The acceptable level of risk for the South African sardine resource

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An acceptable maximum level of risk for the South African sardine resource has been calculated by comparing the depletion of the effective west component spawner biomass from the recent Operating Model being used to develop OMP-18 with the total spawner biomass from previous Operating Models used to develop earlier OMPs. This results in a risk level of approximately 15%. This risk level is higher than that considered acceptable in other countries, but may be argued to be acceptable given the risk to the sardine resource expected even under a no future catch scenario.

OMP-14 Risk

OMP-14 was developed based on an Operating Model (OM) of the sardine (and anchovy) resource conditioned on data up to and including November 2011. The following definitions were used during OMP-14 development:

Risk threshold: the average total sardine 1+ biomass between November 1991 and 1994

Risk definition: the probability that the total sardine 1+ biomass falls below the risk threshold at least once during the projection period of 20 years

Risk level: 21%

The risk threshold and definition remained unchanged from a number of earlier OMPs, based on the understanding that the sardine biomass in the early 1990s had proven sufficient to allow a rebound of the resource, extending even to record abundance levels (de Moor *et al.* 2011). The risk level, however, had adjusted from one OMP to the next to accommodate changes in the understanding of the natural resource dynamics (e.g. an increase in σ_R is an indication that the resource might naturally – without any fishing mortality – fluctuate to lower levels than previously assumed). The "leftward shift" methodology was initially developed to maintain the same level of 'depletion' of the sardine resource between OMPs, despite potential changes in the understanding of the resource dynamics as further data became available and OMs were updated (de Moor *et al*. 2011, de Moor and Butterworth 2008, 2010, 2014). The "leftward shift" method involved maintaining the 20%ile of $B_{final}^{CMP}/B_{final}^{NoCatch}$ to be the same (at 0.68) from one OMP to the next, with (ideally) similar ratios at other lower %iles (Table 1, Figure 1). This ratio was primarily adjusted by 'tuning' the β control parameter in the sardine Harvest Control Rule formula. The distributions were based on total 1+ biomass, and the final projection year obviously changed as new OMPs were developed.

Why the "Leftward Shift" Method Couldn't Be Used Straightforwardly During OMP-18 Development

The sardine OM used to develop OMP-18 was materially different from that used to develop OMP-14 (Table 2). In particular, the updated understanding of the sardine population structure and associated dynamics – particularly with regard to the west component recruitment being the primary contributor to recruitment to the entire population – led to a revision of the risk threshold. The risk threshold was redefined in terms of west component effective spawner biomass as this was the biomass measure – rather than the total (west and south) 1+ biomass as previously used - upon which the

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west component recruitment was modelled to be dependent[1]. The risk definition was also redefined to consider the probability of the risk threshold being breached over the entire projection period rather than the probability of it being breached at least once. This less onerous measure of risk was primarily sought given the current low sardine population size and the subsequently relatively high probability of the risk threshold being breached in the short term, even in the absence of any future fishing effort. The risk threshold and definition for OMP-18 is thus:

Risk threshold: the sardine west component effective spawner biomass in November 2007[2]

Risk definition: the probability that the sardine west component effective spawner biomass falls below the risk threshold over the projection period of 20 years

The "leftward shift" had previously considered the impact of fishing on the total 1+ biomass (Figure 1), which was the same "biomass currency" in which risk was considered. A substantial change in the "biomass currency" in the risk definition due to the updated understanding of the resource dynamics, additionally implied that the impact of fishing on the total 1+ biomass was no longer the primary concern, but rather the primary concern was the impact of fishing on the west component effective spawner biomass. The "leftward shift" for OMP-18 would thus be considered in a different "biomass currency" to that of the previous OMPs.

