MARAM

Exceptional Circumstances in OMP-04

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Introduction

A revision of the Operational Management Procedure (OMP) to be used for setting South African sardine and anchovy total allowable catches (TACs) and sardine total allowable bycatches (TABs) was adopted by the Marine and Coastal Management Pelagic Working Group in June 2004. This OMP, termed OMP-04, was agreed subject to further testing of the thresholds below which exceptional circumstances are declared and the rules governing the TACs and TABs when exceptional circumstances are declared. This document serves to report on such further testing.

Methods

Sardine

Directed sardine TAC is set at the beginning of the year and remains unchanged for the remainder of the year. In OMP-02 the threshold for invoking exceptional circumstances was 150 000t and the rule governing the implementation of exceptional circumstances was a quadratic function (De Oliveria 2003). Subsequent work by De Oliveria (2003) indicated that the threshold for sardine exceptional circumstances may be more appropriately set at 250 000t.

Two dimensions to the sardine exceptional circumstances needed to be tested: the threshold used to invoke exceptional circumstances and the rule governing the implementation of exceptional circumstances. In the former case, thresholds of $T^S = 0$ (i.e. no exceptional circumstances) 250, 400 and 800 thousand tonnes were tested using the quadratic rule:

If $B^S_{y-1,Nov} < T^S$ then $TAC^S_y = TAC^{S*}_y \left(\dfrac{B^S_{y-1,Nov}}{T^S}\right)^2$. (1)

Further, using the threshold of $T^S = 250$ thousand tonnes, three rules were tested, the first being the quadratic as given in (1) above, the second being linear:

If $B^S_{y-1,Nov} < T^S$ then $TAC^S_y = TAC^{S*}_y \left(\dfrac{B^S_{y-1,Nov}}{T^S}\right)$,

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which effectively implies that the exceptional circumstances only serve to remove any constraints that could hinder the decrease of TAC under poor resource conditions (e.g. minimum directed sardine TAC or maximum proportion by which directed sardine TAC can be decreased annually), and the third being a cubic function:

If $B^S_{y-1,Nov} < T^S$ then $TAC^S_y = TAC^{S*}_y \left(\frac{B^S_{y-1,Nov}}{T^S} \right)^3$.

Anchovy

An initial anchovy TAC is set at the beginning of the year for the 'normal season' and is revised in June, when a TAC for the 'additional season' is also allocated. In OMP-02 the threshold for invoking exceptional circumstances was 400 000t and the rule governing the implementation of exceptional circumstances was a quadratic function (De Oliveria 2003).

As for the sardine exceptional circumstances, two dimensions to the anchovy exceptional circumstances needed to be tested: the threshold used to invoke exceptional circumstances and the rule governing the implementation of exceptional circumstances. However, for anchovy these two dimensions needed to be considered in tandem. The initial anchovy TAC exceptional circumstance rules are given by:

If $\frac{B^A_{y-1,Nov}}{T^A} > 1$ then $TAC^{1,A}_y = TAC^{1,A*}_y$, i.e. no exceptional circumstances apply.

If $x < \frac{B^A_{y-1,Nov}}{T^A} < 1$ then $TAC^{1,A}_y = TAC^{1,A*}_y \left(\frac{B^A_{y-1,Nov}}{T^A} - x \right)^2$.

If $\frac{B^A_{y-1,Nov}}{T^A} < x$ then $TAC^{1,A}_y = 0$.

The revised anchovy TAC exceptional circumstance rules are calculated as follows. We estimate the biomass projected to the forthcoming November survey as

$$B^A_{y,proj} = \left(\frac{B^A_{y-1,Nov} e^{-0.9/4}}{w^A_{y,1}} - C^A_{y,1} \right) e^{-3\times 0.9/4} \overline{w}^A_2 + B^A_{y,proj0},$$

where $$B^A_{y,proj0} = \max \text{ of} \left\{ 0; \left(N^A_{y,rec} - \frac{TAC^{2,A*}_y}{\overline{w}^A_{0c}} - C^A_{y,1} - C^A_{y,0bs} \right) e^{-0.9/2} \overline{w}^A_1 \right\},$$

the recruitment in May back-calculated to November of the previous year as

$$N^{A*}_{y-1,rec0} = (\theta\, e^{0.5(1+t^A_y)0.9/12} + C^A_{y,0bs})\, e^{[5+0.5(1+t^A_y)]0.9/12}$$

and an estimate of the number of recruits in May that would give a biomass of T^A thousand tonnes in the forthcoming November as

$$\theta = \frac{[T^A - (B^A_{y,proj} - B^A_{y,proj0})]\, e^{0.9/2}}{\overline{w}^A_1} + \left(\frac{TAC^{2,A*}_y}{\overline{w}^A_{0c}} - C^A_{y,1} - C^A_{y,0bs} \right).$$

If $B^{A}_{y,proj} < T^{A}$ then exceptional circumstances are declared and applied as follows:

If $$\frac{0.7\dfrac{N^{A}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}}{0.7\dfrac{N^{A*}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}} > 1$$, then $TAC^{2,A}_{y} = \max \text{ of } \{TAC^{1,A}_{y}; TAC^{2,A*}_{y}\}$, i.e. no exceptional circumstances apply, which is consistent with $N^{A}_{y-1,rec0} = N^{A*}_{y-1,rec0}$ when $B^{A}_{y,proj} = 400$.

If $$x < \frac{0.7\dfrac{N^{A}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}}{0.7\dfrac{N^{A*}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}} < 1,$$

$$\text{then } TAC^{2,A}_{y} = \max \text{ of } \left\{ TAC^{1,A}_{y}; TAC^{2,A*}_{y} \left(\frac{0.7\dfrac{N^{A}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}}{0.7\dfrac{N^{A*}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}} - x \right)^{2} \right\}$$

If $$\frac{0.7\dfrac{N^{A}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}}{0.7\dfrac{N^{A*}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + 0.3\dfrac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}}} < x,$$ then $TAC^{2,A}_{y} = \max \text{ of } \{TAC^{1,A}_{y}; 0\}$

The additional season anchovy TAC exceptional circumstance rules are calculated using the above equations, replacing $TAC^{1,A}_{y}$ and $TAC^{2,A}_{y}$ with $TAC^{2,A}_{y}$ and $TAC^{3,A}_{y}$ respectively. In the above equations, x denotes the observed November anchovy biomass fraction of the threshold below which no anchovy TAC will be allocated, and T^{A} denotes the threshold below which exceptional circumstances are declared.

