Population Dynamics of *Penaeus indicus* (Crustacea: Penaeidae) in Rekawa Lagoon, Sri Lanka

C. NISSANKA

Department of Zoology
University of Kelaniya
Kelaniya
Sri Lanka

Abstract

Rekawa lagoon which is a small coastal lagoon (area 240 ha) in southern Sri Lanka supports a small-scale fishery. A major portion of its landings is comprised of penaeid shrimps. *Peneaus indicus* is the dominant species accounting for about 84% of the total shrimp catch. Population dynamics of *P. indicus* were studied using FiSAT software package. The analyses were based on data collected from catches of "fish kraals" in the lagoon from October 1994 to June 1995. Asymptotic total length (L_∞) and growth constant (K) of *P. indicus* were determined as 20.3 cm and 1 $year^{-1}$ respectively which were used to estimate mortality and exploitation rate (E). The total mortality rate (Z) estimated by means of length-converted catch curve method was 4.95. Using empirical equations, natural mortality (M) and theoretical age at length zero (t_0) were estimated as 2.02 and -0.18 years respectively. The mean selection length (L_c) was estimated by detailed analysis of the ascending part of the length-converted catch curve was 13.2 cm. Relative yield-per-recruit analyses performed by incorporating probabilities of capture have indicated that the *P. indicus* stock in the lagoon is presently exploited at its optimal level.

This study also indicated that the peak recruitment month in 1994 did not overlap with the spawning season of *P. indicus* in the sea resulting in low shrimp catches in the lagoon during the fishing season in 1994/1995. As evident from previous studies, high yields of shrimps were reported in Rekawa lagoon when the lagoon mouth opening coincided with the spawning season of *P. indicus*. Therefore establishment of a procedure is recommended for deliberate opening of lagoon mouth during June-July and October-November each year during which peak spawning of *P. indicus* takes place in the sea. These could be performed through active participation of fishing communities.

Introduction

Sri Lanka has a coastline of approximately 1760 km. The Southern Sri Lanka has about 300 km long coastline with a number of lagoons and estuaries (Anon. 1994). Most of them are seasonally connected to the sea and closed by narrow sand bars for some part of the year. Rekawa Lagoon (area 240 ha; Fig. 1) supports a small-scale fishery and penaeid shrimps are the major constituent of the landings. About 250 families are totally or partially engaged in lagoon fishing (Jayakody & Jayasinghe 1992).

Shrimp fishery in Rekawa lagoon is highly seasonal and extends from September/October to April/May. The most abundant and commercially the most important penaeid shrimp species is *Penaeus indicus* (H. Milne Edwards) contributing for about 84% of the total shrimp catch. Other penaeid species caught are *Metapenaeus monoceros* (Fabricius), *P. monodon* (Fabricius) *P. semisulcatus* De Haan and *M. dobsorni* (Miers). Four species of Paleomonid prawns are also recovered (Jayakody 1994).

Fishers in the Rekawa lagoon use cast nets, drift gill nets (38 and 44 mm mesh) and kraals (Ja-Kotu) for fishing. The kraals (Fig. 2) are operated from 18.00 hrs to 6.00 hrs.

In the present study, an attempt is made to investigate the population dynamics of *P. indicus* in Rekawa lagoon.

Materials and Methods

Sampling of *P. indicus* in the artisanal fishery was done twice a month at the landing sites from October 1994 to June 1995. *P. indicus* collected from the landings of kraals were measured (Total Length or TL) to the nearest 0.1 cm. Monthly length-frequency data of *P. indicus*, were analysed using "FiSAT" software package (Gayanilo et al. 1995).

The step-wise procedure described by Amarasinghe & De Silva (1992) was adopted in analysing length frequency data of *P. indicus* in Rekawa lagoon to estimate von Bertalanffy growth parameters. The steps were,

1. estimating an initial value of asymptotic length (L_∞) and Z/K (Z = total mortality and K = growth constant) using the Wetherall method (Pauly 1986 a; Wetherall 1986);
2. obtaining preliminary estimates of growth parameters by ELEFAN 1, using the initial estimate of L_∞ estimated by the Wetherall method;
3. estimating probabilities of capture by detailed analysis of the left ascending part of the catch curve, and by constructing a selection curve by using Z and natural mortality (M; see below) values estimate from the preliminary estimates of L_∞ and K;
4. correcting the original length-frequency data using probabilities of capture (Pauly 1986 b); and
5. obtaining improved estimates of L_∞ and K from the corrected length frequency data.

Z value of *P. indicus* was calculated using length-converted catch curves as implemented in the "FiSAT" software package. A value for Z was also estimated using Beverton & Holt (1956) method. M was estimated by the following empirical equation (Pauly 1980) using the L_∞ and K value estimated above and the mean water temperature of 29°C.