Draft OMP-18 Risk

In order to progress with the OMP development, the acceptable level of risk was initially obtained by tuning the β control parameter in the OMP-18 sardine harvest control rule formula (without any red flags) until the level of depletion of the total biomass under Draft OMP-18 was similar to the level of depletion of the total 1+ biomass under previous OMPs (Table 3). In other words, β was adjusted until the 20%ile of $B_{final}^{CMP}/B_{final}^{NoCatch}$ was 0.68. After red flags were included (and the β control parameter further adjusted to achieve an acceptably probability that the predicted west component biomass would be less than 150 000t (de Moor 2018)), the resultant maximum risk level for Draft OMP-18 was:

Risk level: 16%[3]

Bridging the Inconsistencies

In order to try to bridge some of the above inconsistencies in the different "biomass currencies", the level of depletion of the total spawner biomass under previous OMPs has been calculated (Cox *et al*. 2018, Table 1b). The same steps as previously used for Draft OMP-18 (de Moor 2018a,b) were then followed to derive a proposed final β control parameter for OMP-18, this time aiming to maintain the same level of 'depletion' between OMPs in the sardine spawner biomass upon which the majority of sardine recruitment is assumed to be dependent:

1) The β control parameter was tuned until the 20%ile of $B_{west,final}^{effsp,CMP}/B_{west,final}^{effsp,NoCatch}$ from Candidate MPs (without any red flags) was 0.60 – the level of projected depletion of the spawner biomass under OMP-08 and OMP-14 (Table 1b). This is called CMP* (with $\beta = 0.139$) below (Table 3).

[1] In terms of any stock recruitment relationship, though noting that the highly variable small pelagic recruitment is well known to depend on other, e.g. environmental factors, and not only or primarily on spawner biomass.

[2] The lowest historically estimated west component effective spawner biomass, assuming 8% of the south component spawner biomass contributes to west component effective spawner biomass.

[3] If the risk definition were in terms of "at least once over the projection period" this probability would be higher.

2) The realistically achievable target of $p(B_{west} < 150)$ was taken to be that achieved when a preventative red flag of 50% TAC reduction was implemented and β was increased until the average & median catches were similar to that without any red flag[4]. The realistically achievable target is thus $p(B_{west} < 150) = 0.110$ (Table 4).
3) Applying the already selected preventative red flag[5], and retuning β until $p(B_{west} < 150) = 0.110$ gives a control parameter for OMP-18 of $\beta = 0.124$ (Table 4, labelled CMP**).
4) Applying the already selected penalty/benefit red flag[6] with $\beta = 0.124$ gives a final projected risk level of 0.153 for CMP#.

How Does this Compare Internationally

Managing the South African sardine resource under CMP#, with $\beta = 0.124$ would mean that on average the west component effective spawner biomass is projected to be below the lowest historical level (i.e. the risk threshold or B^{sp}_{lim}) 15% of the projection period. This risk level equates to the ICES "Risk1" (ICES 2013). ICES "Risk3" (ICES 2013) would be the maximum probability (over the projection period) that the west component effective spawner biomass is below the threshold (Table 5). In a stationary situation, the distribution of spawner biomass is the same each year and therefore Risk3 = Risk1. In non-stationary conditions, Risk3 > Risk1 and under CMP# Risk3 is 20% (Table 5). By comparison ICES Management Plans require Risk3 < 5% in order to conform to the Precautionary Approach (ICES 2013).

(The former measure of risk used for OMP-14 and earlier OMPs – with the probability calculated against the number of simulations for which the projected biomass falls below the risk threshold at least once during the projection period - corresponds closer to "Risk2", although the risk threshold used when tuning those OMPs was not equivalent to B_{lim}).

Harvest Strategies developed for implementation within Australian waters must ensure that the stock stays above the limit reference point B_{lim} at least 90% of the time (Dichmont *et al*. 2016, DAWR 2018). B_{lim} is defined as the biomass level where the risk to the stock in terms of recruitment impairment is regarded as unacceptably high, typically taken as 20% of B_0, although more conservative limit reference points may be adopted for less productive stocks and/or for key forage species (DAWR 2018).

