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Yield-per-Recruit and Relative Mean Biomass Estimates, and their Management Consequences, to the *Penaeus Indicus* Fishery in the Gulf of Masirah

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خلاصة : استخدمت معايير النمو المعروفة باسم فون بيرت لانفي، بناء على البيانات التي تم جمعها عام ١٩٩٠-١٩٩١ والخاصة بطول الدرقة في الروبيان (بينيس انديكس) من خليج مصيرة بعمان لتقدير قيمة الفقد الكلي وإنتاج الروبيان للمستجدين (متوسط وزن الروبيان من المستجدين تحت ظروف صيد معينة)، ومتوسط الوزن النسبي (وزن الروبيان المستجد والمصاد بالنسبة لغير المصاد) لجماعات الروبيان التي تم أخذ عينات منها. أظهرت دراسة قيمة معامل الفقد الكلي الفوري أن مخزون الروبيان لم يستغل بالكامل في عام ١٩٩٠-١٩٩١. وعند اعتبار سيناريوهات موسمية مختلفة للفقد الكلي الحالي ولكن مع قيم مختلفة للفقد الطبيعي - وجد أن أعلى إنتاج للمستجدين ومتوسط الوزن النوعي من الروبيان كان خلال أشهر أكتوبر - إبريل، ونوفمبر - إبريل من موسم الصيد. ويعتبر موسم الصيد الحالي من أغسطس حتى نهاية إبريل ، متأخراً مما يعني أن تأجيل موسم الصيد لمدة شهر أو شهرين قد يكون مفيداً لهذا الصيد.

ABSTRACT: The von Bertalanffy growth parameters estimated based on the 1990/91 carapace length data of *Penaeus indicus* from the Gulf of Masirah, Oman were used to calculate total mortality, yield-per-recruit (i.e., average weight of a shrimp from a cohort under a given fishing pattern) and relative mean biomass (i.e., exploited cohort biomass over un-exploited cohort biomass) for the population sampled. The instantaneous total mortality coefficient value indicated under exploitation in 1990/91. When different fishing seasons scenarios were considered with the current total mortality level, but with a range of natural mortality values, high yield - per- recruit and relative mean biomass values were shown for October-April and November-April fishing seasons. The fishing season is currently late August to end of April. Thus, a one to two-month delay in the fishing season appears to be beneficial to this fishery.

Two species of penaeid prawns, *Penaeus indicus* H. Milne Edwards and *P. semisulcatus* De Haan, are the major components of the shrimp catch in the Gulf of Masirah, Oman. There has been little stock assessment of Omani shrimp populations other than a short exploratory survey in the Gulf of Masirah by van Zalinge (1982). The present fishery consists of about 500 cast net fishermen who fish at depths less than 5m from fibre glass boats powered by outboard motors and harvest between 150 and 590 metric tons (t) of shrimp annually (Anon, 1994). Most of the catch is exported.

There is hardly any stock assessment investigation reported on Omani shrimp. Our work is a preliminary attempt to fill this gap and we address a few aspects of stock assessment on Omani shrimp. This paper first determines growth and mortality values, and then investigates yield-per-recruit and relative mean biomass trends for *P. indicus*, Oman's primary commercial shrimp species, under different fishing season scenarios. The objective is to identify the best fishing season for shrimp harvest. Because shrimp cannot be directly aged, we used their length-frequency distributions of 1990/91 to estimate yield-per-recruit and relative mean biomass.

Materials and Methods

STUDY AREA: The commercially valuable shrimp stocks in Oman are in the Gulf of Masirah near Mahawt Island. Mangrove, seaweed, and sea grass beds provide nursery areas for the major two shrimp species (Figure 1). Seasonally occurring upwelling appears to have an effect on the shrimp population abundance in this area (Stirn et al., unpublished). The shrimp season lasts eight to nine months, from late August or early September, until the onset of the southwest monsoon in late May or early June.