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

Fishing mortality (F) was estimated by subtracting M from Z, and exploitation rate (E) was calculated by the relationship E = F/Z.

Probabilities of capture of *P. indicus* in different length classes were estimated by projecting the descending part of the catch curve backward and the length at 50% capture (L_c) was calculated from a plot of probabilities of capture against length. Probabilities of capture were incorporated in computing relative yield per recruit (Y'/R) as presented by Pauly & Soriano (1986). Using the Y'/R values at different sizes at first capture (L_c) and E, a Y'/R isopleth (Gayanilo et al. 1995) was drawn in order to determine the optimal level of exploitation and selection patterns.

An approximate value of t_0 (theoretical age at length zero in yrs) was obtained from the following empirical relationship (Pauly 1979).

$$\text{Log}_{10} (-t_0) = -0.3922 - 0.2752 \log_{10} L_\infty - 1.038 \log_{10} K$$

where L_∞ is expressed in cm and K is expressed on yearly basis. Using the von Bertalanffy growth parameters (L_∞ , K and t_0) estimated as above, recruitment patterns of *P. indicus* fishery of Rekawa lagoon were estimated by projecting length frequency data backward to meet the time-axis (Gayanilo et al. 1995).

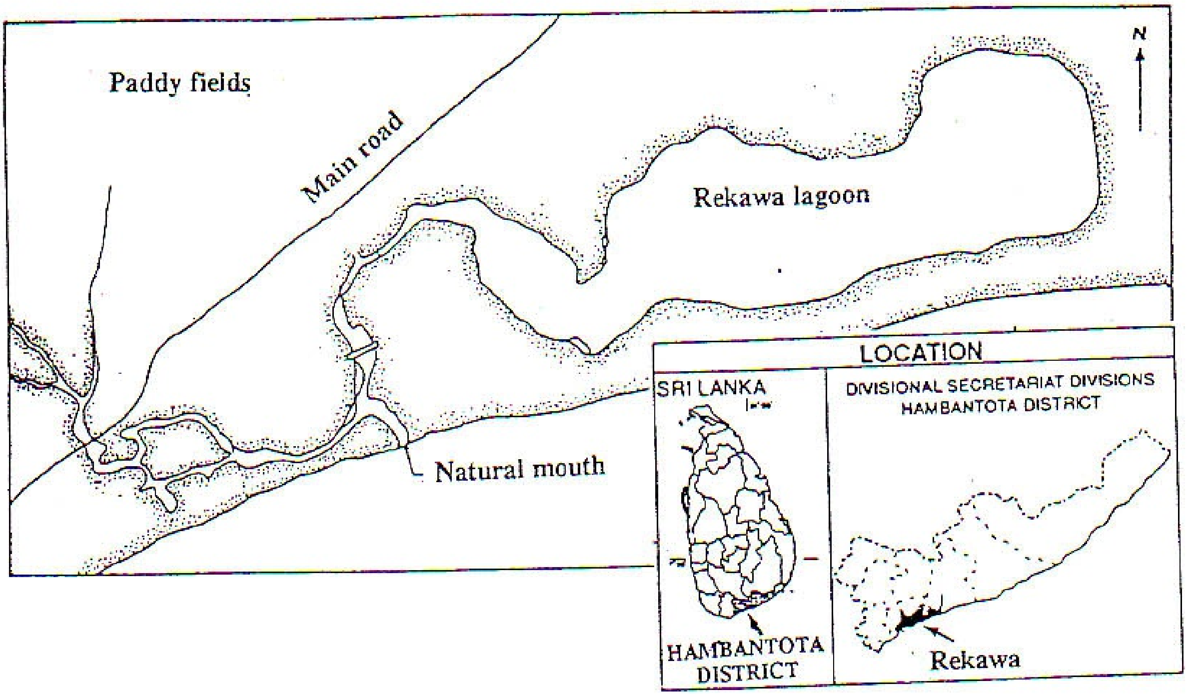

Fig.1. Map of the Rekawa lagoon and its location.

