because this assumption produced growth estimates comparable to those obtained from the preliminary run of ELEFAN I. Furthermore, the recruitment patterns suggest two peaks, roughly four to five months apart, typical for many marine organisms living in monsoon environments.

The 1991 Z estimates were higher than those of 1987-88 and 1988-89, indicating higher fishing pressure in recent years. It appeared that the fishers reached declining returns on the Sadh ground and abandoned harvest efforts before the season ended after fishing out almost all the mature abalone; harvesting continued in the Hadbin area until the end of the season with increased fishing pressure. Thus, although a constant monthly Z was assumed, December F value at Hadbin might have been much higher than in November. Egg-per-recruit, mature biomass-per-recruit and yield-per-recruit analyses (not presented here) indicated increased fishing pressure, and suggested that a 50% reduction in the current Sadh fishing mortality level and increase in the minimum size limit to at least 110 mm SL would be appropriate.

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On the Growth, Mortality and Recruitment of the Spiny Lobster *(Panulirus homarus)* in Sri Lankan Waters[a]

D.S. JAYAKODY

Abstract

Monthly length-frequency data of spiny lobster *Panulirus homarus* collected from the south coast of Sri Lanka during 1988-1990 were analyzed to estimate von Bertalanffy growth parameters. The asymptotic lengths estimated using Wetherall plots were 322 mm and 315 mm total length for the males and females, respectively. Using ϕ' values of 3.53 for males and 3.61 for females, the growth constant (K) was estimated as 0.21·year^{-1} and 0.27·year^{-1} for the males and females, respectively. The estimates of natural and total mortality (M and Z) are 0.98·year^{-1}, 1.96·year^{-1} for males and 0.92·year^{-1}, 1.54·year^{-1} for females respectively. Recruitment appears to occur in two pulses per year.

Introduction

Six species of spiny lobsters have been recorded so far from Sri Lankan waters (De Bruin 1962). Of these, the most important commercially is *Panulirus homarus* (Linn.). Several studies have been carried out on various aspects of its distribution, biology and ecology (George 1965; Berry 1970, 1971, 1974; Bhatia 1974; Radhakrishnan 1977; Heydorn 1978; Sanders and Bouhlel 1984).

P. homarus contributes to a fishery on the south coast of Sri Lanka and supports a lobster tail freezing industry. Nearly 90% of the spiny lobsters caught in Sri Lankan waters are exported to the USA and Japan, generating a considerable amount of foreign exchange.

The fishery is seasonal and usually extends from the beginning of August to the end of April, the off season being due to the occurrence of rough seas during the southwest monsoon. On Sri Lanka's south coast, *P. homarus* species is restricted to shallow waters extending to a maximum depth of 20 m, where it is caught by bottom set nets.

Preliminary information on the distribution, taxonomy, ecology and breeding biology of *P. homarus* in Sri Lanka is available (De Bruin 1962, 1969; Jayakody 1989).

[a]Based on a draft written during a study stage at ICLARM from 7 January to 1 February 1991.

In the present study, an attempt is made to estimate growth, mortality and recruitment parameters of *P. homarus*, as an input to the management of its fishery in Sri Lankan waters.

Materials and Methods

Length-frequency data of *P. homarus* were collected during two consecutive seasons from August 1988 to April 1990 (1988-89 and 1989-90 seasons) from the south coast of Sri Lanka. Six landing sites were selected (Fig. 1) for data collection and were visited fortnightly. Information on the total lobster catch, effort, species composition, sex ratio, etc., were collected from small-scale fishers operating bottom set nets. The number of trips they made to the fishing grounds were taken as a measure of fishing effort. Total and carapace lengths were measured to the nearest mm and weight measurements were taken to the nearest g. The von Bertalanffy growth parameters (L_∞ and K) were estimated using the ELEFAN I computer program (Pauly and David 1981). The data for 1988-89 and 1989-90 were pooled as there was no apparent difference between similar months of each season. Total mortality rate (Z) was estimated using a length-converted catch curve and also by using Beverton and Holt (1956), viz:

