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**Background Paper: SFA 03**

# Stock Assessments and Weight of Evidence for Artisanal Fisheries

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Page





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## 1.1. Stock assessments

Assessments were undertaken for three key indicator species of the demersal handline fishery. For all three species sampled, the number of size samples collected in 2018 decreased compared to 2017.

### 1.1.1. *Aprion virescens*

In 2018, 362 length samples were taken for this species during the 1st and 2nd Quarter, compared to 634 samples collected in 2017. The same growth parameters were used as previous years: age-based growth parameters derived in FMSP Project R6465 were used in FiSAT II (K=0.1, $L_\infty$=89.9, t0=-2.3) to provide estimates of mortality (Z, F, M) and length at first capture ($L_{c50}$). Two estimates of natural mortality (M) were used, the first (M1) from Pauly (1980) with a temperature of 22°C. Since this method tends to overestimate M for slow growing species, we also used the derivation from Jenson (1996; reviewed in Hoggarth et al., 2006), where M = 1.5K to estimate this parameter (M2).

**Table 1.** *Aprion virescens*: Estimates of fishing mortality, and related parameters, for two different estimates of natural mortality (M1 and M2), and corresponding estimates of length at first capture ($L_{c50}$). Length at first maturity ($L_{m50}$) estimates and sample sizes (n) also provided.

| Parameter | 2012 | 2013 | 2014 | 2015 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Z | 0.35 | 0.23 | 0.27 | 0.4 | 0.34 | 0.36 |
| CI of Z | *-0.03*-0.73 | 0.13-0.32 | 0.14-0.39 | -1.27-2.08 | -0.64-1.32 | -0.18-0.91 |
| $r^2$ | 0.99 | 0.99 | 0.99 | 0.90 | 0.95 | 0.99 |

| | | | | | | |
|---|---|---|---|---|---|---|
| M1 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 |
| F | 0.09 | -0.03 | 0.01 | 0.14 | 0.08 | 0.10 |
| E | 0.26 | -0.13 | 0.04 | 0.35 | 0.24 | 0.28 |
| $L_{c50}$ (cm) – Logistic | 75.37 | 76.47 | 66.18 | 79.28 | 68.68 | 73.63 |
| $L_{c50}$ (cm) – Running av. | 68.23 | 67.97 | 67.47 | 69.16 | 68.42 | 68.45 |
| F/M | 0.35 | -0.12 | 0.04 | 0.54 | 0.31 | 0.38 |

| | | | | | | |
|---|---|---|---|---|---|---|
| M2 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| F | 0.20 | 0.08 | 0.12 | 0.25 | 0.19 | 0.21 |
| E | 0.57 | 0.35 | 0.44 | 0.63 | 0.56 | 0.58 |
| $L_{c50}$ (cm) – Logistic | 76.02 | 77.26 | 66.13 | 79.87 | 68.73 | 73.90 |
| $L_{c50}$ (cm) – Running av. | 68.19 | 67.92 | 67.40 | 69.15 | 68.38 | 68.43 |
| F/M | 1.33 | 0.53 | 0.8 | 1.67 | 1.27 | 1.40 |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| $L_{m50}$ (Mees 1992; MRAG 1999) | 62-64; 65 cm | | | | | |
| N | 1309 | 774 | 1036 | 235 | 634 | 362 |

In 2018, based on both estimate of M, $L_{c50}$ was greater than $L_{m50}$, as was the case in previous years. We looked at the ratio F/M as a possible indicator of over-exploitation, considering that F=M has been suggested as a proxy for F(MSY). The conclusions are different depending on the value of M that is assumed. The F/M ratio was 1.27 in 2017 and 1.40 in 2018 with M2=0.15. Similarly, to previous years, total mortality (Z) estimates were subject to large range in CI leading to considerable uncertainties in estimates of F (Table 1).

YPR analyses were not conducted for this species.

1.1.2. *Epinephelus chlorostigma*

The sample size for *E. chlorostigma* in 2018 was was considerably lower to previous years (216). The same growth parameters were used as in previous years, based on average of three estimates from Grandcourt (2002), Mees (1992) and Sanders et al. (1988), where K=0.21 and $L_\infty$=57.19. $L_{c50}$ was assessed against a published maturity estimate for females (Moussac, 1996), rather than for males, since this species is suspected of protogynous hermaphroditism. Maturity was also calculated from $0.5L_\infty$. As was the case with *Aprion virescens*, two estimates of M were applied in the assessment, the first (M1) the standard Pauly (1980) method with a water temperature of 22°C, and the second (M2) calculated using M=1.5K, with K=0.21.

