

## Population dynamics of the shrimp *Penaeus semisulcatus* in the Yemeni Red Sea waters

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### Abstract

Length-based analyses were conducted to assess the stock of the green tiger shrimp *Penaeus semisulcatus*. Monthly carapace length frequency data were collected from commercial catches at two main landing sites on the Yemeni Red Sea coast for eight months. Growth parameters, mortalities, exploitation rate and yield per recruit were estimated for this species in this area. The estimated growth parameters were  $CL_{\infty} = 44.65$  mm,  $K = 1.2$  yr<sup>-1</sup> and  $t_0 = -0.15$  for males and  $CL_{\infty} = 58.8$  mm,  $K = 1.4$  yr<sup>-1</sup> and  $t_0 = -0.12$  for females. The natural mortality coefficient (M) was estimated as 2.19 yr<sup>-1</sup> and 2.27 yr<sup>-1</sup> for males and females respectively. The total mortality coefficient (Z) was 6.55 yr<sup>-1</sup> for males and 5.63 yr<sup>-1</sup> for females. The exploitation rate was 0.67 and 0.60 for males and females, respectively. Yield per recruit analysis showed that the current exploitation rate will result in higher stock biomass than the maximum exploitation rate.

**Keywords:** Growth parameters, Mortalities, Exploitation rate, Length of first capture, Yield per recruit.

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## Introduction

The shrimp fishery is an important fishery in the Yemeni Red Sea waters and contributes significantly to the economy of coastal towns and villages and the livelihoods of communities in the area (European Commission, 2010). Landings over the past decade have varied considerably, reaching over 2500t in 2002 before declining significantly to the current level of less than 1000t (FAO, 2011 and 2013). This decline in landings from their peak in 2002 has been attributed to heavy overexploitation of the stocks by both industrial and artisanal vessels in the years prior to 2002 as well as from illegal and unlicensed fishing activities (FAO, 2006). Industrial fishing is now prohibited and the fishery is wholly artisanal in nature.

The fishery, which is described below, occurs in the Yemeni Red Sea coast (and, to a lesser extent, in the Gulf of Aden) and is based mainly on *Penaeus indicus* and *P. semisulcatus* with *P. semisulcatus* comprising more than 90% of the landings (Bouhleb, 1985). Like other fisheries in Yemen, the shrimp fishery however suffers from a lack of reliable, recent and up to date data on catches, species composition (including by-catch), size composition and fishing effort. Because of this, the proper shrimp stock assessment programs have not been undertaken in recent years, and the fisheries management, and allocation of shrimp fisheries quota has been basically based on earlier stock assessment undertaken in the 1980s and earlier.

The analysis reported here is therefore the first stock assessment of this important

fishery in more than a decade, which will provide the basic data upon which an efficient and improved fisheries management plan can be organized and implemented.

Previous assessments of the shrimp stocks of Yemen have been limited to a few field surveys that were conducted in the 1970's to estimate the maximum sustainable yield (MSY). Agger (1976) estimated the annual allowable catch of shrimp in Yemeni waters as 1800 – 2000 tonnes. Walczak (1977) estimated the MSY as 800 tonnes, followed by the FAO (1978) stating that the Yemeni shrimp stocks could sustain an annual sustainable yield of 800 to 850 tonnes. Later, Bouhleb (1985) conducted a stock assessment in the area around Hudaida, and estimated the annual catch as 300 tonnes. He also concluded that there were two spawning seasons in this area; one in spring around March and the other in autumn around October.

More recently, Abdul-Wahab (1988, 1989 and 2003) updated these stock assessments for the main shrimp species, *P. semisulcatus* and similarly concluded that total allowable catches should be around 800t per annum to avoid over-exploitation of the stocks.

Like previous studies, the analysis reported here focused on the main shrimp species (i.e. *P. semisulcatus*) which comprises over 90% of the catch (Bouhleb, 1985). A biological and statistical data collection program was therefore implemented in the Yemeni Red Sea area between August 2009 and April 2010 (i.e. the 2009/10 fishing season – the fishery is closed each year between April and

August) with the aim of collecting data for stock assessment of the shrimp species *P. semisulcatus*. This stock assessment has provided an updated analysis of the status of the shrimp stocks upon which advice for future management actions will be based to ensure the sustainability of these important resources.