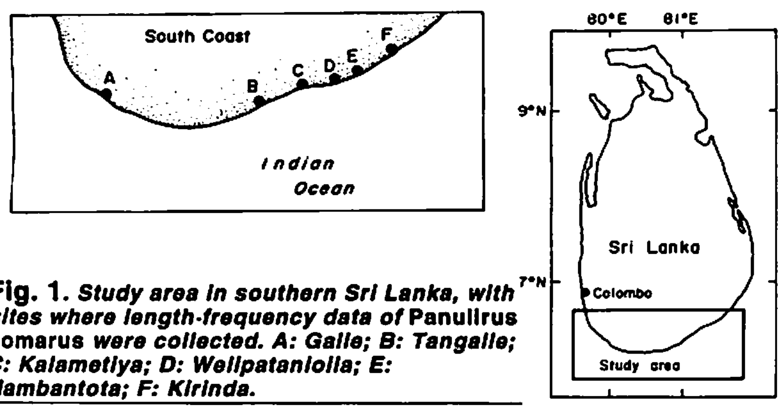


Fig. 1. ***Study area in southern Sri Lanka, with sites where length-frequency data of* Panulirus homarus *were collected. A: Galle; B: Tangalle; C: Kalametiya; D: Wellpatanlolla; E: Hambantota; F: Kirinda.***

$$Z = K\frac{(L_\infty - \bar{L})}{\bar{L} - L'} \qquad ...1)$$

where L_∞ is its asymptotic length; $\bar{L}$ is the mean length of all lobsters recruited to the fishery; L' is the length at which full recruitment is attained and K is the von Bertalanffy growth constant. The growth performance index (ϕ') was estimated using

$$\phi' = \log_{10} K + 2 \log_{10} L_\infty \qquad ...2)$$

(Pauly and Munro 1984)

Z was also estimated using the method of Wetherall (1986), as modified by Pauly (1986), viz

$$\bar{L} - L' = a + b\,L' \qquad ...3)$$

where
$L_\infty = a/-b$ and $Z/K = (1+b)/-b$

Natural mortality rate (M) was estimated using Pauly's empirical formula (Pauly 1980) viz

$$\text{Log}_{10}M = -0.006 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10k} + 0.4634 \log_{10}T \qquad ...4)$$

where L_∞ is the asymptotic length (total length, in cm); K is the growth constant (year^{-1}) and T is the mean annual temperature (in °C) of the water in which the stock lives, about 28°C.

Results and Discussion

The estimation of spiny lobster growth in nature, by any of the presently known methods, is difficult. The adequacy of the von Bertalanffy (1938) growth function as a realistic description of the growth process in palinurids depends on the validity of its key assumption, that the growth rate is constant throughout any one year. This is obviously not the case in the Palinuridae, where the molt frequency varies seasonally. Although temperature changes are not strong in Sri Lankan waters, the monsoons may influence growth. The effects of these seasonal changes in the growth rate on the form of the growth curve have not been examined for spiny lobsters (Morgan 1977). In the present analysis, it is assumed that the growth of spiny lobsters follows the von Bertalanffy type of growth.

Tables 1A and 1B show the length distribution of *P. homarus* in catch samples, from August 1988 to April 1990. The data from corresponding months of the two years were pooled and analyzed using ELEFAN I; the resulting growth curves are shown in Fig. 2. L_∞ was estimated to be 322 mm total length (127 mm carapace length) for males and 315 mm (122 mm carapace length) for females, while the growth constant (K) was estimated as 0.41·year^{-1} for the males and 0.37·year^{-1} for females. These estimates do not appear to be very reliable, as they are associated with low values of the ELEFAN I goodness of fit estimator (Rn). However, Wetherall plots generated very similar values of L_∞ (Table 2, Fig. 3).

Table 3 presents ϕ' values for some palinurids; the results of the present study agree reasonbly well with the literature values.

Since not all palinurid populations are commercially exploited, and since vital statistics have been estimated only for very few of the exploited tropical stocks, the information on mortality rates in the literature is necessarily sparse. Due to the common problem of inability of determining age of crustaceans, all the available methods of mortality rate estimation rely on analysis of length-frequency data rather than of age data.

