[†]Growth and population dynamics of short-neck clam *Paphia malabarica* from Dharmadom estuary, North Kerala, southwest coast of India

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Abstract

Growth and population dynamics of the short-neck clam *Paphia malabarica* from Dharmadom estuary in north Kerala was studied for one year (December 2003-November 2004). The age and growth of *P. malabarica* were studied by continuous sampling of the population and analyzing the changes in size frequency distribution. The growth parameters of the von Bertalanffy growth function was L_∞ = 59 mm, annual K= 0.92, and t_0 = -0.1596. The life span was estimated as 2.5 to 3 years. *P. malabarica* in the estuary attains a length of 35.5 mm and 49.6 mm respectively at the end of the first and second year. The length at first maturity (L_m) was estimated as 22 mm and 50% of the clams matured at the age of 7 months. All the clams above 22 mm were mature *i.*e., before reaching the first year. The total mortality coefficient (*Z*) was 4.65, natural mortality coefficient (*M*) was 1.82 and fishing mortality coefficient (*F*) was 2.83. Virtual Population Analysis showed that F was the maximum in the largest size group (35–38 mm). The mean numbers and catch by length showed that the maximum catch (16.5 t) consisted of 35-38 mm length group. Average yield of *P. malabarica* for the period 2003-2004 calculated from the length-based Thompson and Bell prediction model was 115 t and the maximum sustainable yield (MSY) was 69.3 t. It was found that 80% of the present effort is sufficient to arrive at the MSY.

Keywords: Clam*, Paphia malabarica*, growth, mortality, yield, population dynamics

Introduction

Among the exploited bivalve resources of India, clams are by far the most widely distributed and abundant. Due to realization of high nutritive value and importance in the economy of coastal fishing villages coupled with the development of export market for the frozen clam meat, research was initiated nearly two decades ago on clams (Narasimham, 1991). For increasing and sustaining the production an understanding of the status of distribution, abundance, population size and stock, recruitment to fisheries and basic biological features of resources are essential.

Among clams, the venerid clams are in demand and three genera namely *Meretrix, Katelysia* and *Paphia* are important. Of the fifteen species of *Paphia* five species are distributed along the Indian coast (Appukuttan, 1993). Of these, *Paphia malabarica* is the most widely distributed and continuously exploitated clam along the southwest coast for local consumption as well as for export.

Dharmadom estuary forms a part of Anjarakandy River in North Malabar, Kerala and *P. malabarica* is exploited from the barmouth of the estuary. *P. malabarica* bed extends from the barmouth up to 700 m into the estuary. The bed is exploited throughout the year except when the environmental conditions are not favourable to venture into the estuary.

The determinate growth model most commonly applied to bivalves is the von Bertalanffy growth curve (Appeldoorn, 1983; Jones *et al.,* 1990; Landry *et al*., 1993; Urban, 1996; Devillers *et al*., 1998). From the Indian waters Narasimham (1988) studied

the population dynamics of *Anadara granosa* from Kakinada Bay while Rao (1988) and Appukuttan *et al.* (1999) investigated that of *P. malabarica* from Mulky and Ashtamudi estuary. However no information is available on the age, growth and stock size of any clam species from the North Kerala.

Caddy (1989) while studying the population dynamics of scallop fishery, suggested that the well known yield-per-recruit model of Beverton and Holt (1957) could be used in assessing the likely effect of different size limits and fishing intensities. It is assumed that self replenishing populations of clams have the advantage of free swimming larval life of approximately one to two months permitting uniform dispersal and settlement in the fishing area. Considering these factors in the present study stock assessment models were used since estimates on age, growth, survival and mortality, longevity and maximum sustainable yield are required for judicious exploitation of the resources.

