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# Tier 4 assessments for selected SESSF species (data to 2021)

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# Executive Summary

Three Tier 4 assessments were performed for the following species and/or stocks:

- ❖ Mirror Dory - East (*Zenopsis nebulosa*)
- ❖ Mirror Dory - West (*Zenopsis nebulosa*)
- ❖ Western Gemfish Zone 50 (*Rexea solandri*)

**Mirror Dory - East:** The 2022 estimated RBC was 137.77 t, an increase of 24.83 t compared to the 2021 estimated RBC (112.93 t). The increase in RBC of approximately 25 t can be mostly attributed to an increase in the most recent annual catch-per-unit-effort (CPUE) (including discards) and hence the mean of the most recent four-year average which is used to calculate the RBC. The 2022 RBC is greater than the reported catch of approximately 77.6 t in 2021 for this stock. Also, the CPUE in 2021 is above the CPUE limit based on the Tier 4 Harvest Control Rule (0.49) compared to the previous CPUE (in 2020) which is at the CPUE limit.

**Mirror Dory - West:** The 2022 estimated RBC was 48.72 t, a decrease of 7.46 t compared to the 2021 estimated RBC (56.18 t). The decrease in RBC of approximately 7.5 t can be attributed to a decrease in the mean of the most recent four-year average CPUE which is used to calculate the RBC. The 2022 RBC is greater than the reported catch of approximately 29 t in 2021 for this stock.

**Western Gemfish Zone 50:** The 2022 estimated RBC was approximately 221.37 t, an approximate 201.69 t decrease compared to the 2019 estimated RBC (423.06 t; Sporcic 2019). The decrease in RBC of approximately 202 t can be mostly attributed to a decrease in the most recent CPUE (including discards) and hence the mean of the most recent four-year average which is used to calculate the RBC. The 2022 RBC is greater than the reported catch of approximately 75.1 t in 2021 for this stock.

# 1 Introduction

## 1.1 Tier 4 Harvest Control Rule

The Tier 4 harvest control rules are the default procedure applied to species which only have catches and catch-per-unit-effort (CPUE) data available; specifically, there is no other reliable information on either current biomass levels or current exploitation rates.

Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher Tier analyses; this is now explicitly implemented by imposing a 15% discount factor on the Tier 4 RBC as a precautionary measure unless there are good reasons for not imposing such a discount on particular species. The application of the discount factor will occur unless RAGs generate explicit advice that alternative equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels (AFMA, 2009).

Tier 4 assessments require as a minimum, a time series of total catches and of standardized CPUE, along with an agreed reference period and reference points.

The current Tier 4 assessment and control rule underwent Management Strategy Evaluation (Wayte, 2009; Little et al., 2011), which demonstrated its advantages over an earlier implementation used in 2007 and 2008.

## 1.2 Tier 4 Assumptions

### 1.2.1 Informative CPUE

There is a linear relationship between CPUE and exploitable biomass; if there is hyperstability (CPUE remain stable while stock size changes) or hyperdepletion (CPUE decline much faster than stock size changes) then the standard Tier 4 assessment would provide biased results.

### 1.2.2 Consistent CPUE Through Time

The character of the estimated CPUE has not changed in significant ways through the period from the start of the reference period to the end of the most recent year. If there has been significant effort creep altering the catchability, or there have been changes to the fleet that have altered the relative efficiency of the vessels fishing, or the catchability of the species by the fleet has been altered by other changes then the comparability of recent CPUE with the target period may be compromised. Such changes would obviously reduce the responsiveness of the Tier 4 method to change and may generate completely inappropriate management advice. Included in this clause are the effects of targeting or not targeting of deep water or aggregated species. When CPUE are extremely variable through time, such that mean estimates become unreliable measures of stock status, then the Tier 4 approach cannot be validly applied.

### 1.2.3 Plausible Target Reference Period

The reference period provides a good estimate of the stock when at a depletion level of 48 % unfished spawning biomass ( $B_{48\%}$ ); the Tier 4 method is based on CPUE and thus relates to exploitable biomass and

not spawning biomass. As a minimum the reference period will refer to a period when the stock was in an acceptable, productive and sustainable state. However, there can be no guarantees that the target aimed for is really  $B_{48\%}$ .

#### **1.2.4 Accurate Total Catch History**

Accurate estimates are required for all catches from the stock under consideration during the accepted target period, irrespective of what method was used or whether it was retained or discarded. This assumption is especially vulnerable to being breached when large proportions of catches are discarded. While there is a procedure for adjusting the standardized CPUE for these missed catches the uncertainty over the actual amount of fish killed remains.

#### **1.2.5 Some Implications of the Assumptions**

The outcomes of the Tier 4 assessment should not be regarded with the same confidence as those from Tier 1 assessments. Even though they are termed stock assessments, in actuality they are empirical considerations of catches and CPUE. Any uncertainty in the catch or CPUE time series is propagated directly through to the outputs of the analysis. For quota species the catches and reported CPUE is usually relatively well founded because of the quota catch disposal records and other compliance requirements. However, where there is a relatively high degree or variable discarding of catches this can lead to much greater levels of uncertainty.

The assessments for those species that are conducted using a Tier 4 assessment should be reviewed for their inter-annual consistency and how the fishery has been responding to the management advice derived from the Tier 4 assessments.