Table 4 presents our estimates of Z (see also Fig. 4).

According to the literature, Z values for panulirids range from 0.5 to 2.4·year^{-1} (Table 2); for *P. homarus* the range is 2.0-2.3 (Sanders and Bouhlel 1984).

There are several methods available to estimate natural mortality (M), but most have data requirements that are difficult to meet (Rikhter and Efanov 1976; Sanders 1977;

Table 1A. Length-frequency data for male *Panulirus homarus* sampled off the southern coast of Sri Lanka (total length).

Mid-length (mm)	Lobster season 1988-89 Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	1989-90 Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
35			2															
45			2									4						
55			1	3								3	5					
65			2	3								1	2					
75		1	2	4	4				4			1	3	2				
85		4	7	6	1		1		1		5	4	7	3		1		
95		3	6	15	2	5	3		2		4	5	13	3	3	5		2
105		0	7	21	4	14	0		4	1	3	9	22	6	16	1		6
115	4	6	11	26	3	45	4	4	3	6	5	12	31	4	50	5	7	8
125	14	3	20	54	30	39	14	10	30	17	4	17	50	31	36	10	13	9
135	28	18	39	74	52	65	17	24	52	27	13	43	84	61	52	19	27	27
145	20	19	61	91	51	60	28	27	51	24	22	56	86	60	51	22	21	33
155	57	40	60	65	41	71	30	40	41	61	37	55	68	44	54	38	25	20
165	74	35	51	43	32	68	28	23	32	82	45	71	66	42	47	25	23	21
175	80	44	65	39	28	54	16	20	28	97	33	68	41	22	52	18	23	23
185	94	68	93	40	15	47	17	18	15	82	62	84	44	23	44	18	17	24
195	61	56	104	59	11	42	11	17	11	74	71	125	69	29	28	10	13	29
205	44	53	18	103	14	38	7	12	33	37	37	86	86	24	33	5	16	16
215	30	42	85	107	23	38	12	7	23	37	31	94	109	15	30	9	6	9
225	19	17	60	93	11	23	7	6	11	26	17	52	88	14	21	9	3	9
235	14	8	31	61	30	19	8	4	30	12	9	30	42	35	15	7	4	9
245	7	3	12	21	21	7	5	6	21	4	1	11	25	22	5	3	4	13
255	5	1	6	8	6	9	1	0	6	4	1	7	10	4	4	2	1	2
265		1	4	9	1	8	1	2	1		3	3	9	1	6	1	1	1
275			0	4		5		1			1	1	1	2			1	0
285			5	3		1						3	0	0				1
295			2	1		1						1	2					
305				1									1					

Table 1B. Length-frequency data for female *Panulirus homarus* sampled off the southern coast of Sri Lanka (total length).

Mid-length (mm)	Lobster season 1988-89 Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	1989-90 Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
35			1	1														
45			3	1								4	2					
55			3	0								3	1					
65			4	4								3	4					
75			5	2			2					3	3			1		
85			4	9		3	0					5	7		4	0		
95		4	10	10		6	2					6	11	8	7	1		
105		7	6	11	1	14	4	3				4	8	12	21	8	3	
115		4	9	19	5	19	10	5	3			2	11	19	22	14	3	2
125	9	19	40	10	38	34	24	4	7	2	8	20	25	11	38	27	2	5
135	10	3	40	22	64	60	40	13	13	4	3	6	53	20	64	48	15	9
145	9	50	50	23	75	63	68	30	12	3	6	38	58	27	75	66	41	14
155	7	44	26	21	77	60	44	28	8	17	3	60	31	25	77	48	31	17
165	19	50	40	38	57	56	31	19	14	32	19	31	38	42	57	40	32	15
175	4	31	24	20	55	41	26	11	30	37	40	37	29	52	48	31	11	8
185	28	49	30	61	32	23	34	24	16	65	44	56	37	79	32	41	28	14
195	44	101	40	54	26	27	19	14	15	74	57	76	46	62	26	32	13	15
205	43	144	74	30	23	19	18	15	18	50	51	86	59	32	23	20	18	12
215	24	100	60	28	18	20	17	9	20	61	28	97	73	37	18	17	21	21
225	30	91	57	19	21	12	11	9	30	28	36	64	37	23	21	21	13	35
235	20	47	28	12	14	10	9	10	31	24	16	64	34	16	14	13	13	36
245	19	39	20	8	7	3	10	9	25	23	8	51	29	8	7	11	9	29
255	13	18	15	7	4	7	9	4	12	12	12	20	18	10	4	13	4	13
265		5	8	7	9	2	7	5	9		4	10	7	11	2	8	3	7
275		2	6	6	4	4	6	4	8		5	8	3	4	5	6	2	7
285		6	7	4	4				3		5	7	6	1	1			
295													1					
305																		