Material and methods

Age and growth of *P. malabarica* were estimated based on length-frequency distribution data collected biweekly during December 2003-November 2004. For obtaining the length-frequency data samples were collected from six substations in three stations along a transect parallel to the coast using a 25 x 25 cm metal quadrat. The samples were pooled and sub-sample was taken for estimation of length frequency (Rao, 1988). The total number of clams used for the age and growth study was 3,711. Vernier caliper with 0.01mm accuracy was used for measuring the total length of the clam in anterio-posterior axis.

The length-frequency data were grouped into 3 mm class intervals. The length-frequency distribution in the sample biomass was raised to the total number of clams exploited by the fishers on the sampling day. The data thus obtained from different samplings in a month were pooled to arrive at catch in numbers for all the sampling days, which in turn, were raised to the monthly catch (Appukuttan *et al.*, 1999). The basis of the growth study is the growth equation formulated by von Bertalanffy (1934).

The length-frequency data were analysed using the ELEFAN I module of FiSAT software (2.1) (Gayanilo and Pauly, 1997) without prior decomposition of data and also through modal progression analysis after decomposition of multi-cohort samples into their component distributions. Estimation of L_∞ and Z/K were made using Powell-Wetherall method (Pauly, 1986; Wetherall, 1986).

The growth parameters were estimated using ELEFAN I programme in the FiSAT software by identifying the best fit to the peaks. L_∞ and K were used as input to the catch curve analysis. The resultant catch curve was estimated following the procedure recommended by Pauly (1986). Using growth increments data resulting from the linking of means, growth parameters were estimated (Gulland and Holt, 1959). The t_o was calculated by using Pauly's empirical equation (Pauly, 1979). The length at first maturity was determined by the methodology followed by Kings (1995).

The total mortality coefficient (Z) was estimated from the length-frequency data by using length-converted catch curve method of Pauly (1983). The natural mortality coefficient of *P. malabarica* was calculated by the method of Srinath (1990). The probability of capture by length (Pauly, 1983) of *P. malabarica* was calculated from the ratio between the points of the extrapolated descending arm of the length-converted catch curve using FiSAT software. The instantaneous fishing mortality coefficient (F) was computed from the following relationship:

$$F = Z - M.$$

Exploitation rate (U) was estimated by using the equation suggested by Beverton and Holt (1957) and Ricker (1945), and exploitation ratio (E) as suggested by Sparre and Venema (1992). The MSY was calculated from the length-based Thompson and Bell model. For Virtual Population Analysis (VPA), the annual catch obtained from a single cohort during the exploited phase was used to calculate the abundance and fishing mortality rates of the cohort in each year (Gulland, 1965). The yield/recruit was estimated using the relative yield/recruit model of Beverton and Holt (1957).

Results

The estimated L_∞ was 56.7 mm and $Z/K = 3.096$ (Fig. 1). Using this estimate the length-frequency data were subjected to FiSAT routine for the scan of K value, response surface analysis and automatic search routine. From these analyses the best fitting (with high goodness of fit) growth curve was selected. The values obtained from ELEFAN I with an *Rn* value of 0.190 was L_∞ =59 mm and annual $K = 0.92$, (Fig. 2). The values of L_∞ and K obtained by ELEFAN I plot were taken to represent the growth of *P. malabarica*. By using Pauly's formula (1969), the t_0 was estimated as -0.1596.
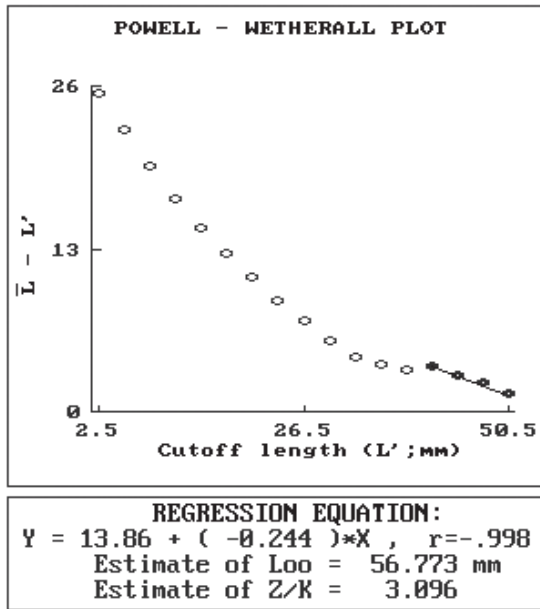