## 2 Mirror Dory East Discard

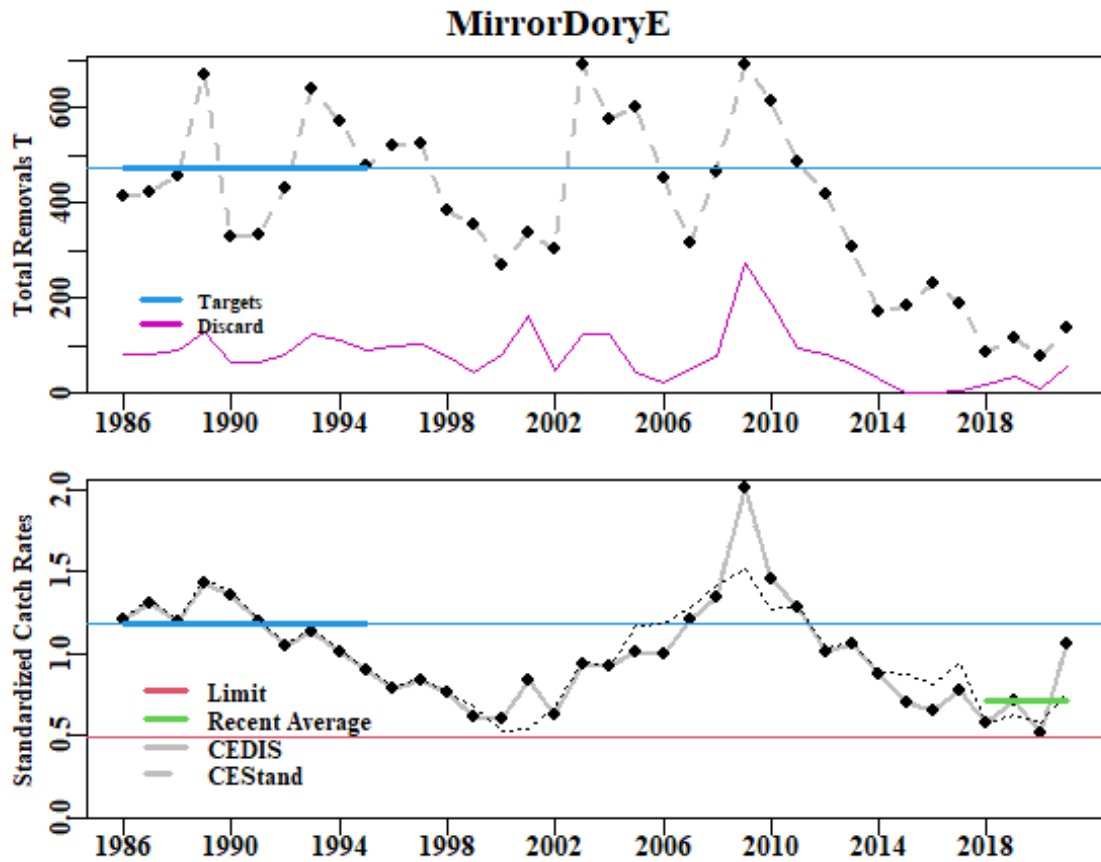


Figure 1: Mirror Dory 10 – 30 Discard. Top plot is the total removals with the fine blue line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine blue line representing the target CPUE and the lower red line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE. The thin black dotted line is the unmodified standardized CPUE before the inclusion of discards.

Table 1: Mirror Dory 10 – 30 Discard - RBC calculations.  $C_{\text{targ}}(t)$  and  $\text{CPUE}_{\text{targ}}(\text{CE\_Target})$  are the targets identified in the figure above,  $\text{CPUE}_{\text{Lim}}$  is 20% of the  $B_0$  proxy (which relate to the  $\text{CPUE}_{\text{targ}}$ ), and the most recent CPUE is the average CPUE over the last four years ( $\text{CE\_Recent}$ ). Recommended biological catch (RBC;  $t$ ). The RBC calculation does not account for discards of State catches.  $\text{Wt\_Discard}$  is the weighted average discards from the last four years. E: east; W: west. Total Allowable Catch (TAC).

Parameter	Value	Parameter	Value
Reference_Years	1986 - 1995	Scaling	0.2905
CE_Target	1.1842	Previous combined TAC (E+W) (t)	144
CE_Limit	0.493	$C_{\text{targ}}$	474.282
CE_Recent	0.7170	RBC	137.768
Wt_Discard	37.968		



Table 2: Mirror Dory 10 – 30 Discard - data for the Tier 4 calculations. Total (t) is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized CPUE (Sporcic, 2022). GeoMean is the geometric mean CPUE. Discards (D) are estimates from 1986 to present (see also details in Sporcic and Day 2021; Deng et al., 2022). Total Allowable Catch (TAC) are combined east and west.

