

**Fishery, growth and mortality of coral grouper, *Plectropomus maculates* Bloch, 1790 (Teleostei: Serranidae), in the coral reefs, Red Sea, Sudan.**

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**SUMMARY**

The fishery, growth and mortality of coral grouper (najil), *Plectropomus maculates* Bloch, 1790 from deep water coral reef and the coastal fringing reef, Arakiyai, Sudanese Red Sea was described. A total of 451,861 kg from more than 48 fish species, in addition to 24,465 kg from sharks and 2,048 kg from lobster were landed during 2007 in the central fish market, Port Sudan. *P. maculates* formed 5.2% from the total fish landing and the lowest landing (860kg) was in January and the highest landing (4195kg) was in August 2007. Samples of *P. maculates* were collected during 2003-2004 by cast and gill nets and hook and lines. Mean total length was ranged from 31 cm to 63.9 cm and mean weight from 827.5 to 4550.0g. Length-weight relationship was obtained as  $W = 0.0251L^{3.003}$ . The relative condition factor value ranged from 0.944 to 1.060, with mean value of 0.999. The lengths of fish were 31, 41, 48, 54, 59 and 64 cm for the ages 1-6 years respectively. The growth model was  $L_t = 83 [1 - e^{-0.192(t + 1.492)}]$ . The growth performance index ( $\phi$ ) of the species was computed as 3.12. Total mortality rate ( $Z$ ) was computed as 0.568, natural mortality rate ( $M$ ) as 0.441, fishing mortality rate ( $F$ ) as 0.127 and the exploitation ratio was 0.224, indicating that the coral grouper stock in Sudanese Red Sea is under exploitation.