In Chile, any TAC may not impose more than a 10% risk on the resource, although a higher risk level has been accepted for some fisheries, including most recently up to 30% for sardine (SUBPESCA 2018). The risk threshold is 50% of SSB0, the level

[4] This was originally based on the idea of using a preventative red flag to conserve the west component biomass without influencing catch.
[5] If the survey estimated sardine biomass west of Cape Agulhas is below the threshold of 100 000t, then at most 40% of the directed sardine TAC is taken west of Cape Agulhas.
[6] The proportion $\acute{p}_y$ of the HCR-calculated TAC that is recommended as final output from OMP-18 begins at 1. In every subsequent year the following readjustment (if any) to this proportion takes place:

i) The proportion is readjusted towards 1, where $\acute{p}_y = 0.2 + 0.8p_{,y-1}$.
ii) If the proportion of the directed sardine TAC taken west of Cape Agulhas in year $y-1$ was greater than or equal to $1.2 \times \left[0.905035 \times \left(1 - exp\left\{-0.416847\left(B^{obs,S}_{west,y-2}/0.70783\right)/TAC_{y-1}\right\}\right)\right]$, then $p_y = \acute{p}_y - 0.1$.
iii) Else if the proportion of the directed sardine TAC taken west of Cape Agulhas in year $y-1$ was less than or equal to $\left[0.905035 \times \left(1 - exp\left\{-0.416847\left(B^{obs,S}_{west,y-2}/0.70783\right)/TAC_{y-1}\right\}\right)\right]/1.2$ then $p_y = \acute{p}_y + 0.01$.
iv) Else $p_y = \acute{p}_y$.

of spawner biomass in the absence of catch[7]. Comparatively, CMP# results in a long-term (2027-2036) average 74% chance of west component effective spawner biomass being below 50% west component effective SSB0; there is a 55% chance of this occurring under a no future catch scenario. These methods are, however, currently undergoing review in Chile.

In the USA, the Magnuson-Stevens Fishery Management and Conservation Act recognises that there is a trade-off between conservation and utilization, but conservation takes precedence over minimising impacts on fishing communities (USA Department of Commerce 2007). The Acceptable Biological Catch (ABC) in any one year for a Tier 1 (data-rich) stock - like South African sardine - is 96% of the Overfishing Level[8] (OFL). This reduction is to account for scientific uncertainty and the preferred level of risk aversion to overfishing (Ralson *et al*. 2011, Dichmont *et al*. 2011). The probability of overfishing is taken to be 0.45 for Tier 1 stocks (Ralson *et al*. 2011). A stock is considered to be in an overfished state if it is below the Minimum Stock Size Threshold (MSST), where $0.5B_{MSY} \leq MSST \leq B_{MSY}$. The Annual Catch Level (ACL) is then set to a level below (or equal to) the ABC to reflect social, economic and other ecological factors as well as increasing the rate at which overfished stocks rebuild to the target biomass (Dichmont *et al*. 2016). While risk is considered in lowing the catch level from that corresponding to F_{MSY}, it appears the USA does not routinely consider the risk of a stock falling below a limit reference point. However, should a stock fall below $0.5B_{MSY}$ a rebuilding plan is initiated, in which the minimum time to rebuild to B_{MSY} with a 50% probability is considered that possible under F=0 and the maximum time to rebuild is 10 years (if T_{min}<10) or T_{min} + 1 generation time for that species.

Japan has also considered the risk of a stock reducing to an undesirable level (taken as B_{lim} when recruitment may be impaired) when developing and selecting Harvest Control Rules (Ohshimo and Yamakawa 2018). This risk is to be minimised, but there has been no prescribed maximum acceptable risk level (Kurota pers comm.). The most recent evaluated risk for the two Japanese sardine stocks was 0-3% (http://abchan.fra.go.jp/digests2018/index.html). Japanese fishery management is undergoing some change, with B_{ban} being defined as a biomass threshold with 'seriously bad recruitment' associated with a fishing ban and B_{lim} being defined as a biomass threshold with 'moderately bad recruitment' (Okamura pers comm.).

Dynamic B_0

The most recent sardine assessment was conditioned on data up to November 2015. Projecting forward, the baseline median west component effective spawner biomass under CMP# would have been 18% of B_0 in 2016, 21% of B_0 in 2017 and 28% of B_0 in 2018. However, based on the November 2018 hydroacoustic survey, de Moor (2019) indicates a substantially poorer status in November 2018.