#### Description of the Fishery

The artisanal shrimp fishery in the Yemeni Red Sea waters is seasonal with a closed season extending from mid-August to mid-April each year. Fishing is carried out in the area between Maydi near the northern border of Yemen and Saudi Arabia to Hudaida (Fig. 1). Shrimp

distribution is closely related to the existence of mangrove areas which are considered as "nursery areas" for juvenile shrimp. Adult shrimp occur in 3 – 30m depth with the main species available in this region being *P. semisulcatus*, *P. indicus*, and *Metapenaeus monoceros*. Other species such as *P. monodon*, *P. japonicus* and *P. latisulcatus* also occur in the area but are rare. The total annual shrimp production during the last ten years ranged from 864 to 2541 tonnes with an estimated average of 1385 tonnes (Fig. 2) (FAO, 2013).



Figure 1: Location of the fishing grounds in the Yemeni Red Sea. Source: FAO, 2013.

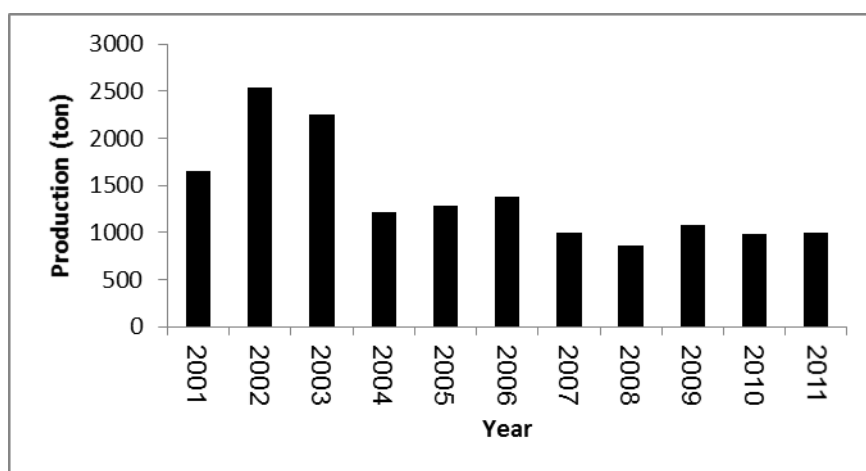
The fishing fleet consists of artisanal boats called "Sambouks". A "Sambouk" is 12-15m long with 15-75 hp main engine. The fishing gear is shrimp bottom trawl with cod end mesh size of 20-25 mm.

#### Materials and methods

Carapace length frequency data of *P. semisulcatus* were measured monthly from two main landing sites on the Red Sea coast, i.e. Hudaida and Salif (Fig. 2)

during the period August 2009 to April 2010 although there was no sampling in February 2010. Carapace length (straight length from posterior margin of the orbit to the median dorsal posterior edge of the

carapace) was measured to the nearest millimeter using a vernier caliper for both sexes. Total body weight of individuals and total length were recorded.



**Figure 2: Shrimp production during the last ten years from the Yemeni Red Sea.**

The data were processed and analyzed to estimate the biological parameters. The von Bertalanffy growth equation in the form:

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

was applied to estimate the growth parameters using ELEFAN I method (Pauly, 1987), where:

$L_t$  is the carapace length (mm) at age  $t$ ,

$L_\infty$  is the asymptotic carapace length,

$K$  is the curvature value,

$t_0$  is the age at which the theoretical length is zero

The initial parameter,  $t_0$ , was estimated using Pauly's formula (Pauly, 1983a):

$$\log(-t_0) = -0.3922 - 0.2752 \log L_\infty - 1.038$$

$\log K$

Bhattacharya (1967) method was used to identify the cohorts in the monthly length distribution.

Pauly's formula (1980) was used to estimate natural mortality coefficient ( $M$ ) as:

$$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4637 \log T$$

Where  $L_\infty$  is the total length in centimeter and  $T$  is the annual mean sea surface temperature which, in the fishing area, equals to 25°C (Mistafa, 2005).

The equation  $W = aL^b$  was used to express the relation between weight and length for both sexes combined, where:

$W$  is total body weight (g),

$L$  is carapace length (mm),

$a$  and  $b$  are constants.

The total mortality coefficient ( $Z$ ) was estimated from the length converted catch curve method of Pauly (1983b).

