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Background Paper: SFA 03

Stock Assessments for Artisanal Fisheries

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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 2014 increased compared to 2013, however, in 2015 the number of samples was considerably lower.

1.1.1. *Aprion virescens*

In 2014, 1036 samples were taken for this species, however in 2015, only 235 samples were collected. 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	2009	2010	2012	2013	2014	2015
Z	0.34	0.43	0.35	0.23	0.27	0.4
CI of Z	*-0.30*-0.98	*-0.72*-1.57	*-0.03*-0.73	0.13-0.32	0.14-0.39	-1.27-2.08
r^2	0.98	0.96	0.99	0.99	0.99	0.90
M1	0.26	0.26	0.26	0.26	0.26	0.26
F	0.08	0.17	0.09	-0.03	0.01	0.14
E	0.23	0.39	0.26	-0.13	0.04	0.35
L_{c50} (cm) – Logistic	72.08	75.45	75.37	76.47	66.18	79.28
L_{c50} (cm) – Running av.	68.51	69.09	68.23	67.97	67.47	69.16
F/M	0.30	0.65	0.35	-0.12	0.04	0.54
M2	0.15	0.15	0.15	0.15	0.15	0.15
F	0.19	0.28	0.20	0.08	0.12	0.25
E	0.56	0.65	0.57	0.35	0.44	0.63
L_{c50} (cm) – Logistic	72.20	75.71	76.02	77.26	66.13	79.87
L_{c50} (cm) – Running av.	68.48	69.07	68.19	67.92	67.40	69.15
F/M	1.27	1.87	1.33	0.53	0.8	1.67

L_{m50} (Mees 1992; MRAG 1999)	62-64; 65 cm					
N	530	579	1309	774	1036	235

Similarly to 2013, the estimate of total mortality (Z) in 2014 was relatively low resulting in a very small estimate of fishing mortality with M1=0.26. With M2= 0.15, the estimate of fishing mortality was 0.12 (Table 1). In contrast, for 2015, the estimate of total mortality (Z) was subject to considerable uncertainty.

In 2014, L_{c50} was slightly lower compared to previous years however they were still greater than L_{m50} for both estimate of M, as was the case in previous years. Similarly, for 2015, the L_{c50} was greater than $L_{m50.}$ 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 0.8 in 2014 and 1.67 in 2015 with M2=0.15.

YPR analyses were not conducted for this species.

1.1.2. *Epinephelus chlorostigma*

The sample size for *E. chlorostigma* in 2014 was very high compared to previous years (1437 samples). However, in 2015, the sample size dropped to 161. 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_{∞}=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	**2009**	**2010**	**2012**	**2013**	**2014**	**2015**
Z	1.82	0.68	0.72	1.52	0.87	0.99
CI of Z	-*3.44*-7.07	0.02-1.35	-*1.85*-3.29	-2.59-5.62	0.83-0.91	0.32-1.65
r^2	0.95	0.84	0.93	0.96	1	0.99
M1	0.48	0.48	0.48	0.48	0.48	0.48
F	1.34	0.20	0.24	1.04	0.39	0.51

E	0.74	0.29	0.33	0.68	0.45	0.52
L_{c50} (cm) – Logistic		36.22	35.03	36.98	33.56	35.79
L_{c50} (cm) – Running av.	34.81	33.65	33.60	34.85	34.05	34.24
F/M	2.80	0.42	0.50	2.17	0.81	1.06

M2	0.315	0.315	0.315	0.315	0.315	0.315
F	1.51	0.28	0.41	1.21	0.56	0.68
E	0.83	0.47	0.56	0.79	0.64	0.68
L_{c50} (cm) – Logistic		36.28	35.01	37.01	33.55	35.80
L_{c50} (cm) – Running av.	34.81	33.61	33.56	34.84	34.02	34.22
F/M	4.80	0.89	1.30	3.84	1.78	2.16

L_{m50} ($0.5L_{\infty}$; Moussac , 1986)	28.95 cm TL; 31 cm TL for females					
N	250	437	143	152	1437	161

In contrast to previous years where total mortality (Z) estimates were subject to considerable uncertainty, in 2014 and 2015 the confidence intervals were much better. The total mortality (Z) was 0.87 in 2014 and 0.99 in 2015 (Table 2). 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= 0.48, the F/M ratio is 0.81 and 1.06 in 2014 and 2015 respectively, whilst with M2=0.315, the ratio is 1.78 and 2.16 for 2014 and 2015, respectively.

