Tropical Life Sciences Research, 21(1), 83–90, 2010

The Use of Per Recruit Models for Stock Assessment and Management of Greasy Grouper *Epinephelus tauvina* in The Arabian Gulf Waters off Qatar

Mehdat A Abdel Barr, Abdel Fattaqh M El-Sayed* and Amany M Osman

Oceanography Department, Faculty of Science, Alexandria University, Alexandria, Egypt

Abstrak: Model-model per rekrut telah digunakan untuk menilai stok *Epinephelus tauvina* di perairan teluk di luar pantai Qatar. Hasil per rekrut (Y/R) bertambah secara cepat dibawah nilai-nilai kematian ikan (F) yang rendah. Pada nilai kematian alamiah (M = 0.17 per tahun) dan umur pada tangkapan pertama (Tc = 7.6 tahun), nilai Y/R meningkat bersama nilai F ikan untuk mencapai nilai maksimum iaitu 1067.8 g per rekrut pada F = 0.65 per tahun. Di atas aras kematian ikan ini, Y/R mendatar atau turun sedikit. Aras F kini lebih tinggi daripada titik-titik rujukan biologikal $F_{0.1}$ (0.15 per tahun), $F_{SB40\%}$ (0.13 per tahun), $F_{SB50\%}$ (0.08 per tahun) and $F_{SB25\%}$ (0.24 per tahun). Pertambahan Tc sebanyak satu tahun telah mendorong pengurangan nilai Y/R. Pada nilai M, pertambahan nilai Tc telah mengakibatkan peningkatan nilai F yang diperlukan untuk mencapai nilai maksimum Y/R, sehingga mencapai suatu tahap tidak-maksimum pada umur paling tua pada Tc. Pada tahap F kini, meningkatkan nilai Tc sebanyak satu tahun boleh mengakibatkan suatu peningkatan yang kecil dalam biomas per rekrut (B/R), manakala peningkatan yang berterusan akan mengakibatkan penurunan nilai B/R. Pada tahap F yang lebih tinggi, sebarang peningkatan nilai Tc akan mengakibatkan suatu peningkatan pada B/R, diikuti dengan penurunan selepas mencapai suatu nilai Tc yang tertentu. Keputusan ini telah memberi bukti terhadap lebih hasil tangkapan pada semua tahap menangkap ikan yang optimum, $F_{0.1}$, $F_{SB40\%}$, $F_{SB50\%}$ dan pada tahap ambang, $F_{SB25\%}$. Oleh yang demikian, pemuliharaan dan kelestarian *greasy grouper* di perairan Qatar memerlukan penurunan nilai F kepada tahap yang lebih rendah daripada $F_{0.1}$ and $F_{SB40\%}$, yang boleh dicapai menerusi pengurangan dalam penangkapan ikan tetapi bukan dalam peningkatan Tc.

Kata kunci: Model-model per rekrut, *Epinephelus tauvina*, Teluk Arabia

Abstract: Per recruit models were applied to assess greasy grouper, *Epinephelus tauvina*, stock in the gulf waters off Qatar. Yield per recruit (Y/R) increased rapidly at low values of fishing mortality (F). At present natural mortality (M = 0.17 per year) and age at first capture (Tc = 7.6 years), the Y/R increased with increasing F to reach a maximum value of 1067.8 g per recruit at F = 0.65 per year. Above this level of F, Y/R was constant or slightly decreased. The current level of F is higher than the biological reference points $F_{0.1}$ (0.15 per year), $F_{SB40\%}$ (0.13 per year), $F_{SB50\%}$ (0.08 per year) and $F_{SB25\%}$ (0.24 per year). Increasing the Tc by one year resulted in a slight increase in the Y/R, while additional increases in Tc led to a decrease in Y/R values. At constant M, the increase in Tc caused an increase in F required to obtain the maximum Y/R until reaching a non-maximum state at the oldest Tc. At the current level of F, increasing the Tc by one year would result in a small increase in biomass per recruit (B/R), while further increases would lead to a decrease in B/R. At higher levels of F, any increase in Tc would cause a gradual increase in B/R, followed by a decline after a certain value of Tc. These results provide evidence of recruitment over-fishing at all optimum fishing levels, $F_{0.1}$, $F_{SB40\%}$, $F_{SB50\%}$ and at the threshold level, $F_{SB25\%}$. Therefore, sustainable management and conservation of greasy