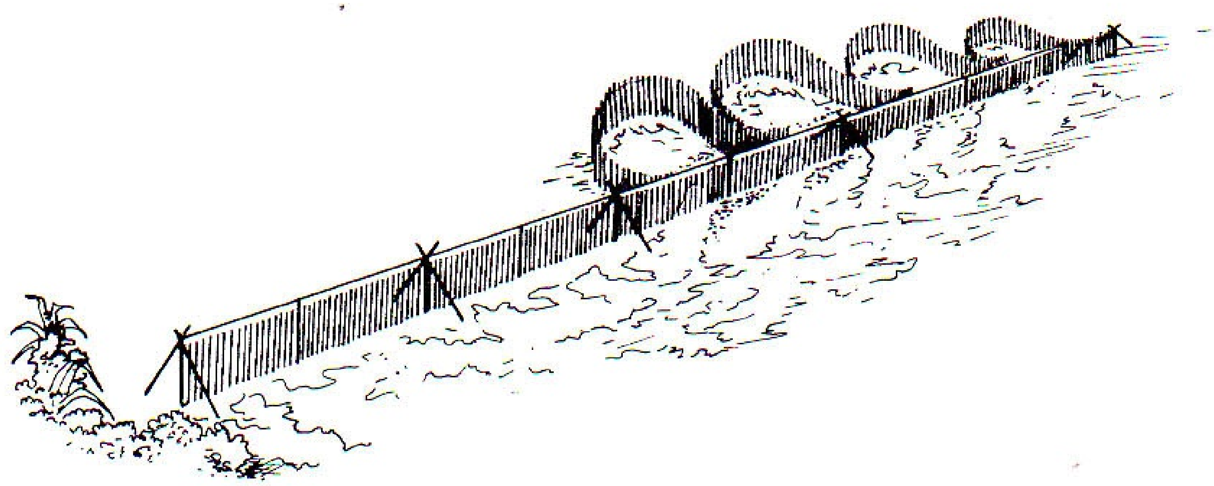

Fig.2. Fish Kraal.