The "leftward shift" method applied above is, in part, based on the idea of considering the impact of harvesting in the context of what could be expected under a no catch scenario. This idea also partially underlies the reason some harvest impacts are considered against a 'dynamic B_0' – in which the reference level (B_0) is calculated under the prevailing

[7] For some fisheries (including sardine) this level was calculated based on a historical period in which SSB was approximately in equilibrium, taking into account the fishing mortality over that period (SUBPESCA 2015).

[8] OFL is the catch that corresponds to F_{MSY} or a proxy thereof.

environmental conditions – since for some resources B_0 may not be stationary, but subject to, for example regime shifts (e.g. MacCall *et al*. 1985, Punt *et al*. 2014).

For South African sardine, the risk to the resource under a no catch scenario is 7%, which could be considered to be high if a risk threshold of 5-10% were to be imposed.

Dynamic B_0 typically considers the B_0 in recent years when setting future quotas or selecting Harvest Strategies (e.g. DAWR 2018). As this is not immediately available for South African sardine, Table 6 gives an alternative comparison, being the long-term projected effective west component spawner biomass under CMP# as a proportion of that under the baseline no catch scenario.

In Summary

- Applying the "leftward shift" method in comparing the final year depletion of total single stock spawner biomass under OMP-14 to the west component effective spawner biomass under OMP-18 would result in CMP# with $\beta = 0.124$ with an associated probability of the west component effective spawner biomass falling below the lowest historical level of 15.3%.
- This level of risk is higher than that typically considered acceptable in other countries (being 5-10%).
- The long-term west component effective spawner biomass under CMP# has a 95% probability of being at least 45% of that under a no catch scenario and a 90% probability of being at least 50% of that under a no catch scenario.

References

Cox S, Gaichas S, Haddon M and Punt AE. 2018. International Review Panel Report for the 2018 International Fisheries Stock Assessment Workshop, 26-30 November 2018. Document MARAM/IWS/2018/GEN/05.

Cunningham CL and Butterworth DS. 2007. Base Case Assessment of the South African Sardine Resource. Marine and Coastal Management Document MCM/2007/SEP/SWG-PEL/06.

DAWR 2018. Guidelines for the Implementation of the Commonwealth Fisheries Harvest Strategy Policy. Department of Agriculture and Water Resources, Canberra, June 2018. Available at www.agriculture.gov.au/publications

de Moor CL. 2018. Further results towards finalising HCRs for OMP-18. DAFF: Branch Fisheries Document FISHERIES/2018/NOV/SWG-PEL/36.

de Moor CL. 2019. Is OMP-18 robust to alternative assumptions about anchovy dynamics? DAFF: Branch Fisheries Document FISHERIES/2019/JUL/SWG-PEL/17.

de Moor CL and Butterworth DS. 2008. OMP-08. Marine and Coastal Management Document MCM/2008/SWG-PEL/23.

de Moor CL and Butterworth DS. 2009. The 2004 re-assessment of the South African sardine and anchovy populations to take account of revisions to earlier data and recent record abundances. *African Journal of Marine Science* 31:333-348.

de Moor CL and Butterworth DS. 2010. Items to be considered in the development of an updated management procedure for the South African pelagic fishery (OMP-12). MARAM International Stock Assessment Workshop, 29 November – 3 December 2010, Cape Town. Document MARAM IWS/DEC10/S/P1.

de Moor CL and Butterworth DS. 2013. The simulation testing framework used during the development of OMP-13. DAFF: Branch Fisheries Document FISHERIES/2013/OCT/SWG-PEL/26.

de Moor CL and Butterworth DS. 2014. OMP-14. DAFF: Branch Fisheries Document FISHERIES/2014/DEC/SWG-PEL/60.

de Moor CL and Butterworth DS. 2015. Assessing the South African sardine resource: two stocks rather than one? *African Journal of Marine Science* 37:41-51.