Table 2. Summary of parameter values estimated from the modified Wetherall plot (Pauly 1986).

Parameter	Male	Female
a	64.14	66.80
b	-0.200	-0.211
r	-0.985	-0.998
L_∞	320 (TL)	317 (TL)
Z/K	3.747	3.395

Table 4. Estimates of Z for *Panulirus homarus* in southern Sri Lanka.

Method	Males ($year^{-1}$)	Females ($year^{-1}$)
Length-converted catch curve	2.10	1.60
From mean length	1.87	1.36
From Wetherall plot[a]	0.73	1.00

[a]with substitution of K values obtained via ϕ'.

Table 3. Growth parameters and mortality estimates of panulirid lobsters from different regions of the world. (CL - carapace length).

Source	Location	Species	Sex	CL_∞ (mm)	K ($year^{-1}$)	Z	Mortality ($year^{-1}$)	ϕ'
Bowen Chittleborough (1966)	Western Australia	*P. cygnus*	-	-	-	0.8-2.4	0.59-2.1	-
Morgan (1977)	Australian waters	*P. cygnus*	-	-	-	0.87-1.01	0.23	-
Munro (1974)	Caribbean waters	*P. argus*	-	-	-	0.5-1.52	-	-
Sanders and Bouhlel (1984)	Yemen	*P. homarus*	Male Female	136 118	0.46 0.44	2.41 2.03	0.85 0.85	3.93 3.78
Chittleborough (1976)	Australian waters	*P. longipes*	both	113	0.46	-	-	3.77
Smale (1978)	South Africa	*P. homarus*	Male Female	120 94	0.18 0.34	- -	- -	3.40 3.48
Ebert and Ford (1986)	Marshall Islands	*P. penicillatus*	Male Female	146 96	0.21 0.58	- -	- -	3.65 3.73
Arellano (1989)	Philippines	*P. penicillatus*	Male Female	161 153	0.13 0.17	- -	- -	3.35 3.60
Mohammed and George (1968)	India	*P. homarus*	Male Female	122[a] 118[a]	0.72 0.62	- -	- -	- -
This study	Sri Lanka	*P. homarus*	Male Female	127 121	0.41[b] 0.39[b]	2.1[c] 1.6[c]	0.98 0.92	3.34 3.59

[a]Converted from total length through multiplication with 0.39.
[b]K value computed from average ϕ' and from L_∞, obtained through a Wetherall plot.
[c]From length-converted catch curves (see Table 3).