The length at first capture ( $L_c$ ) was estimated by the analysis of catch curve using the method of Pauly (1983b).

The exploitation rate ( $E$ ) was estimated as  $E=F/Z$  (Gulland, 1971), where  $F$  is the fishing mortality coefficient and equals to  $Z - M$ .

The relative yield per recruit ( $Y/R'$ ) and relative biomass per recruit ( $B/R'$ ) were estimated using Beverton and Holt model (1966) as modified by Pauly and Soriano (1986).

## Results

### Size structure

Monthly carapace length (CL) distribution of *P. semisulcatus* is shown in Figures 3 and 4 for males and females respectively. It was observed that females attain larger sizes than males. Generally, the carapace length of males ranged from 15 to 43mm while that of females ranged from 15mm to 56mm. For both sexes, it is observed that small size shrimps appeared in August and December.

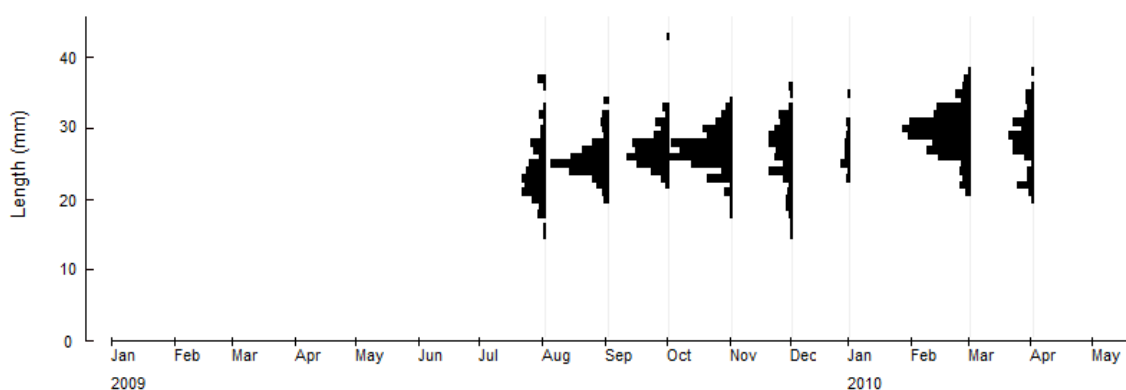


Figure 3: Length frequency of male *P. semisulcatus* in the Yemeni Red Sea

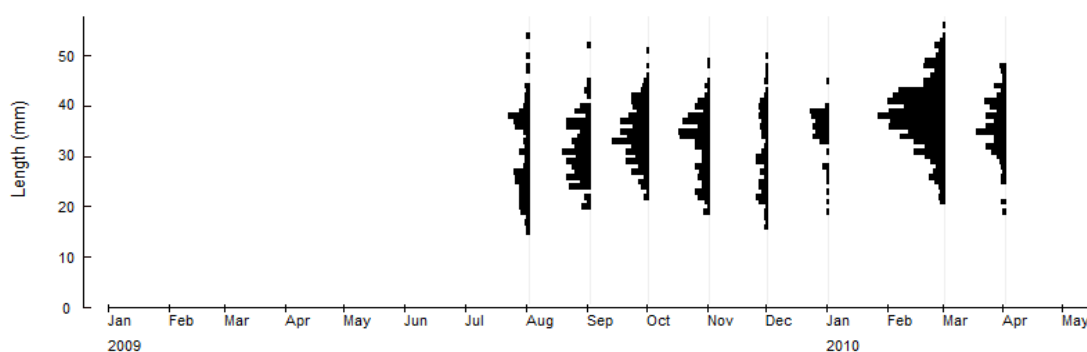


Figure 4: Length frequency of female *P. semisulcatus* in the Yemeni Red Sea.

### Growth

The growth parameters obtained using ELEFAN I were  $CL_{\infty} = 44.65$  mm,  $K = 1.2 \text{ y}^{-1}$  and  $t_0 = -0.1505$  for males and they were  $CL_{\infty} = 58.8$  mm,  $K = 1.4 \text{ y}^{-1}$  and  $t_0 = -0.1203$  for females. The von Bertalanffy equations with the calculated constants are:

$$L_t = 44.65 [1 - e^{-1.2(t+0.1505)}] \text{ for males}$$

$$L_t = 58.8 [1 - e^{-1.4(t+0.1203)}] \text{ for females.}$$

### Weight-length relationship

The values of the weight-length relationship constants  $a$  and  $b$  were estimated as  $a = 0.0024$ ,  $b = 2.6979$ , the correlation coefficient,  $r = 0.974$  and the number of shrimps measured,  $n = 1305$ . Fig 5 shows this relationship.