In OMP-02 and the provisionally accepted OMP-04 exceptional circumstance rules, $T^{A} = 400$ and $x = 0$. Attempting a cubic function, as was tested for the sardine exceptional circumstances, did not provide the recovery necessary when anchovy biomass was simulated to reach very low levels. Instead the above rule was tested since it allows for zero catch once anchovy biomass reaches a low percentage of the threshold level, thereby preventing any further industry-induced decline once the resource reaches dangerously low levels. In this document thresholds of 400 and 700 thousand tonnes were tested, together with $x = 0$ and $x = 0.25$. In addition, the exceptional circumstances threshold of $T^{A} = 400$ and rule $x = 0$ was tested on an underlying model of alternative anchovy stock-recruitment assumptions (Cunningham and Butterworth 2004b). The changes to the stock-recruitment parameters from 2005 onwards in fishery management system were:

$a^{A}_{new} = 0.76a^{A}$

$b^{A}_{new} = 0.71b^{A}$

$$\sqrt{0.4^2+\left(\lambda_0^A\right)^2}_{new}=0.87\sqrt{0.4^2+\left(\lambda_0^A\right)^2}$$

$$s_{new,cor}^A=0.65 s_{cor}^A$$

and $$K_{new}^A=a_{new}^A e^{\frac{1}{2}\left(0.4^2+\left(\lambda_0^A\right)^2{}_{new}\right)}\left[\sum_{a=1}^{4}\overline{w}_a^A e^{-M_{ju}^A-(a-1)M_{ad}^A}\right]$$

Results and Discussion

In all tests, the 10 trajectories that resulted in the lowest future true biomass were monitored in order to see the effect of alternative thresholds and rules under exceptional circumstances. In essence, the exceptional circumstances provisions should facilitate avoidance of problems of low resource size that would occur in their absence, while at the same time minimising any deterioration in the catch-related performance of the OMP.

Sardine

The probability density functions (pdf) and cumulative density functions (cdf) for the lowest 10% of future true sardine November biomass trajectories resulting from alternative thresholds for the sardine exceptional circumstances can be seen in Figure 1. Figure 1b indicates that there was little difference in the probability of the resource reaching low biomass levels for choices between $T^S=250$ and $T^S=400$ thousand tonnes. The corresponding cdf for the full sample (not just the lowest 10% as shown in Figure 1) indicates that there is only a 10% probability that, under OMP-04 and a threshold of 250 thousand tonnes, the true sardine biomass will fall below 1 650 000 tonnes in the next two decades (figure not shown). The risk threshold for sardine used in developing OMP-04 was taken to be the average adult sardine biomass between November 1991 and November 1994 (Cunningham and Butterworth 2004a). The mean of this distribution used in the testing of OMP-04 was about 946 thousand tonnes. Table 1 indicates that the true sardine November biomass falls below 950 thousand tonnes between 2 and 3% of the time in future simulations using OMP-04. If only the lowest 10% of the future biomass trajectories are considered, then true sardine November biomass is simulated to drop below 950 thousand tonnes in between 20 and 28% cases (Table 1).

Another consideration is the percentage of occasions that the simulations suggest exceptional circumstances would be declared. Although the aim is to declare exceptional circumstances in sufficient time to prevent any irreparable damage to the resource, if exceptional circumstances are declared too frequently, then the TACs will vary too rapidly for industry to function with stability. Of the thresholds considered, the maximum percentage of times that exceptional circumstances were simulated to be declared was 5% for $T=800$ thousand tonnes, which translates to once in every 20 years on average (Table 1).

Directed sardine catch was estimated to be on average 365.9 thousand tonnes under OMP-04, using the preliminary exceptional circumstances thresholds and rules used in Cunningham and Butterworth (2004c). Given a zero threshold for anchovy exceptional circumstances used when testing the sardine exceptional circumstances, the average directed sardine catch over the next 20 years is simulated to be 365.8 thousand tonnes when $T^S = 250$, with only small adjustments to 365.7 thousand tonnes in the absence of any sardine exceptional circumstances and to 364.3 thousand tonnes if the threshold were increased to 800 thousand tonnes (Table 1). Thus catch-related performance of OMP-04 scarcely differs for these various choices for T^S.

These results indicate that there is little risk of the sardine biomass falling below the average November 1991 to November 1994 biomass (distribution mean 946 thousand tonnes) given the current state of the resource and future management under OMP-04, using a threshold of 250 thousand tonnes. Thus there appears to be little need from an ecosystem point of view to increase the sardine exceptional circumstances threshold beyond 250 thousand tonnes.

Given the high sardine biomass in November 2003, the fishery management system used to simulate OMP-04 predicts little chance of observed sardine biomass falling below 250 thousand tonnes in the next two decades. Figure 2, however, shows the effect on some of the worst-case trajectories under the alternative rules, using $T^S = 250$ thousand tonnes. Figure 2a is an example demonstrating the collapse of the resource in the absence of exceptional circumstances, but increased rates of recovery in linear, quadratic and cubic rules. The quadratic rule, as used in OMP-02 appears to provide for a sufficiently rapid recovery from exceptional circumstances, while the linear rule does not provide for as rapid or as substantial a recovery. Hence there appears to be little reason to change from the quadratic rule.