Fig. 1. Estimation of L_∞ and Z/K of *Paphia malabarica* using Powell-Wetherall Plot
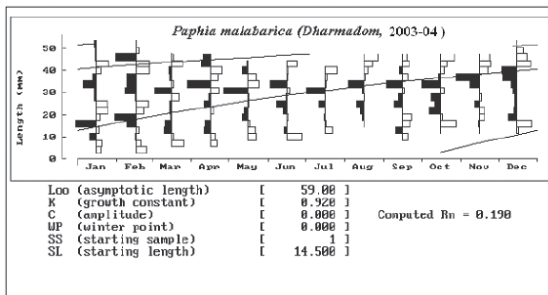

Fig. 2. Estimation of L_∞ of *P. malabarica* using ELEFAN I method

The life span estimated for clams in Dharmadom estuary was about 2.5 to 3 years. By VBGF it was estimated that *P. malabarica* in the estuary attains a length of 35.5 mm at the end of the first year and 49.6 mm at the end of second year. Since the length at first maturity (L_m) has been estimated at 22 mm, 50% of the clams is found to mature in 7 months of life. It was also observed that all the clams above 22 mm were mature and it can be assumed that the clams mature before reaching one year (Fig. 3).
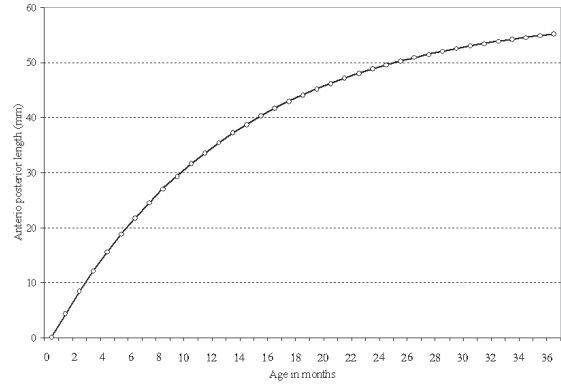

Fig. 3. The VBGF curve for *P. malabarica* with selected growth parameters

The total mortality coefficient (Z) was 4.65. The mortality estimates by catch curve method is shown in Fig. 4. The natural mortality coefficient (M) was 1.82. The value of fishing mortality coefficient (F) estimated was 2.83. The exploitation rate (U) was estimated at 0.59 and exploitation ratio (E) was 0.6.
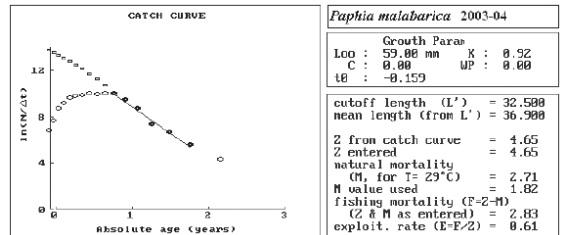

Fig. 4. Total mortality estimation of *P. malabarica* using Pauly's linearised length converted catch curve method and estimation of exploitation during 2003-04 in Dharmadom estuary