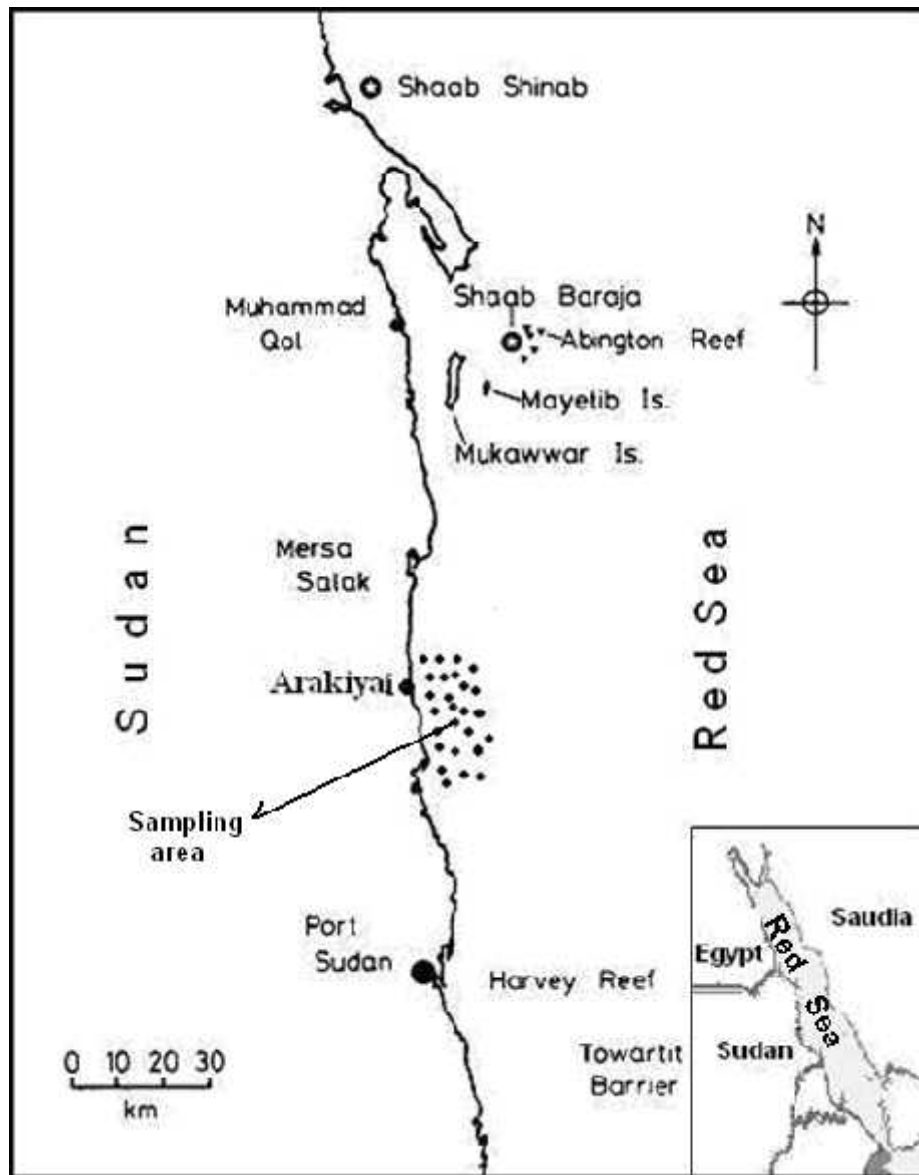
## Introduction

Most of the Sudanese coast on the Red Sea is bordered by fringing reefs 1-3 km wide, even though the reefs are separated by deep channels from a barrier reef of 1–14 km offshore, and the outer barrier drops steeply to several hundred meters depth. These are amongst the richest reefs in the Red Sea, with a high diversity of species, for example 71 coral species occur on Sanganeb and Wingate Reefs (11). There are three types of coral reef: fringing reefs, barrier reefs and atolls. Sanganeb atoll, 35 km northeast of Port Sudan, has been an internationally recognized Marine National Park since 1990. Two other potential marine reserve areas have been surveyed and identified, namely Makawar Island and Dongonab Bay, approximately 176 km north of Port Sudan (5). Serranidae (seabasses and groupers) are mostly demersal fishes of tropical and subtropical areas ranging from shallow coastal waters to moderate depths, rarely occurring beyond 200 m. Some serranids show preference for seagrass beds and mud or sandy bottom, but most are fishes of the coral and rocky reefs (15). The members of this family exhibit all forms of hermaphroditism in the wild (18). Serranidae is represented by two subfamilies (Epinephelinae and Serraninae) in the Western Indian Ocean (Fishing Area 51), comprises 12 genera and 68 species, ranging in size from a few centimeters to over 2 m and 400 kg. The other two subfamilies (Liopropominae and Anthiinae) are mostly small fishes and not of commercial importance (10). The genus *Plectropomus*, belonging to the family Serranidae, is represented by 5 species in the western Indian Ocean; *Plectropomus maculatus* (Bloch, 1790), *P. leopardus*, *P. laevis*, *P. punctatus* and *P. truncatus*. The Bar cheek coral trout or Spotted coral grouper, *P. maculatus* known locally as “Najil” is distributed throughout the western Indian Ocean north of about 27°S, including the Red Sea but not the Arabian Gulf. Also present in the eastern Indian Ocean and the western Central Pacific, extending eastward to southern Japan and northern Australia (15; 17). This species can be distinguished from other coral trout due to its larger and less numerous blue dots, and due to the short, bluish lines on the upper head. As with the common coral trout, the bar-cheeked coral trout is reddish-brown to tan or brown and have distinct bars over their cheeks, hence the name, bar-cheeked coral trout (4). Coral grouper is among the top nine most importance finfish occurring throughout the Sudanese Red Sea, which they account for about 60-70% of the finfish catches. Coral grouper is a key export market species (2). Estimates for finfish potential in the Sudanese waters vary, ranging from 6 000 to 35 000

t/yr. However, applying a precautionary approach, a fish potential of 10 000 t/yr has been adopted (8). There is however no published account on the biology of coral grouper from the Sudanese Red Sea. Most of the available biological information about this species was conducted in the Australian waters (9; 1; 27). However, the vertical distribution of 38 species of fish inhabiting coral reefs in the Sudanese Red Sea, including coral grouper has been studied by (6) and some biological aspects of fish by-catch from Sudanese Red Sea shrimp trawling (7). The present study deals with the fishery, growth and mortality of coral grouper, *P. maculatus* from the Sudanese Red Sea.