---

*Corresponding author: afelsayed@sci.alex.edu.eg

grouper in Qatari waters would require a decrease in F to levels less than $F_{0.1}$ and $F_{SB40\%}$, which can be achieved through a reduction in fishing effort but not through an increase in Tc.

Keywords: Per recruit models, *Epinephelus tauvina,* Arabian Gulf

INTRODUCTION

The greasy grouper, *Epinephelus tauvina* (Forsskål, 1775), is a member of the family Serranidae (subfamily: Epinephelinae). These fish are widely distributed throughout the Indo-Pacific in a region stretching from the Red Sea to South Africa, eastward to Ducie in the Pitcairn Group, north to Japan and south to New South Wales and Lord Howe Island (Ben-Tuvia & Lourie 1969; Por 1978; Heemstra & Randall 1993). Groupers are generally long-lived with low natural mortality rates (Ferreira & Russ 1994; Grandcourt *et al.* 2005).

Groupers (locally known as *hamoor*) are a major component of fishing in the Arabian Gulf region, and they have an extremely high market value (El-Sayed 1993; El-Sayed & Abdel-Bary 1999). They are caught using dome shaped wire traps (locally known as *gargoor*) of different sizes. Seven species of grouper have been recorded in the Arabian Gulf waters (El-Sayed & Abdel-Bary 1999). However, *E. tauvina* is, by far, the most important and dominating species of grouper in the Arabian Gulf and Indian Ocean (El-Sayed 1993; El-Sayed *et al.* 2007a, b).

Grouper populations in the Arabian Gulf have been heavily exploited (Samuel *et al.* 1987; Siddeek *et al.* 1999; Grandcourt *et al.* 2005). Therefore, it is essential to frequently evaluate their biological status and the health of the fisheries in order to sustainably manage these fish.

We conducted this study to assess the stock status of the greasy grouper *E. tauvina* in the Arabian Gulf waters off Qatar. We used yield per recruit (Y/R) (Beverton & Holt 1957) and biomass per recruit (B/R) (Sparre & Venema 1998) models, which are widely used to define management measures, such as minimum size limit, closed season and optimum fishing strategy (Al-Husaini *et al.* 2002).

MATERIALS AND METHODS

The greasy grouper samples used in the present study were collected bi-monthly from commercial catch of *gargoor* trap nets in the Doha fish market, Qatar. A total of 860 fish representing a wide range of total lengths (24–97 cm) and weights (0.2–14.5 kg) were collected. The total length (cm) and weight (g) of each fish were recorded, and their sex, stage of sexual maturity and age were determined. These data were previously used by El-Sayed *et al.* (2007a, b) to estimate Von Bertalanffy growth parameters (L_∞ = 136.26 cm, K = 0.059, t_0 = –1.68 year) and mortality rates (Z = 0.57 per year; M = 0.17 per year; F = 0.4 per year), which are used as input parameters of the per recruit models in the present study.

Yield Per Recruit Analysis
The Y/R as a function of fishing mortality, F was calculated using the Beverton and Holt (1957) method:

$$Y/R = F \exp(-M(Tc - Tr)) W\infty[1/Z - 3S/(Z+K) + 3S^2/(Z+2K) - S^3/(Z+3K)]$$

where F = fishing mortality coefficient, M = natural mortality coefficient, Tc = age at first capture in years, Tr = age at first recruit in years, Z = total mortality coefficient, S = exp [–K (Tc–T_0)], and W∞ and K are growth constants of the Von Bertalanffy growth formula.

