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Age and Growth of Octopus, *Octopus aegina* (Gray, 1849) from Mandapam Coastal Waters (Palk bay), Southeast Coast of India

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ABSTRACT
The growth of the cephalopods *Octopus aegina* was studied on individuals sampled from Mandapam waters (Palk bay), Southeast Coast of India, between October, 2000 and December, 2002. There were no definite relation found between the season and availability of the octopus. During the study period, maximum quantity *O. aegina* landed during July/August months. The size of *O. aegina* ranged between 3.3-8.7 cm in mantle length. The dominant size groups of the *O. aegina* landed by trawlers were 5.5-5.9 cm for both males and females. The mortality rates were estimated as total mortality (Z) = 5.68, natural mortality (M) = 3.02 and fishing mortality (F) = 2.66. The exploitation rate was worked out as 0.47, which was below the maximum exploitable rate of 0.5730, but above 50% exploitable level. This indicated that further addition of units for octopus fishing is advisable since exploitation has not reached the maximum sustainable yield. The observed maximum dorsal mantle length of *O. aegina* in the commercial catch was 8.7 cm which was 87% of the estimated L8 of 10.0 cm. The curvature parameter (K) was estimated at 1.366.

Key words: *Octopus aegina,* mantle length, mortality, Palk bay, parameter

INTRODUCTION
In the phylum Mollusca, class Cepholopoda are commercially the most important group, containing the nautilus, cuttle fishes, squid and Octopuses. Octopuses are bottom-dwelling species usually limited to the neritic province. The class Cephalopoda contains 21 families, each consisting of a large number of species, many of them are of high commercial importance. The genus Octopus consists of more than 100 species and occurs in all marine habitats of the world. *Octopus vulgaris* is the most important and widely distributed species occurring throughout the tropical and temperate waters of the world (Amaratunga, 1983). Knowledge of the age and growth of fish is also essential to determine the mortality and survival rate of various year classes and the success of the yearly brood, all of which contribute towards a rational exploitation of the stocks. Most of the studies using field data utilized a single mathematical function to describe growth through the life cycle or through the size range of animals sampled. The von Bertalanffy's asymptotic growth function has been commonly used in this manner (Caddy, 1983). A variety of different growth models have been proposed for cephalopods. Most field data for octopods fit a von Bertalanffy's type curve (Guerra, 1979; Hatanaka, 1979; Arreguin-Sanchez, 1992). The most important features of

octopus growth and its research challenges have been reviewed by Semmens *et al.* (2004). Several ageing studies have been conducted on octopus beaks (Hernandez-Lopez *et al.*, 2001; Raya and Hernandez-Gonzalez, 1998); however, they have so far proved inadequate for ageing purposes.

Several studies have been carried out to investigate the form of Octopus growth curves as a time function (Van Heukelem, 1976; Joll, 1977; Forsythe, 1984; Forsythe and Toll, 1991; Domain *et al.*, 2000), although few have studied the Octopus growth as a function of food intake level (Van Heukelem, 1976; Joll, 1977; Klaich *et al.*, 2006; Leporati *et al.*, 2007). In octopus it is well known that growth curves have two phases, beginning with an exponential form and shifting to a low power phase (Forsythe and van Heukelem, 1987; Semmens *et al.*, 2004). In octopus, growth is a rectilinear function of food intake level (Van Heukelem, 1976; Joll, 1977; Klaich *et al.*, 2006; Leporati *et al.*, 2007), implying that a the weight gained for an octopus has no an upper limit, b) there is no additional energetic cost due to increasing food intake and c) the partial growth efficiency has no dependence on food intake.

However, preliminary results using chemical marking in stylets (Hermosilla *et al.*, 2010) and beaks (Oosthuizen, 2003; Perales-Raya, 2001 unpublished results) have shown a daily deposition of increments in adults of this species, although definitive shown a daily deposition of increments in adults of this species, although definitive validation is still necessary for ageing common octopus. The main objectives of this were to estimate the age and growth pattern of *O. aegina* and to estimate the instantaneous rate of total mortality (Z), natural mortality (M), fishing mortality (F) and relative yield per recruit. The aim of this study was to investigate the age and growth parameters of *O. aegina* from Mandapam waters (Palk bay), Southeast Coast of India.