### **Material and methods**

The Sudanese coast is approximately 750 km long, extending from 18°N at the Eritrean border to 22°N at the Egyptian border, with a shelf area of 22 300 km<sup>2</sup>. In most parts of the Sudanese coast water transparency is very high, reaching up to 70 m. Surface temperatures range between 20°C in February and 33°C in August, and salinity is high between 39 and 45 ‰ (8). Coral grouper specimens were collected during the fishing season of October 2003-May 2004 using various fishing gears, such as hook and lines from the deep-water coral reef (100-200m), and cast and gill nets from the coastal fringing reef, Arakiyai (Latitude 20° 00' and Longitude 37° 10'), Sudanese Red Sea (Fig. 1). Arakiyai village is about 60 km north Port Sudan. Statistics on fish landed through January-December 2007 were obtained from the Marine Fisheries Department at the central fish market, Abu-Hashish, Port Sudan. Specimens were identified after (26). Fishes were measured to the nearest (mm) for total length and weighed to the nearest (g) for total body weight.



**Fig. 1. Map of the Sudanese coast on the Red Sea showing sampling location**

Parameters of the length-weight relationship were obtained by fitting the power function (16)  $W = aL^b$  to length and weight data, where  $W$  is the total weight (g),  $a$  is a constant determined empirically,  $L$  is the total length (cm), and  $b$  is close to 3.0 for species with isometric growth. The relative condition factor ( $K_n$ ) was calculated from the formula ( $K_n = W'/W$ ), where  $W'$  = the calculated weight and  $W$  = the observed weight (3).

The fish age was determined from opercular bones. (12) method was applied for treatment of opercular bones. The yearly increase in length for each of the ages was found by subtracting the mean length of each age from the next older ages. In this study the most popular theoretical growth curve, the von Bertalanffy equation  $L_t = L_\infty (1 - e^{-k(t-t_0)})$ , was used to fit the calculated average lengths at age data. The growth parameters of the von Bertalanffy's growth equation such as theoretical mean asymptotic size ( $L_\infty$ ), growth coefficient ( $K$ ) and theoretical time of the beginning of growth ( $t_0$ ) were obtained by using the method of Beverton (23). The growth performance index ( $\phi$ ) was computed according to the formula of (20) in order to provide a basis for the comparison of growth characteristics in terms of length as:

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

The Beverton and Holt model (25) was applied to estimate the total mortality coefficient ( $Z$ ):  $Z = K \cdot (L_\infty - L'') / (L'' - L')$ , where  $L_\infty$  and  $K$  are growth parameters,  $L'$  = cut-off length and  $L''$  = mean length above  $L'$ . Natural mortality rate in the population was calculated by the following equation (19):

$$\ln M = -0.0152 - 0.279 \cdot \ln L_\infty + 0.6543 \cdot \ln K + 0.463 \cdot \ln T$$

where the annual water temperature of the study area ( $T$ ) entered was 26 °C. The fishing mortality coefficient ( $F$ ) was calculated as:  $F = Z - M$ . The exploitation rate ( $E$ ) was calculated using the formula of (14) as:  $E = F/Z$ .