Year	Catch	Discards	Total	(D/C)+1	CE	DiscCE	TAC	State
1986	334.6	80.511	415.071	1.241	1.2256	1.2134		276.903
1987	338.6	81.472	420.029	1.241	1.3300	1.3168		272.612
1988	368.9	88.771	457.657	1.241	1.2099	1.1979		297.038
1989	539.5	129.831	669.342	1.241	1.4531	1.4386		398.256
1990	266.0	64.013	330.018	1.241	1.3778	1.3641		211.547
1991	269.9	64.955	334.874	1.241	1.2130	1.2009		170.055
1992	345.4	83.127	428.559	1.241	1.0612	1.0506		153.925
1993	516.7	124.344	641.052	1.241	1.1534	1.1419	800	223.733
1994	459.2	110.500	569.682	1.241	1.0199	1.0097	800	175.184
1995	384.1	92.433	476.538	1.241	0.9168	0.9077	800	158.953
1996	417.5	100.476	518.002	1.241	0.8029	0.7949	800	166.212
1997	421.4	101.400	522.767	1.241	0.8537	0.8452	800	68.904
1998	303.2	79.336	382.526	1.262	0.7616	0.7668	800	26.987
1999	310.4	42.245	352.629	1.136	0.6738	0.6109	800	36.886
2000	189.5	81.075	270.612	1.428	0.5340	0.6084	800	11.044
2001	172.7	164.425	337.144	1.952	0.5378	0.8377	800	10.346
2002	257.2	45.702	302.865	1.178	0.6721	0.6317	640	21.648
2003	563.2	124.877	688.027	1.222	0.9602	0.9362	576	68.408
2004	451.9	122.593	574.476	1.271	0.9137	0.9270	576	106.362
2005	557.4	44.287	601.720	1.079	1.1747	1.0119	700	73.403
2006	426.6	23.351	449.927	1.055	1.1842	0.9967	634	85.430
2007	264.5	50.836	315.360	1.192	1.2786	1.2164	788	28.716
2008	390.3	75.461	465.806	1.193	1.4219	1.3540	634	22.089
2009	416.2	273.903	690.105	1.658	1.5212	2.0128	718	34.930
2010	428.7	186.822	615.559	1.436	1.2722	1.4576	718	12.019
2011	391.4	92.850	484.248	1.237	1.3004	1.2839	718	6.091
2012	339.2	80.479	419.728	1.237	1.0323	1.0192	718	5.630
2013	246.9	58.567	305.448	1.237	1.0717	1.0581	1077	3.650
2014	137.9	32.711	170.599	1.237	0.8920	0.8807	808	1.787
2015	183.1	1.105	184.228	1.006	0.8738	0.7015	437	0.595
2016	230.5	1.339	231.813	1.006	0.8191	0.6574	325	5.715
2017	183.8	4.821	188.581	1.026	0.9439	0.7730	235	0.322
2018	69.8	1.833	71.681	1.026	0.5820	0.4766	253	0.056
2019	80.2	36.077	116.283	1.450	0.6236	0.7215	188	0.006
2020	70.4	8.839	79.288	1.125	0.5722	0.5139	137	0.003
2021	77.6	57.523	135.086	1.742	0.7657	1.0642	144	0.000

## 2.1 Discussion

The most recent catch and standardized CPUE has increased relative to the previous year (Table 2). Revised estimates of NSW State catches included in the previous assessment were also included in this assessment. Discard estimates used for Mirror Dory East were based on both Althaus et al. (2022) and Deng et al. (2022). The coefficient of variation (CV) of the 2018 discard estimate was originally greater than 100 % (i.e., ~189 %; Table 2 in Althaus et al., 2020). Therefore, as agreed by SESSFRAG (meeting 20-22 August 2019), it was replaced with the 2017 estimate (0.02; CV: 52 %) and repeated this year.

The 2022 estimated RBC was 137.77 t (Table 1), an increase of 24.84 t compared to the 2021 estimated RBC (112.93 t; Sporcic 2021). The increase in RBC of approximately 25 t can be mostly attributed to an increase in the most recent CPUE (including discards) and hence the mean of the most recent four-year average which is used to calculate the RBC. The 2022 RBC is greater than the reported catch of approximately 77.6 t (135 t including estimated discards) in 2021 for this stock (Table 2). Also, the CPUE in 2021 is above the CPUE limit based on the Tier 4 Harvest Control Rule (0.49) compared to the previous CPUE (in 2020) which is at the CPUE limit.