Biomass Per Recruit Analysis
The B/R as a function of age was calculated using the Sparre and Venema (1998) model:

$$B/R = Y/R (1/F)$$

The Biological Reference Point
The biological reference point, $F_{0.1}$ (the value of F at marginal increase in Y/R is 10% of its value at F = 0) was calculated according to Gulland and Boerema (1973), as described by Cadima (2003):

$$dV/dF = dY/dF - 0.1B_0 = 0 \text{ or } dY/dF = 0.1B_0$$

where V = Y – $0.1B_0$, dY is the change in the Y/R, dF is the change in the F and B_0 is the B/R when F = 0. Therefore, the value of F at which dY/dF = $0.1B_0$ represents the value of $F_{0.1}$. $F_{0.1}$ can then be calculated by maximising the function V = Y – $0.1B_0$. Note that V is at a maximum when F = 0.1, i.e., when dV/dF = 0.

RESULTS

Yield Per Recruit

Effect of fishing mortality
The response of Y/R to different values of F and age at first capture, Tc is represented in Figure 1. Y/R increased rapidly at low values of F. At present natural mortality, M (0.17 per year) and Tc (7.6 year), the Y/R increased with increasing F to reach a maximum value of 1067.8 g per recruit at F = 0.65 per year. Above this level of F, Y/R was constant or slightly decreased. This value of Y/R is very close to the value attained at F (current value) = 0.4 per year (1058.6 g per recruit).

The current level of F is higher than $F_{0.1}$ (0.15 per year), $F_{SB25\%}$ (0.24 per year), $F_{SB40\%}$ (0.13 per year) and $F_{SB50\%}$ (0.08 per year) (SB25%, SB40% and SB50% are different level of stock biomass in relation to the virgin biomass, which is the biomass at F = 0). At these levels of reference points, the Y/R were 1106, 1039, 936, and 796 g per recruit, respectively.

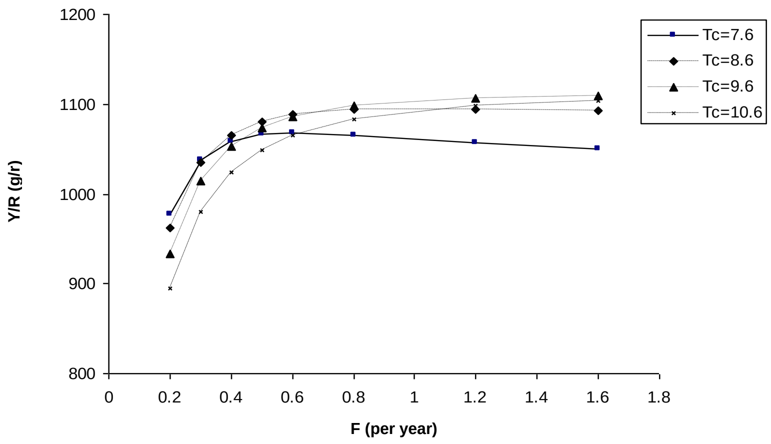

Figure 1: Y/R as a function of F and Tc for *E. tauvina* caught in the Arabian Gulf off Qatar.

Effect of Tc on Y/R

At the present level of F, increasing the Tc by one year resulted in a slight increase in the Y/R, while further increases in Tc led to a decrease in Y/R values (Fig. 1). At Tc values of 7.6 (current value), 8.6, 9.6 and 10.6 years, the Y/R were 1058.6, 1065.6, 1053.1 and 1024.3 g per recruit, respectively. At constant M, the increase in Tc caused an increase in the F required to obtain the maximum Y/R until reaching a non-maximum state at the oldest Tc (Fig. 1).