de Moor CL and Butterworth DS. 2016a. Chapter 11: Incorporating technological interactions in a joint management procedure for South African sardine and anchovy. *In* Edwards CTT and Dankel DJ (Eds). *Management Science in Fisheries: An Introduction to simulation-based methods*. Routledge p205-231.

de Moor CL and Butterworth DS. 2016b. Assessment of the South African sardine resource using data from 1984-2015: Results at the joint posterior mode for the two mixing-stock hypothesis. DAFF: Branch Fisheries Document FISHERIES/2016/JUL/SWG-PEL/22REV2.

de Moor CL, Butterworth DS and De Oliveira JAA. 2011. Is the management procedure approach equipped to handle short-lived pelagic species with their boom and bust dynamics? The case of the South African fishery for sardine and anchovy. *ICES Journal of Marine Science* 68:2075-2085.

Dichmont CM, Punt AE, Dowling N, De Oliveira JAA, Little LR, Sporcic M, Fulton E, Gorton R, Klaer N, Haddon M and Smith DC. 2016. Is risk consistent across tier-based harvest control rule management systems? A comparison of four case-studies. *Fish and Fisheries*. 17:731-747.

MacCall AD, Klingbeil RA and Method RD. 1985. Recent increased abundance and potential productivity of Pacific mackerel (*Scomber japonicus*). CalCOFI Report 26:119-129.

Ohshimo S and Yamakawa T. 2018. Harvest Control Rules. Chapter 11. Fish Population Dynamics, Monitoring, and Management. Sustainable Fisheries in the Eternal Ocean. Eds: Aoki I, Yamakawa T, Takasuka A. Springer Japan KK and the Japanese Society of Fisheries Science.

Punt AE, A'mar T, Bond NA, Butterworth DS, de Moor CL, De Oliveira JAA, Haltuch MA, Hallowed AB and Szuwalski C. 2014. Fisheries management under climate and environmental uncertainty: control rules and performance simulation. *ICES Journal of Marine Science* 71:2208-2220.

SUBPESCA 2015. Puntos Biológicos de Referencia. Comité Científico Técnico Pesquerías de Pequenos Pelagicos. 42pp.

SUBPESCA 2018. Informe Técnico CCTPP 5/2018, II parte. Sexta sesión del Comité Científico Técnico de Pesquerías de Pequenos Pelágicos, ano 2018. 36p.

USA Department of Commerce. 2007. Magnuson-Stevens Fishery Conservation and Management Act as Amended Through January 12, 2007.

Table 1a. The ratio of the lower percentiles of the distribution of sardine total 1+ biomass at the end of the projection period under OMP-04, OMP-08 and OMP-14 to that under a no future catch scenario.

	OMP-04	OMP-08	OMP-14
Maximum level of sardine risk under OMP	0.098 <0.1	0.178 <0.18	0.209 <0.21
10%ile	0.49	0.50	0.59
20%ile	0.65[9]	0.68	0.68
30%ile	0.67	0.72	0.73
40%ile	0.69	0.73	0.76
50%ile	0.68	0.72	0.78

[9] During the development of OMP-08, the depletion ratios considered from OMP-04 were based on only 500 samples from the posterior distribution giving ratios of 0.59, 0.68, 0.69, 0.71 and 0.72 at the 10, 20, 30, 40 and 50%iles, respectively.

Table 1b. The ratio of the lower percentiles of the distribution of sardine spawner[10] biomass at the end of the projection period under OMP-04, OMP-08 and OMP-14 to that under a no future catch scenario.

	OMP-04	OMP-08	OMP-14
10%ile	0.49	0.46	0.51
20%ile	0.65	0.60	0.60
30%ile	0.67	0.65	0.63
40%ile	0.69	0.66	0.69
50%ile	0.68	0.66	0.69

Table 2. The differences in some key assumptions in the baseline sardine OM underlying the development of OMP-14 to that of OMP-18.

