Growth, Mortality and Recruitment of Omani Abalone (*Haliotis mariae*)

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Abstract

Historical length-frequency data of Omani abalone (*Haliotis mariae*) from two areas (Sadh and Hadbin) of the Dhofar coast of the Sultanate of Oman were used to estimate growth parameters by nonlinear least square fitting. The results were verified using the ELEFAN I program and then combined to calculate total mortality (Z) and recruitment patterns. The growth parameters values with combined sexes were L_∞ = 137 mm shell length (SL), K = 0.75·year^{-1} and t_0 = 0.73·year^{-1}. The 1987/89 Z values were 1.7·year^{-1} and 1.57·year^{-1} on Sadh male and female, respectively. The female Z value in Hadbin was 1.55·year^{-1} in 1989/90. The 1991 Z values for combined sexes were 2.37·year^{-1} in Sadh and 1.66·year^{-1} in Hadbin, showing much higher fishing pressure in recent years. There were two recruitment pulses, a major one in January and a minor one in May.

Introduction

Abalone (*Haliotis mariae*) stocks of the Dhofar coast, North Arabian Sea in the southern region of the Sultanate of Oman, are by far the most valuable export commodity among the marine living resources of Oman. Although the fishery probably existed since the 1950s, stock assessment efforts did not begin until the early 1980s. Sanders (1982) in his preliminary stock assessment of the Dhofar abalone fishery concluded that yield-per-recruit could be increased by increasing fishing effort and decreasing the size at first capture. This optimistic picture faded in the latter part of 1980s (Johnson 1990) and a minimum size limit of 90 mm shell length (SL) with a shortened harvest season (November and December) were introduced in 1991. These management measures were largely based on educated guesses rather than indepth analysis of fisheries and biological data.

A detailed stock investigation started in 1991 and stock assessment was initiated with available historical data. Shell length data used here were collected from the abalone fishery in the Dhofar region since 1987. Shell aging is a recent innovation in abalone stock assessment and requires validation for Omani stocks. Consequently, a length-frequency analysis of 1987-91 data was pursued to estimate growth, instantaneous total mortality (Z) and recruitment patterns.

Materials and Methods

The primary abalone stocks of the Dhofar coast are near Sadh, Hadbin and Sharbithat (located in 17°-18° North latitude and 55°-55°, 30' East longitude). Prior to 1987, there were no abalone fishery regulations and the harvest season was determined by the duration of the intermonsoon calm period and an available abalone density sufficient to encourage diving efforts. In 1987, a regulation established a season which started just after the southwest monsoon period, 1 October and ended 31 March, as premonsoon weather was beginning.

Shell length data collected from the Sadh and Hadbin fisheries beginning in November 1987 provided enough sequential length-frequency data for least square fitting of the growth curve and for using the ELEFAN I program (Gayanilo, Jr. et al. 1989). Because the ELEFAN programs are more suitable for short-lived species (Pauly et al. 1984; Isaac 1990), and *H. mariae* has a life span extending to 5-10 years, the ELEFAN I results were used merely for validation of modal progression analysis followed by nonlinear least square fitting (Prager et al. 1989). For this analysis, the modes of each length-frequency distribution were determined by the Bhattacharya method. The best growth parameter values were then used to estimate Z and recruitment patterns.

Results

Preliminary ELEFAN I runs with the historical data grouped into 5-mm and 2-mm intervals produced K values ranging from 0.67 to 0.89·year^{-1} and L_∞ values ranging from 139 mm to 145 mm SL (Table 1). The best values of the goodness of fit index (Gayanilo, Jr. et al. 1989) were low, Rn = 0.127-0.254. This indicated that finer grouping only introduced noise in the run of possible growth curves through modes rather than adversely affecting the locations of progressing primary modes. Nevertheless, low Rn values suggested multiple recruitment pulses. The minimum K value resulting from the two groupings was 0.67·year^{-1} and

Table 1. Preliminary estimates of growth parameters using the ELEFAN I program for 5-mm and 2-mm shell length intervals from 1987 to 1990 female (f) and male (m) Omani abalone length-frequency data.

Area	Period	Sex	5-mm intervals			2-mm intervals		
			L_∞ (mm)	K (year^{-1})	Rn	L_∞ (mm)	K (year^{-1})	Rn
Sadh	Nov 87-Feb 88	F	140	0.69	0.164	139	0.71	0.145
		M	141	0.75	0.254	144	0.67	0.162
Hadbin	Nov 89-Mar 90	F	140	0.76	0.210	143	0.72	0.127
		M	145	0.89	0.144	140	0.80	0.145

the range of L_∞ values was reasonable. The L_∞ and K estimates did not differ much when seasonal growth was assumed, and hence growth was assumed not to vary seasonally.

This was followed by decomposing the length-frequency data into normal components using the Bhattacharya method (also included in the Compleat ELEFAN package) and fitting a growth curve to the resulting progression of modal lengths by nonlinear least square fitting (Prager et al. 1989). Modal decomposition was carried out separately on male and female length-frequency data, but growth parameters for different sexes appear similar. Modal lengths resulting from successful decomposition were used for growth estimation; a plausible age of 1.5 years was assigned to 60 mm SL, thus generating ages for successive modal lengths.