**Table 2.** *Epinephelus chlorostigma*: Estimates of fishing mortality, and related parameters, for two different estimates of natural mortality (M1 and M2), and corresponding estimates of length at first capture ($L_{c50}$). Length at first maturity ($L_{m50}$) estimates, based on $0.5L_\infty$ and Moussac (1986), and sample sizes (n) also provided.

| Parameter | 2012 | 2013 | 2014 | 2015 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Z | 0.72 | 1.52 | 0.87 | 0.99 | 0.53 | 1.25 |
| CI of Z | *-1.85*-3.29 | -2.59-5.62 | 0.83-0.91 | 0.32-1.65 | -3.34-4.40 | 0.18-2.31 |
| $r^2$ | 0.93 | 0.96 | 1 | 0.99 | 0.75 | 0.99 |
| | | | | | | |
| M1 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 |
| F | 0.24 | 1.04 | 0.39 | 0.51 | 0.05 | 0.77 |
| E | 0.33 | 0.68 | 0.45 | 0.52 | 0.09 | 0.62 |
| $L_{c50}$ (cm) – Logistic | 35.03 | 36.98 | 33.56 | 35.79 | 30.04 | 34.90 |
| $L_{c50}$ (cm) – Running av. | 33.60 | 34.85 | 34.05 | 34.24 | 30.55 | 33.73 |
| F/M | 0.50 | 2.17 | 0.81 | 1.06 | 0.10 | 1.60 |

| | | | | | | |
|---|---|---|---|---|---|---|
| M2 | 0.315 | 0.315 | 0.315 | 0.315 | 0.315 | 0.315 |
| F | 0.41 | 1.21 | 0.56 | 0.68 | 0.22 | 0.94 |
| E | 0.56 | 0.79 | 0.64 | 0.68 | 0.41 | 0.75 |
| $L_{c50}$ (cm) – Logistic | 35.01 | 37.01 | 33.55 | 35.80 | 29.93 | 34.91 |
| $L_{c50}$ (cm) – Running av. | 33.56 | 34.84 | 34.02 | 34.22 | 30.39 | 33.68 |
| F/M | 1.30 | 3.84 | 1.78 | 2.16 | 0.70 | 2.98 |
| $L_{m50}$ (0.5$L_\infty$; Moussac , 1986) | 28.95 cm TL; 31 cm TL for females | | | | | |
| N | 143 | 152 | 1437 | 161 | 601 | 216 |

For both estimates of M, the $L_{c50}$ was greater than the $L_{m50.}$ The F/M ratio varies depending on the estimate of M used. With M1, the F/M ratio is 1.60, whilst with M2, the ratio is 2.98 indicating a high fishing pressure. The Z estimate were subject to large range in CI (0.18 – 2.31) (Table 2). There is a need to improve the sample size to get a better representativeness of the size classes of fish caught.

1.1.3. *Lutjanus sebae*

**Mortality and capture estimates**

In 2018, the sample size was only sufficient to carry out analyses at the plateau level.

Due to problems in obtaining reliable performance of the YPR models in the Yield software using point estimates of growth parameters, we use an average of 2 age-based estimates (Grandcourt et al. 2008 and Newman 2000) and 2 length-based estimates (Mees 1996), where K = 0.163; $L_\infty$ = 88.6; t0 = -0.95. We used an estimate of natural mortality based on an average derived from two methods; M = 1.5K and an age-based estimate derived by Grandcourt et al. (2008) using the Hoenig (1983) empirical equation.

At the plateau level, the estimate of total mortality (Z) of 0.46 in 2018 was relatively lower compared to estimates in 2015 and 2017. However, both estimates of $L_{c50}$ was lower than the $L_{m50}$. (Table 3). The F/M ratio was lower in 2018 (1.54) compared to the previous two years, however, it still indicates a relatively high fishing pressure.