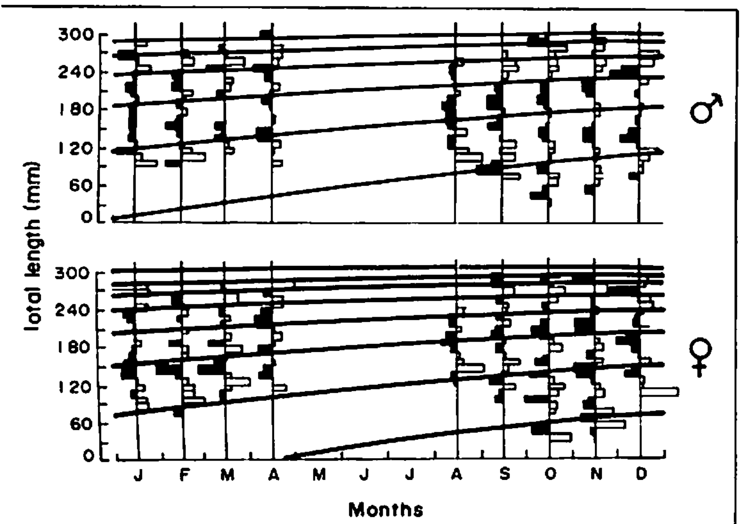


Fig. 2. *Length-frequency data (from Table 1) for male and female* Panulirus homarus, *as restructured by the ELEFAN I program and with superimposed tentative growth curves.*

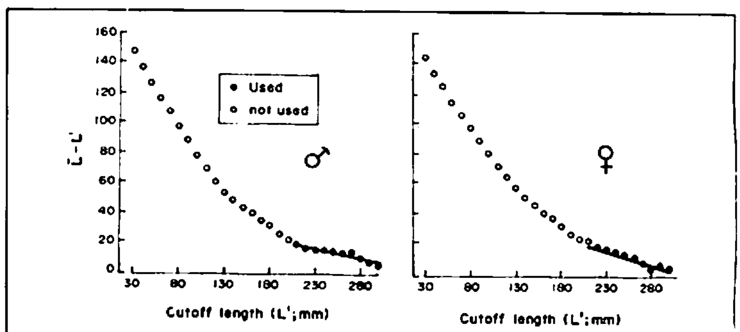


Fig. 3. *Wetherall plots for* Panulirus homarus *sampled off southern Sri Lanka.*

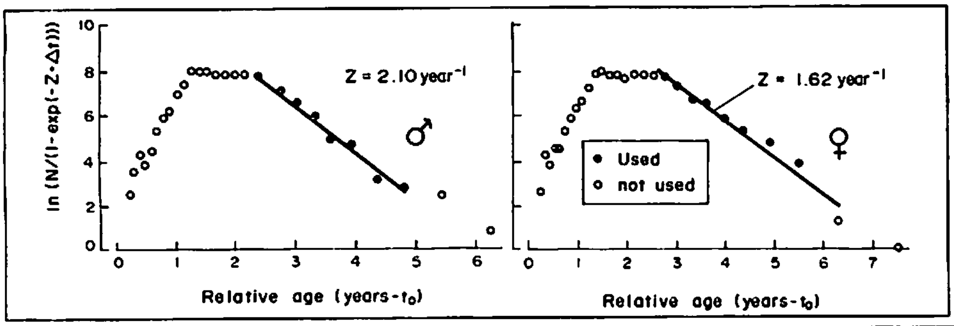
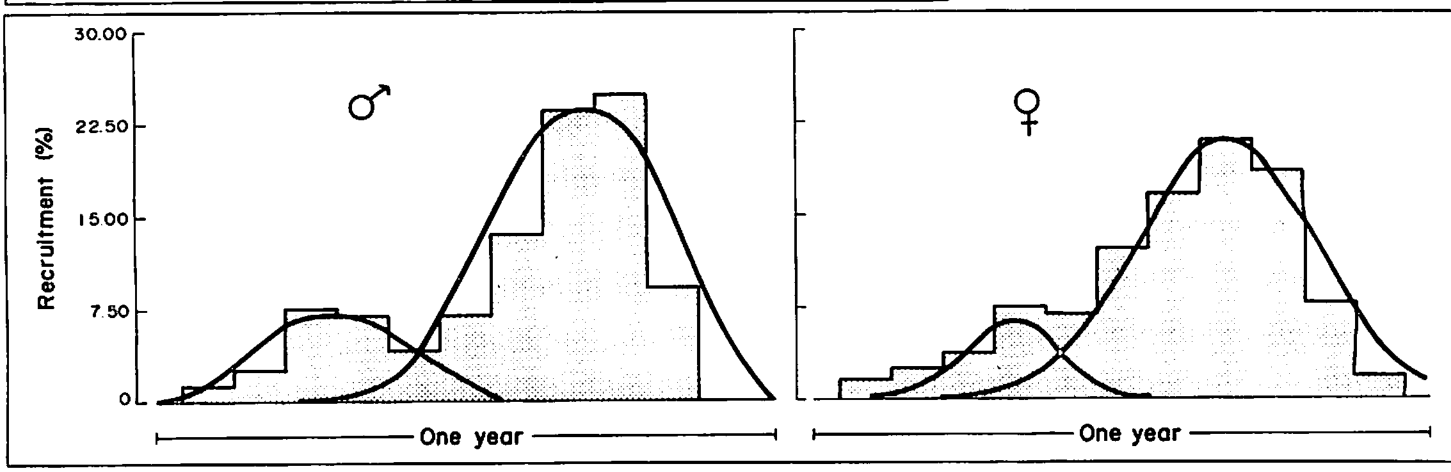