	OMP-14 (de Moor and Butterworth 2015)	OMP-18 (de Moor and Butterworth 2016)
Population structure	Single homogenous population	Two mixing stocks
Spawner biomass	2+ biomass	Maturity-at-length ogive
	Weight-at-age	Weight-at-length
Survey trawl selectivity	Three levels, with reduced availability at smaller and larger lengths	Logistic (allowing for some escapement of smaller fish)
Commercial selectivity	Time-invariant with 'inverted lognormal' distribution at larger lengths	Estimated separately for 4 time periods with logistic distribution at larger lengths
Bycatch	No observation error for bycatch	$F_{bycatch}$ estimated
Prior(Nov acoutic bias)	$k_{ac}^S \sim N(0.714, 0.077^2)$	$ln(k_{ac}^S) \sim N(-0.310, 0.094^2)$
Von-Bertalanffy growth parameters	Estimate κx L_∞ and L_∞	Estimate L_1 and L_3
t_0	Time invariant	Varies annually

Table 3. The ratio of the lower percentiles of the distribution of sardine west component effective spawner biomass at the end of the projection period under alternative CMPs to that under a no future catch scenario.

	Draft OMP-18 without red flags		CMP*	CMP[#]
Sardine risk	0.182[11]	0.166	0.166[12]	0.153
β	0.175	0.138	0.139	0.124
10%ile	0.50	0.55	0.55	0.59
20%ile	0.56	0.61	0.60	0.64
30%ile	0.57	0.61	0.61	0.65
40%ile	0.58	0.63	0.63	0.66
50%ile	0.62	0.65	0.65	0.68

[10] Sardine spawner biomass was calculated in the OM underlying OMP-04 to be 1+ biomass (de Moor and Butterworth 2009, de Moor *et al.* 2011), and in the OM underlying OMP-08 (Cunningham and Butterworth 2007, de Moor and Butterworth 2016) and OMP-14 (de Moor and Butterworth 2013, 2015) to be 2+ biomass.
[11] $\alpha = 1.313$ with $Risk_A = 0.134$ using previous anchovy baseline OM (de Moor 2018).
[12] $\alpha = 1.16$ with $Risk_A = 0.089$ using revised anchovy baseline OM (de Moor 2019).

Table 4. Summary performance statistics for CMP*, CMP* with preventative red flags if the survey estimated sardine biomass west of Cape Agulhas is low (first using a 50% reduction in the TAC to determine the realistically achievable $p(B_w^S < 150)$, and then implementing an explicit spatial management scenario with a maximum of 40% of the TAC taken west of Cape Agulhas) and CMP**. Where appropriate, medians and 90%iles are provided, and for some statistics the means are shown additionally in **bold**. All biomasses are given in thousands of tons. All scenarios assume the proportion of catch taken west of Cape Agulhas during years of implicit spatial management is at least 0.4.

	Corrective Measure once red flag raised:	N/A (CMP*)	Implicit 0.50*TAC	Implicit 0.50*TAC	CMP* with red flag	CMP**
Red Flag at $B_{y-1}^{obs,S} < 100$[13]	β	0.139	0.139	0.149	0.139	0.124
	$Risk_S$	0.166	0.154	0.156	0.160	0.155
	$p(B_w^S < 150)$	0.116	0.108	0.110	0.112	0.110
	C_{tot}^S	**94** 77 [31,200]	**90** 73 [18,200]	**93** 78 [18,200]	**94** 77 [31,200]	**89 70** [31,200]

Table 5. The annual probability that the west component effective spawner biomass is below the risk threshold of the 2007 west component effective spawner biomass level under CMP[#]. The average and maximum over the projection period are also given.

Year	$p(effSSB_{w,y}^S < effSSB_{w,2007}^S)$	
2017	0.203	
2018	0.142	
2019	0.147	
2020	0.158	
2021	0.151	
2022	0.145	
2023	0.146	
2024	0.165	
2025	0.150	
2026	0.143	
2027	0.142	
2028	0.141	
2029	0.152	
2030	0.151	
2031	0.140	
2032	0.143	
2033	0.152	
2034	0.163	
2035	0.161	
2036	0.165	
	Risk1 = average $p(effSSB_{w,y}^S < effSSB_{w,2007}^S)$	Risk3 = max$p(effSSB_{w,y}^S < effSSB_{w,2007}^S)$
All 20 years	0.153	0.203
1st 10 years	0.155	0.203
Last 10 years	0.151	0.165

13 The corrective measure is implemented smoothly over a linear range from full implementation at 110 000t (100 000t – 10%) to no corrective measure at 90 000t (100 000t + 10%).