**Table 3**. *Lutjanus sebae*: Estimates of mortality and corresponding estimates of length at first capture ($L_{c50}$) from 2012 to 2018. Length at first maturity ($L_{m50}$) estimates, based on Mees (1992), and sample sizes (n) also provided.

| Parameter | 2012 | 2013 | 2014 | 2015 | 2017 | 2018 |
|---|---|---|---|---|---|---|
| Z | 0.52 | 0.44 | 0.40 | 0.54 | 0.55 | 0.46 |
| CI of Z | 0.36-0.68 | 0.32-0.56 | 0.31-0.50 | 0.45-0.63 | 0.45-0.66 | 0.43-0.49 |
| $r^2$ | 0.97 | 0.98 | 0.98 | 0.99 | 0.99 | 0.99 |
| M | 0.182 | 0.182 | 0.182 | 0.182 | 0.182 | 0.182 |
| F | 0.34 | 0.26 | 0.22 | 0.36 | 0.37 | 0.28 |
| E | 0.65 | 0.59 | 0.55 | 0.66 | 0.67 | 0.60 |
| $L_{c50}$ (cm) – Logistic | 63.86 | 60.03 | 60.35 | 62.21 | 60.77 | 58.54 |
| $L_{c50}$ (cm) – Running av. | 57.86 | 57.71 | 57.73 | 57.84 | 59.71 | 58.68 |
| F/M | 1.87 | 1.43 | 1.18 | 1.98 | 2.03 | 1.54 |
| Maturity | 62 cm FL | | | | | |
| N | 2040 | 1585 | 2268 | 889 | 861 | 413 |

Due to the low number of samples in the different sectors, estimates of mortality were not estimates for different Sectors. A YPR analysis was carried out for all sectors combined for 2018.

**Application of Yield software**

*Yield per recruit*

<u>All sectors</u>

The yield-per-recruit analysis indicated that MSY would occur when F is around 0.83. However, the SSB would be reduced to less than 20% (a usual limit reference point) when F = 0.28 (CI= 0.17-0.52) (Fig. 1). From the histograms, maximum yield-per-recruit is achieved when F is around 0.35-0.65 (median= 0.55, CI=0.43-0.67) (Fig. 2), but at the expense of reducing the spawning stock biomass to unacceptable levels. To maintain SSB per recruit at 20% of unexploited biomass, F should be below in the range of 0.23-0.28 (median= 0.31, CI= 0.29-0.32) (Fig. 3). The estimate of current F for 2018 (0.28; range = 0.25-0.31) is within the range of $F_{SSB20\ per\ recruit}$, however, the upper range of F exceeds the upper limit.

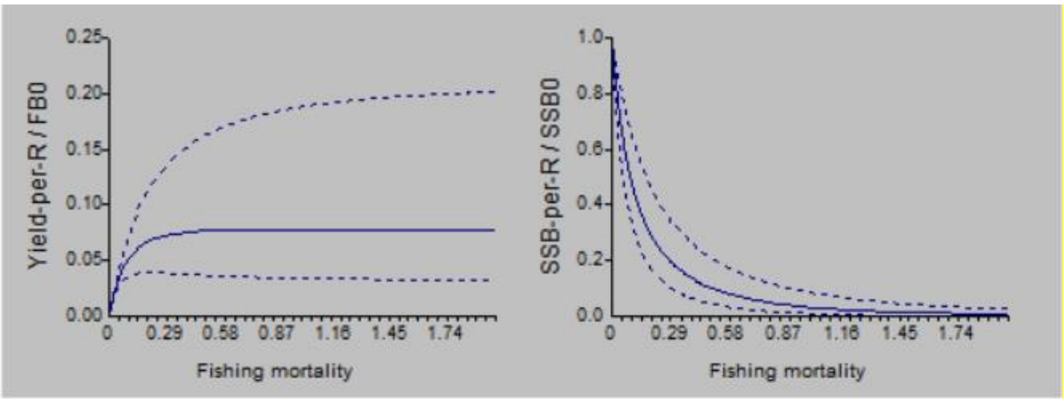


**Figure 1.** Yield per recruit and Spawning Stock Biomass per recruit against levels of fishing mortality for all sectors combined

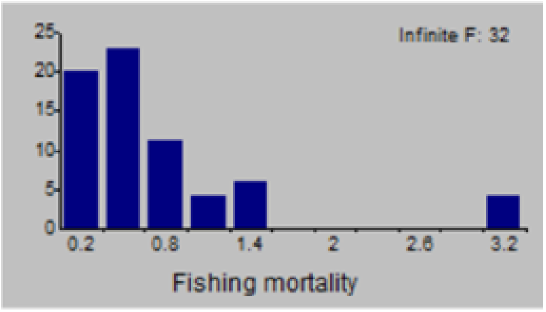


**Figure 2.** Frequency distribution of fishing mortality that produces maximum yield-per-recruit for all sectors combined