## Results

The information presented in Table (1) and Figure (2) is gathered from the Marine Fisheries Department in Port Sudan (Red Sea State) during 2007. A total of 451,861 kg from more than 48 fish species, in addition to 24,465 kg from sharks (mainly *Carcharhinidae* and *Sphyrnidae*) and 2,048 kg from lobster were landed during 2007 in the central fish market, Abu-Hashish, Port Sudan (Table 1). The arabi, *Mugil* spp., was the most abundant species comprising 18.3%, followed by shaoor *Lethrinus* spp., bayad *Caranx* spp., gushar *Epinuphelus* spp, farisi *Aprion* spp. and najil *P. maculates*. These six

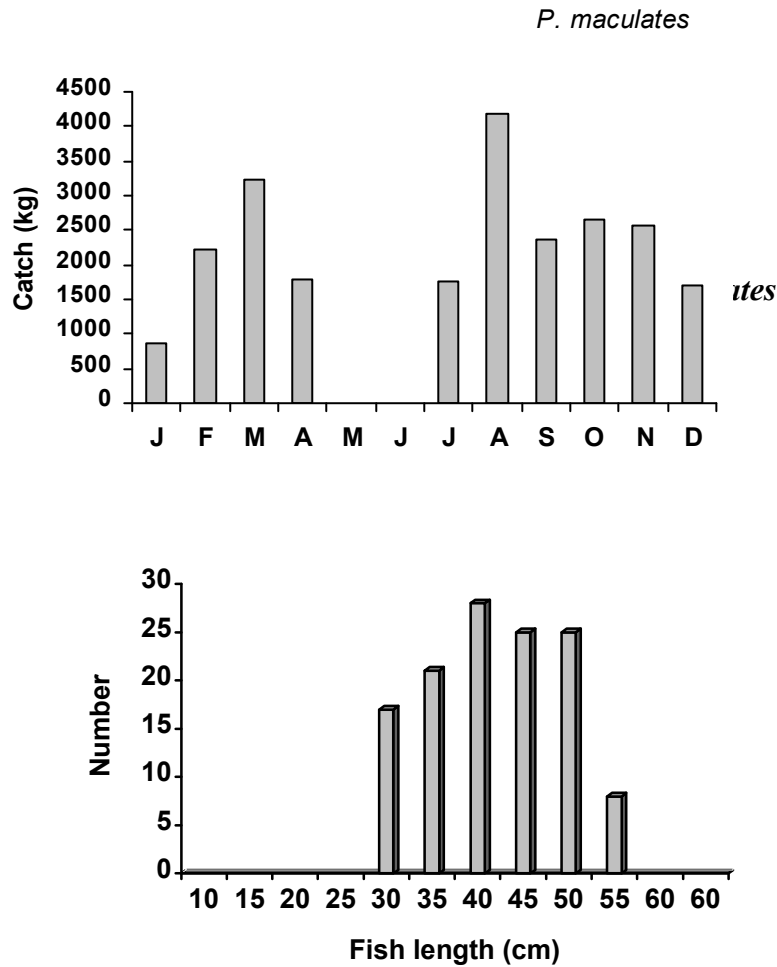
species accounted for over 46.6% of the total catches. *P. maculatus* formed 5.2% from the total fish landing. The monthly fluctuations in total and *P. maculatus* landings in the central fish market, Port Sudan during 2007 are presented in Fig. 3. The lowest landing (860kg) was in January and the highest landing (4195kg) was in August 2007, most of landings were during August to November. In total, 124 specimens were examined during the study period collected from Arakiyai region. The sex ratio for coral grouper collected in this study was 40 males: 84 females, or 1:2.1. Fish size ranged from 31 cm to 63.9 cm (mean  $\pm$  S.D = 44.9  $\pm$  10.1, n = 124) and their weight varied from 827.5 g to 4550.0 g (2550  $\pm$  585, n = 124). The size range 40–45cm dominated the catch and formed 22.6% (Fig.3). Fish <30cm were not

**Table 1. Composition of fish landing in the Port Sudan, Red Sea during 2007**

| Scientific name               | Local name | Catch (kg) | %     |
|-------------------------------|------------|------------|-------|
| <i>Mugil</i> spp.             | Arabi      | 82618      | 17.27 |
| <i>Lethrinus</i> spp.         | Shaoor     | 28757      | 6.01  |
| <i>Caranx</i> spp.            | Bayad      | 27217      | 5.68  |
| <i>Epinuphelus aerolatus</i>  | Gushar     | 24667      | 5.15  |
| <i>Aprion</i> spp.            | Farisi     | 24492      | 5.11  |
| <i>Plectropomus maculatus</i> | Najel      | 23372      | 4.88  |
|                               |            |            |       |
| Other species                 |            | 240786     | 50.33 |
| sharks                        |            | 24465      |       |
| Lobster                       |            | 2048       |       |
|                               |            |            |       |
| Total catch                   |            | 478422     |       |