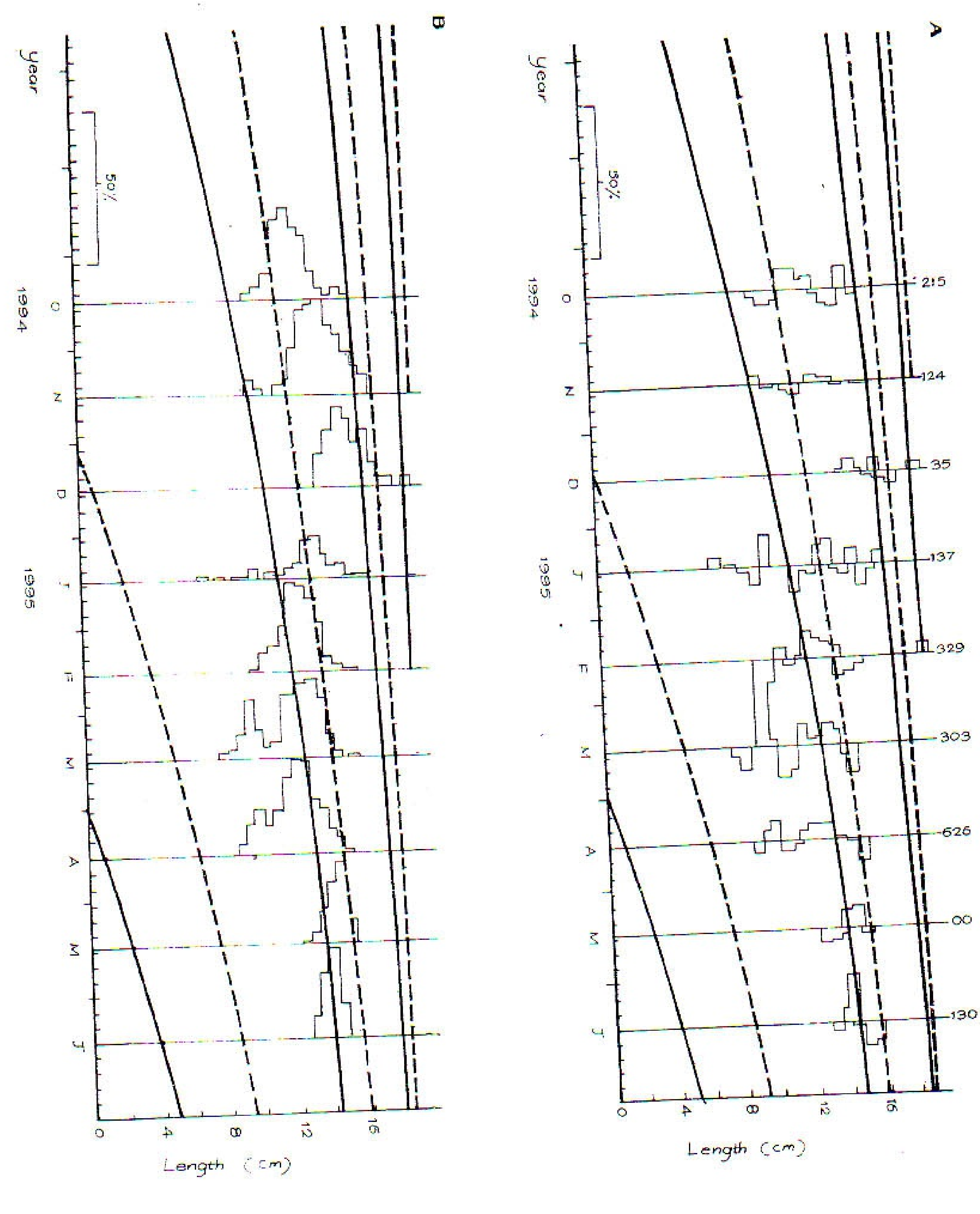

Fig.3. Growth curves (solid curve) of *P. indicus*, superimposed on the length frequency distributions. The curve of broken lines indicates a growth curve of same growth parameters representing another peak recruitment. A. Restructured length-frequency data (Brey et al. 1988) of *P. indicus*. B. Percentage length-frequency data of *P. indicus*. (Sample sizes in each month are also indicated here).

Results

Growth parameters (from Wetherall method and ELEFAN technique), mortality rates and L_c are given in Table 1. The calculated growth curves superimposed on length frequency distributions of *P. indicus* is shown in Fig. 3. Length-converted catch curve of *P. indicus* and selection curve are given in Figs 4A and 4B respectively. Y'/R values as functions of exploitation rates for different L_c i.e., Y'/R isopleth are shown in Fig 5. Recruitment patterns of *P. indicus* are shown in Fig. 6.

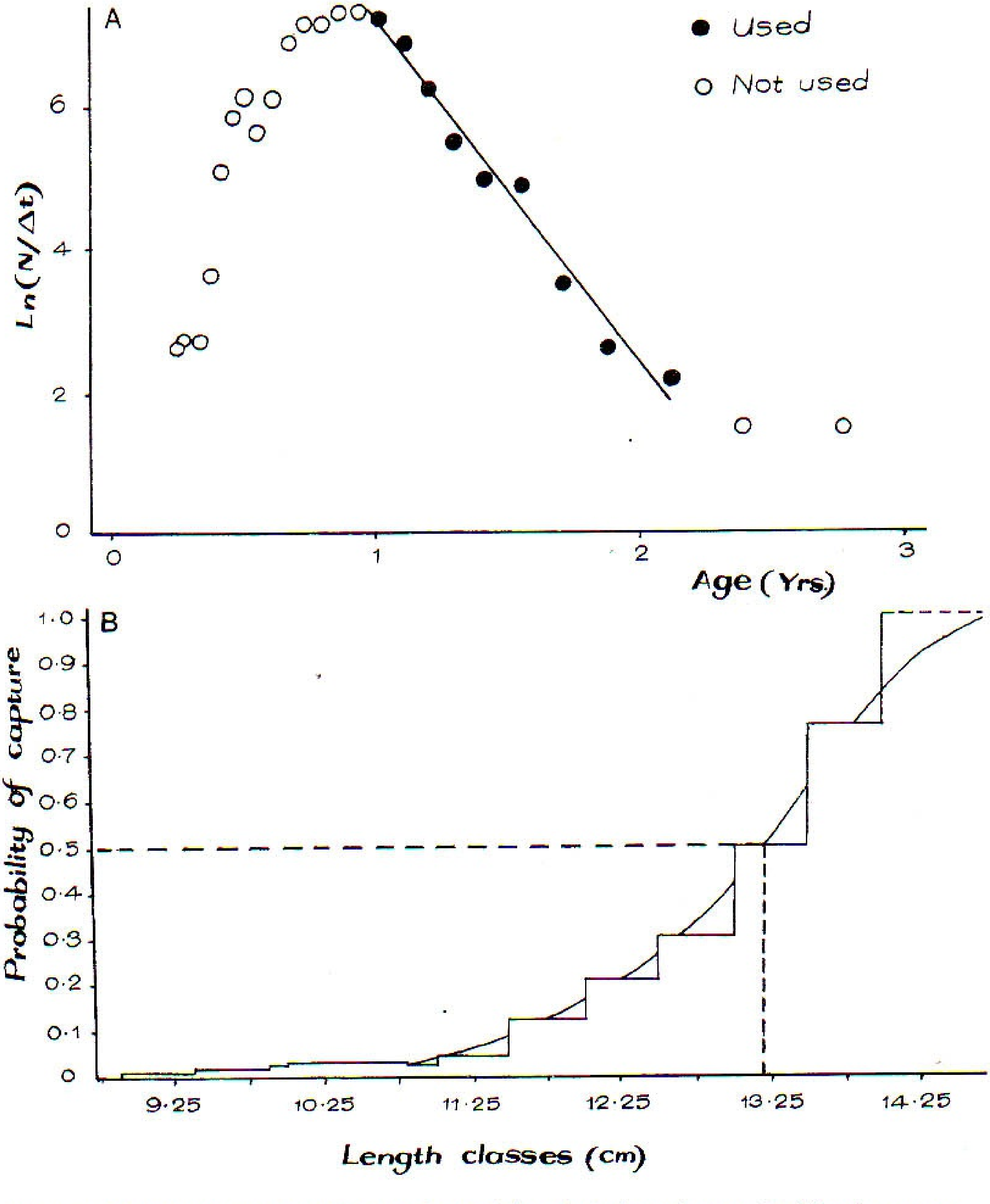

Fig.4. A. Length-converted catch curve for *P. indicus* in Rekawa lagoon. B. Selection curve of *P. indicus* in Rekawa lagoon.

