



Populations dynamics of *Aristeus alcocki* Ramadan, 1938 (Decapoda: Penaeoidea: Aristeidae) from southwestern India

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ABSTRACT

The deepwater shrimp *Aristeus alcocki* Ramadan, 1938 constitutes a valuable resource among the commercially important Indian fish stocks along the southern coast of India. However, in recent years, its landing showed a declining trend. The present study reports the first information on its biology and stock characteristics of this species derived from the five year data collected from the south west coast of India. A total of 6,312 specimens were examined, the species exhibits sexual dimorphism, with females (Carapace length (CL): 13–56 mm) showing a wider size range with bigger size than males (CL: 13–31 mm). Monthly age classes varied from one to four in females and males corresponding to four generations viz., 0+, 1+, 2+, and 3+, respectively. von Bertalanffy growth curve indicated larger growth in females than males with a mean growth parameter for females: $CL_{\infty} = 55.78$, $K = 0.60$, $R_n = 0.253$ and males: $CL_{\infty} = 30.51$, $K = 0.64$, $R_n = 0.358$. Monthly mean size, CL_{max} sex ratio, longevity, and growth performance indices (Φ) were in favor of females. K values for both the sex are the highest reported for the species, suggesting a higher growth rate and a lower longevity. Estimated values for total, natural and fishery mortality were also greater in females. In both the sex, an exploitation rate $E > 0.5$ was lesser than E_{max} . The results of the current study signify that the species has remained stable during the study period, in terms of its life span, size frequency distribution and biological parameters, such as growth and mortality. These data should be taken into account for carrying out the stock assessment in future and additional data on deep sea recruitment success are needed to empirically parameterize population models for quantitatively assessing the sustainability of current harvest levels.

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1. Introduction

Aristeus alcocki Ramadan (1938) (Arabian red shrimp) is a deep-water shrimp, lives on the muddy bottom of the upper continental slope. The bathymetric distribution of the species ranges from 270 to 3200 m depth in the Indian Ocean. The geographical distribution extends from the Gulf of Aden through the Arabian Sea to the Bay of Bengal (Holthuis, 1980; Suseelan, 1989; Pérez Farfante and Kensley, 1997). It forms one of the most important crustacean resource exploited at depths between 250 to 800 m, having economic value among the deepwater fishery along the southern coast (Suseelan et al., 1989a, b; Madhusoodana Kurup et al., 2008; Chakraborty et al., 2015) and remains practically unexploited in the northern coast of India. *A. alcocki* contributes nearly 21–50% to the total deep-water shrimp landings recorded during 2012 to 2016 (CMFRI, 2012, 2013, 2014, 2015, 2016) and forms a profitable fishery (profitability ratio: 0.35–0.38) compared to the other deep sea shrimps (Shanis et al.,

2014). However, the landing trend showed a significant decline during 2014–2016 (CMFRI, 2016).

Information on the biological parameters of the species forms the prime need for the development and implementation of management strategies for the sustainable harvest of the fishery. Knowledge about the population dynamics of *A. alcocki* is scarce and limited reports are available on the bathymetric distribution and abundance (Suseelan, 1985; Suseelan et al., 1989b; Madhusoodana Kurup et al., 2008; Radhika Rajasree, 2011), sex ratio (Suseelan, 1985), taxonomy (Chakraborty et al., 2015), stock structure (Purushothaman et al., 2017a) and reproductive biology (Purushothaman et al., 2017b) of the species in the continental slope of the southwest coast of India.

The fishery is even being referred for certification in Marine Stewardship Council (MSC) by the Indian Government, mostly concerned with the sustainability of *A. alcocki*, being the main target of the deep sea shrimp fishery. The present study aimed to provide the first information on the population dynamics (size at capture, age classes, length-weight models, growth, and mortality) of *A. alcocki* in the southwest coast of India in order to support

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additional recommendations for the sustainable exploitation of this deep-water resource.

2. Material and methods

A. alcocki samples were collected fortnightly during January 2012 to December 2016 from the deep-sea bottom trawlers with a cod-end mesh size of 20–26 mm, operated at a depth of 200–900 m off the southwestern coast of India (Fig. 1). Date, time, trawling speed (2 nm h^{-1}), depth of operation (m), fishing duration (1–2 h haul $^{-1}$), catch (kg), and species composition was recorded for each trawl operation. Data were collected from January to December except for the monsoon ban (June to August). In total, 6312 specimens of *A. alcocki* were collected and transported in fresh condition in an insulated icebox to the laboratory for further analysis. Males and females were identified by the presence of petasma and thelycum respectively. Morphological identification of *A. alcocki* followed the taxonomic keys of Alcock (1901) and Suseelan (1989).

2.1. Data analysis

The size of specimens carapace length (CL: distance from the posterior edge of the eye orbit to the outer edge of the carapace) and total length (TL: distance from the anterior edge of the rostrum to the tip of the telson) were measured to the nearest millimeter using vernier calipers. The body weight (BW) was measured (with 0.0001 g accuracy) using a Mettler Toledo, ME203E (Mettler, Greifensee, Switzerland) weighing balance. The carapace length–weight relationships were estimated for each sex separately, based on the exponential regression equation (Le Cren, 1951)

$$W = aCL^b$$

where, W is the weight (g), CL the carapace length (mm), and a , b are the constants.