### 3 Mirror Dory West

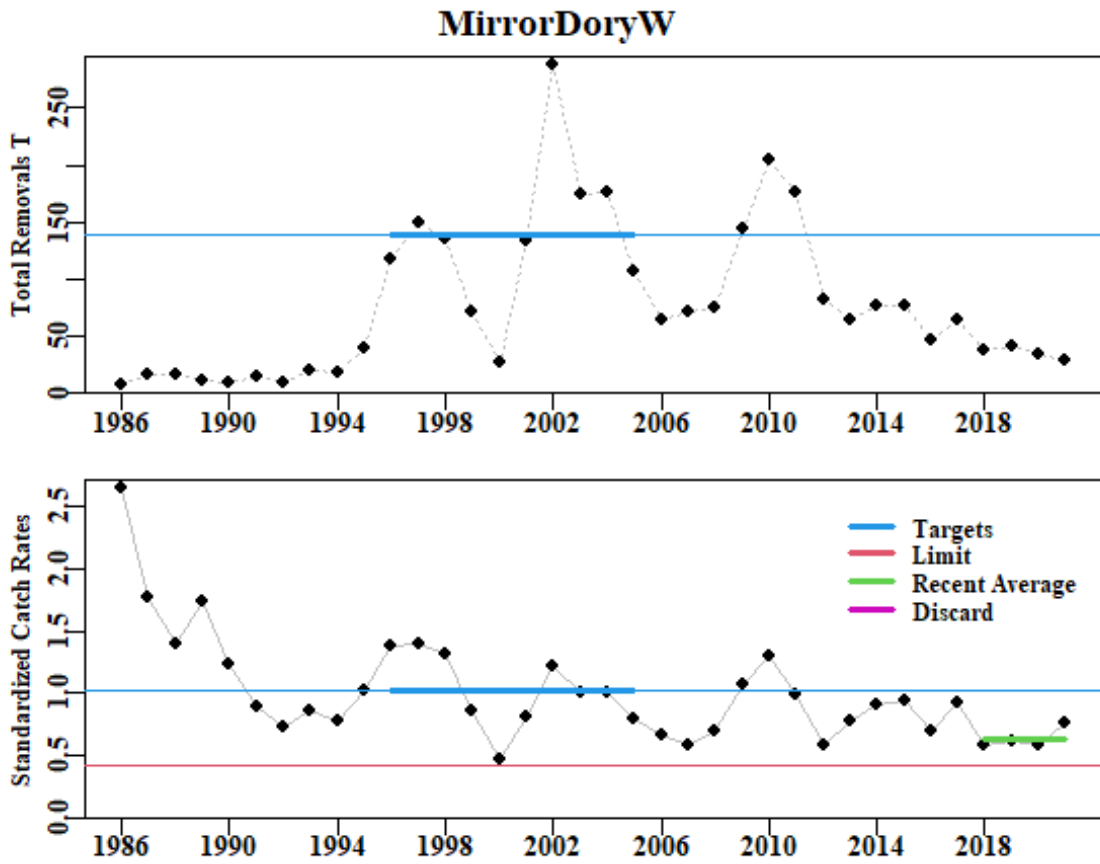


Figure 2: Mirror Dory 40 – 50. Top plot is the total removals with the fine blue line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine blue line representing the target CPUE and the lower red line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE.

Table 3: Mirror Dory 40 – 50 - RBC calculations.  $C_{targ}(t)$  and  $CPUE_{targ}(CE\_Target)$  are the targets identified in the figure above,  $CPUE_{Lim}$  is 20% of the  $B_0$  proxy (which relate to the  $CPUE_{targ}$ ), and the most recent CPUE is the average CPUE over the last four years ( $CE\_Recent$ ). Recommended biological catch (RBC; t). The RBC calculation does not account for discards of State catches.  $Wt\_Discard$  is the weighted average discards from the last four years. E: east; W: west. Total Allowable Catch (TAC).

Parameter	Value	Parameter	Value
Reference_Years	1996 - 2005	Scaling	0.3525
CE_Target	1.0244	Previous combined TAC (E+W) (t)	144
CE_Limit	0.4268	$C_{targ}$	138.224
CE_Recent	0.6374	RBC	48.722
Wt_Discard			

Table 4: Mirror Dory 40 – 50 - data for the Tier 4 calculations. Total (t) is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized CPUE (Sporcic, 2022). GeoMean is the geometric mean CPUE. Total Allowable Catch (TAC) are combined east and west.

Year	Catch	Discards	Total	State	CE	GeoMean	TAC
1986	8		7.800		2.6471	1.2972	
1987	16		16.123		1.7819	1.5483	
1988	17		17.104		1.4014	1.7778	
1989	11		11.227		1.7371	2.3869	
1990	10		10.151		1.2277	2.0904	
1991	15		14.928		0.8977	1.1307	
1992	10		9.770	0.480	0.7254	0.7876	
1993	19		19.330	0.720	0.8557	0.9697	800
1994	19		18.646	0.334	0.7833	0.8948	800
1995	39		39.305	0.738	1.0294	0.8720	800
1996	117		117.407	0.238	1.3749	1.2823	800
1997	150		150.000	0.138	1.3945	1.2331	800
1998	136		136.183	0.000	1.3172	1.2107	800
1999	72		71.677	0.006	0.8560	0.8484	800
2000	28		27.792	0.001	0.4726	0.3890	800
2001	134		133.762		0.8173	0.7598	800
2002	288		287.994	0.002	1.2110	1.1229	640
2003	175		174.927	0.060	1.0066	1.0533	576
2004	176		175.911	0.024	1.0012	0.9925	576
2005	107		106.584	0.039	0.7924	0.7712	700
2006	65		64.651	0.005	0.6585	0.7689	634
2007	71		71.390	0.005	0.5903	0.6372	788
2008	74		74.123	0.014	0.6998	0.7207	634
2009	145		144.958		1.0655	0.9280	718
2010	204		204.199		1.2990	1.0633	718
2011	177		177.025	0.001	0.9916	0.8292	718
2012	82		82.141		0.5816	0.6026	718
2013	65		65.201	0.001	0.7826	0.7772	1077
2014	77		76.918		0.9019	0.8979	808
2015	77		77.272		0.9378	0.8410	437
2016	46		46.370		0.6888	0.7381	325
2017	65		64.531		0.9224	0.9911	235
2018	37		37.387		0.5801	0.6378	253
2019	41		41.458		0.6202	0.7178	188
2020	34		33.929		0.5875	0.6747	137
2021	29		29.229		0.7620	0.7562	144

### 3.1 Discussion

With the fishery only beginning to report significant catches from about 1996 onwards the reference period used is relatively recent. Nevertheless, there are now 12 years between the reference period and the start of the most recent four years used to denote the current state of the fishery.

The 2022 estimated RBC was 48.72 t (Table 3), a decrease of 7.46 t compared to the 2021 estimated RBC (56.18 t; Sporcic 2021). The decrease in RBC of approximately 7.5 t can be attributed to a decrease in the mean of the most recent four-year average CPUE which is used to calculate the RBC. The 2022 RBC is greater than the reported catch of approximately 29 t in 2021 for this stock (Table 4).