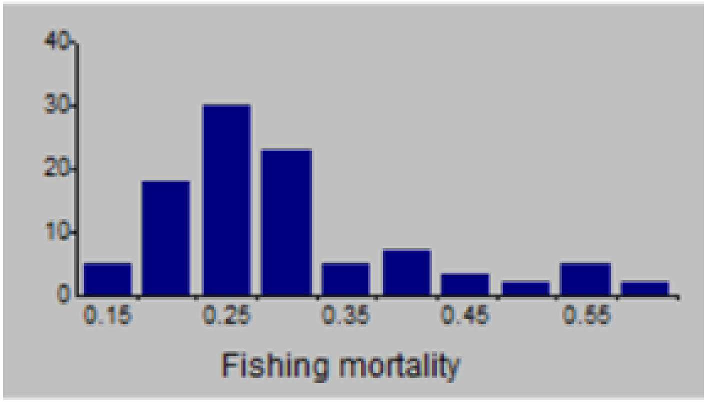


**Figure 3.** Frequency distribution of fishing mortality that maintains Spawning Stock Biomass at 20% of its unexploited value for all sectors combined

In summary, at the Mahe plateau level, $F_{current}$ is within the range of estimates of the limit reference point $F_{SSB20}$, however, the upper limit of F exceedsthe range of estimates of $F_{SSB20}$ (Table 5). In addition, considering the mortality estimates derived, it can be concluded that there is a possibility that this species is overexploited.

Caution should be taken in interpreting the stock status given the sample size was considerably lower compared to previous years.

**Table 5.** Summary results of the YPR for *Lutjanus sebae*. Estimates of F required to achieve maximum yield per recruit ($F_{MSYPR}$) and F to maintain spawning stock biomass at 20% of unexploited biomass ($F_{SSB20}$).

| | **All sectors 2018** |
|---|---|
| $F_{MSYPR}$ | 0.83 |
| $F_{SSB20}$ | 0.23-0.28 |
| $F_{current}$ (CI) | 0.28 (0.25-0.31) |

## 2. Weight of Evidence Approach

The Seychelles Fishing Authority (SFA) adopted the Weight of Evidence (WoE) method to determine the stock status of key species for different fisheries in 2015. This follows the recommendation made at the Commission meeting of the South West Indian Ocean Fisheries Commission (SWIOFC) in 2014, whereby member countries were encouraged to adopt this approach as a standard tool for the assessment of the status of fish stocks. Subsequently, in 2014, a workshop was held to train scientist from the member countries on how to apply this approach.

The WoE framework is a structured and scientific process for assembly and review of indicators of biomass status and levels of fishing mortality. A range of indicators are used in order to reliably determine the stock status. The process involves documenting key evidences and the rationale for the decisions based on the evidence. Expert judgement plays a key role in interpreting the documented evidence in order to derive the stock status.

The steps of the WoE approach are summarized below:

1. Describe the attributes of the species and fishery
2. Compile lines of evidence for status
3. Status determination (weighing of evidence)

The information are compiled in Excel templates (see example for *Lutjanus sebae*).

The WoE framework was used to determine the stock status for thirteen different species and one species group for six different fisheries. The fisheries assessed are as follows:

- Demersal handline fishery
- Semi-pelagic handline fishery
- Trap fishery
- Semi-industrial longline fishery
- Lobster fishery

- Sea cucumber fishery

In future, the WoE approach will also be applied to the encircling gillnet fishery and other key species in the fisheries mentioned above.

The biomass and fishing mortality status of the different species classified under each fishery are summarised in the tables below:

| | | | | | | |
|---|---|---|---|---|---|---|
| Fishing mortality | | Not subject to overfishing | | Subject to overfishing | | Uncertain |
| Biomass | | Not overfished | | Overfished | | Uncertain |

<u>Demersal hand-line fishery</u>

| **Fishery status** | **2016** | | **2017** | | **Comments** |
|---|---|---|---|---|---|
| **Biological status** | Fishing mortality | Biomass | Fishing mortality | Biomass | |
| Emperor red snapper (*Lutjanus sebae*) | | | | | Overall decline in fishing effort since 2008, declines in catches. Catch exceeded MSY over past 10 years |
| Green Jobfish (*Aprion virescens*) | | | | | Declines in standardised CPUE observed from 2008 to 2013. Catches have been fluctuating around MSY level. declines in catch and nominal CPUE from 2009 to 2015 |
| Brown marbled grouper (*Epiniphelus chlorostigma*) | | | | | Declines in standardised CPUE observed from 2002 to 2013. Catches fluctuating between MSY levels. |