MATERIALS AND METHODS

Study area: The samples were collected from Mandapam region, Palk Bay (Lat. 9° 45'N; Long. 79°13'E) southeast coast of India. Live *O. aegina* caught in trawl nets were collected, transported and maintained in the laboratory (Fig. 1).

Age determination: During October, 2000 to December, 2002, totally 2675 individuals of *O. aegina* were analysed, off Mandapam waters. They ranged between 34 and 36 cm in length. Mantle length was taken as the standard measurement for determining age and growth of Octopuses. Data on Dorsal Mantle Length (DML) of *O. aegina* were grouped into 5 mm class intervals and their frequencies in various classes were worked out. The data pertaining to trawl, this was the major single gear in the exploitation of Octopuses used for the analysis. Growth and mortality parameters were estimated using FISAT software (Gayanilo *et al.*, 1996). Growth was modeled following Von Bertalanffy's Growth Function (VBGF).

Where:

$L_t = L_8 (1\text{-}e^{-k(t\text{-}t)o})$

L_t = length at age t

L_∞ = Theoretical maximum length

K = Growth co-efficient

t_0 = Age at 0 length (taken as 0)

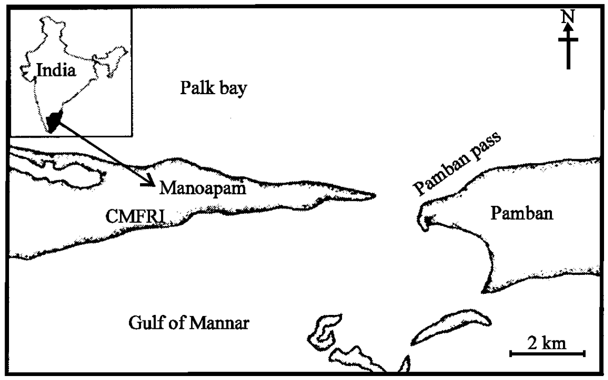

Fig. 1: Map showing the study area (Mandapam region, Palk Bay)

The total instantaneous mortality coefficient (Z) was estimated from the length frequency based catch curve method. The instantaneous natural mortality coefficient (M) was found out by the following method Pauly (1980) and relative yield per recruitment Y/R was estimated by Beverton and Holt (1957).

Growth determination: Growth and mortality parameters were estimated using FISAT software (Gayanilo *et al.*, 1996). Growth was modeled following Von Bertalanffy's Growth Function (VBGF). The seasonal growth oscillation of the von Bertalanffy's growth equation was calculated using the method proposed by Pauly and Gaschütz (1979) and Pauly and David (1981) also contained in the ELEFAN I software package (Gayanilo *et al.*, 1994).

RESULTS

The monthly size frequency of *O. aegina* exploited from Palk Bay (Mandapam) is shown in (Fig. 2), the monthly size frequency of *O. aegina* was varied from maximum mantle length 9.70 cm and minimum mantle length 3.20 cm. This data was applied in Powell Wetherall plot and the initial estimate of growth parameter L_∞ was obtained 11.020 cm and Z/K as 5. 49 (Fig. 3). The Powell Wetherall plot in and the initial estimate growth parameters was ranged from Y value 1.70 (-0.154) and r value - .926. Using this estimate the length frequency data was further run in the scan of K values (Fig. 4), from these analysis the best fitting (with high goodness of fit) growth curves were selected. The L_8 was estimated at 10.0 cm and K at 1.366. The corresponding growth curve with restructured L/F data is shown in Fig. 5. The growth curve of *O. aegina* fitted to restructured length frequency maximum in 9.34 and minimum in 7.45 cm of mantle length.