## 4 Western Gemfish Zone 50 Discard

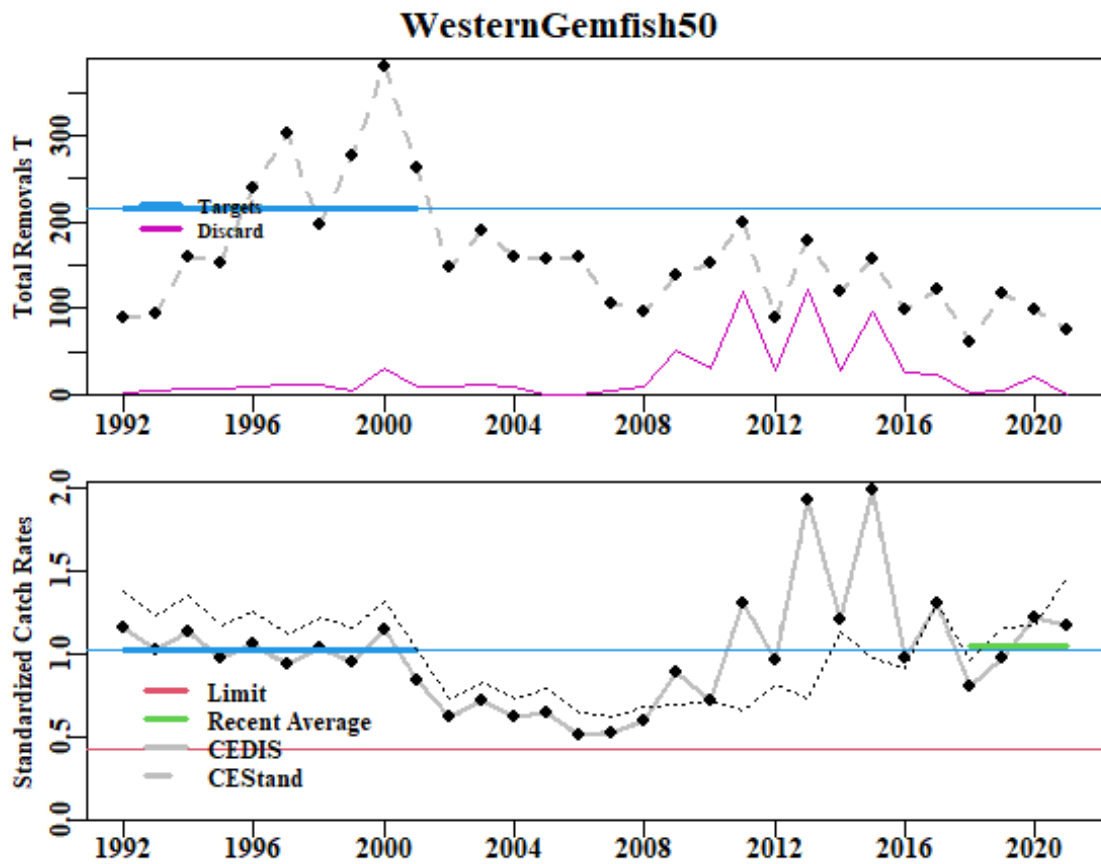


Figure 3: Western Gemfish Discard. Top plot is the total removals with the fine blue line illustrating the target catch. Bottom plot represents the standardized CPUE with the upper fine blue line representing the target CPUE and the lower red line the limit CPUE. Thickened lines represent the reference period for catches, CPUE, and the recent average CPUE. The thin black dotted line is the unmodified standardized CPUE before the inclusion of discards.

Table 5: Western Gemfish Discard - RBC calculations.  $C_{\text{targ}}(t)$  and  $\text{CPUE}_{\text{targ}}(\text{CE\_Target})$  are the targets identified in the figure above,  $\text{CPUE}_{\text{Lim}}$  is 20% of the  $B_0$  proxy (which relate to the  $\text{CPUE}_{\text{targ}}$ ), and the most recent CPUE is the average CPUE over the last four years ( $\text{CE\_Recent}$ ).  $\text{Wt\_Discard}$  is the weighted average discards from the last four years. Recommended biological catch (RBC; t). Total Allowable Catch (TAC).

Parameter	Value	Parameter	Value
Reference_Years	1992 - 2001	Scaling	1.0283
CE_Target	1.0289	Previous TAC (t)	343
CE_Limit	0.4287	$C_{\text{targ}}$	215.285
CE_Recent	1.0459	RBC	221.367
Wt_Discard	7.27		

Table 6: Western Gemfish Discard - data for the Tier 4 calculations. Total (t) is the sum of Discards, State, Non Trawl and SEF2 catches. All values in Tonnes. CE is the standardized CPUE (Sporcic, 2022). GeoMean is the geometric mean CPUE. Discards (D) are estimates from 1992 to present (see also details in Sporcic and Day 2021; Althaus et al., 2022; Deng et al., 2022). Total Allowable Catch (TAC).

Year	Catch	Discards	Total	(D/C)+1	CE	DiscCE	TAC
1992	84.4	3.820	88.204	1.045	1.3863	1.1599	300
1993	90.5	4.097	94.586	1.045	1.2318	1.0306	300
1994	153.1	6.930	160.016	1.045	1.3507	1.1301	300
1995	146.9	6.652	153.592	1.045	1.1722	0.9808	300
1996	228.4	10.339	238.717	1.045	1.2627	1.0565	300
1997	288.8	13.076	301.914	1.045	1.1276	0.9434	300
1998	185.4	12.000	197.371	1.065	1.2225	1.0419	300
1999	271.8	5.010	276.800	1.018	1.1643	0.9491	300
2000	349.2	29.997	379.233	1.086	1.3240	1.1508	300
2001	253.4	9.001	262.412	1.036	1.0207	0.8460	330
2002	138.9	9.135	148.050	1.066	0.7290	0.6219	330
2003	177.5	12.584	190.090	1.071	0.8348	0.7156	300
2004	149.8	8.922	158.763	1.060	0.7332	0.6218	300
2005	156.6	1.582	158.197	1.010	0.7934	0.6415	300
2006	159.8	0.545	160.319	1.003	0.6412	0.5150	167
2007	99.5	5.125	104.596	1.052	0.6161	0.5186	200
2008	86.7	9.034	95.702	1.104	0.6794	0.6005	167
2009	87.6	51.075	138.677	1.583	0.6988	0.8855	125
2010	121.7	31.956	153.633	1.263	0.7169	0.7245	109
2011	79.7	120.448	200.158	2.511	0.6524	1.3113	94
2012	60.4	28.715	89.159	1.475	0.8180	0.9658	199
2013	54.1	123.223	177.357	3.276	0.7360	1.9301	199
2014	91.2	29.035	120.214	1.318	1.1405	1.2036	199
2015	61.9	95.931	157.782	2.551	0.9730	1.9868	183
2016	73.4	25.563	98.968	1.348	0.9095	0.9815	247
2017	97.7	23.832	121.528	1.244	1.3087	1.3031	199
2018	59.0	2.671	61.666	1.045	0.9682	0.8101	200
2019	110.7	6.339	117.051	1.057	1.1549	0.9774	200
2020	75.2	22.619	97.836	1.301	1.1718	1.2200	300
2021	75.1	0.403	75.541	1.005	1.4614	1.1760	343