Semi-pelagic hand-line fishery

| Fishery status | 2016 | | 2017 | | Comments |
|---|---|---|---|---|---|
| **Biological status** | Fishing mortality | Biomass | Fishing mortality | Biomass | |
| Yellowspotted trevally (*Carangoides fulvoguttatus*) | | | | | Standardised CPUE increased from 1999 to 2004. Declines in CPUE observed from 2004 to 2013. Nominal CPUE shows a decline from 2013 to 2016 |
| Bludger (*Carangoides gymnostethus*) | | | | | From 1998 to 2005 standardised CPUE showed an increasing trend. From 2005 to 2013 CPUE shows a declining trend. Nominal CPUE shows a declining trend from 2011 to 2015. However, a peak in CPUE can be observed in 2016 |
| Kawakawa (*Euthynnus affinis*) | | | | | Catches show high interannual variability. CPUE increasing over last two years. Assessment of stock carried out by IOTC |

Trap fishery

| Fishery status | 2016 | | 2017 | | Comments |
|---|---|---|---|---|---|
| **Biological status** | Fishing mortality | Biomass | Fishing mortality | Biomass | |
| Siganidae (*Siganus sutor*, *Siganus argenteus*, *Siganus corallinus*) | | | | | CPUE for the main fishing fleets are relatively stable over time, slight increase from 2013 to 2016. Decrease in fishing effort from 2011 to 2016 |

Semi-industrial long-line fishery

| **Fishery status** | **2016** | | **2017** | | **Comments** |
|---|---|---|---|---|---|
| **Biological status** | Fishing mortality | Biomass | Fishing mortality | Biomass | |
| Yellowfin tuna (*Thunnus albacares*) | 2016 | 2016 | 2018 | 2018 | New stock assessment carried out by IOTC in 2018, indicating overexploitation. On the local level the CPUE peaked in 2015, however, a declining trend can be observed in recent years |
| Bigeye tuna (*Thunnus obesus*) | 2016 | 2016 | | | The last stock assessment by IOTC was in 2016. The stock status was updated on the basis of the 2016 stock assessment and other indicators. On the local level, a declining trend can be observed in the CPUE from 2015 to 2017. |
| Swordfish (Xiphias gladius) | | | | | Stock assessment carried out by IOTC in 2017. The local CPUE shows that there is an steep increase in CPUE trend. CPUE of the local fishery shows a slow stable increase from 2008 to 2012. A declining trend from 2014 to 2017 |

Lobster fishery

| Fishery status | 2017 | | 2018 | | Comments |
|---|---|---|---|---|---|
| **Biological status** | Fishing mortality | Biomass | Fishing mortality | Biomass | |
| Pronghorn spiny lobster (*Panulirus penicillatus*) | | | | | Surveys carried out in 2018, a declining trend can be observed in the CPUE for all sized lobsters caught. However, a slight increase can be observed in the CPUE for legal sized lobsters caught. This indicates an increase in the biomass and abundance of larger lobsters and a possible decline in smaller lobsters. As a precautionary approach the fishery for the 2018/2019 season remained closed to allow the recovery of this component of the stock. |
| Long-legged spiny lobster (*Panulirus longipes*) | | | | | Surveys carried out in 2018, a declining trend can be observed in the CPUE for all sized lobsters caught. However, an increasing trend can be observed in the CPUE for legal sized lobsters caught. This indicates an increase in the biomass and abundance of larger lobsters and a possible decline in smaller lobsters. As a precautionary approach the fishery for the 2018/2019 season remained closed to allow the recovery of this component of the stock. |

Sea cucumber fishery

| Fishery status | 2016 | | 2017 | | Comments |
|---|---|---|---|---|---|
| **Biological status** | Fishing mortality | Biomass | Fishing mortality | Biomass | |
| White teatfish (*Holothuria fuscogilva*) | | | | | Declines in catches and CPUE observed. Assessment of references cases shows evidence of population declines with significant declines in stock size from their pre exploited state |
| Flower teatfish (*Holoturia sp. (Pentard)*) | | | | | Declines in catches and CPUE observed. Assessment of references cases shows evidence of population declines with significant declines in stock size from their pre exploited state |

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