The values were substituted in the von Bertalanffy's growth equation is given below $L_t = 10$ $(1\text{-}e^{-1.366\ (t\text{-}t)}o)$. The growth data obtained in the present study that the *O. aegina* have a life span of about 3 years and they have grown up to 7. 45 cm and 9.34 cm (Mantle length) after first and second year, respectively (Fig. 6). The age and growth of curve of *O. aegina* varied from 9.83-4.9 cm in, respectively. Probability of capture analysis estimated the length (mantle length) at which 25, 50 and 75% (L-25; L-50 and L-75) octopuses are retained in the trawl nets. The analysis showed that the L-25; L-50 and L-75 values were 4. 636, 5.055 and 5.500 cm, respectively (Fig. 7). It can be seen that the E-max is at 0.5730 while the present rate of exploitation is 0. 47

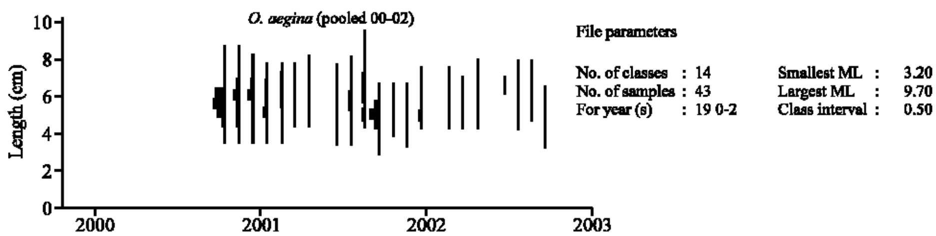

Fig. 2: Monthly size frequency of *O. aegina* exploited from Mandapam (Palk Bay) landing centre

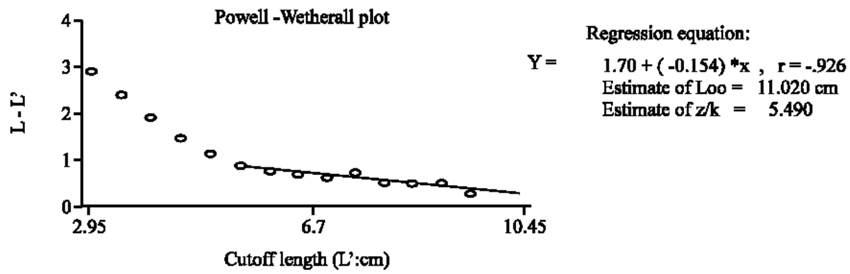

Fig. 3: Initial estimation of L8 and Z/K using Powell-Wetherall plot

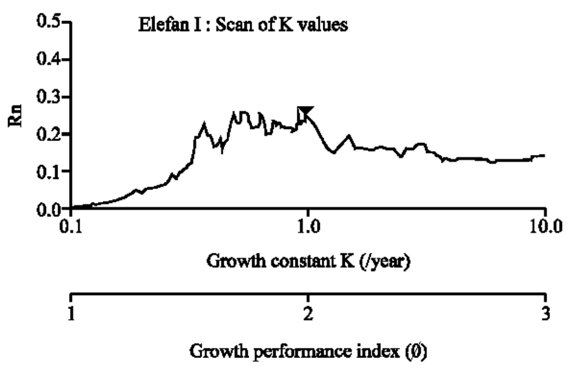

Fig. 4: Scan of K values to fix K values for *O. agenia*

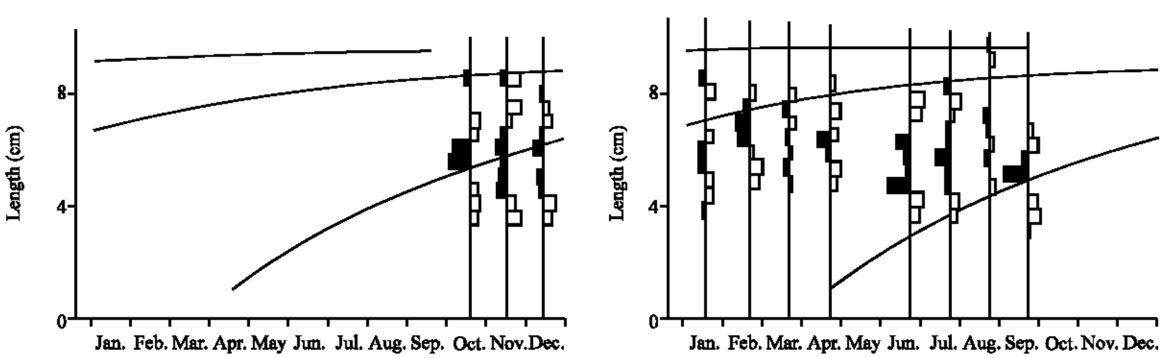

Fig. 5: Growth curve of *O. aegina* fitted to restructured length frequency data using L-10.0 cm, K-1.366, starting length 4. 95 cm