## 4.1 Discussion

The 2022 estimated RBC was approximately 221.37 t (Table 5), an approximate 201.69 t decrease compared to the 2019 estimated RBC (423.06 t; Sporcic 2019). The decrease in RBC of approximately 202 t can be mostly attributed to a decrease in the most recent CPUE (including discards) and hence the mean of the most recent four-year average which is used to calculate the RBC. The 2022 RBC is greater than the reported catch of approximately 75.1 t (75.5 t including estimated discards) in 2021 for this stock (Table 6).

## 5 References

- AFMA (2009). SESSF Stock Assessment Methods and TAC Setting Process Version 1.5. 8p.
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## 6 Appendix: Methods

### 6.1 Tier 4 Harvest Control Rule

The data required are time series of catches and standardized CPUE. The analyses have been conducted on total catches across the entire SESSF (including State catches, SEF2 landing records, and any discards). For some species, where there is only a single stock and a single primary fishing method, analyses are presented using standardized CPUE data (e.g., Haddon, 2014). For other species, there may be multiple stocks or areas or multiple methods and selecting which time series of CPUE to use in the analyses is not always straightforward. In those cases, the standardized CPUE time series for the method now accounting for the majority of current catch was used.

All 2010 data relating to catches and discards, from both State waters and SEF2 data sets, were provided by AFMA, with initial processing by N. Klaer and J. Upston of CSIRO. All CPUE data were derived from the standard commercial catch and effort database processed by the data services Team at CSIRO Hobart.

Standard analyses were set up in the statistical software, R Core Team (2021), which provided the tables and graphs required for the Tier 4 assessment. The data and results for each analysis are presented for transparency. The Tier 4 harvest control rule formulation essentially uses a ratio of current CPUE with respect to the selected limit and target reference points to calculate a scaling factor for the current year. This scaling factor is applied to the target catch to generate an RBC. To generate a TAC, known discards and State catches are first removed and then, if applicable, the 15% discount is applied. The TAC calculations are conducted by AFMA. This report focusses on providing the estimates of the Recommended Biological Catches.

$$\text{Scaling Factor} = SF_t = \max\left(0, \frac{\overline{CPUE} - CPUE_{\text{lim}}}{CPUE_{\text{targ}} - CPUE_{\text{lim}}}\right)$$

$$RBC = C_{\text{targ}} \times SF_t$$

If new data becomes available, for example, more State data has become available this year, or other large changes occur in the CPUE then the RBC could undergo large changes. Such changes are constrained by the following limits:

$$\begin{aligned} RBC_y &= 1.5RBC_{y-1} & RBC_y > 1.5RBC_{y-1} \\ RBC_y &= 0.5RBC_{y-1} & RBC_y < 0.5RBC_{y-1} \end{aligned}$$

where

1.  $RBC_y$  is the RBC in year  $y$ ,
2.  $CPUE_{\text{targ}}$  is the target CPUE for the species,
3.  $CPUE_{\text{lim}}$  is the limit CPUE for the species =  $0.4 * CPUE_{\text{targ}}$ ,
4.  $\overline{CPUE}$  is the average CPUE over the past  $m$  years;  $m$  tends to be the most recent four years,
5.  $C_{\text{targ}}$  is a catch target derived from a period of historical catch that has been identified as a desirable target in terms of CPUE, catches and status of the fishery, e.g. 1986 – 1995. This is an average of the total removals for the selected reference period, including any discards.

$$C_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} L_y}{(yr2 - yr1 + 1)}$$

where  $L_y$  represents the landings in year  $y$ .



$$CPUE_{\text{targ}} = \frac{\sum_{y=yr1}^{yr2} CPUE_y}{(yr2 - yr1 + 1)}$$

where  $CPUE_y$  is the CPUE in year  $y$ ,  $yr2$  and  $yr1$  represent the last and the first years in the reference period respectively.