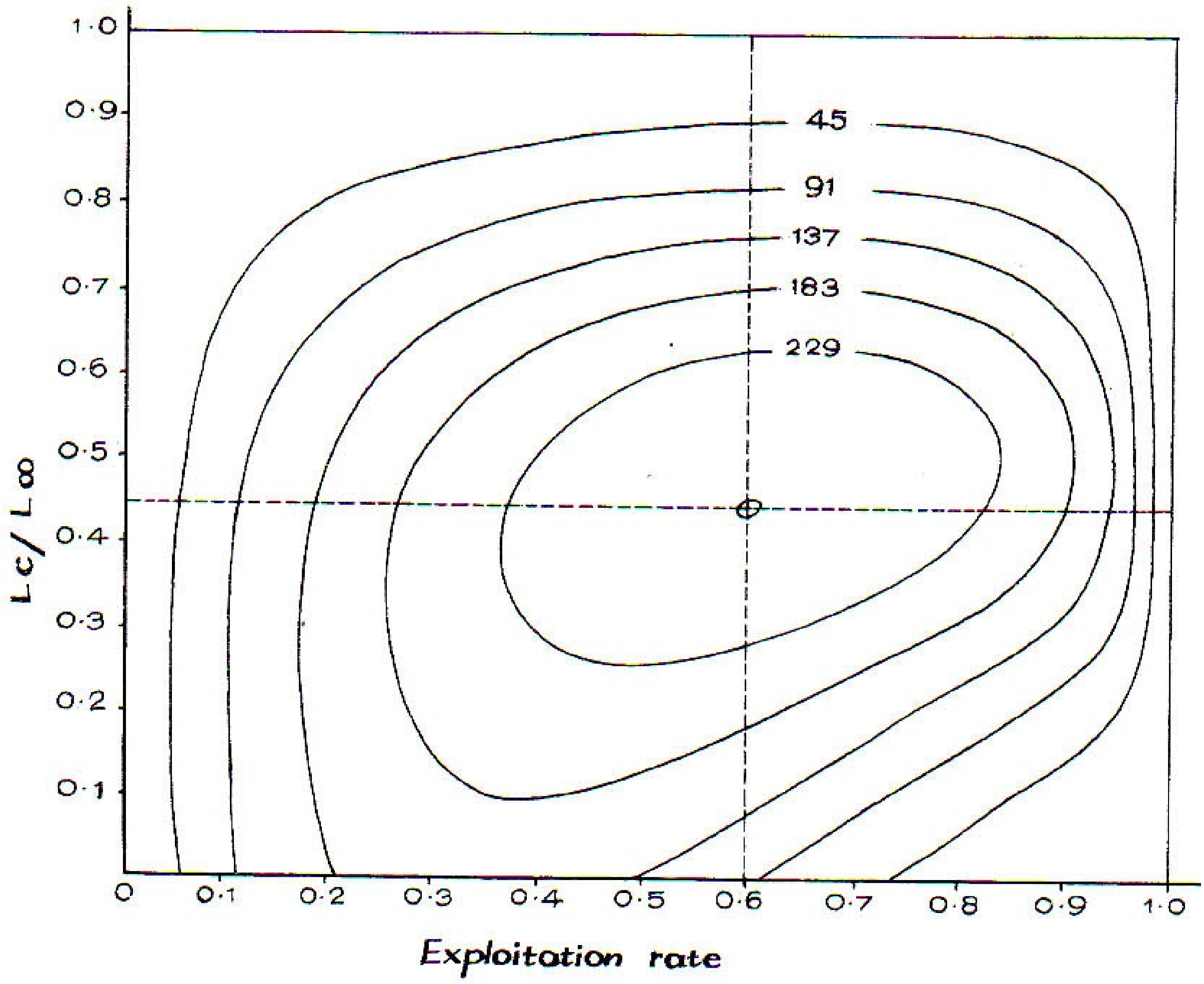

Fig.5. Relative yield-per-recruit (Y'/R) isopleth at different sizes at first capture (L_c) and exploitation rates (E). The horizontal and vertical broken lines indicate the present levels of L_c/L_∞ and E respectively. Y'/R values (in arbitrary units) corresponding to different contours are also indicated here.