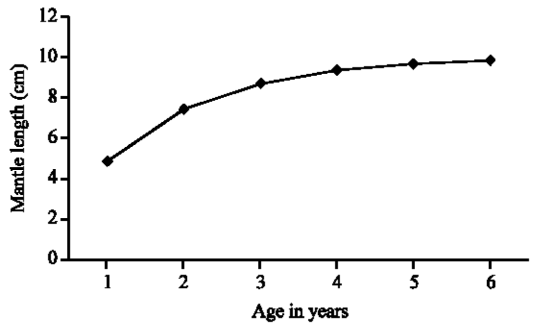

Fig. 6: Growth of curve of *O. aegina*

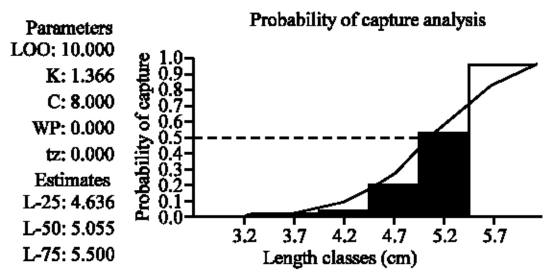

Fig. 7: Probability of capture analysis

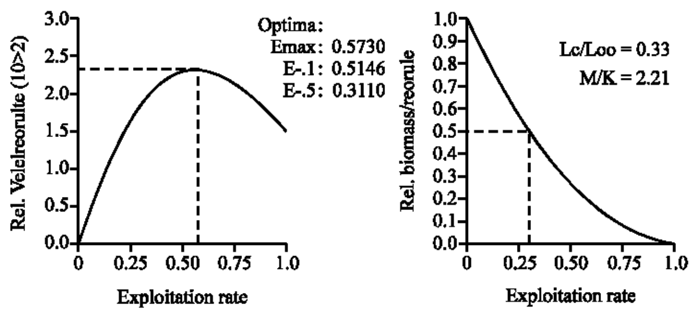

Fig. 8: Relative yield per recruit and relative biomass per unit area

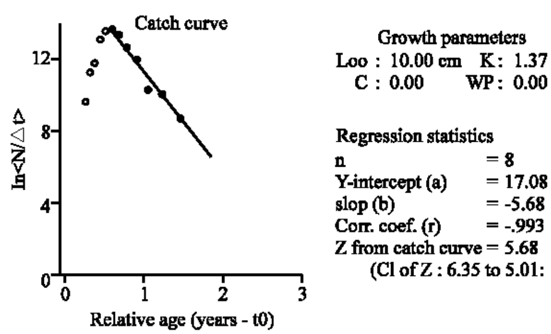

Fig. 9: Estimation of Z using length converted catch curve

(Fig. 8). The Z estimated by length converted catch curve method was using Pauly (1980) equation and was 3. 02. The instantaneous fishing mortality co efficient (F) was 2. 66. The exploitation rate (E) was estimated as 0.47 (Fig. 9).

DISCUSSION

The field studies provide valuable information on the age and growth of cephalopods populations in nature and are essential in evaluating potential fisheries and managing existing ones. Methods utilizing length frequency modal analysis are the primary means of evaluating and describing growth from field data (Hixon, 1980; Lange, 1980; Summers, 1983). Most field data for Octopus fit a von Bertalanffy's type curve (Mangold, 1983). In the present study, an attempt was made to fit von Bertalanffy's growth curve on *O. aegina* growth based on data collected from field observations. In the estimation of age mantle length of octopus was taken as the standard measure rather than total length because of the fact that most of the octopus might have lost their tentacles during fishing operation and calculation of total length will be erroneous in most of the time.