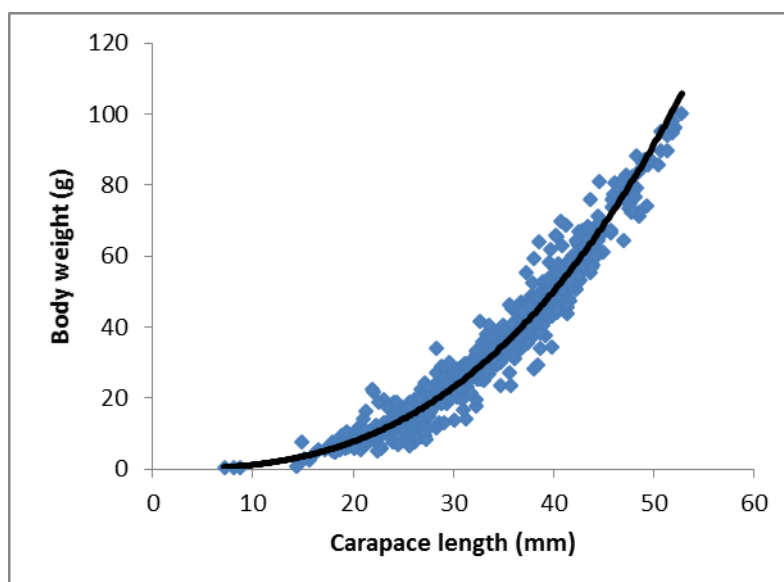


Figure 5: Weight-length relationship.

### Total length-carapace length relationship

The linear equation  $TL = a + b CL$  was applied to describe the total length – carapace length relationship for both sexes combined, where  $TL$  is total length,  $CL$  is carapace length in millimeter and  $a$  and  $b$  constants. The obtained values of the constants were  $a = 30.344$ ,  $b = 3.4375$  and  $r = 0.9866$ .

### Mortalities and exploitation rate

The asymptotic total length ( $TL$ ) in centimeters, was calculated to estimate the natural mortality coefficients for each sex separately. These were 18.4 and 23.2 cm for males and females respectively. Accordingly, the instantaneous natural mortality coefficient ( $M$ ) was estimated using Pauly's formula (1980) for both males and females with these estimates

being 2.19 and 2.27 yr<sup>-1</sup> for males and females respectively.

Total mortality coefficients (Z) were estimated as 6.55 yr<sup>-1</sup> for males and 5.63 yr<sup>-1</sup> for females (Fig. 6).