Biomass Per Recruit

Effect of fishing mortality

The relationship between B/R and F is illustrated in Figure 2. At the current level of F, the B/R (2646.6 g per recruit) is about 18% of biomass at the unexploited level. The B/R decreased with increasing F.

Effect of Tc on B/R

At the current level of F, increasing Tc by one year would result in a small increase in B/R, while further increases would lead to a decrease in B/R (Fig. 2). At Tc values of 7.6 (current value), 8.6, 9.6 and 10.6 years, the corresponding B/R values were 2646.6, 2664.1, 2632.7 and 2560.5 g per recruit, respectively, indicating that the B/R showed a slight decrease only at older Tc (9.6 and 10.6 year). At higher levels of F, the increase in Tc causes a gradual increase in B/R until a certain threshold, after which any further increase in Tc leads to a decline in B/R.

The values of B/R computed at different levels of reference points, namely, $F_{0.1}$ (0.15 per year), $F_{SB25\%}$ (0.24 per year), $F_{SB40\%}$ (0.13 per year) and $F_{SB50\%}$ (0.08 per year), were 6077.7, 4174.4, 6679 and 8348.8 g per recruit, respectively.

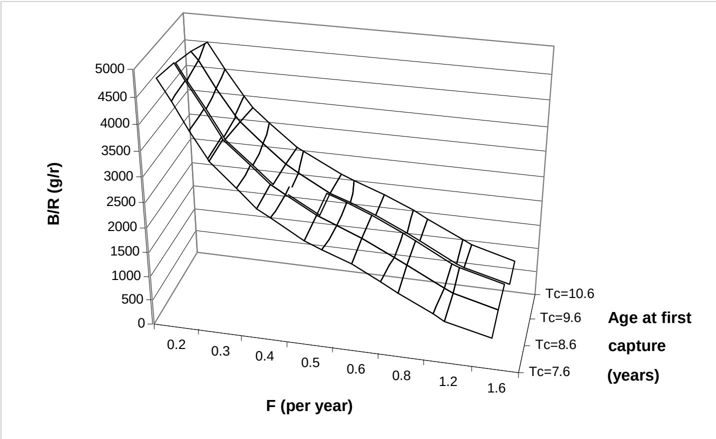

Figure 2: B/R as a function of F and Tc for *E. tauvina* caught in the Arabian Gulf off Qatar.

DISCUSSION

These results indicate Y/R of greasy grouper *E. tauvina* increases with increasing F, reaches a peak, and then slightly declines with further increases in F. Increasing Tc by one year caused a small increase in Y/R, while further increases in Tc resulted in a decline in Y/R. This finding indicates that increasing Tc does not improve the yield status of these fish. The current level of Y/R was achieved at a higher level of F than $F_{0.1}$, which is the reference point at which the yield is marginally stable with the least risk of collapse (Punt 1993; Clark 1993; Mace 1994). When compared with other levels of reference points such as $F_{SB25\%}$, $F_{SB40\%}$ and $F_{SB50\%}$ (0.08 per year), it appeared that the current F is higher than that of computed levels. This suggests that grouper stocks in Qatari waters are subject to high fishing pressure.

Theoretical predictions of the B/R also showed a decrease in B/R with increasing F. The current biomass level is equivalent to 18% of the unexploited level (virgin biomass, i.e., no F). This indicates heavy loss in the population biomass, presumably due to increasing fishing pressure on grouper stocks.

Increasing the Tc by one year caused a small increase in B/R, whereas further increases in Tc caused a decline in B/R. This suggests that there are not enough adult fish being taken from the stock, which in turn indicates recruitment overfishing. The Tc in the present study (7.6 years) is older than the age at first maturity (5–6 years) previously recorded (Lee & Al-Baz 1989), which would support this view. Therefore, it appears that grouper in Qatari waters are not fished under the age of first maturity; instead, fishing operations appear to target the large, adult individuals. Thus, increasing the Tc may not improve the state of the stocks of these fish.

