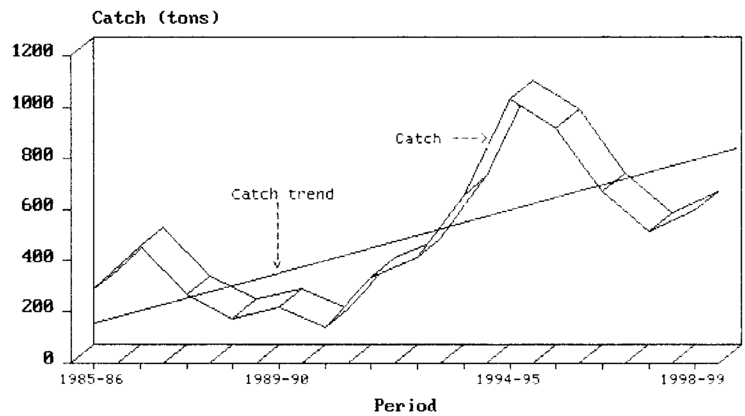

Fig. 1. Growth in cephalopod fishery at Kakinada by trawls during 1985-'99.

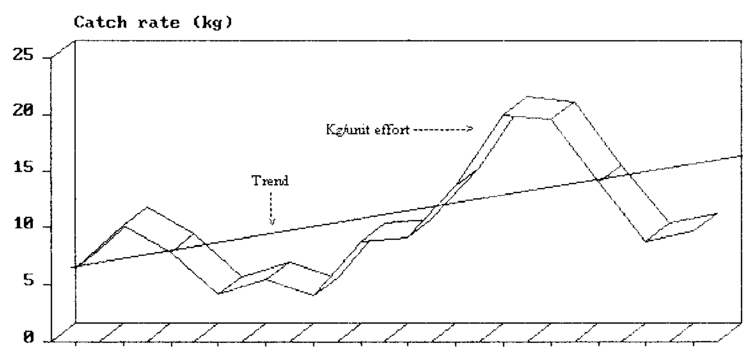

Fig. 2. Fluctuation in the catch rate of cephalopods by trawls during 1985-'99.

Catch composition and seasonal abundance

Fishery was supported by four species each of squids (25.9%) and cuttlefishes (74.1%) (Fig. 3). Among squids, *Loligo duvauceli* dominated (78.1%) the catch. Other species supporting fishery are *L. uyii, Doryteuthes spp.* and *Loliolus spp. Sepia pharaonis*_(41.6%), *S. aculeata* (22.6%) and *S. brevimana* and *Sepiella inermis* (31.4%) supported cuttlefish fishery. Fishery occurred round the year, with nearly 50% of the catches during August-October (Fig 4). Peak fishery and abundance of cuttlefishes occurred during this period, whereas that of squids during March-May (Table 1). Peak abundance and fishery of *L. duvauceli* followed their peak period of spawning.

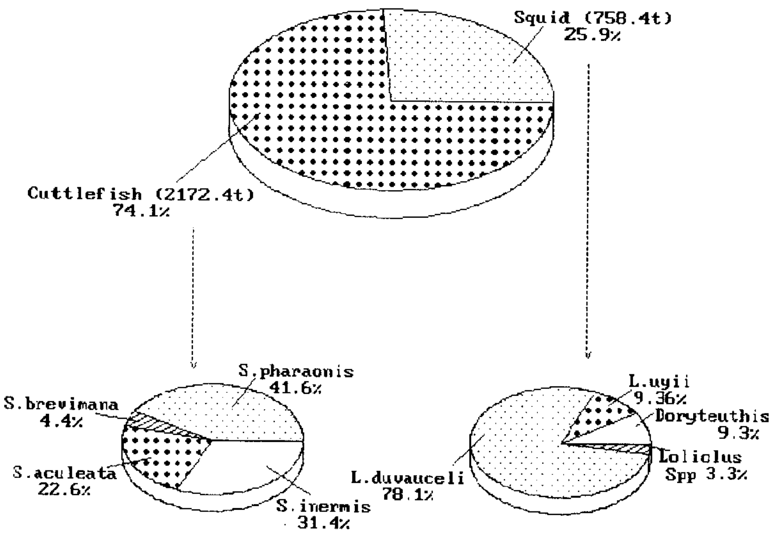

Fig 3. Average annual species composition of cephalopods landed by trawls during1995-'99.

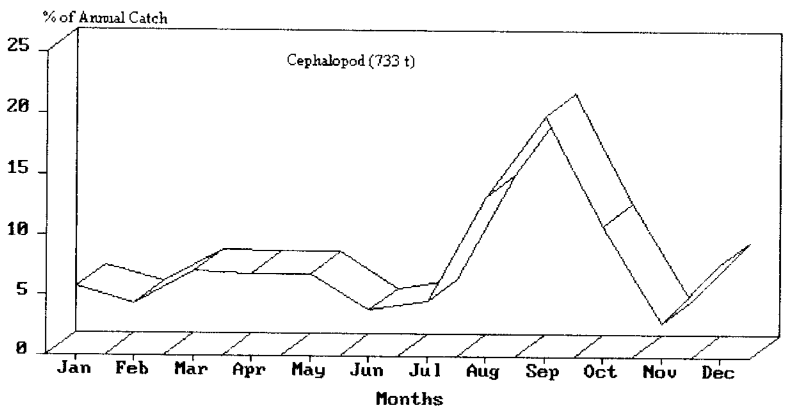

Fig. 4. Seasonal pattern of cephalopod fishery at Kakinada during 1995-'99.