GROWTH AND MORTALITY: Carapace lengths (CL), posterior margin of the orbit to the median dorsal posterior edge of the carapace, of shrimp were measured to the nearest 1.0 mm using a vernier calliper. Carapace-length measurements of 1990/91 fishing season (1990 September to 1991 April) catches

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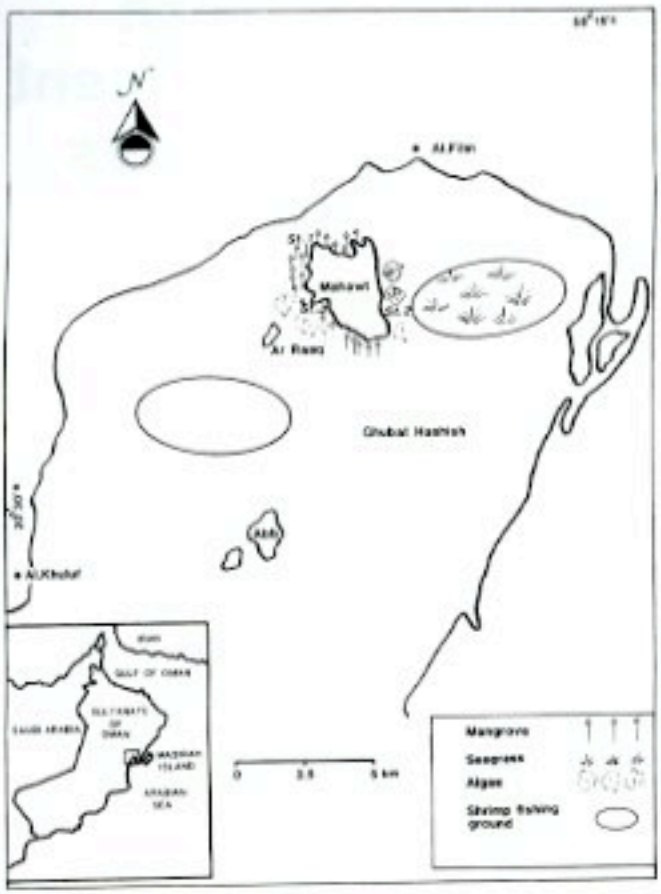

Figure 1. Map showing Mahawt Island and shrimp fishing grounds in the Gulf of Masirah.

were grouped into 2.0 mm intervals, and the length frequencies were used to estimate L_∞, K and t_0 of the von Bertalanffy growth curve by the FISAT software (Gayanilo Jr. et al., 1994) and non linear least square fitting (Prager et al., 1989). We used FISAT tor determine L_∞ and K, and then fixed these values in the non linear least square fitting routine to estimate t_0. This procedure was followed because the non linear routine produced optimal values of L_∞ and K at the extremities of their input range of values for our (limited) data. We did not use the seasonalized von Bertalanffy growth equation because the fishery life span of Oman shrimp rarely exceeds one year and we considered only a single season's data in this paper. For the non linear least square fitting, we subjectively selected progressive modal lengths and assigned ages considering the peak spawning time (28 February) and the sampling month. We estimated the growth parameters of males, females, and combined sexes.

We calculated the Z values by the following length-converted linearized catch curve method (1) incorporated in the FISAT software:

$$\ln (C_i / \Delta t) = a - Zt_i \qquad (1)$$

where,

C_i = catch in numbers for length class i,

$$\Delta t = \frac{(L_\infty - L_1)}{K(L_\infty - L_2)} ,$$

$t_i = - (1/K) \ln (1 - (L_1 + L_2)/2L_\infty)$,

L_1 and L_2 are lower and upper class boundaries of the ith class,

a = constant, and

L_∞ and K are von Bertalanffy growth parameters.

We used the growth and mortality parameter estimates in the subsequent yield-per-recruit and relative mean biomass calculations.

YIELD-PER-RECRUIT AND RELATIVE MEAN BIOMASS: We calculated yield-per-recruit (Y/R) and relative mean biomass (RMB) of the males, females, and combined sexes by the Thompson and Bell method (Ricker, 1975). The estimations were carried out for a range of annual natural mortality (M) values (1.8, 2.4 and 3.0) reported for tropical coastal penaeid shrimps (Naamin, 1984; Garcia, 1985; Garcia and Le Reste, 1981; Jayakody and Costa, 1988; Siddeek, 1991), at the 1991 total mortality (Z) value, and different fishing seasons to identify optimal fishing seasons. The fate of 1000 shrimp recruited to the fishery on 1st September and growing season on 30 April was determined for Y/R and RMB estimation. Based on the mean modal length of 26.11 mm CL from our 24 September 1990 sample, we estimated the peak spawning season by the growth curve to be 28 February 1990. This peak spawning date was reasonable considering independent maturity data (Mohan and Siddeek, unpublished). The ages of shrimp on different calendar dates were then determined from this spawning time as the origin for our Y/R and RMB calculations. Thus, from the date of spawning, the age of the shrimp cohort entering the fishery on 1 September would be 6.1 mo, and its age on 30 April would be 14.1 mo.