Our results indicate that decreasing the value of current F to levels of reference points ($F_{0.1}$, $F_{SB25\%}$, $F_{SB40\%}$ and $F_{SB50\%}$) would cause an increase in B/R. These reference points can be used by fishery managers to evaluate and manage fish stocks in their various locations and systems, as has been reported by many authors (Hilden & Lehtonen 1982; Clark 1991; Punt 1993; Mace 1994; Griffiths 1997; Booth & Buxton 1997; Kirchner 2001). Previous studies have used various reference points, and reference points differ according to the conditions of the stocks and the availability of application of the reference points that provide better management of these stocks. Clark (1991) reported that $F_{SB35\%}$, the F that reduces the stock to 35% of the unexploited stock, would provide high yield at low risk, regardless of the spawner-recruit relationship. However, Punt (1993) showed that the $F_{SB35\%}$ strategy sometimes reduced the spawner biomass to less than 20% of unexploited levels. Therefore, Clark (1993) and Mace (1994) recommended a strategy of $F_{SB40\%}$.

Other studies found that the marginal yield strategy, $F_{0.1}$, is the most stable reference point, and could be adopted with the least risk of stock depletion (Punt 1993; Clark 1993; Mace 1994). Booth and Buxton (1997) clarified this assumption at levels of $F > 0.4$ per year (the present level of F) and found that spawner B/R would be reduced to 1 or 2 year classes. They also suggested that maintaining such high F is risky if a year class failure occurs.

Based on our results, we recommend reducing the present F of grouper stock in Qatari waters to the level of $F_{0.1}$ (0.15 per year) or $F_{SB40\%}$ (0.13 per year). Such a reduction in F would likely result in a higher B/R than under current levels. It also appears that mortality of grouper in Qatari waters has a stronger effect on the B/R than Tc. Thus, controlling fishing effort would be a more effective and reliable strategy to manage grouper stock than changing Tc through technical changes in the fishing gear (*gargoor* trap nets).

In conclusion, these results indicate that the current level of F in grouper fisheries in Qatari waters should be reduced to $F_{0.1}$ (0.15 per year) or $F_{SB40\%}$ (0.13 per year). Strategies directed at controlling fishing effort, such as closing fishing area or seasons, should be adopted.

REFERENCES

Al-Husaini M, Al-Baz A, Al-Ayoub S, Safar S, Al-Wazan Z and Al-Jazzaf S. (2002). Age, growth, mortality, and yield-per-recruit for nagroor, *Pomadasys kakaan*, in Kuwait's waters. *Fisheries Research* 59: 101–115.

Ben-Tuvia A and Lourie A. (1969). A Red Sea grouper *Epinephelus tauvina* caught on the Mediterranean coast of Israel. *Israel Journal of Zoology* 18: 245–247.

Beverton R J H and Holt S J. (1957). On the dynamics of exploited fish population. *Fisheries Investigation Series II* 19: 1–533.

Booth A J and Buxton C D. (1997). Management of the panga *Pterogymnus laniarius* (Pisces: Sparidae) on the Agulhas Bank, South Africa using per recruit models. *Fisheries Research* 32: 1–11.

Cadima E L. (2003) *Fish stock assessment manual. FAO fisheries technical paper (393).* Rome: DANIDA, 66.

Clark W G. (1993). The effect of recruitment variability on the choice of a target level of spawning biomass per recruit. In G Kruse, D M Eggers, R J Marasco, C Pautzke and T J Quinn (eds.). *Proceedings of the International Symposium on Management Strategies for Exploited Fish Population. Alaska Sea Grant College Program Report* 233–246.

_______. (1991). Groundfish exploitation rates based on life history parameters. *Canadian Journal of Fisheries and Aquatic Science* 48: 734–750.

El-Sayed A-F M. (1993). Fisheries resources in the Gulf Cooperation Council (GCC). *Attaawun* 31: 51–80.