Anchovy

The probability density functions (pdf) and cumulative density functions (cdf) for the lowest 10% of future true anchovy November biomass trajectories resulting from alternative thresholds and rules for anchovy exceptional circumstances are shown in Figure 3. By considering the high probability accorded to low biomass values under $T^A = 0$, this Figure clearly indicates the need for some form of exceptional circumstance rules for OMP-04. The cumulative probability at low anchovy November biomass levels increases from the higher threshold of $T^A = 700$ to the lower threshold of $T^A = 400$ and from the option of zero catch when observed or projected November biomass is below a quarter of the threshold ($x = 0.25$) to the option of zero catch only once biomass reaches zero ($x = 0$) (Figure 3b). The corresponding cdf for the full sample indicates that there is a 9% probability that anchovy November biomass will fall below 200 thousand tonnes under the case of $T^A = 400$ and $x = 0.25$, which is less than one in every 11 years (Table 2, figure not shown).

The risk threshold for anchovy used in developing OMP-04 was taken to be 10% of the average adult anchovy biomass between November 1984 and November 1999 (Cunningham and Butterworth 2004a). The mean of this distribution used in the testing of OMP-04 was about 118 thousand tonnes. Table 2 indicates that, in the absence of future catch, there is a 2% probability that true anchovy November biomass will fall below 120 thousand tonnes. When OMP-04 is simulated in the absence of any anchovy exceptional circumstances, then this probability increases to 20%. However, when OMP-04 is simulated with the alternative thresholds and rules for exceptional circumstances considered in this document, then the true anchovy November biomass is simulated to fall below 120 thousand tonnes in between 3% and 7% of the cases. If only the lowest 10% of the future biomass trajectories are considered, then true anchovy November biomass is simulated to drop below 120 thousand tonnes in between 15% and 34% of the time (Table 2).

(Doug: I've added a 200 000t comparison as well – does this help from ecosystem point of view or not?)

As for the sardine exceptional circumstances, the percentage of times exceptional circumstances were declared for anchovy given the alternative options, were considered (Table 2). The rule and threshold of $T^A = 400$ and $x = 0$, from OMP-02, resulted in exceptional circumstances being declared 14.8% of the time, or about one in every seven years. This decreases to about one in every eight years for $x = 0.25$. For the higher threshold of $T^A = 700$, exceptional circumstances are simulated to be declared once in every four to five years, which would be too frequent in terms of maintaining stability in the industry.

Anchovy catch was estimated to be on average 300.2 thousand tonnes under OMP-04, using the preliminary exceptional circumstances threshold of $T^A = 400$ and rule (where $x = 0$) used in Cunningham and Butterworth (2004c). Given the lack of sardine exceptional circumstances when testing the anchovy exceptional circumstances here, the average anchovy catch under $T^A = 400$ and $x = 0$ is 304.7 thousand tonnes (Table 2). If the rule is adjusted such that no catch is taken once the observed anchovy November biomass falls below 100 000t, then the average catch increases to 307.3 thousand tonnes. As for sardine, it can be seen that the catch-related performance of OMP-04 doesn't differ greatly between the alternative exceptional circumstance thresholds and rules considered (Table 2).

These results indicate that although the higher threshold of $T^A = 700$ would allow for a smaller probability of anchovy November biomass falling to low levels, this threshold would result in exceptional circumstances being declared too frequently, thereby resulting in a high variability in the annual anchovy TAC. The new option of setting TAC to be zero below a quarter of the threshold results in a more rapid recovery of the resource, thereby resulting in exceptional circumstances being declared less often. In addition, this rule results in a lower probability of anchovy November biomass falling to low levels when compared to the option of $x = 0$ for the same threshold.

In addition to these above results, the effect of these rules on individual anchovy November biomass trajectories, and in particular the trajectories that reach the lowest biomass under the $T^A = 400$ and $x = 0$ case (from OMP-02), should be considered. The ten trajectories that reach the lowest biomass under $T^A = 400$ and $x = 0$ are shown in Figure 4. The trajectories simulated in the absence of any future catch are given for comparison, as are the trajectories simulated using OMP-04, but without any exceptional circumstances rules (i.e., $T^A = 0$). In most of the cases the application of exceptional circumstances rules enables the resource to recover from the decline that would occur in the absence of any exceptional circumstances.

Table 3 indicates the vast improvement in the anchovy biomass level under OMP-04 under the exceptional circumstances using $T^A = 400$ and $x = 0$ (OR $x = 0.25$) in comparison to what would result 5 years after the biomass simulated if no exceptional circumstances rules were implemented dropped below 100 000t. It can also be seen that using a threshold of $T^A = 700$ would, on average, result in a more rapid recovery of the anchovy resource than using a threshold of $T^A = 400$, and that using $x = 0.25$ would, on average, result in a more rapid recover of the resource than using $x = 0$ (Table 3).

I wanted to say here that Figure 5 would demonstrate that the rapid decline and increase possible in future anchovy biomass levels may be due to larger variance in recruitment, but now I don't think we can say that anymore…!

Recommendation

The results presented and discussed in this paper indicate that the quadratic rule previously used for sardine exceptional circumstances in OMP-02 would be sufficient to allow the resource to recover should the sardine spawner biomass be observed to be low. In addition, the threshold of 250 thousand tonnes (which relates to survey estimates), which corresponds in turn to an actual biomass of about 347 thousand tonnes given a bias factor in the November surveys of 0.72, appears to be sufficiently high to allow for exceptional circumstances to be declared prior to irreparable damage being done to the resource. Hence the authors recommend that the sardine exceptional circumstances for OMP-04 remain as:

If $B^S_{y-1,Nov}$ < 250 000 tonnes then $TAC^S_y = TAC^{S*}_y \left(\frac{B^S_{y-1,Nov}}{250}\right)^2$.