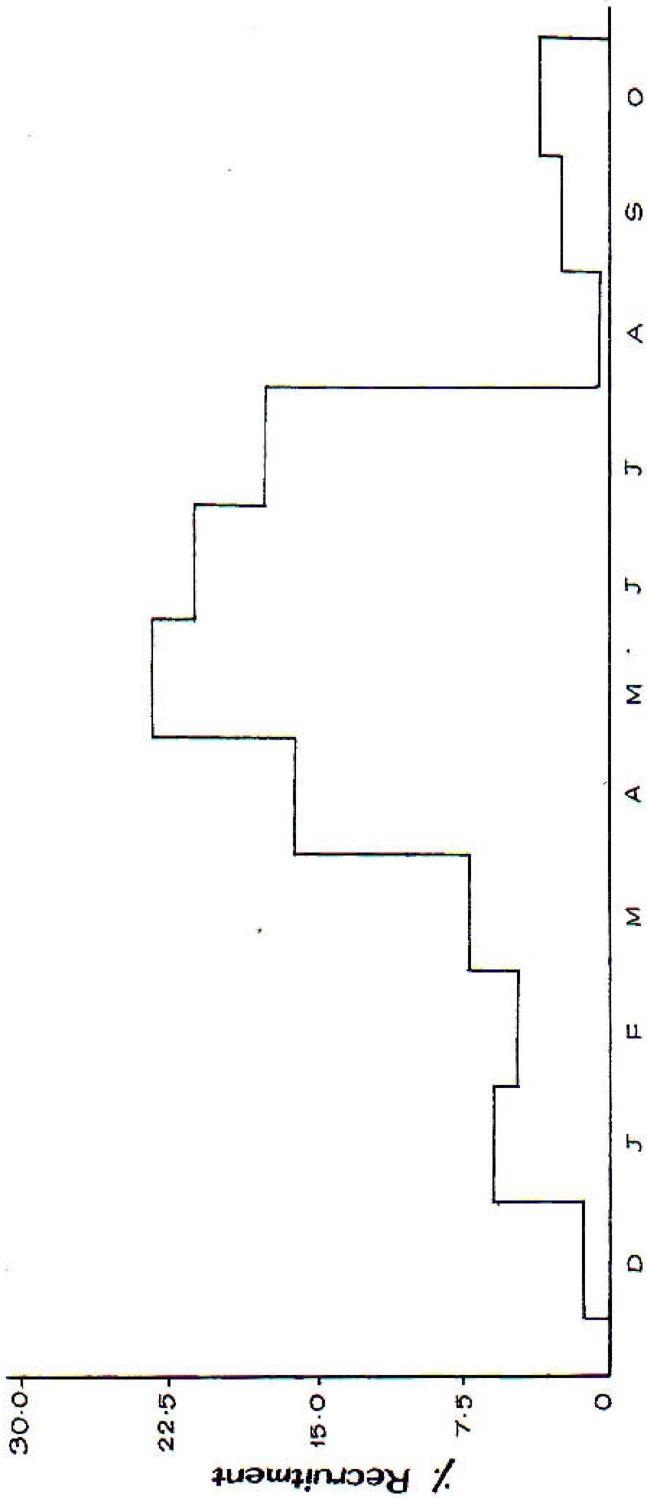

Fig. 6. Recruitment pattern of *P. indicus* in Rekawa lagoon.

Discussion

P. indicus as most other penaeid shrimps, spawns in deeper areas of the sea and eggs and larvae are found in surface and sub-surface waters. The juveniles that move to the lagoon/estuaries migrate back to the sea at the sub adult stage (Macintosh 1982).

The accurate procedure of analysing length-frequency data using length-based stock assessment methods is to use length-frequency data of unbiased catch samples. In the catches of 'kraal' fishery, this requirement is fulfilled due to the reason that beyond a certain size, probabilities of capture of all size classes of shrimps are expected to be close to unity. The smaller ones can escape through the space between the Palmirah strips of the traps (Fig. 2), and only smaller size classes are affected by gear selection. The growth parameters estimated using ELEFAN (Gayanilo et al. 1995) method are biologically reasonable because the estimated values of growth performance index ($\phi' = \log K + 2 \log L_\infty$; Moreau et al. 1986) of *P. indicus* in different localities fall within narrow range (Table 2).

Table 1. Growth parameters, mortality rates, exploitation rate (E) and size at first capture (L_c) of *P. indicus* in Rekawa lagoon.