Table 6. The annual percentiles of the west componnet effective spawner biomass under CMP# compared to that under the baseline no catch scenario.

Year	5%ile	10%ile	median
2027	0.47	0.55	0.69
2028	0.47	0.53	0.69
2029	0.47	0.54	0.70
2030	0.47	0.53	0.70
2031	0.48	0.53	0.70
2032	0.47	0.54	0.69
2033	0.45	0.54	0.69
2034	0.47	0.54	0.70
2035	0.46	0.53	0.70
2036	0.47	0.53[14]	0.70

[14] This is the 10%ile of $B_{west,final}^{effsp,CMP}/B_{west,final}^{effsp,NoCatch}$, while Table 3 gives the 10%ile of $B_{west,final}^{effsp,CMP}$ / 10%ile of $B_{west,final}^{effsp,NoCatch}$.

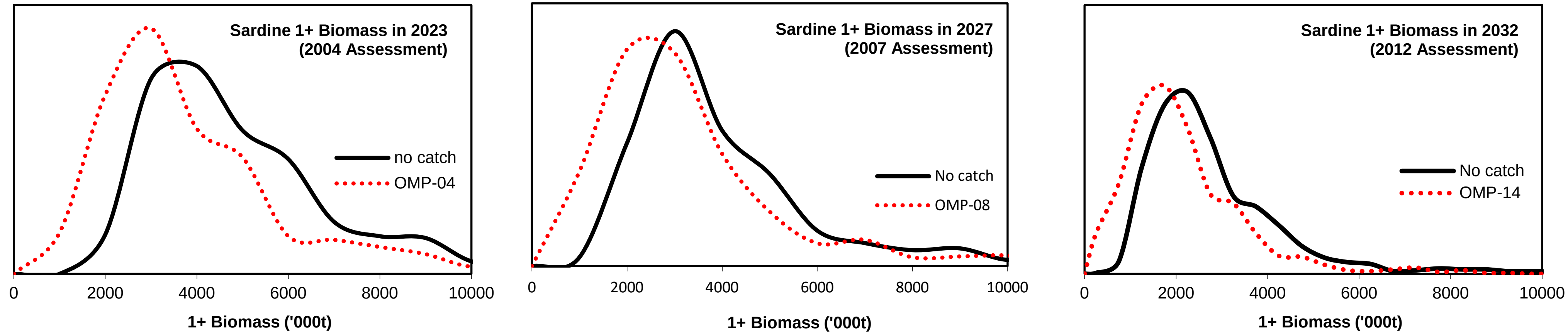

Figure 1. The distribution of total biomass in the final projection year under OMP-04, OMP-08 and OMP-14 compared to that projected using the same OM but assuming no future catches.

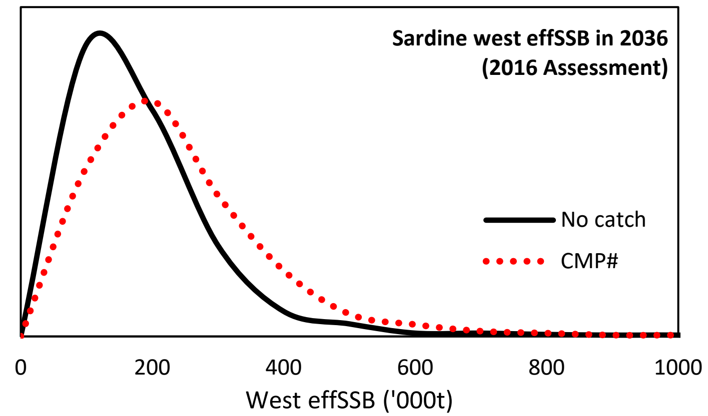

Figure 2. The distribution of west component effective spawner biomass in the final projection year under CMP# compared to that projected under a no catch scenario.