The results presented and discussed in this paper indicate that the quadratic rule previously used for anchovy exceptional circumstances in OMP-02 would not be sufficient to allow the resource to recover should the anchovy spawner biomass be observed to be low. Instead, the rule has been extended such that there would be no anchovy TAC once the observed anchovy November biomass falls below a quarter of the threshold. The threshold of 400 thousand tonnes (which relates to survey estimates), which corresponds in turn to an actual biomass of about 286 thousand tonnes given a bias factor in the November surveys of 1.4, appears to be sufficiently high to allow for exceptional circumstances to be declared prior to irreparable damage being done to the resource while at the same time not so high as to result in the declaration of exceptional circumstances too frequently. Hence the authors recommend that the anchovy exceptional circumstances for OMP-04 be changed to:

If $B^A_{y,proj} < 400000$ tonnes then exceptional circumstances are declared and applied as follows:

$$TAC_y^{2,A} = \max \text{ of } \begin{cases} TAC_y^{1,A} ; TAC_y^{2,A*} \left(\dfrac{0.7 \dfrac{N_{y-1,rec0}^{A}}{\overline{N}_{y-1,rec0}^{A}} + 0.3 \dfrac{B_{y-1,Nov}^{A}}{\overline{B}_{Nov}^{A}}}{0.7 \dfrac{N_{y-1,rec0}^{A*}}{\overline{N}_{y-1,rec0}^{A}} + 0.3 \dfrac{B_{y-1,Nov}^{A}}{\overline{B}_{Nov}^{A}}} - 0.25 \right)^2 & \text{if } 0.25 < \dfrac{0.7 \dfrac{N_{y-1,rec0}^{A}}{\overline{N}_{y-1,rec0}^{A}} + 0.3 \dfrac{B_{y-1,Nov}^{A}}{\overline{B}_{Nov}^{A}}}{0.7 \dfrac{N_{y-1,rec0}^{A*}}{\overline{N}_{y-1,rec0}^{A}} + 0.3 \dfrac{B_{y-1,Nov}^{A}}{\overline{B}_{Nov}^{A}}} < 1 \\ TAC_y^{1,A} ; 0 & \text{if } \dfrac{0.7 \dfrac{N_{y-1,rec0}^{A}}{\overline{N}_{y-1,rec0}^{A}} + 0.3 \dfrac{B_{y-1,Nov}^{A}}{\overline{B}_{Nov}^{A}}}{0.7 \dfrac{N_{y-1,rec0}^{A*}}{\overline{N}_{y-1,rec0}^{A}} + 0.3 \dfrac{B_{y-1,Nov}^{A}}{\overline{B}_{Nov}^{A}}} < 0.25 \end{cases}$$

No direct rules exist for the implementation of exceptional circumstances on sardine TAB. However, in the event of exceptional circumstances applying to anchovy, the reduction of the anchovy TAC will cause a reduction in sardine TAB (c.f. equations (A.5), (A.8) and (A.14) of Cunningham and Butterworth (2004c)).

References

Cunningham, C.L., and Butterworth, D.S. 2004a. Risk Re-Definition for OMP-04, given Bayesian Assessment Results. MCM document WG/PEL/MAY04/01.

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Table 1. Statistics indicating the percentage of occasions sardine exceptional circumstances are declared, the average directed sardine catch and the probability of falling below certain levels (including the some 950 thousand tonnes which constitutes the risk threshold in terms of distribution mean) for alternative thresholds for declaring sardine exceptional circumstances.

		$T^S = 0$	$T^S = 250$	$T^S = 400$	$T^S = 800$
Full Distribution	% Times Exceptional Circumstances Declared	0%	0.9%	1.3%	4.7%
	Cumulative probability at 950 000t	0.03	0.03	0.03	0.02
	Cumulative probability at 1 500 000t	0.08	0.08	0.08	0.07
	Cumulative probability at 2 000 000t	0.17	0.17	0.17	0.17
	Average directed sardine catch	365.7	365.8	365.7	364.3
Lowest 10%	Cumulative probability at 950 000t	0.26	0.28	0.26	0.20
	Cumulative probability at 1 500 000t	0.43	0.42	0.42	0.39
	Cumulative probability at 2 000 000t	0.55	0.54	0.54	0.52
	Average directed sardine catch	258.7	258.3	257.2	257.7

Table 2. Statistics indicating the percentage of occasions anchovy exceptional circumstances are declared, the average anchovy catch and the probability of falling below certain levels (including the some 120 thousand tonnes which constitutes the risk threshold in terms of distribution mean) for alternative thresholds for declaring and rules for implementing anchovy exceptional circumstances.

		No Catch	$T^A = 0$	$T^A = 400$ $x = 0$	$T^A = 400$ $x = 0.25$	$T^A = 700$ $x = 0$	$T^A = 700$ $x = 0.25$
Full Distribution	% Times Exceptional Circumstances Declared	1.6%	0%	14.8%	12.7%	21.8%	19.9%
	Cumulative probability at 120 000t	0.02	0.20	0.07	0.05	0.04	0.03
	Cumulative probability at 200 000t	0.03	0.23	0.11	0.07	0.05	0.09
	Average directed sardine catch	0	308.2	304.7#	307.3	306.3	304.7
Lowest 10%	Cumulative probability at 120 000t	0.04	0.60	0.34	0.25	0.22	0.15
	Cumulative probability at 200 000t	0.07	0.62	0.41	0.34	0.30	0.23
	Average directed sardine catch	0	126.5	193.3	207.2	208.2	213.9

Note that this differs from the 300.2 thousand tonnes reported in Cunningham and Butterworth (2004c) since the results in above table were obtained in the absence of exceptional circumstances rules for sardine.

Doug, I'm not sure which you want to use for the comparison – either T=400 with x=0 or x=0.25.