Parameters	Values
Asymptotic Total Length (L_∞)	
ELEFAN method	20.3 cm
Wetherall method	20.6 cm
Growth constant (K)	1.00 yr^{-1}
Theoretical age at length zero(t_0)	-0.18 yrs
Total mortality (Z)	
From catch curve	4.93
From mean length; Beverton & Holt (1956)	4.98
Natural mortality (M)	2.02
Fishing mortality (F)	2.91
Exploitation rate (E)	0.59
Length at 50% selection (L_c)	13. 2 cm

Table 2. Comparison of growth parameters of *P. indicus* in different localities in Sri Lanka. L_∞- Asymptotic total length; K - Growth constant; t_0 - Theoretical age at length zero; ϕ' - Growth performance index.

Locality	L_∞ (cm)	K ($year^{-1}$)	t_0 (years)	ϕ'	Authority
Negombo	18.2	1.8	-0.1	2.78	Jayakody & Costa 1988
	20.5	1.5	-	2.79	Jayawickrama 1990
Chilaw	18.2	1.5	-	2.78	Jayawickrama 1990
Rekawa	20.3	1.0	-0.18	2.62	Present study

As stated by Basson et al. (1988), estimation of growth parameters from length-frequency data using ELEFAN is effective when L_∞ is known or approximated to a narrow range. Since *P. indicus* is a migratory species, their mature stages are found in the sea. Therefore as indicated by Pinto (1986) L_c cannot be estimated from the biggest specimen of the sample collected from the lagoon itself. In the present study, approximate values of L_∞ and K were obtained from the published data (Jayakody & Costa 1988; Jayawickrama 1990) as root values in the ELEFAN technique. The value for L_∞ obtained from the Wetherall method (20.6 cm) is also closely similar to values reported in these publications.

The estimated Z values from length-converted catch curve method (4.95) and the calculated value using Beverton & Holt (1956) method (4.98) are closely similar indicating the reliability of the estimates. The empirical method presented by Pauly (1980) was used to estimate M of *P. indicus* in Rekawa lagoon. Due to the unavailability of a relationship between time-series data on Z and fishing effort, I was compelled to use Pauly's (1980) empirical model to estimate M.

Y'/R analysis incorporating probabilities of capture, as performed in the present study is more realistic than that is based on the assumption of knife-edge recruitment, especially for short-lived species such as *P. indicus*. According to present analysis, at the present level of exploitation (E = 0.59) by reducing L_c to 9.0 cm TL (Fig. 5) high yields of *P. indicus* can be achieved in Rekawa lagoon. Since the shrimps are short-lived species it is obvious that Y'/R value could be maximised by catching smaller (<11.0 cm) individuals. By reducing the space between the Palmirah stripes, the size at first capture can be decreased in the kraal fishing. However as in most artisanal fisheries, in Rekawa lagoon, fishers might tend to increase fishing efficiencies so that maximisation of shrimp yield by reducing L_c below present level is not advocated.

Sand bar formation was identified as the main natural barrier for shrimp recruitment (Jayakody 1993). Recruitment of juvenile shrimps from the sea to the lagoon takes place when the fishers open the sand bar between the lagoon and the sea. This occurs mostly during November-December periods. Also the opening of the sand bar naturally during some seasons is generally influenced by the rainfall pattern in the area.

When the lagoon mouth is open, recruitment of post-larvae to the lagoon takes place. Hence for maximum recruitment of post-larvae to the lagoon, spawning season and lagoon mouth opening must overlap. Such an overlap was reported to occur during 1993, which resulted in high shrimp yield in the lagoon (Jayakody 1994).

The recruitment pattern of *P. indicus* (Fig. 6) obtained by projecting length frequency sample backward on the time axis using growth parameters indicates that peak recruitment season occurred in May 1994 when the sand bar was cut open by the farmers. However, this has not coincided with the spawning season of *P. indicus* in the sea which resulted in low recruitment of post-larvae to the lagoon. As such, the low yields of *P. indicus* were resulted in 1995. The average yield of *P. indicus* per kraal was 0.2 kg per day, a very low value when compared to the kraal yields of 10.2 kg per day in 1994.

About 50% of people living around Rekawa lagoon belong to fishing communities, whose income is mainly derived from the fishery (Anon.1994). For the improvement of living standards of these fishing communities, sustainable management of the fishery resource is essential. It is recommended that the opening of lagoon mouth during June-July each year coinciding with the spawning season of *P. indicus* in the sea be carried out if natural opening does not take place. This can be effectively implemented in the Rekawa lagoon by organising a lagoon management committee among fishing communities, as suggested by Roy (1995) who highlighted the idea of encouraging fishers to manage their fishery resources.

Acknowledgements

I am thankful to Dr. D.S. Jayakody, Director, Engineering Technology Division and presently Director General of NARA (Sri Lanka) who provided me with facilities to collect data of the present study and to Dr. U.S. Amarasinghe, Senior Lecturer, Department of Zoology, University of Kelaniya (Sri Lanka), who helped me in analysing data and preparing the manuscript. I also wish to thank Mr. T.K. Shantha Kumara for drawing the figures.