Results of the VPA using the pooled length frequency data for the year showed that *F* was the maximum in the largest size group (35-38 mm). The

mean numbers, in each length group showed that catch constituted mainly of 35-38 mm length group and maximum catch (16.5 t) was obtained in the size class 34.1-37.0 mm. The yield increased from 185 g in the size class 4.1-7.0 mm to the maximum of 16.5 t in the size class 34.1 – 37.0 mm and gradually reduced to 0.3 t in 53 mm size class (Fig. 5).
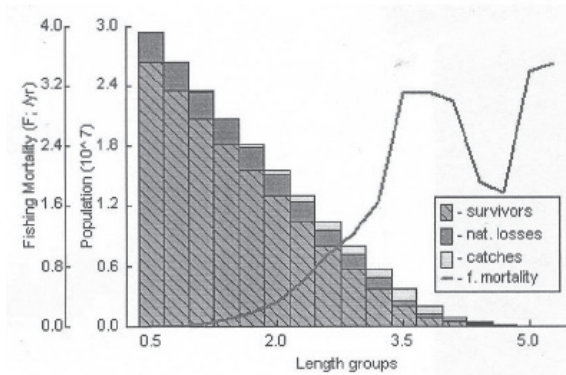

Fig. 5. Length- structured Virtual Population Analysis of *P. malabarica* the length groups are represented in cm

In Dharmadom estuary *P. malabarica* was taken by scoop nets. The yield (*Y*) of *P. malabarica* was 68.8 t. The estimated stock using Gulland's formula and MSY were 115 t and 57 t respectively. The approximate MSY calculated using length-based Thompson and Bell prediction model was 69.3 t. Thompson and Bell prediction model indicates that 80% of the effort would have produced MSY and 20% of the effort was in excess (Fig. 6).
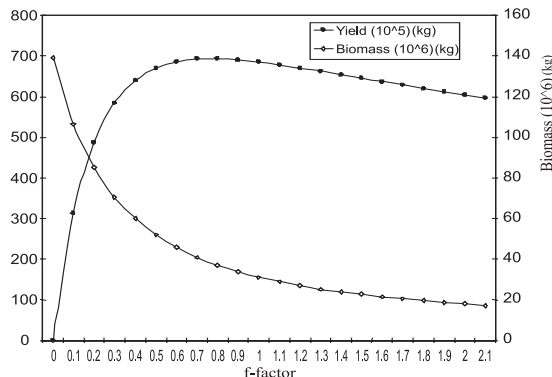

Fig. 6. Thompson and Bell analysis for *P. malabarica* in Dharmadom estuary during December 2003- November 2004

The parameters used as input for Beverton and Holt's yield-per-recruit analysis and the different *Y/R* values obtained against respective *F* values for *P. malabarica* are presented in Fig.7. The $E_{-0.1}$ was 0.5545 and $E_{-0.5}$ was 0.03321. As per *Y/R* curve maximum yield per recruit E_{max} is 0.63 and the present exploitation is 0.59. This indicates that at present the species is exploited around the maximum exploitation level and any exploitation beyond 0.63 will not yield more. Thus yield-per-recruitment analysis indicates that the present exploitation is close to the optimum yield.
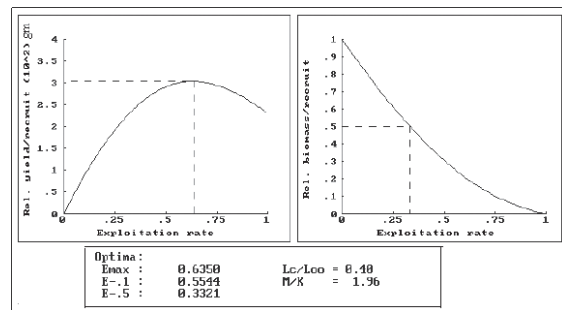

Fig. 7. Results of relative yield-per-recruit and biomass-per-recruit analysis for *P. malabarica* indicating $E_{0.1}$ and $E_{0.5}$ (length- frequency data pooled for 2003-04)

Discussion

Bivalve fishery in India is dominated by venerid clams and mussels. The estimated catch in Dharmadom estuary for the period 2003-2004 was 68.8 t for an effort of 3,902 persons using scoop nets operated manually by diving. Annual landing of clams and cockles for the period 1996-2000 was estimated as 52,537 t in Kerala (Kripa and Appukuttan, 2003). The bivalves are one of the least managed resources along the Indian coast. Barring the management measures on the short-neck clam fishery of Ashtamudi estuary in Kerala, there is no regulation for effective utilization and conservation of these sedentary marine resources (Kripa and Appukuttan, 2003). The results of the present study indicate that length range of *P. malabarica* within 31-40 mm contributed the maximum to the fishery. Since there is a market preference for large-sized clams, the exploitation is more on this size group.