Table 3. The ratio of anchovy November biomass under alternative options to the biomass under the option of $T^A = 400$ *and* $x = 0$, *together with the ratio of biomass under the option of* $T^A = 400$ *and* $x = 0$ *to the biomass under the no exceptional circumstances option, for the 10 trajectories that result in the lowest anchovy biomass under the* $T^A = 400$ *and* $x = 0$ *case. The year chosen for comparison is five years after the trajectory resulting from OMP-04 with no exceptional circumstances has dropped below 100 000t. (Doug – a bit clumsy…?)*

$T^A = 400$, $x = 0$ / $T^A = 0$	$T^A = 400$, $x = 0$ - $T^A = 0$	$T^A = 400$, $x = 0.25$ / $T^A = 400$, $x = 0$	$T^A = 700$, $x = 0$ / $T^A = 400$, $x = 0$	$T^A = 700$, $x = 0.25$ / $T^A = 400$, $x = 0$
2204.07	1.93	4.11	3.10	9.55
9023.89	29.50	1.85	1.76	2.95
9358.39	8.83	1.57	1.66	6.06
60689.10	36.99	10.22	11.09	15.60
19055.46	3.87	1.77	1.67	3.48
155095.71	237.40	1.31	1.71	3.76
31157.67	66.53	1.48	3.69	4.01
422600.07	40.49	3.23	2.44	3.29
8417.48	2.69	1.03	1.02	1.76
110422.04	2092.29	1.78	3.42	3.52

OR

Table 3. The ratio of anchovy November biomass under alternative options to the biomass under the option of $T^A = 400$ *and* $x = 0.25$, *together with the ratio of biomass under the option of* $T^A = 400$ *and* $x = 0.25$ *to the biomass under the no exceptional circumstances option, for the 10 trajectories that result in the lowest anchovy biomass under the* $T^A = 400$ *and* $x = 0$ *case. The year chosen for comparison is five years after the trajectory resulting from OMP-04 with no exceptional circumstances has dropped below 100 000t.*

$T^A = 400$, $x = 0.25$ / $T^A = 0$	$T^A = 400$, $x = 0.25$ - $T^A = 0$	$T^A = 400$, $x = 0$ / $T^A = 400$, $x = 0.25$	$T^A = 700$, $x = 0$ / $T^A = 400$, $x = 0.25$	$T^A = 700$, $x = 0.25$ / $T^A = 400$, $x = 0.25$
9056.56	7.93	0.24	0.76	2.32
16711.78	54.64	0.54	0.95	1.59
14669.60	13.84	0.64	1.06	3.87
620466.04	378.13	0.10	1.08	1.53
33743.89	6.85	0.56	0.94	1.97
203050.89	310.81	0.76	1.31	2.87
46203.59	98.67	0.67	2.49	2.71
1363864.10	130.66	0.31	0.76	1.02
8638.70	2.76	0.97	0.99	1.72
196764.88	3728.34	0.56	1.92	1.97

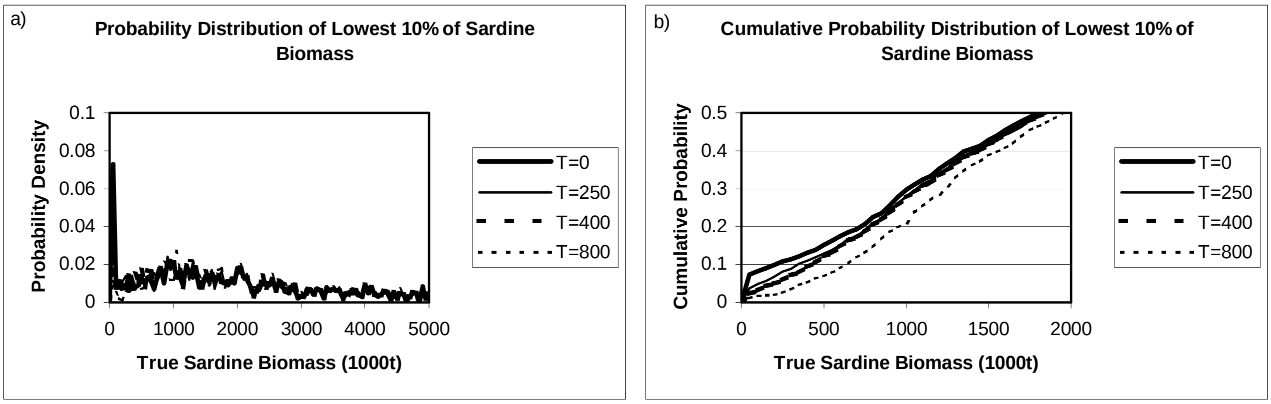

Figure 1. The a) probability density function and b) cumulative probability density function for the lowest 10% of sardine biomass trajectories over the projection period, under alternative thresholds for sardine exceptional circumstances.

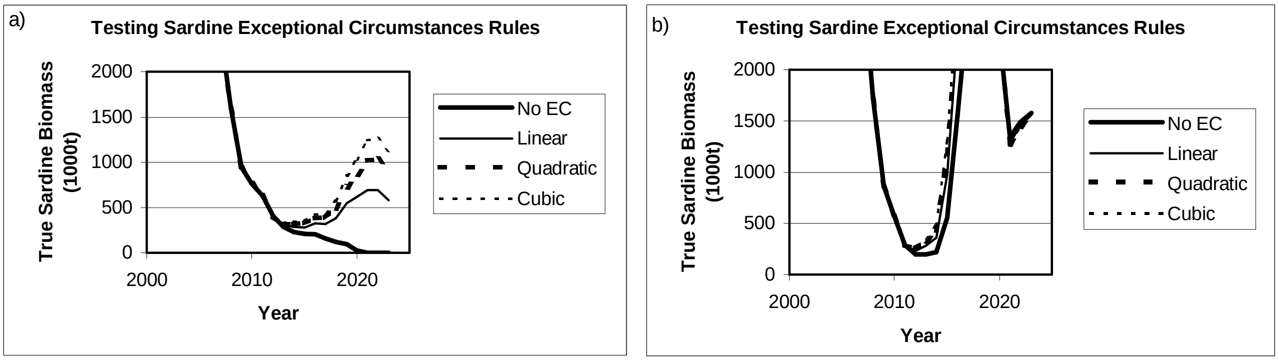

Figure 2. Some future sardine November biomass trajectories, under alternative thresholds for sardine exceptional circumstances.