We calculated the Y/R and RMB of a cohort by the following steps:

(a) The mean lengths (at age) at the middle of each month were determined for September to April using the following von Bertalanffy equation:

$$L_t = L_\infty(1 - e^{-K(t-t_0)}) \qquad (2)$$

where,

L_t = length at age t,
t = age,
t_0 = theoretical age at which length is zero, and others are growth parameters previously defined.

(b) The mean length was converted into weight using the following weight - length relationship with the a and b values given in Table 1:

$$W_t = a + L_t^b \qquad (3)$$

where,

W_t = weight in gram of shrimp of length L_t (mm), and

a and b are constants.

The yield at age was determined by

$$Y_t = \frac{F(N_t - N_{t+1})\ W_t}{Z} \qquad (4)$$

TABLE 1

Estimates of growth parameters of Penaeus indicus *in the Gulf of Masirah using 1990/91 data (goodness of fit measure used in FISAT).*

	Sex	L_∞ (mm CL)	K (yr^{-1})	t_0 (yr)	Rn
(a)	Estimates of L_∞ and K by using FISAT				
	Male	49.50	2.16	-	452
	Female	55.70	2.21	-	535
	Combined Sexes	54.70	2.08	-	439
(b)	Estimates of t_0 by non linear least square fitting of growth curve (Analysis of variance showed highly significant fit, $p < 0.001$)				
	Male	49.50	2.16	0.2046	-
	Female	55.70	2.21	0.2546	-
	Combined Sexes	54.70	2.08	0.2517	-

L_∞ = maximum carapace length (mm CL), K = growth rate, t_0 = age at zero carapace length, and Rn = $10^{(ASP+ASP)/10}$.
* Rn is calculated from ESP (explained sum of peaks) and ASP (available sum of peaks) (see Sparre et al., 1989).

Where,

N_t = cohort number at age t, and

N_{t+1} = cohort number at age t + one month until the end of the fishing.

The Y/R of the entire cohort was determined using

$$Y/R = \sum Y/1000 \qquad (5)$$

The percentage of exploited mean biomass over un-exploited mean biomass was calculated using

$$RMB = \frac{\sum(N_t - N_{t+1})W_t\ /\ Z}{\sum(N'_t - N'_{t+1})W_t\ /\ M}100 \qquad (6)$$

where,

N'_t = cohort number at age t under no fishing, and

N'_{t+1} = cohort number at age t + one month under no fishing.

Results

GROWTH: Male *P. indicus* reached maximum size of 49.5 mm CL whereas the maximum size of female was 55.7 mm CL. Growth rates ranged from 2.16 to 2.21 for males and females, respectively, but decreased to 2.08 for sexes combined (Table 2). They were used in the total mortality, yield-per-recruit, and relative mean biomass calculations.

TOTAL MORTALITY: We estimated the annual Z values for the 1990/91 combined sexes data by the catch curve method disregarding the points representing larger relative age groups to reduce the effect of migration on the Z estimate. The 95% confidence interval of Z was 3.6 - 5.1 with a mean value of 4.4. Considering the

TABLE 2

Estimates of total mortality (Z) of Penaeus indicus *in the Gulf of Masirah for the 1990/91 season by the catch curve method.*

Sex	Z	n	r
Male	7.96	8	-0.96
Female	5.40	5	-0.98
Combined Sexes	4.35	6	-0.99

r = correlation coefficient and n = number of data points.
All regression coefficients are significant ($p < 0.05$).