**Table 2. Relative condition factor of *P. maculatus* in the study region**

| Length range (cm) | Number of fish | Mean weight (g) | Calculated weight (g) | Relative condition factor (Kn) |
|-------------------|----------------|-----------------|-----------------------|--------------------------------|
| 30 – 35           | 17             | 827.5           | 869.5                 | 0.952                          |
| 35 – 40           | 21             | 1416.0          | 1336.2                | 1.059                          |
| 40 – 45           | 28             | 1875.7          | 1945.7                | 0.964                          |
| 45 – 50           | 25             | 2865.0          | 2717.2                | 1.054                          |
| 50 – 55           | 25             | 3764.0          | 3669.7                | 1.026                          |
| 55 - 60           | 8              | 4550.0          | 4822.3                | 0.944                          |



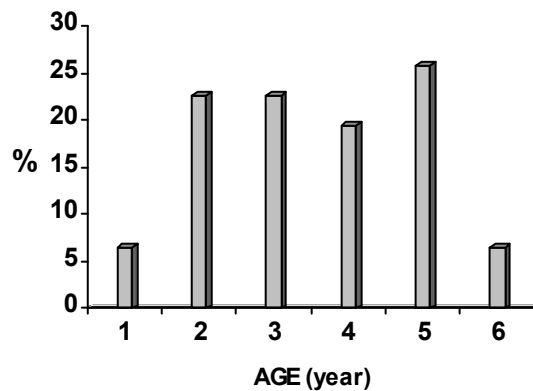
**Fig. 3. Length–frequency distribution of *P. maculatus* in the study region (2003-2004)**

appeared in the catch. The length–weight relationship was represented with the following equation:  $W = 0.0251 L^{3.0026}$  ( $r^2 = 0.993$ , 31.1-63.9 cm TL). No statistically significant difference was found from the value 3 ( $P > 0.05$ ), which means an isometric growth pattern. The relative condition factor ranged from 0.944 for size range 30–35cm to 1.060 for size range 40–45cm, with mean value of 0.999 (Table 2). Estimated ages of 124 individuals (31.1-63.9 cm TL) ranged from 1 year to 6 years. However, fish of five years old were the highest contribution (25.8%) in the sample (Fig. 4). The obtained results revealed that the growth of coral grouper during the first six years of its life was 31, 41, 48, 54, 59 and 64 cm, respectively (Fig. 5). During the first two

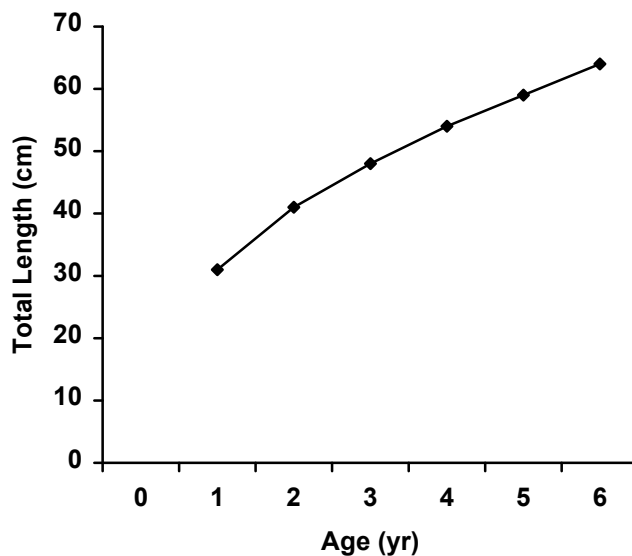
years of life, the species grew rapidly in length, with average increases of 31cm during the first year and 10cm during the second. The estimated von Bertalanffy growth parameters for the species were  $L_{\infty}=83$  cm,  $K=0.192/\text{yr}$ , and  $t_0=1.492$  yr. The growth performance index ( $\phi$ ) of the species was computed as 3.12. The annual total mortality rate ( $Z$ ) of the species was estimated to be 0.568 and the natural mortality rate ( $M$ ) was 0.441. Consequently, the fishing mortality rate ( $F$ ) was 0.127; hence the exploitation rate ( $E$ ) was 0.224.