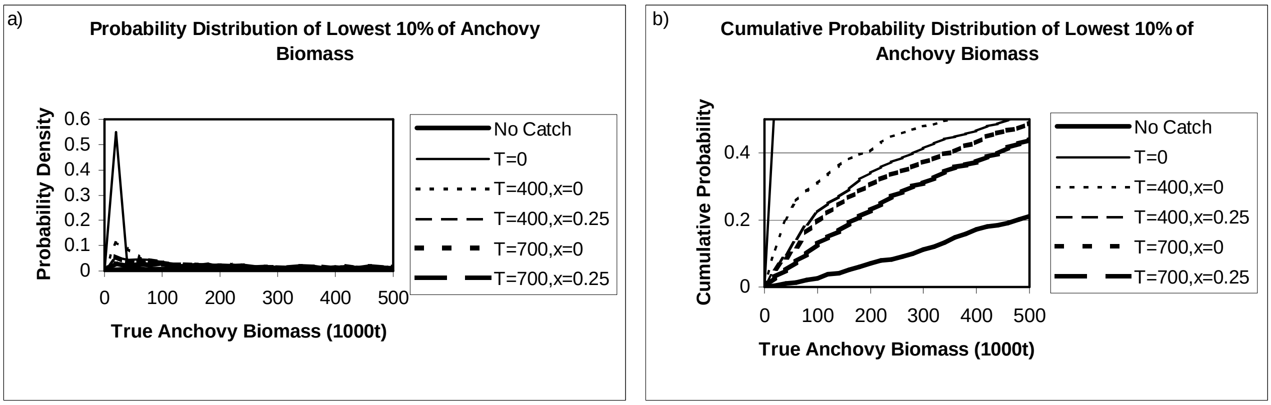

Figure 3. The a) probability density function and b) cumulative probability density function for the lowest 10% of anchovy biomass trajectories over the projection period, under alternative thresholds and rules for anchovy exceptional circumstances.

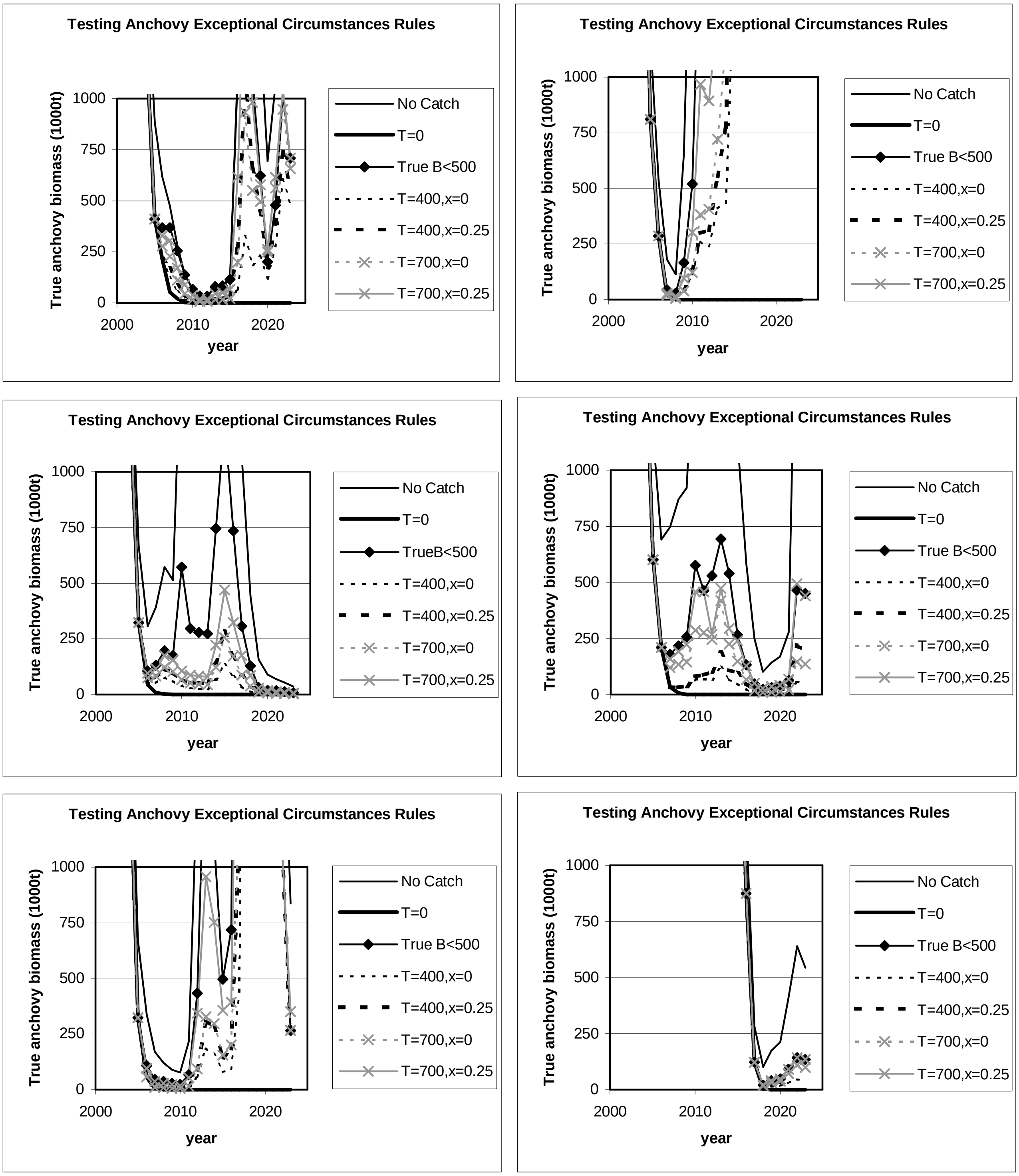

Figure 4. The future anchovy November biomass trajectories which reach the lowest biomass under the exceptional circumstances threshold and rule used in OMP-02, compared to trajectories under alternative anchovy exceptional circumstances thresholds and rules.