In Ashtamudi estuary also exploitation is maximum on the size group of 34-36 mm (Appukuttan, 1993).

Growth has been defined as a change, either positive or negative in the size of an individual organism or in the mean size of a population (Malouf and Bricelj, 1989). Bivalves exhibit a broad range of growth rates in nature and these growth rates to a certain extent reflect survival strategy of a given species (Seed and Brown, 1978). Growth rate and other population parameters obtained for *P. malabarica* during the present study seem to be comparable with that of other species. Winckworth (1931), while evaluating the growth rate of *Paphia undulata* from Indian waters indicated that this species lives for less than two years, breeds during May- August and the young ones show rapid growth. Mane and Nagabhushanam (1979) noted 23 mm, 38 mm and 47 mm as the growth of *Paphia laterisulca* for three consecutive years. The population parameters of *P. malabarica* from Mulky estuary (Karnataka) and Ashtamudi estuary (Kerala) estimated by Rao (1988) and Appukuttan *et al.* (1999) and the present study are given in Table 1.

and size, as larger species or groups generally would have less rate of predation. Since M is linked to longevity and longevity to growth coefficient K, the M/K ratio is found constant among closely related species and sometimes within similar taxonomic groups (Beverton and Holt, 1957; Banerji, 1973). M/K ratio usually ranged from 1 to 2.5 (Beverton and Holt, 1957). In the present study, the M/K ratio obtained for *P. malabarica* falls within this range. F was obtained from the relationship $Z = M+F$. The Y/R estimates show that with increase in length at capture the yield-per-recruit can be increased. The present exploitation rate (E) = 0.59 is almost equal to E_{max} of 0.63, hence there is no scope for increasing the effort. In the light of the results obtained from Thompson and Bell yield analysis, it is evident that there exists no scope for increasing the fishing effort to result in higher economic yield and that the fishery is already operating near biologically optimal level. Beyond MSY the exploitation is that of the lower size group which will not be economical. In Dharmadom estuary judicious exploitation coupled with semiculture practice may increase the production in future.

Table 1. Comparison of K and $L\infty$ and growth rate of *P. malabarica* in three estuaries in Kerala and Karnataka; NA = not available

Estuary	K	L_∞ (mm)	Length (mm) at age (months)					Reference
			6	9	12	24	36	
Mulky Karnataka	1.425	59.0	36.6	43.1	48.1	NA	NA	Rao (1988)
Ashtamudi, South Kerala	0.839	44.4	N.A	N.A	30.0	38.0	41.0	Appukuttan *et.al* (1999)
Dharmadom, North Kerala	0.92	59.0	N.A	N.A	35.5	49.6	55.3	Present study

It is observed that the growth rate was higher in Dharmadom estuary than in Ashtamudi estuary. The reason for the differences in the growth rate in three estuaries could be attributed to the population density, nature of the substratum and environmental conditions prevailing in the area. Caddy (1989) has described plasticity in the growth of sedentary molluscs, which can produce wide variations in growth rate or meat yield.

The natural mortality is influenced by several biological and environmental factors and it is difficult to get an accurate estimate (Pauly, 1983). The instantaneous mortality rates of *P. malabarica* were $Z = 4.65$, $M = 1.82$ and $F = 2.83$. The values of Z, M and F for *P. malabarica* in Ashtamudi estuary was 2.11, 1.17 and 0.94 (Appukuttan *et al.,* 1999). The natural mortality (M) is closely related to age

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