References

Amarasinghe, U.S. & S.S. De Silva 1992.
Population dynamics of *Oreochromis mossambicus* and *O. niloticus* (Cichlidae) in two reservoirs in Sri Lanka. Asian Fisheries Science 5:37-61.

Anon. 1994.
Site elevation and design criteria for pond shrimp culture in the Rekawa lagoon area. Report prepared by Aquatic Resources Management Consultants. 1994. 120 pp.

Basson, M., A.A. Rossenberg & J. R. Beddington 1988.
The accuracy and reliability of two new methods for estimating growth parameters from length frequency data. Journal du Consiel. Consiel International Exploration de la Mer 44: 277-285.

Beverton, R.J.H. & S.J. Holt 1956.
A review of methods for estimating mortality rates in fish populations with special reference to source of bias in catch sampling. Rapport et proces-Verbaus des Reunions, Conseil International pour 1'Exploration de la Mer 140: 67-83.

Brey, T., M. Soriano & D. Pauly 1988.
Electronic Length Frequency Analysis A Revised and Expanded User's Guide to ELEFAN 0, 1 and 2 (2nd Edition). Berichte aus dem Institut fur Meereskunde an der Christian-Albrechts-Universitat Kiel. 31p.

Gayanilo, F.C., Jr., P. Sparre & D. Pauly 1995.
FAO-ICLARM Stock Assessment Tools (FiSAT) User's Guide. FAO Computerised Information Series (Fisheries) No. 8., Rome, FAO, 126p.

Jayakody, D.S. 1993.
Causes for the decline of finfish and shellfish catches of three selected lagoons; Malala, Rekawa and Mawella on the South coast of Sri Lanka and the current status. Proceedings of NARA Annual Scientific Sessions 1993: 11-13.

Jayakody, D. S. 1994.
Shrimp recruitment study of Rekawa lagoon. Interim report submitted to the NAREPP, NAREPP, Colombo 28 pp.

Jayakody, D. S. & H.H. Costa 1988.
Population dynamics of Indian shrimp (*Penaeus indicus*, Milne Edwards) on the West coast of Sri Lanka, Asian Fisheries Science 1: 135-146.

Jayakody, D.S. & J.M.P.K. Jayasinghe 1992.
Report of the Development Potential of Rekawa lagoon 23 p. NARA unpublished report, NARA, Colombo.

Jayawickrama, S. J. C. 1990.
Status of *Penaeus indicus* (H. Milne Edwards) stocks from Negombo and Chilaw, Sri Lanka. Journal of National Science Council of Sri Lanka 18(2): 159-166.

Macintosh, D. J. 1982.
Fisheries and Aquaculture significance of mangrove swamps, which special reference to the Indo-West Pacific region. In: Resent Advances in Aquaculture (J. F. Muir & R. J. Roberts eds). pp. 3-85. Croom Helm Ltd., London.

Moreau, J., C. Bambino & D. Pauly 1986.
Indices of overall growth performances of 100 tilapia (Cichlidae) populations. In: The first Asian Fisheries Forum (J. L. Maclean, L. B. Dizon & L. V. Hosillos eds.) pp. 201-206. Asian Fisheries Society, Manila.

Pauly, D. 1979.
Gill size and temperature as governing factor in fish growth: a generalization of von Bertalanffy's Growth Formula. Berichte aus dem Institut fur Meereskunde an der Christian-albrechts-Universitat Kiel, No. 63, 156 p.

Pauly, D. 1980.
On the relationship between natural mortality, Growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil. Conseil International Exploration de la Mer 39(3): 175-192.

Pauly, D. 1986a.
On improving and use of the ELEFAN programs. Part II. Improving the estimation of L_∞. Fishbyte 4(1): 18-20.

Pauly, D. 1986b.
On improving operation and use of the ELEFAN programs. Part III. Correcting Length-Frequency data for the effects of gear selection and/or incomplete recruitment. Fishbyte 4(2):11-13.

Pauly, D. & J. L. Munro 1984.
Once more on the comparison of growth in fish and invertebrates. Fishbyte 2(1): 21.

Pauly, D. & M. Soriano 1986.
Some practical extensions to Beverton & Holt's relative yield-per-recruit model. In: The First Asian Fisheries Forum (J. L. Maclean, L. B. Dizon & L. V. Hosillos eds.). pp. 491-495. Asian Fisheries Society, Manila.

Pinto L. 1986.
Use of ELEFAN programs for emigrating species. Fishbyte 4(1): 14-15.

Roy, R. 1995.
Encouraging Fisherfalk to manage their fisheries: How communication and awareness can help. Bay of Bengal News 11(1): 4-8.

Wetherall, J. A. 1986.
A new method for estimating growth and mortality parameters from length frequency data. Fishbyte 4(1): 12-14.