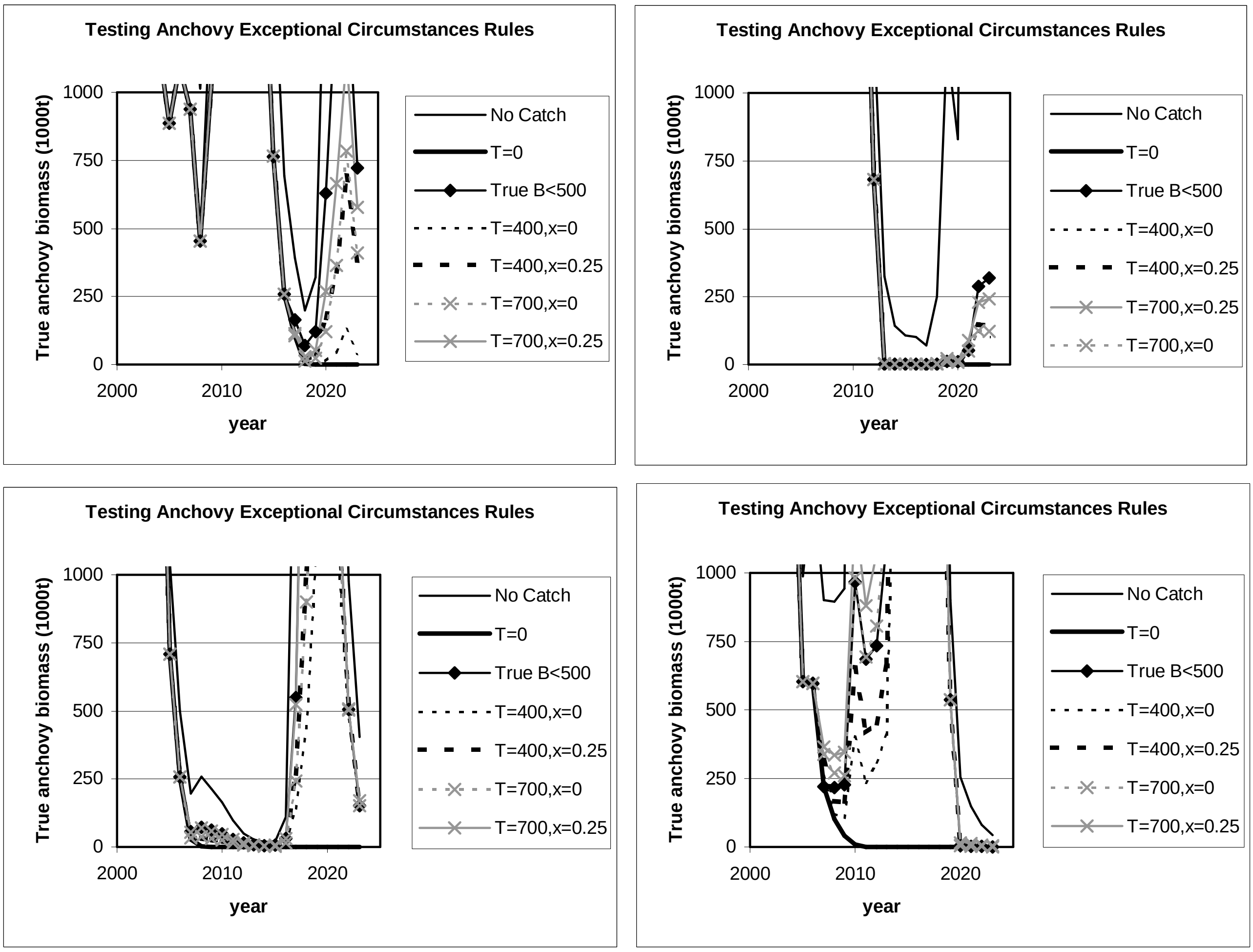

Figure 4 (continued). The future anchovy November biomass trajectories which reach the lowest biomass under the exceptional circumstances threshold and rule used in OMP-02, compared to trajectories under alternative anchovy exceptional circumstances thresholds and rules.