TABLE 3

Estimates of a and b in the weight-length relationship formula of Penaeus indicus *in the Gulf of Masirah.*

Category	a	b	n	R^2	Significance
Male	0.0044	2.498	208	0.95	$p<0.001$
Female	0.0046	2.476	192	0.97	$p<0.001$
Combined sexes	0.0048	2.471	400	0.96	$p<0.001$

probable annual M value (2.4), this Z suggested under exploitation. The monthly sex ratio during January 1991 favoured males (male:female ratio of 62:38), suggesting a spawning migration (unpublished data). Consequently, Z estimates of males and females in 1990/91, which were calculated considering all age groups because of difficulty in finding a clear emigrating group, were probably inflated (Table 3).

YIELD-PER-RECRUIT AND RELATIVE MEAN BIOMASS: We observed high Y/R values for the September to April and December to April seasons for all categories and for different natural mortality values. RMB steadily increased with delay in opening the season and ranged from 8 to 61% for the respective seasons and different natural mortality values. In order to keep RMB at a reasonably high (above 20%) level to guarantee sufficient recruitment the season should be delayed from the current opening date (Figure 2).

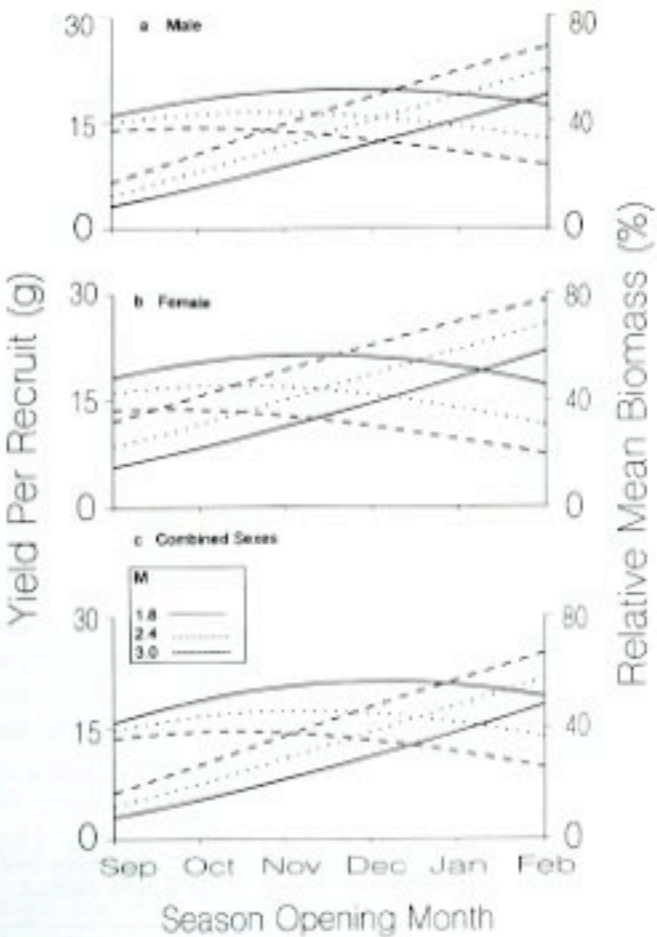

Figure 2. Yield-per-recruit (concave downwards) and relative mean biomass (concave upwards) against seasonal fishing mortality for three values of M for (a) male, (b) female, and (c) combined sexes of Penaeus indicus in the Gulf of Masirah.

Discussion

Different sets of L_∞ and K values are possible for a given data set (Sparre et al., 1989). Our L_∞ values were comparable to Jayakody and Costa's (1988) results (54.7 against 56 mm CL), but the K values were higher (2.08 against 1.8), indicating a higher growth rate.

Because fishing operations were restricted to shallow depths (< 5m), the older shrimp were under represented in the catch; therefore, the Z values were probably inflated when all the points on the right hand limb of the catch curve were considered. However, for the combined sexes we excluded the older age groups and obtained what we believe to be a reasonable estimate of total mortality.

The Y/R and RMB results at the reasonable annual M value of 2.4 suggested that a one- or two-month delay in opening the fishery will maximize Y/R and maintain the RMB within the acceptable 20-40%. As the price of shrimp increases with size, this delay will enhance the overall monetary value of the catch. For pelagic fish populations living in a volatile environment, Patterson (1992) suggested a critical biomass level of 20-40% of the un-exploited level above which no negative effects of fishing on recruitment occur. We believe that this RMB level is adequate for the highly fecund *P. indicus* to produce sufficient number of recruits in this upwelling environment in Oman.

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