Table 1. Seasonal fluctuation in catch rate (kg/hour) of different species of cephalopods in trawls during 1995-'99

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
L. duvauceli	0.81	0.73	0.41	0.24	0.20	0.65	0.27	0.17	0.45	0.44	0.53	1.05
L .uyii	0.09	0.73	0.04	0.04	0.03	0.08	0.02	0.01	0.06	0.05	0.10	0.13
Doryteuthes	0.08	0.22	0.07	0	0.004	0.004	0.03	0.01	0.04	0.04	0.07	0.12
Loliolus spp	0.01	0.005	0.01	0.05	0.007	0.04	0.02	0.04	0.04	0.01	0.03	0.04
S.pharaonis	0.19	0.28	0.05	0.12	1.76	2.52	1.27	1.08	0.84	0.40	0.15	0.11
S.aculeata	0.31	0.24	0.10	0.22	0.85	1.19	0.54	0.54	0.36	0.24	0.18	0.20
S.brevimana	0.06	0.06	0.04	0.05	0.10	0.15	0.09	0.06	0.11	0.07	0.10	0.06
S.inermis	0.68	0.04	1.32	0.84	0.52	0.91	1.03	0.67	0.72	0.63	0.36	0.30

Population characteristics of L. duvauceli

Growth : Growth parameters, $L\infty$ and K were estimated as 211mm and 1.68/year respectively and 't_0' as 0.0083 years. Their growth against time can be described by von-Bertalanffy growth equation as;

$$Lt = 211\ [1- e^{-1.68\,(t\ -0.0083)}]$$

Length at age data obtained from the above relation shows that they grow to 70.4, 118.6, 150.3 and 171.1 mm respectively by 3, 6, 9 and 12 months. They attain 203.6 and 209.6 mm by the end of 2^nd^ and 3^rd^ year respectively.

Size composition : Their fishery in trawl was supported by 10-170 mm animals with 71.0 mm as mean (Table 2). Zero-year group formed more than 97% of the catch. Juveniles entered trawl fishery at 10-20 mm size almost round the year with peak during January-March. They were caught in large numbers along with *Acetes* and other prawns. Their age at this stage was between 0.45 and 0.8 months. Size and age of the species at first capture was estimated as 38.9 mm and 1.6 months respectively.

Sexual maturity : Species show sexual maturity from 65 mm size onwards. However, their size at first maturity was estimated from probability curve as 86.5 mm for males and 94.5 mm for females and age as 3.9 and 4.3 months. These estimates indicate that they spawn during the first year itself.

Spawning and recruitment pattern : Recruitment pattern showing time of origin of the stock representing fishery (Fig. 5) and presence of animals with matured and spent gonads and small juveniles in the catch indicates that they spawn round the year with peak activity during December-February.

Table 2. Annual size range, modal classes, mean size and commercial size of *L. duvauceli* in the trawl catch at Kakinada during 1995-'99

Period	Size range (cm)	Modes	Mean size (cm)	Commercial size (cm)
1995-'96	20-160	70-80, 130-140	71.2	40-110
1996-'97	20-150	50-60, 80-90,	76.3	50-100
1997-'98	10-150	110-120, 60-70	68.6	50-100
1998-'99	20-170	40-50, 70-80	66.0	60-110
1995-'99	10-170	70-80	70.9	50-110

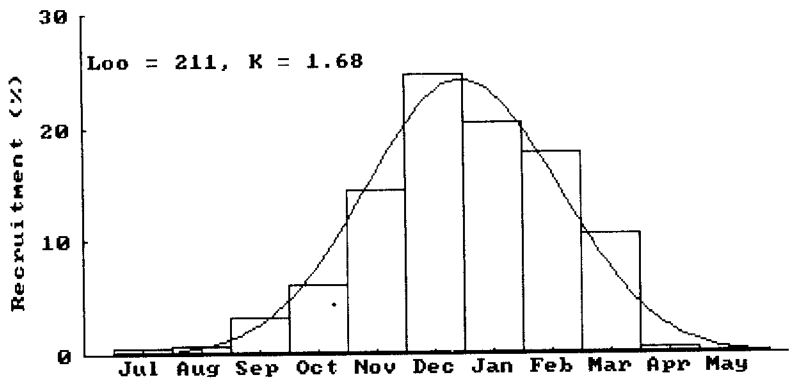

Fig. 5. Recruitment pattern of *L. duvauceli.*

Mortality rates : Estimates of total mortality rates ranged between 10.26 and 13.37 during 1995-'99 with 11.05 as mean (Table 3). Natural mortality was 2.86. Fishing mortality during the period was 8.19 and it varied between 7.4 and 10.5.