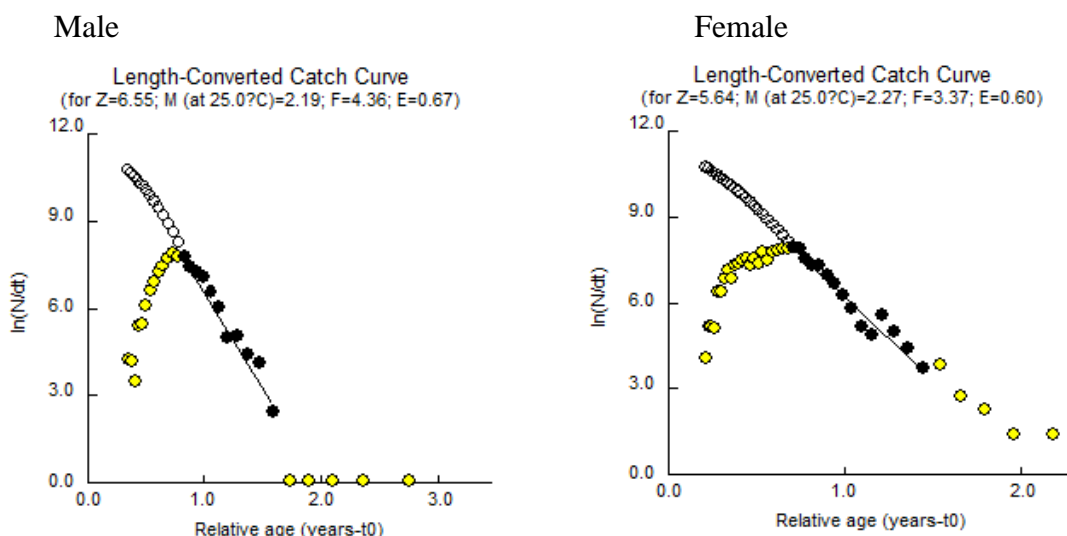


Figure 6: Length converted catch curve of *P. semisulcatus* in the Yemeni Red Sea.

Fishing mortality coefficient (F) estimates were 4.36 and 3.37 yr<sup>-1</sup> for males and females respectively, while the exploitation rate was estimated at 0.67 for males and 0.60 for females.

The length of first capture (Lc), the length at which 50% of the shrimp at that size are vulnerable to capture, was estimated as 26.1 and 33.99 mm for males and females, respectively (Fig. 7).

*Length of first capture*

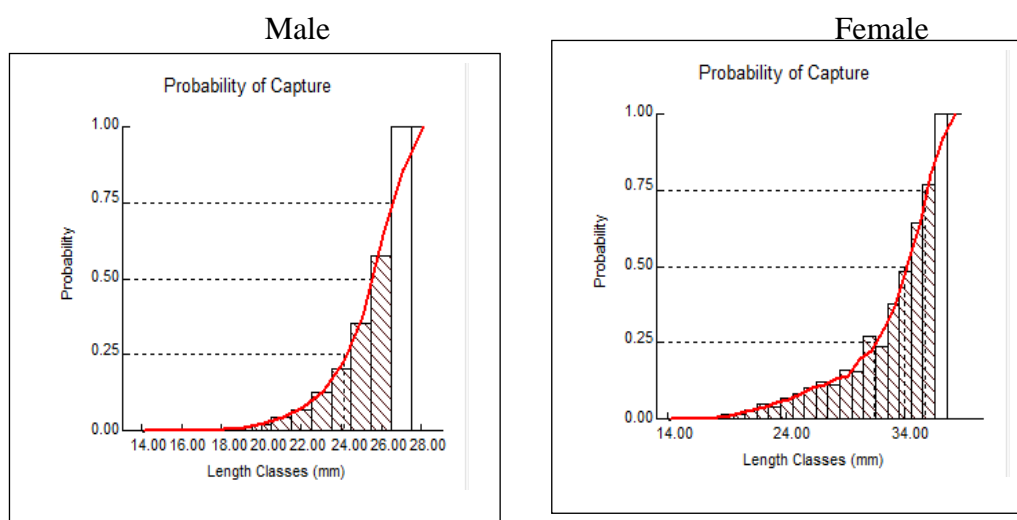


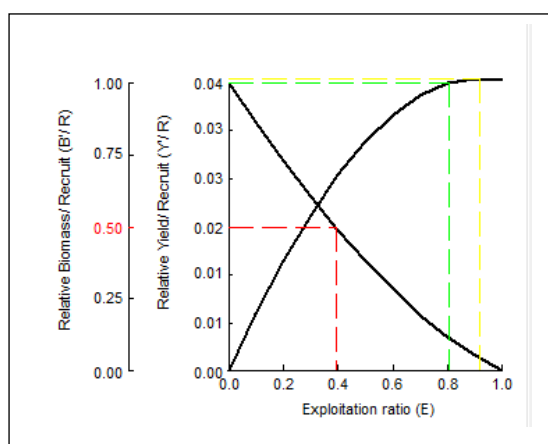
Figure 7: Probability of capture of *P. semisulcatus* in the Yemeni Red Sea.

### Relative yield per recruit

The plots of yield per recruit ( $Y/R'$ ) and biomass per recruit ( $B/R'$ ) against exploitation rate ( $E$ ) (Figure 8) showed that for males the maximum yield per recruit  $E_{max}$  was 0.918, the  $E_{0.1}$  (the level of exploitation at which the marginal increase in yield per recruit reaches 1/10 of the marginal increase computed at a

very low value of  $E$ ) was 0.804 and  $E_{0.5}$  (the exploitation level which will result in a reduction of the unexploited biomass by 50%) was 0.391. For females those were,  $E_{max} = 0.855$ ,  $E_{0.1} = 0.753$ ,  $E_{0.5} = 0.387$ .