The L_∞ which indicates the maximum theoretical length of an organism under a given rate of growth was estimated as 10.0 cm in the present study. The maximum observed mantle length (L_{max}) was 8.7 cm, which is near to the estimated value for L_∞. The K value of an organism reflects its growth rate. In the present study, the K value was 1.366. The value of K estimated by Guerra (1979) and Hatanaka (1979) for *O. vulgaris* and lower than the value estimated by Ramirez *et al.* (1986). The growth curve developed for using ELEFAN by Arreguin-Sanchez (1992) estimated similar values for K as estimated from present study. While considering the $L\alpha$ and life span, the growth rate obtained in the present study was found to be more appropriate. By applying the growth parameters, the estimated growth of *O. aegina* was 7.45 cm mantle length at the end of first year and 9.34 cm at the end of second year. From these results, it can be assumed that *O. aegina* takes more than 36 months to reach asymptotic length of 10 cm. But the time taken to reach the observed maximum length of 8.7 cm was 1.5 years. The previous studies indicated that octopus reproduce only once in their life time and die after the spawning. It is reasonable to infer that the life span of octopus is around 3 years, but because of its semelparatic behavior, most of the octopuses live only for 1-2 years, i.e., the time taken to reach maturity and observed maximum length.

The instantaneous rates of mortality of *O. aegina* are estimated as Z = 5.68, M = 3.02 and F = 2.66. The present value of Z is similar to one reported for *O. maya* by Arreguin-Sanchez (1992). He derived the Z from length converted catch curve and the same method was adapted in the present study also. The instantaneous natural mortality estimated is high (3.02). The fact that most of the octopuses die after their spawning may be a reason for this high values for 'M'. In this study the present exploitation rate is 0.47. This value is very well below the E-max level of 0.5730 and above the 50% exploitation level of 0.3110. Since, the current yield of exploitation is below the MSY level, it will be advantages if efforts are increased to fish them to obtain biologically optimum yield.

Previous studies on octopus growth have used, von Bertalanffy's model to describe the growth in different populations of *O. vulgaris* (Guerra, 1979; Hatanaka, 1979; Pereiro and de Lguna, 1980). Although there is a controversy exists about the use of von Bertalanffy's equation for cephalopod growth (Forsythe and Hanlon, 1980; Hanlon and Forsythe, 1985; Forsythe and van Heukelem, 1987; Cortez, *et al.*, 1999). The studies on *O. maya*, showed the von Bertalanffy's model is adequate for expressing cephalopods growth (Arreguin-Sanchez, 1992).

For the majority of sections there was a high level of precision between replicate counts, with deviations between counts well below the maximum limit (10%) commonly set for other cephalopod ageing studies (Jackson and Lu, 1994; Pecl, 2004). Quantifying growth increments in stylets is a direct and highly advantageous method to assess age in octopuses. It is the only method thus far that will allow field captured animals to be aged throughout their life cycle and growth examined at a population level (Semmens *et al.*, 2004). The potential applications of increment derived age data, once periodicity is validated, is broad and varied in cephalopods. Through increment-based ageing, growth rate, age and cohort structure, recruitment patterns, hatching dates, age at maturity, longevity and the inter- and intra-annual variability of such characteristics have been successfully investigated in natural populations of squid and cuttlefish (for example: Jackson and Domeier, 2003; Jackson *et al.*, 2003; Pecl, 2004; Quetglas and Morales-Nin, 2004)

In the present study growth of *O. aegina* can sufficiently be described using von Bertalanffy's growth model. The results of the present study on *O. aegina* showed that the species is available for exploitation in the shallow coastal areas and adjacent deeper waters, throughout the year. The current rate of exploitation is well below the maximum sustainable yield and more units can be operated in this water for octopus fishing. This study will potentially have critical implications for gaining an accurate understanding of octopod age and growth characteristics. The key role *O. aegina* based ageing has played in the analysis and management of fish and squid populations further highlights the vital contribution ageing will afford to octopus biology, ecology and fisheries management.

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