El-Sayed A-F M and Abdel-Bary K. (1999). Reproductive biology of grouper *Epinephelus tauvina* in the Arabian Gulf waters*. Indian Journal of Marine Science* 28: 89–91.

El-Sayed A-F M, Abdel-Barr M and Osman A. (2007a). Age, growth and population structure of grouper (*Epinephalus tauvina*) (Teleostei: Serranidae) in the Arabian Gulf waters off Qatar. *Egyptian Journal of Aquatic Research* 33(1): 352–361.

_______. (2007b). Estimation of total mortality rates and virtual population analysis of grouper (*Epinephelus tauvina*) from Arabian Gulf, Qatar. *Egyptian Journal of Aquatic Research* 33(1): 362–370.

Ferreira B P and Russ G R (1994). Age validation and estimation of growth rate of the coral trout, *Plectropomus leopardus*, (Lacepede 1802) from Lizard Island, Northern Great Barrier Reef. *Fishery Bulletin* 92(1): 46–57.

Forsskal P. (1775). *Descriptiones animalium, avium, amphibiorum, piscium, insectorum, vermium; quae in intinere orientali observavit petrus Forsskal*. Montana, USA: Kessinger Publishing, 164.

Grandcourt E M, Al Abdessalaam T Z, Francis F and Al Shamsi A T. (2005). Population biology and assessment of the orange-spotted grouper, *Epinephelus coioides* (Hamilton, 1822), in the southern Arabian Gulf. *Fisheries Research* 74: 55–68.

Griffiths M H. (1997). The application of per recruit models to *Argyrsomus indorus*, an important South African sciaenid fish. *Fisheries Research* (4): 46–61

Gulland J A and Boerema L K. (1973). Scientific advice on catch levels. *Fishery Bulletin* 71(2): 325–335.

Heemstra P C and Randall J E. (1993). FAO species catalogue. Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. *FAO Fisheries Synopsis* 16(125): 382.

Hilden M and Lehtonen H. (1982). Management of the bream, *Abramis brama* (L.) stock in the Helsinki sea area. *Finnish Fisheries Research* 4: 46–61.

Kirchner C H. (2001). Fisheries regulations based on yield–per-recruit analysis for the linefish silver kob *Argyrosomus inodorus* in Nambian waters. *Fisheries Research* 52: 155–167.

Lee J U and Al-Baz A F. (1989). Assessment of fish stocks exploited by fish traps in the Arabian Gulf area*. Asian Fisheries Sciences* 2: 213–231.

Mace P M. (1994). Relationship between biological reference points used as thresholds and targets for fisheries management Common strategies. *Canadian Journal Fisheries and Aquatic Sciences* 51: 110–122.

Por F D. (1978). *Lessepsian migration. The influx of Red Sea biota into the Mediterranean by way of the Suez Canal.* Berlin: Springer Verlag.

Punt A E. (1993). The use of spawner biomass-per-recruit in the management of linefisheries. In L E Beckley and R P van der Elst (eds.). *Fish, fishers and fisheries. Proceedings of the Second South African Marine Linefish Symposium,* Durban 23–24 October 1992, Oceanographic Research Institute, Special Publication, 2: 80–89.

Samuel M, Mathews C P and Bawazeer A S. (1987). Age and validation of age from otoliths for warm water fishes from the Arabian Gulf. In R C Summerfelt and G E Hall (eds.). *Age and growth of fish.* Ames, Iowa: Iowa State University Press, 253–265.

Siddeek M S M, Fouda M M and Hermosa G V. (1999). Demersal fisheries of the Arabian Sea, the Gulf of Oman and the Arabian Gulf. *Estuarine, Coastal and Shelf Science* 49(Suppl. A): 87–97.

Sparre P and Venema S C. (1998). Introduction to tropical fish stock assessment. Part 1: Manual. *FAO Fisheries Technical Paper* 306: 1–337.