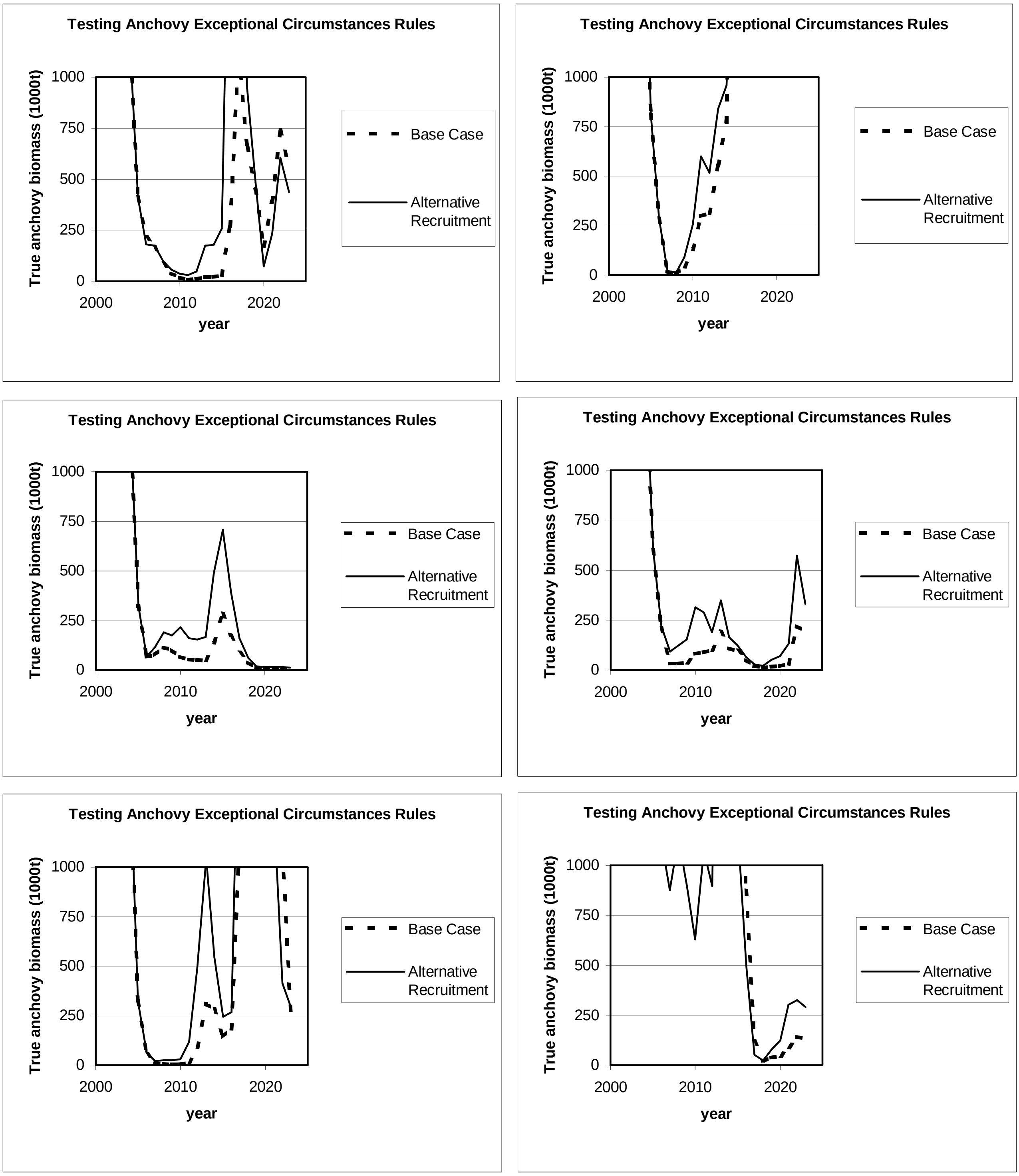

Figure 5. A comparison between the future anchovy November biomass trajectories under the base case exceptional circumstances threshold and rule of $T^A = 400$ *and* $x = 0.25$ *(as in figure 4), and the same trajectory resulting from the alternative anchovy stock-recruitment assumptions.*

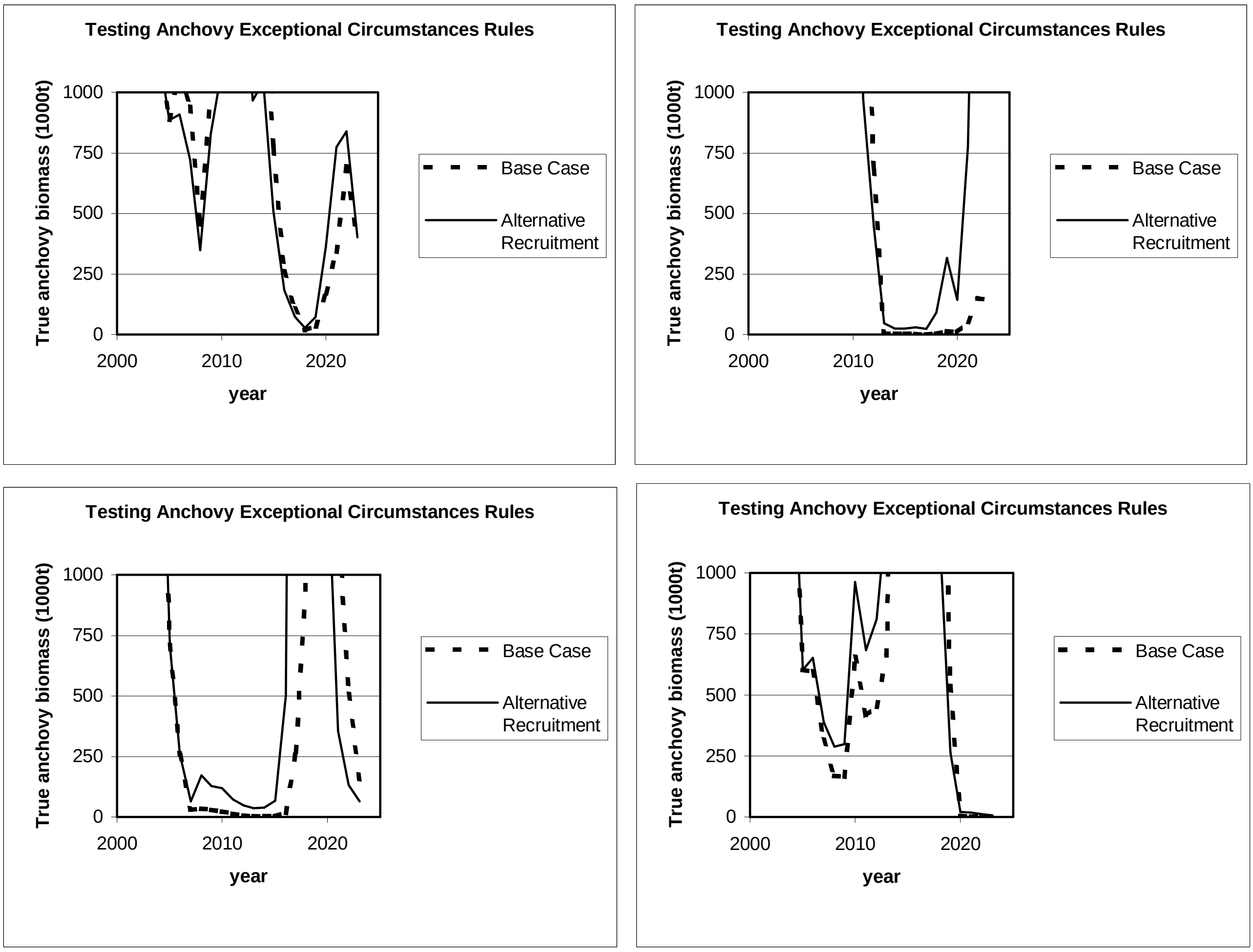

Figure 5 (continued). A comparison between the future anchovy November biomass trajectories under the base case exceptional circumstances threshold and rule of $T^A = 400$ *and* $x = 0.25$ *(as in figure 4), and the same trajectory resulting from the alternative anchovy stock-recruitment assumptions.*