Male



Female

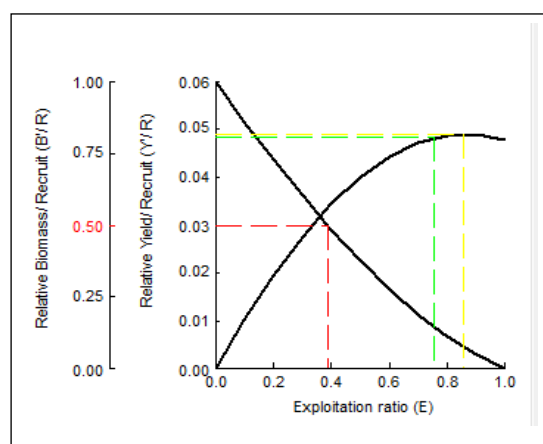


Figure 8: Relative yield per recruit analysis of *P. semisulcatus* in the Yemeni Red Sea.

### Discussion

The change in monthly length distributions of *P. semisulcatus* were used to estimate growth parameters and, from that, to estimate other population parameters for this species. The length distribution showed that, like other Penaeid species, females attained larger sizes than males and also had a higher growth rate than males. In the present study two cohorts of females were identifiable throughout the study period Which, is consistent with the observations of Bouhlel (1985) that there are two periods of recruitment to the fishery. However, only one cohort

of males was identifiable in most months except in August, December and April where there were two cohorts present. This may indicate selective separation or migration of the sexes and/or cohorts during some periods of the year.

The estimated growth parameters ( $L_{\infty}$  and  $K$ ) of *P. semisulcatus* were, generally, consistent with those reported in other studies for the same species in other regions (Bouhlel, 1985; Siddeek *et al.*, 2001; Abdul-Wahab, 2005; Niamaimand *et al.*, 2007).

In the absence of any data to directly measure natural mortality, Pauly's (1980) formula was used to



estimate the natural mortality ( $M$ ) from environmental and growth data. Pauly *et al.* (1984) noted that the formula can be used for shrimp (prawn) and any other invertebrates, because these marine organisms generally share the same habitats, resources and predators as fish, and that therefore, they are not likely to differ widely in their vital parameters. Hence Pauly's equation allows a rough estimation of  $M$  in shrimp stock where  $L_{\infty}$ ,  $K$  and  $T$  are known. The measured values of the natural mortality coefficient in this study lie within the range reported by Garcia and Le Reste (1981) for penaeid shrimps of 2 to 3.

The total mortality coefficient ( $Z$ ) differs between the two sexes. In the length converted catch curve (Fig. 6) the length groups comprising the ascending part of the curve were excluded as these groups were considered not yet fully recruited to the fishery. Also, also the last five length groups were excluded as they are too close to  $L_{\infty}$  (Sparre and Venema, 1992). Males have a slightly higher  $Z$  value than females. Fishing mortality was higher for both sexes than the values of  $F_{opt.}$  given by Gulland (1971) and Pauly (1987) indicating rather high level of exploitation of *P. semisulcatus* in this area.

Yield per recruit analysis showed that for both sexes the values of current  $E$  are less than the values of  $E_{max}$  and  $E_{0.1}$ .

The yield per recruit analysis indicates that the current exploitation

rate,  $E$ , is the best compromise and results in higher stock biomass and higher catch rate than  $E_{max}$  and  $E_{0.1}$ . Therefore, due to the lack of accurate and current information on the fishing effort (number of boats, number of fishing days, etc.) it is recommended to maintain the current management arrangements and fishing effort at the present level since the average annual total catch is consistent with the estimated MSY from previous surveys. However, further studies on the biology and stock assessment of the shrimps in the Yemeni Red Sea are needed, Also, it is strongly recommended that accurate catch and effort statistics for the shrimp fishery as well as for other artisanal fisheries in Yemen be collected on a regular, ongoing basis since such basic information would not only improve the precision of stock assessment analyses but would also facilitate improved management of the fishery. Nursery grounds should also be identified and protected from illegal and destructive fishing. Also, there is a need to identify and study the non target and by-catch species scientifically due to their importance ecologically.

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