Percent discards are estimated from ISMP observations from 1998 to the current year. Discards for earlier years, prior to ISMP sampling, are generally estimated by taking the overall average percent discard from 1998 to the 2006 and applying that discard rate to the reported landings for the earlier years. The year 2006 was selected as the final year as discarding practices altered at about that time following the structural adjustment and the introduction of the Harvest Strategy Policy. For eastern Gemfish the average discard rate was determined for 1998-2002 to allow for the non-target nature of the fishery following 2002. The calculation of the earlier discards is done so that the total catches can be estimated even though only the landed catches are available. To calculate the discards for a given year we used:

$$D_y = \frac{C_y \bar{D}_{98-06}}{(1 - \bar{D}_{98-06})}$$

Discard proportions for the projected year for which the RBC is being calculated are taken as a weighted mean of the previous four years:

$$D_{\text{CUR}} = (1.0 D_{y-1} + 0.5 D_{y-2} + 0.25 D_{y-3} + 0.125 D_{y-4})/1.875$$

where  $D_{\text{CUR}}$  is the estimated discard rate for the coming year  $y$ ,  $D_{y-1}$  is the discards rate in year  $y-1$ . The discard rate in year  $y$  is the ratio of discards to the sum of landed catches plus those discards (this can vary between 0 – 100 %):

$$D_y = \frac{\text{Discard}_y}{(\text{Catches}_y + \text{Discard}_y)}$$

For each species, reference years were selected by the RAGs to generate estimates of target catches and target CPUEs. In addition, a decision was required as to whether the fishery could be considered as fully developed or otherwise. Where a fishery was not considered to be fully developed the target CPUE,  $CPUE_{\text{targ}}$ , was divided by two as a proxy for expected changes to CPUEs as the fishery develops and the resource stock size declines towards the target of 48% unfished biomass.

Plots are given of the total removals illustrating the target catch level. In addition, the standardized CPUE are illustrated with the target CPUE and the limit CPUE. Finally, where the data are available, plots are given of the total removals contrasted with State removals, and of discards and non-trawl catches.

## 6.2 The Inclusion of Discards

Some species, especially Redfish (*Centroberyx affinis*) and inshore Ocean Perch (*Helicolenus percoides*), have experienced high levels of discarding but the reported CPUEs relate only to the estimated landed weights. In those species where discarding makes up a significant proportion of the catch (in some years more Redfish were discarded than landed and more inshore Ocean Perch tend to be discarded than landed) it is reasonable to ask how the discards would have affected CPUE. This is an important question because standardized commercial CPUE are used in Australian stock assessments as an index of relative abundance (e.g., Haddon, 2014); if ignoring discards leads to a consistent bias this could affect the outcome of the assessments and thus, the assessments should become aware of the effects of discards.

CPUEs are used in assessments as an index of relative abundance through time and it is the trends exhibited by the CPUEs that are important rather than their absolute values. If the discard levels are relatively constant through time and evenly distributed amongst the fleet, then their inclusion would not

be expected to influence the trends in CPUEs except to add noise. In all cases the discard rates are estimates based on sub-sampling the fleet of vessels. That the estimates are uncertain can be seen simply by considering the summary data tables in this document; where discards rates are not low they are very variable between years. Redfish provide an extreme where in 1998 the estimate was 2324 t, which was nearly 56 % of the total catch, while in 1999 discards estimated at only 69 t, making up on about 5 % of the total catch. So in those cases where discard levels are low, adding discards to the estimation of CPUEs is not expected to alter outcomes.

For those species, such as Redfish and Ocean Perch, where discard rates are much higher it was decided to include those estimated catches to determine their effect on the outcome of the Tier 4 assessments. In 2010 it was concluded that while the inclusion of discards contributed a great deal of noise to the analyses, for those species where discarding made up significant proportions of the overall catch the discard augmented CPUEs should be examined each year as a sensitivity analysis to contrast with the outcome from the un-augmented CPUEs (Haddon, 2010).

### 6.2.1 Analyses Including Discards

Discard rates cannot simply be added to known catches on the way to calculating CPUEs. The standardized CPUEs are estimated from individual catch and effort records but the estimates of discards are summary estimates for each fishery. While a method for incrementing the standardized CPUE has been developed it should be noted that this ignores all complications relating to unknown aspects of discarding behaviour (e.g., Is the discard rate constant across all catch sizes, across all vessels, across all areas?). This means that including discard catches into the annual CPUE estimates introduces an unknown amount of uncertainty into the analysis. It should also be noted that the discard estimates are highly variable from year to year and derive from relatively small samples of all trips contributing to catches.

The method developed was to find the multiplier needed to adjust ratio mean CPUE and apply that to the standardized CPUE (Haddon, 2010). The ratio mean CPUE require the annual sum of catches for the fishery along with the sum of effort and ratio means calculated for each year. The discard estimates from the fishery can be added to the catch totals and new ratio means calculated and compared. The multiplier needed to make the same changes to the ratio mean CPUE can then be developed and applied to the standardized CPUE.

The ratio mean is simply the sum of all catches divided by the sum of effort

$$\hat{I}_{R,t} = \frac{\sum C_t}{\sum E_t}$$

where  $\hat{I}_{R,t}$  is the ratio mean CPUE for year  $t$ ,  $\sum C_t$  is the sum of landed catches in year  $t$ , and  $\sum E_t$  is the sum of effort (as hours trawled) in year  $t$ . If  $\sum D_t$  is the sum of discards in year  $t$  then the discard incremented ratio mean CPUE would be:

$$\hat{I}_{D,t} = \frac{\sum C_t + \sum D_t}{\sum E_t}$$

The same values of  $\hat{I}_{D,t}$  can also be obtained using the following multiplier:

$$\hat{I}_{D,t} = [(\sum D_t / \sum C_t) + 1] \times I_t$$

where  $I_t$  is the CPUE estimate to be modified by the inclusion of discards. If this is the ratio mean then the augmented CPUEs would be identical to the first equation dealing with  $\sum D_t$ . In practice, the CPUEs used with the multiplier are the standardized CPUEs (e.g. Haddon, 2014; Sporcic 2022).