## Discussion

Sudan territorial waters are rich in intensive coral formations in the inner and outer continental shelf. These corals represent attractive feeding localities and refuge areas for coralline fish as well as resorts for tourism activities. The fish resources associated with the coral formations and their vicinity can contribute, apart from food security, in supporting a vigorous ornamental fish industry. Management is currently focused on finfish, crustaceans (shrimps, prawns and lobsters) and molluscs. However, most of the management efforts were directed towards finfish (5). Estimates for finfish potential in the Sudanese waters vary, ranging from 6 000 to 35 000 t/yr. However, for precautionary approach measures, a fish potential figure of 10 000 t/year is adopted. Of this, the current annual finfish landing did not exceed 5 000 t (8). The Sudanese artisanal fleet in the Red Sea is comprised exclusively of locally made wooden boats. Handling is the principal fishing method, and accounts for over 80 percent of catches. Each line is typically rigged with 1 to 3 hooks. Stones are used as sinkers. The most popular baits are sardines and to a lesser extent grey mullets. These are usually caught in the inlets by fishermen using cast nets. The most productive areas are the inner edges of the offshore reefs. Main species taken by the hand line fisheries include groupers, emperors, coral trout and snapper (24; 21). There are an estimated 400 small fishing boats in Sudan and about 300 slightly larger boats of 9 to 10 m (22). There are 1,800 registered local fishermen operating 410 fishing crafts including 3-5m dugout canoes (Houris), 5-7m wooden and steel boats (Felucca) and 7-10m lunches (Sambouk). The majority of the Houris is maneuvered by wooden oars and bamboo staff while the other fishing vessel are fitted with outboard or inboard engines ranging between 10 and 100hp. Over and above, there are some 50 medium size wooden boats and steel



**Fig. 4. Age distribution of *P. maculatus* in the study region (2003-2004)**



**Fig. 5. Growth of *P. maculatus* in the study region (2003-2004)**

trawlers of capacities in the tune of 20 – 25t each most of them operate on seasonal basis. (5).

Port Sudan is the main center for fish consumption in Sudan. Other important landing sites include Dongonab Bay, Abu Hashish, Mohammed

Gol, Arakikyai, Suakin, Heidob and Sheik Ibrahim (21). The annual fish landing in the central fish market, Abu-Hashish during the present study was 451.86t. However, (22) mentioned that the current annual total national catch by artisanal fisheries was 1,200t. Most of the coral grouper, *P. maculatus* landings in the present study were during August to November. The fishing season is generally May to December; it is dependent on the monsoon season rather than any legislative control (21).

(6) described the vertical distribution of fish inhabiting coral reefs in the Sudanese Red Sea and observed more groupers (Serranidae) for example *P. maculatus*, at Shaab Baraja Reef (100 km north Port Sudan) than at Harvey Reef (about 18 km south Port Sudan); this may be related to the decreased fishing pressures which might be expected at these less accessible reefs. They found the species in Harvey Reef at depth 20m only, while in Shaab Baraja Reef at reef crest and at depths 5 to 20m, but most of them at depth 5m (Fig. 1). The exponent of length-weight relationship of *P. maculatus* in the Sudanese waters is close to 3.0, so that the species probably shows little change in body proportions with growth (3). Also, this value is similar to what mentioned from (15) for the species in Australian waters.