1.1.3. *Lutjanus sebae*

Mortality and capture estimates

In 2014, the sample size was sufficient to carry out analyses at the plateau level and for sectors 8, 9 and 10 combined. However, in 2015, analyses were conducted only at the Plateau level as sample sizes were not sufficient to perform analyses for different sectors.

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_{∞} = 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 0.40 in 2014 was relatively lower compared to previous years. However, in 2015, the Z estimate of 0.54 was comparable to values obtained from 2009 to 2012. In 2014, both estimates of length at first capture (60.35 cm and 57.73 cm) were lower than the length at first maturity (62 cm) for all sectors combined (Table 3). In 2015, the length at first capture increased slightly, the logistic estimate was equal to length at maturity whilst the other estimate was below. The F/M ratio was 1.18 in 2014 which is lower compared to previous years, however, in 2015, the F/M ratio increased to 1.98

Table 3. *Lutjanus sebae*: Estimates of mortality and corresponding estimates of length at first capture (L_{c50}) from 2009 to 2015. Length at first maturity (L_{m50}) estimates, based on Mees (1992), and sample sizes (n) also provided.

Parameter	2009	2010	2012	2013	2014	2015
Z	0.56	0.56	0.52	0.44	0.40	0.54
CI of Z	0.44-0.68	0.41-0.63	0.36-0.68	0.32-0.56	0.31-0.50	0.45-0.63
r^2	0.99	0.98	0.97	0.98	0.98	0.99
M	0.182	0.182	0.182	0.182	0.182	0.182
F	0.38	0.38	0.34	0.26	0.22	0.36
E	0.68	0.68	0.65	0.59	0.55	0.66
L_{c50} (cm) – Logistic	60.50	62.23	63.86	60.03	60.35	62.21
L_{c50} (cm) – Running av.	57.55	58.67	57.86	57.71	57.73	57.84
F/M	2.09	2.09	1.87	1.43	1.18	1.98
Maturity	62 cm FL					
N	2975	2243	2040	1585	2268	889

For sectors 8, 9 and 10 in 2014 (Table 4), the estimated parameters were very similar to that obtained for the whole plateau. For this reason, YPR analysis was only carried out for all sectors combined for 2014 only.

Table 4. *Lutjanus sebae*: Estimates of mortality and corresponding estimates of length at first capture (L_{c50}) for 2014 – Sectors 8, 9 and 10. Length at first maturity (L_{m50}) estimates, based on Mees (1992), and sample sizes (n) also provided

Parameter	2014 (Sectors 8,9,10)
Z	0.39
CI of Z	0.30-0.49
r^2	0.98
M	0.182
F	0.21
E	0.53
L_{c50} (cm) – Logistic	60.73
L_{c50} (cm) – Running av.	58.06
F/M	1.15
Maturity	62 cm FL

N	471

Application of Yield software

Yield per recruit

All sectors

The yield-per-recruit analysis indicated that MSY would occur when F is around 0.8. However, the SSB would be reduced to less than 20% (a usual limit reference point) when F = 0.30 (CI= 0.17-0.58) (Fig. 1). From the histograms, maximum yield-per-recruit is achieved when F is around 0.3-0.7 (median= 0.53, CI=0.37-0.69) (Fig. 2), but at the expense of reducing the spawning stock biomass to unacceptable levels. To prevent SSB per recruit to reach the limit level of 20% of unexploited biomass, F should be below 0.17-0.39 (median= 0.30, CI= 0.26-0.33) (Fig. 3). The estimate of current F for 2014 (0.22; range = 0.13-0.32) is below the range of $F_{SSB20\ per\ recruit}$ however the upper confidence level of F is within the range of F that would push the spawning stock biomass below the critical values.