Fig. 4. *Length-converted catch curves for* **Panulirus homarus** *sampled off southern Sri Lanka.*

Fig. 5. *Recruitment patterns for* **Panulirus homarus** *sampled off southern Sri Lanka.*



Sanders and Kedidi 1983; Munro 1984). As only two years worth of L/F were available for this study, there was no choice but to use Pauly's empirical formula. This led to M being estimated as 0.98 for males and 0.92·year^{-1} females. These values match values previously estimated for *P. homarus* by Sanders and Bouhlel (1984) (Table 3).

Fig. 5 shows the recruitment patterns that were obtained, and which suggest that annual recruitment occurs in two wide pulses of unequal strength. Although it is difficult to match these peaks with certain months of the year (because t_0 was not estimated), a relationship to the two monsoons is suggested.

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MAPPER, a Low-Level Geographic Information System

GRACE CORONADO and RAINER FROESE

Abstract

A Low-Level Geographic Information System (LL-GIS) was developed to provide a simple low-cost mapping program which can be executed in any personal computer, by individuals with different levels of knowledge in computing. MAPPER is an add-on module of FishBase - a global database with key information on the biology of fish - where it creates on-screen maps with information on biodiversity and the occurrence of species. In another application, MAPPER is used to display and analyze geographical information on the Philippines.

Introduction

Geographic information systems (GIS) are important tools that deal with spatial data. To date, the main use of GIS by government and other agencies is to produce colorful thematic maps of areas of special interest to help the decisionmaking process. While it is convenient to have such maps generated by the computer, one has to realize that the very same output can also be produced by handcoloring photocopies of existing maps, which is still much faster and cheaper.

A GIS is only justified when one or both its main capabilities are used, i.e., i) to automatically produce a variety of maps out of a continuously changing database and ii) to analyze spatial data in a nontrivial way to provide insights which, for example, cannot be gained by putting three transparencies on top of each other.

The disadvantages that must be evaluated carefully before the user invests in the development or acquisition of a GIS are:

- the high cost of commercial GIS packages can only be justified if there is a continuous, substantial supply of spatial data, e.g., from remote sensing or a long-term monitoring program. Such data are normally very expensive to obtain;
- the initial effort of converting existing geographic data into a format suitable for GIS through digitizing, scanning, or related data conversion is substantial;
- a large amount of technical as well as financial overhead is required to maintain a GIS unit (e.g., computer, digitizer, color printer, large plotter, skilled technicians, software maintenance, etc.).

The main objective of this study was to develop a Low-Level Geographic Information System which performs basic capabilities of a commercial GIS but only requires an IBM compatible personal computer with 640KB RAM, a VGA color monitor, a hard disk, a mouse and a dot matrix or laser printer. The system was designed for different levels of users with different levels of computer experience.

Specifically, the study aimed to develop the following routines/algorithms:

- a "digitizer-like" routine for creating/editing maps and overlays using a mouse or the keyboard;
- a plotting routine to draw a map (any part of the world) and overlay data files of different types (points, lines, polygons);
- an algorithm for computing perimeters and areas;
- miscellaneous routines for zooming, printing, saving, and redrawing the displayed map.

Procedure

The program was written in the computer language C using the Borland C++ compiler and the MetaWINDOW