The growth and mortality parameters of the coral grouper, *P. maculatus* obtained in the present study were compared with the status of this species in the central Great Barrier Reef, Australia (9). The asymptotic length ( $L_{\infty}$ ) obtained in this work (83cm) is higher than those recorded by (9) in Australia waters ( $L_{\infty}$ = 72cm,  $K$ = 0.206,  $t$  = -0.945), and is lower than those mentioned in FishBase ( $L_{\infty}$ = 120cm,  $K$ = 0.21) by (15). A method of validating growth parameters involves the comparison of growth performance index ( $\Phi$ ) in terms of growth in length with other estimates obtained for the same or a similar species (13). Growth performance index for *P. maculatus* ( $\Phi$ = 3.12) in the present study falls above the value (3.01) obtained for this species in Australia waters (9), and when compared with the growth trends observed in the other groupers, growth performance of the species fall well within the values recorded in FishBase for other grouper species (eg. *Epinephelus maculatus*,  $\Phi$  = 2.65 and *E. aeneus*,  $\Phi$  = 3.44). These different data from different regions may be related to the environmental conditions. The value of total rate of mortality of *P. maculatus* found in the present study (0.568) is close to the value of 0.569 calculated for the same species in the central Great Barrier Reef, Australia (9). (14) reported that the optimum exploitation rate of any exploited stock is about 0.5. It could be concluded that the *P. maculatus* stock in the Sudanese coast is now underexploitation ( $E$ = 0.224) and to exploit this

valuable fish resource, the exploitation rate should be increased to the optimum value by increasing fishing pressure on stock of this species. No significant stock assessment has been conducted in Sudan's waters. However, work by United Kingdom Overseas Development Administration (ODA) indicated a total MSY of around 35,000 metric tons. In comparison to current annual total national catch of around 1,400 metric tons. Sudan considers its marine fish resources to be lightly exploited. The effect of illegal fishing on Sudan's fish stocks is not known (21).

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## مصائد ونمو ونفوق اسماك الهامور المرجاني *Plectropomus maculatus*

Bloch, 1790 في الشعب المرجانية، البحر الأحمر، السودان

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### الخلاصة

وصفت مصائد ونمو ونفوق اسماك الهامور المرجاني (*Plectropomus coral grouper*) (الناجل) في الشعب المرجانية في الميه العميقة والساحلية للبحر الأحمر، السودان. بلغت كميات الأسماك المطروحة في سوق الأسماك المركزي، ميناء بورسودان حوالي 451,861 كغم تمثل أكثر من 48 نوع، إضافة إلى 24,465 كغم من الكواسج و2,048 كغم من جراد البحر خلال عام 2007. تباينت كمية اسماك الناجل المطروحة بين 860 كغم خلال كانون الثاني الى 4195 كغم خلال آب 2007 وشكلت النوع 5.2% من كميات الأسماك الكلية. جمعت عينات اسماك الناجل خلال موسم 2003-2004 بواسطة الشباك الخيشومية والسلية وخيوط الشص. تراوح معدل الطول الكلي للاسماك بين 31.0-63.9 سم ومعدل الوزن بين 827.7-4550.0 كغم. كانت علاقة الطول بالوزن للأسماك  $W = 0.0251 L^{3.003}$ . تراوحت قيم معامل الحالة النسبي بين 0.944 - 1.060 وبمعدل 0.999. بلغت أطوال الأسماك 31، 41، 48، 54، 59 و 64 سم خلال الأعمار الست الأولى على التوالي. وصف نمو الأسماك بالمعادلة التالية:  $L_t = 83 [1 - e^{-0.192(t + 1.492)}]$ . بلغ دليل كفاءة النمو ( $\emptyset$ ) للنوع 3.12. ان قيم النفوق الكلي (Z) والطبيعي (M) 0.568 و0.441 والصيد (F) 0.127 ومعدل الاستغلال 0.224، مما يشير إلى إن مخزون اسماك الناجل في المياه السودانية تحت مستوى الاستغلال المثالي وان هناك إمكانية لزيادة معدل الاستغلال لهذا النوع من الأسماك.