Table 3. Types and extent of mortalities operating in the exploited population of *L. duvauceli* during 1995-'99

Period	Total mortality (Z)	Natural mortality (M)	Fishing mortality (F)
1995-'96	13.37	2.86	10.51
1996-'97	10.26	2.86	7.40
1997-'98	12.32	2.86	9.46
1998-'99	11.65	2.86	8.79
Mean	11.05	2.86	8.19

Exploitation rates and maximum sustainable yield : Exploitation rate (E) varied between 0.72 and 0.79, with 0.74 as mean during 1995-'99 (Table 4). E_{max} is small, 0.441, when compared to present levels of exploitation indicating excessive fishing pressure over the stock (Fig. 6). Maximum sustainable yield (MSY) of the species from the present fishing ground is 279 tons/year.

Table 4. Catch, exploitation rate and stock of *L. duvauceli* during 1995- '99.

Period	Catch (tons)	Exploitation rate (E)	Stock (tons)
1995-'96	216	0.786	275
1996-'97	95	0.721	132
1997-'98	126	0.768	164
1998-'99	156	0.755	207
Average	184	0.741	248

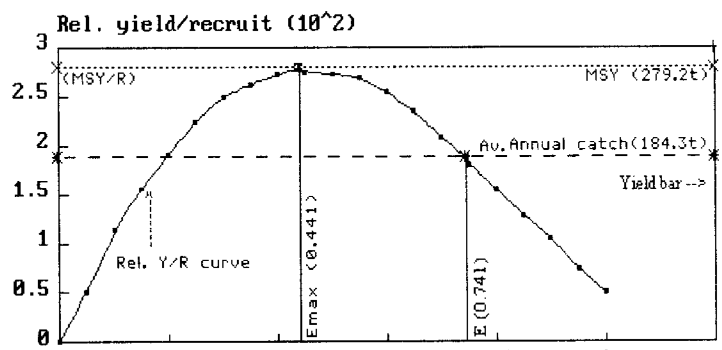

Fig. 6. Relative yield/recruit of *L duvauceli* at different levels of exploitation, super imposed with yield bar showing MSY.

Stock : Total stock of *L. duvauceli* in the present fishing grounds fluctuated during 1995-'99 (Table 4). Average stock during the period was 248 tons. Stock was 275 tons during 1995-'96. It declined sharply to the lowest level of 132 tons during 1996-'97. It showed signs of recovery during the subsequent years.

Discussion

Catch and catch rate of cephalopods continued to increase, with increased fishing effort over the years during 1985-'95 and thereafter it declined sharply. Catch and stock of the major species also showed similar fluctuations with declining trend after 1995. Growth in catch and catch rate was more pronounced during mid-nineties, after the introduction of voyage fishing, which resulted in the extension of fishing activity to deeper waters beyond 50 m depth.

Estimates of L_∞ and growth co-efficient (K) of *L. duvauceli* were comparable to the earlier estimates from east coast (Silas *et.al.* 1985, Meiyappan *et.al.* 1993), whereas L_∞ was very small and K was large compared to that from west coast (Kasim 1985, Rao 1988, Meiyappan and Srinath 1989, Vidyasagar and Deshmukh 1992, Meiyappan *et.al.* 1993, Mohamed 1996, Mohamed and Rao 1997). The relatively small size of the species in catch along the east coast and the above variations observed on their estimated growth parameters between east and west coast, suggested either size over-fishing of the resource along the east coast or existence two separate stocks on east and west coast.

Mainly zero year groups supported the fishery and their size and age at first capture was very small. Moreover, present level of exploitation is at a higher side compared to Emax. These suggested heavy fishing pressure on the stock. Species being spawning in shallow inshore waters and young ones feed on shrimps and small fishes in the shelf area, they are vulnerable to trawls from their early juvenile stage onwards. This issue will be more severe for the stocks along the east coast where extent of shallow shelf area is limited compared to west coast, thus forcing the young ones to concentrate on relatively narrow belt. Trawls being aimed primarily for resources like shrimps, mesh size of the gear is expected to be very small. So mesh size regulation to conserve this resource alone is not a practically viable proposal. The only alternative is regulating the effort to reduce fishing pressure in coastal waters especially during peak period of their abundance. Fishing pressure on the stock can also be reduced by diverting large trawlers to deeper waters, for exploitation of other under-exploited resources.

Since they attain full sexual maturity at an age of around 4 months and spawn round the year, large proportion of the stock may get at-least a chance to spawn before being caught. So the present level of exploitation, though high, may not have immediate adverse effect on recruitment. This assumption is further supported by the rapid improvement in the stock after a sharp decline during 1996-'97. However, care must be taken to regulate the fishery to avoid further increase in effort.

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