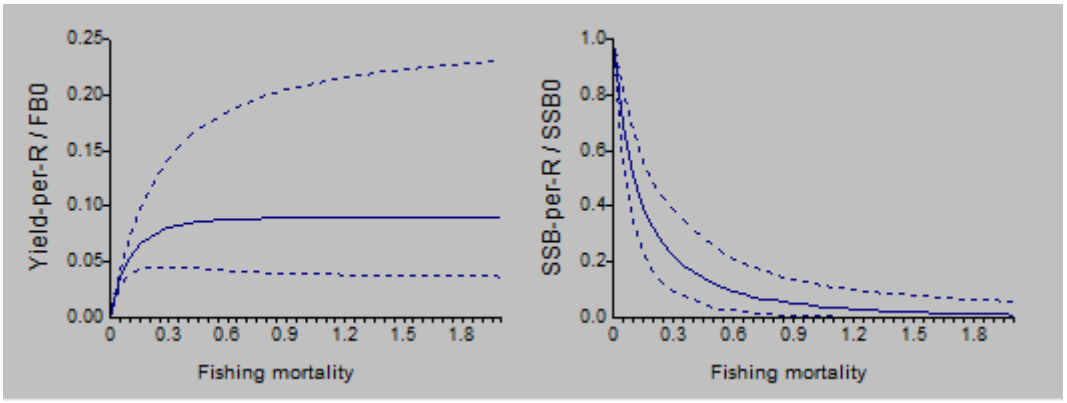

Figure 1. Yield per recruit and Spawning Stock Biomass per recruit against levels of fishing mortality for all sectors combined

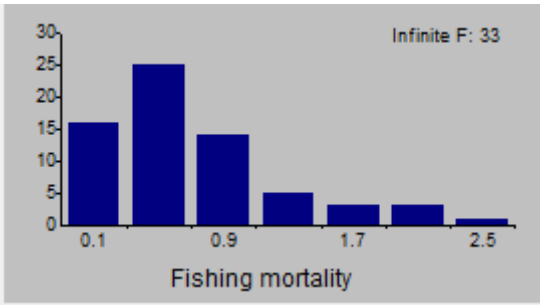

Figure 2. Frequency distribution of fishing mortality that produces maximum yield-per-recruit for all sectors combined

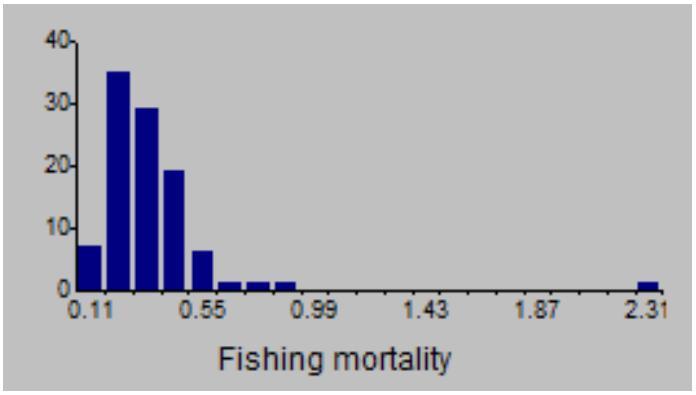

Figure 3. Frequency distribution of fishing mortality that maintains Spawning Stock Biomass at 20% of its unexploited value for all sectors combined

In summary, at the Mahe plateau level, $F_{current}$ is below the range of estimates of the limit reference point F_{SSB20}, however, the upper limit of F is within the range of estimates of F_{SSB20}. The F/M ratio has decreased in 2014 compared to previous years, however in 2015 the ratio increased to 1.98 suggesting that fishing pressure increased between the two 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 2014
F_{MSYPR}	0.8
F_{SSB20}	0.26-0.33
$F_{current}$ (CI)	0.22 (0.13-0.32)

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