## 6.2.2 The Limitations of Including Discards

The discard rates are estimated as the proportion of the total catch (= landed catch plus discards), which means that discard proportions greater than 0.5 imply that more fish are discarded than landed. To calculate the discarded catches from a discard rate and the landed catches we use:

$$D_t = \left( \frac{C_t}{1 - P_t} \right) - C_t$$

where  $D_t$  is the discarded catches in year  $t$ ,  $C_t$  is the total landed catches in year  $t$ , and  $P_t$  is the proportion of discards in year  $t$ . Because the divisor is  $1 - P_t$  as  $P_t$  tends to 1.0 the divisor becomes very small and hence acts as a multiplier on total landed catch  $C_t$ . The effect of this is that when  $P_t$  is estimated to be above 0.5 the multiplying effect in the calculation of discards becomes grossly exaggerated (Figure A.1).

It is recommended that once discard proportions are estimated to be above 0.5 or 0.6 then attention needs to be paid to whether or not the inclusion of discards into the CPUE and the calculation of the RBC can be considered valid. In such cases, for example Inshore Ocean Perch, the Tier 4 assessment may need to be rejected and some alternative adopted.

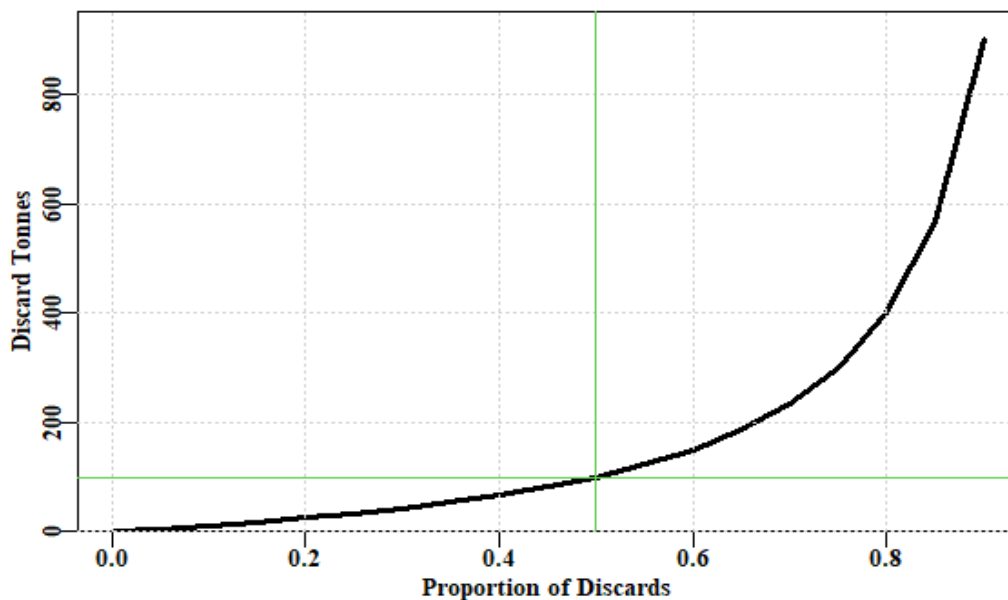


Figure A.1: The influence of the proportion discarded on estimates of discarded catches. As the proportion of discards approaches 1.0 the multiplying effect in the estimation of discard amounts becomes greatly amplified.

## 6.3 Selection of Reference Periods

The Tier 4 requires a reference period to be selected in order to establish target and limit levels of CPUEs and associated target levels of catch that are deemed by the RAG to act as a proxy for the desired state for the fishery. These act as a proxy for the Harvest Strategy Policy reference points of 48% and 20% unfished spawning biomass. The original Tier 4 rule that used a linear regression of the last four year's CPUE to determine whether catches increase or decrease was not able to rebuild a resource towards a desired target level and the current approach was developed so as to be able to manage a fishery towards a target and away from a limit.

The essence of the Tier 4 control rule is that it sets a RAG agreed target CPUE, which has an associated target catch. An estimate of current CPUE (usually the average of the last four years) is compared with the


target and a multiplier is estimated which is to be applied to the target catch to generate the recommended biological catch.

To select a reference period requires a time series of comparable CPUE. For this reason the use of standardized CPUE should be an improvement over using, for example, the observed arithmetic or geometric mean CPUE. CPUE data is available in the SESSF for all targeted species from 1986 - 2011, although it needs to be noted that the character of the fishery has changed markedly during that period. Little et al. (2009) provide a discussion on how reference periods might be selected. They proposed a default 10-year period of 1986 – 1995, stating: “We have assumed that the average CPUE from 1986 to 1995 corresponds to that which would be attained if the stock were at the level that provides the maximum economic yield,  $B_{MEY}$ . The limit CPUE is 40 % of this CPUE.” (Little et al., 2009, p 234).

For each species, reference years were selected by the RAGs to generate estimates of target catches and target CPUE. In addition, a decision was required as to whether the fishery could be considered as fully developed or otherwise during the reference period or not. Where a fishery was not considered to be fully developed the target CPUE,  $CPUE_{target}$ , was divided by two as a proxy for expected changes to CPUE as the fishery develops and the resource stock size declines towards the assumed proxy target for 48 % unfished biomass.

Little et al. (2009) proposed three rules used to estimate the CPUE target:

1. The CPUE target for stocks fully exploited at or prior to 1986 is based on the average CPUE from 1986-1995.
2. Where fishing exploitation up to 1986 is thought to be minimal, the CPUE determined in Step 1 is halved (to provide a CPUE proxy for  $B_{MEY}$ ).
3. Where fishing exploitation after 1986 is low, the first year in which catches are above 100 t signifies the start of the 10-year period for which CPUE targeted is calculated.



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