The Kolmogorov–Smirnov two-sample (KS) test was used to detect possible differences between the size frequency of males and females and the Mann–Whitney test was used to compare the medians. The annual length frequency distributions (LFD) in 2 mm class intervals were used to estimate the age class by Bhattacharya method (1967) in FISAT II package version 1.2.2 (Gayani et al., 2005). These estimations were analyzed for males and females separately. The CL_{max} and its confidence limits at 95% probability were estimated from extreme CL values, using ‘maximum length estimation’ as incorporated in FISAT II.

The growth parameters of *A. alcocki* were estimated from the monthly length frequency distributions for the study period (2012–2016) and also for each year separately. For each month, normally distributed components of length-frequencies were separated by NORMSEP routine (Gayani Jr et al., 1996) and an age-length key was determined by fixing a value for absolute age to the respective cohorts (lengths) from time zero or birth. Where, time zero ($t = 0$) was defined as the minimum length of recruits at birth. The age–length key obtained for this population was used to fit the von Bertalanffy growth function (VBGF) with the ELEFAN I package incorporated in FISAT II (Somers, 1988). The following model has been used to estimate the CL_{∞}

$$CL_t = CL_{\infty}(1 - \text{EXP}(-K(t - t_0) + S(t_s) + S(t_0)))$$

where, $S(t_s) = (CK/2\pi) \sin(2\pi(t - t_s))$, $S(t_0) = (CK/2\pi) \sin(2\pi(t_0 - t_s))$, CL_t is the predicted length at age t (in years), CL_{∞} is the asymptotic length, K is the von Bertalanffy growth coefficient (rate of growth towards the asymptote), t_0 is the hypothetical age at zero length, t_s is the time between birth and the onset of the first growth oscillation (age at the beginning of growth oscillation).

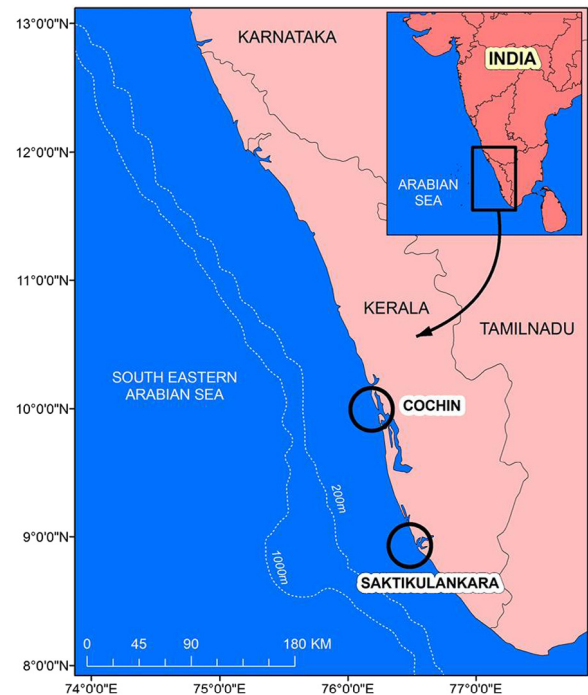


Fig. 1. Location of sampling areas of *Aristeus alcocki* along the southwest coast of India during 2012–2016.

Growth performance indices Φ (Pauly, 1980; Pauly and Munro, 1984), was estimated which was incorporated in FISAT II, this model as

$$\Phi = \log(K) + 2 \cdot \log(CL_{\infty})$$

where, CL_{∞} is the asymptotic length, K = growth coefficient

Longevity (T_{max}) (in years) was calculated using inverted VBGF (Pauly et al., 1984), using the model as $T_{\text{max}} \approx 3/K$.

Total mortality ($Z \text{ year}^{-1}$) was calculated as the average Z , estimated using the following three methods incorporated in FISAT II: The length-converted catch curve analysis (Pauly, 1990). Growth parameters (CL_{∞} , K) obtained from ELEFAN I were used for the estimation of total mortality (Z):

$$\log(N) = a + b \times t$$

where, N is the number of shrimps in (pseudo) cohorts “sliced” by means of successive growth curves, t is the relative age of the shrimp in that pseudo cohort, while b , with sign changed, provides an estimate of Z , t_0 is a facultative entry not required for the estimation of Z . The Pauly (1980) method, as incorporated in FISAT II:

$$\begin{aligned} \log(M) = & -0.0152 - 0.279 \log(L_{\infty}) + 0.6543 \log(K) \\ & + 0.463 \log(T) \end{aligned}$$

where, L_{∞} = asymptotic total length (as estimated by allometric relationship $TL-CL$, where $CL = CL_{\infty}$), K = growth coefficient, T = mean annual temperature of the species habitat. The mean annual temperature of the species habitat was defined at 10.5 to 13.5 °C (mean value at 272 m and at 430 m depth (Suseelan, 1985)).

3. Results

3.1. Population structure

4568 females and 1744 males ($N = 6312$) were measured during the five-year study period. Overall and year wise size frequency distributions of both sexes are presented in Fig. 2. Mean

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