The male data from Hadbin did not provide convergent results. The growth estimates obtained from the rest of the data sets by nonlinear least square fitting, and subsequently confirmed by the ELEFAN I program, are given in Table 2. Except for the L_∞ value of Sadh female, the rest of the ELEFAN I results were close to those obtained by nonlinear least square fitting. The average values of male and female growth parameters were L_∞ = 137 mm SL, K = 0.75·year^{-1} and t_0 = 0.73·year^{-1}. Fig. 1 shows the growth curve fitted to the 1987/88 Sadh combined sexes length-frequency data with these parameter values.

Table 2. Estimates of growth parameters (± standard error) of Sadh and Hadbin abalone by sex using FISHPARM (F; nonlinear regression fitting) and ELEFAN (E).

Sample		L_∞ (mm SL)	K (year^{-1})	t_0 (year)	R^2	Rn
Sadh female	F	135±12.8	0.76±0.23	0.71±0.18	0.95	-
	E	142	0.76	-	-	0.175
Sadh male	F	139±26.5	0.75±0.45	0.74±0.36	0.80	-
	E	141	0.76	-	-	0.251
Hadbin female	F	140±5.3	0.77±0.13	0.72±0.16	0.98	-
	E	140	0.76	-	-	0.210

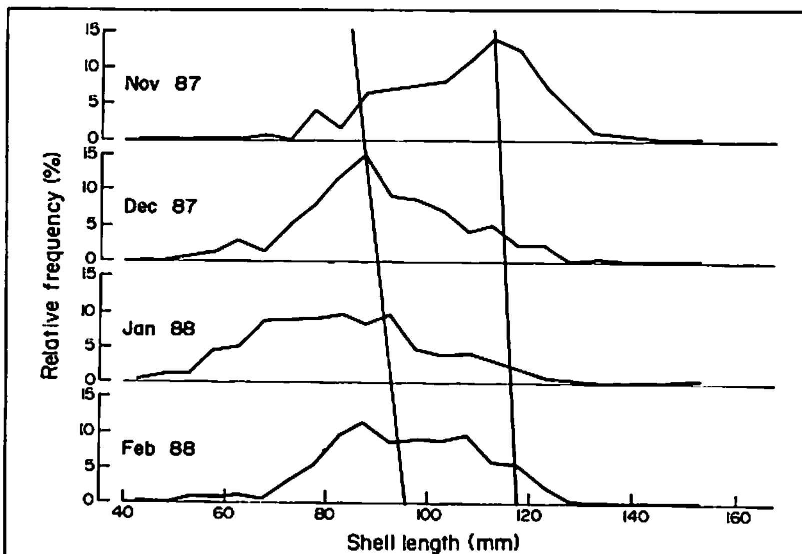

Fig. 1. *Growth curve fitted to the 1987-1988 Sadh combined sexes abalone length frequency data with L_∞ = 137 mm SL, K = 0.75·year^{-1} and t_0 = 0.73 year.*

Total Mortality

The length-converted catch curve method incorporated in the Compleat ELEFAN package produced Z values of 1.7·year^{-1} and 1.57·year^{-1} on Sadh male and female, respectively, during the 1987-89 period. The Z value for female in Hadbin was 1.55·year^{-1} in 1989-90. The Z values during the 1987-88 to 1989-90 seasons were similar in both areas and suggested overexploitation (F/Z was at least 0.68). The November 1991 length-frequency sample for combined sexes from Sadh generated a Z value of 2.37·year^{-1} while the November-December 1991 combined sexes samples from Hadbin produced a Z value of 1.66·year^{-1} indicating differential total mortality in each area.

Recruitment Patterns

The recruitment patterns obtained with the estimated growth parameters from the Compleat ELEFAN package indicated one major and one minor peak, four to five months apart, for each sex at Sadh and for female at Hadbin. Preliminary maturity investigations (unpublished data) and upwelling studies (Savidge et al. 1986, 1988) suggest that the major spawning season of *H. mariae* may be November-January.

Discussion

While most K estimates of abalone reported in the literature are between 0.2 and 0.5·year^{-1} (Day and Fleming, in press), the K estimates for the Omani abalone are consistently high. The Omani abalone, *H. mariae*, inhabiting one of the largest upwelling systems in the world (Savidge et al. 1988) displays exceptional growth in its nutrient rich subtemperate habitat. Sanders (1982) obtained a K value of 0.75·year^{-1}, similar to this study, but with a low L_∞ of 119 mm SL, compared to the current L_∞ values of 139 to 145 mm SL which approach the maximum shell size observed (152 mm SL). Isaac (1990) noted that when the length interval was increased, K was underestimated and L_∞ overestimated. If this was true, the K estimates from the preliminary run of ELEFAN I would have been at least higher than 0.67·year^{-1}, the lowest value listed in Table 1. This may justify the current best K estimates of 0.75-0.67·year^{-1}.

The groups of modal lengths used in the nonlinear least square fit were assumed to be six months apart in age for the purpose of growth estimation. Although this needs stronger justification, it appears to be plausible 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]

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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 $0.21 \cdot year^{-1}$ and $0.27 \cdot year^{-1}$ for the males and females, respectively. The estimates of natural and total mortality (M and Z) are $0.98 \cdot year^{-1}$, $1.96 \cdot year^{-1}$ for males and $0.92 \cdot year^{-1}$, $1.54 \cdot year^{-1}$ 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.