# Alternative hypotheses of two mixing stocks of South African sardine: Some projections assuming no future catch

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## Introduction

This document shows projections of the sardine 1+ biomasses under a no catch scenario for a number of the alternative hypotheses considered by de Moor et al. (2014). The alternatives are summarised again below for ease of reference, together with details of any changes in the simulation testing framework of de Moor and Butterworth (2013).

Projections are shown from the results at the joint posterior mode (even though some of these have not converged, see de Moor et al. (2014)), which thus only incorporate simulated future random error, and from the posterior distributions of a limited number of hypotheses which did converge at the joint posterior mode. Given the limited time available to run MCMC, full convergence diagnostics were not checked for any results presented here. Samples were randomly drawn with resampling from a segment of the chain[123].

For simplicity, the average sardine catch weight at age is kept constant at the baseline values for all hypotheses.

## Alternative Two Stock Hypotheses

*Alternative A (Effective Spawning Biomasses)*

This alternative hypothesis assumes that a portion of the west/south spawning stock biomass (SSB) forms part of the "effective spawning biomass" of the other stock. The hypotheses considered are as follows:

| | |
|---|---|
| Baseline: | 0% of south SSB contributes to effective west SSB |
| | 0% of west SSB contributes to effective south SSB |
| Alt A-1: | **10%** of south SSB contributes to effective west SSB |
| | 0% of west SSB contributes to effective south SSB |
| Alt A-2: | **18%** of south SSB and 100% of west SSB contributes to effective west SSB |
| | 0% of west SSB and **82%** of south SSB contributes to effective south SSB |
| Alt A-3: | **18%** of south SSB and **98%** of west SSB contributes to effective west SSB |
| | **2%** of west SSB and **82%** of south SSB contributes to effective south SSB |

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[1] The chain for A-1 was 25 900 000 long. Samples were drawn after a burn-in of 4000 000 was discarded and the remaining chain thinned at intervals of 1000.

[2] The chain for B-1, B-2 and B-3 were 29 5000 000, 26 900 000 and 27 100 000 long, respectively. Samples were drawn after a burn-in of 5000 000 was discarded and the remaining chain thinned at intervals of 1000.

[3] The chain for D-1 was 27 500 000 long. Samples were drawn after a burn-in of 5000 000 was discarded and the remaining chain thinned at intervals of 1000.

Alt A-4: **10%** of south SSB and **29%** of west SSB contributes to effective west SSB
**0.5%** of west SSB and **46%** of south SSB contributes to effective south SSB

Alt A-5: **13%** of south SSB and **29%** of west SSB contributes to effective west SSB
**0.5%** of west SSB and **59%** of south SSB contributes to effective south SSB

The changes to the operating model (de Moor and Butterworth 2013) are as follows:

Given the spawning stock biomass:

$$SSB^S_{j,y} = \sum_{a=2}^{5+} N^S_{j,y,a} w^S_{j,y,a} \qquad y = y_1, \ldots, y_n \qquad (1)$$

the effective spawning stock biomass is calculated as:

$$SSB^{eff\ S}_{1,y} = SSB_{w\_w} \times SSB^S_{1,y} + SSB_{s\_w} \times SSB^S_{2,y}$$

$$SSB^{eff\ S}_{1,y} = SSB_{w\_s} \times SSB^S_{1,y} + SSB_{s\_s} \times SSB^S_{2,y}$$

and the recruitment is related to the effective rather than actual spawning stock biomass as follows:

$$N^S_{j,y,0} = f\left(SSB^{eff\ S}_{j,y}\right) e^{\varepsilon^S_{j,y}} \qquad y = y_1, \ldots, y_n \qquad (2)$$

Here:

$N^S_{j,y,a}$ is the model predicted number (in billions) of sardine of age *a* at the beginning of November in year $y$ of stock $j$;

$w^S_{j,y,a}$ is the mean mass (in grams) of sardine of age *a* of stock $j$ sampled during the November survey of year *y*;

$SSB_{w\_w}$ is the proportion of the west SSB contributing to the effective west SSB;

$SSB_{w\_s}$ is the proportion of the west SSB contributing to the effective south SSB;

$SSB_{s\_w}$ is the proportion of the south SSB contributing to the effective west SSB;

$SSB_{s\_s}$ is the proportion of the south SSB contributing to the effective south SSB;

$f(\ )$ denotes the assumed stock-recruitment relationship; and

$\varepsilon^S_{j,y}$ is the annual lognormal deviation of sardine recruitment.

*Alternative B (Varied Recruit Distributions)*

In this hypothesis, the recruits surveyed west of Cape Infanta thus consist of west stock recruits and a portion of south stock recruits. For simplicity as an initial test, it is assumed that these south stock recruits surveyed west of Cape Infanta are not caught west of Cape Agulhas. The alternatives tested are:

Baseline: 0% of south stock recruits distributed west of Cape Infanta at the time of the survey

Alt B-1: **10%** of south stock recruits distributed west of Cape Infanta at the time of the survey

Alt B-2: **20%** of south stock recruits distributed west of Cape Infanta at the time of the survey

Alt B-3: **50%** of south stock recruits distributed west of Cape Infanta at the time of the survey

The changes to the model (de Moor and Butterworth 2013) are as follows:

$$N'^{S,obs}_{1,y,r} = k^S_{j,r}\left(N^{S,pred}_{1,y,r} + obs \times N^{S,pred}_{2,y,r}\right)e^{\varepsilon^S_{1,y,rec}}$$

$$N'^{S,obs}_{2,y,r} = k^S_{j,r}\left((1-obs)\times N^{S,pred}_{2,y,r}\right)e^{\varepsilon^S_{2,y,rec}} \qquad (3)$$

Here:

$N^{S,pred}_{j,y,r}$ is the model predicted number (in billions) of juvenile sardine of stock $j$ at the time of the recruit survey in year $y$; and

$k^S_{j,r}$ is the constant of proportionality (multiplicative bias) between survey estimated and model predicted 1+ biomass, drawn from posterior distributions estimated by the operating models; and

$obs$ is the time-invariant proportion of south stock recruits surveyed west of Cape Infanta.

The errors, $\varepsilon^S_{j.y.rec}$, are calculated in the same manner as before (de Moor and Butterworth 2013). de Moor and Butterworth (2013) took account of both the estimated stock-recruitment relationship, with autocorrelated error and the survey estimate of recruitment west of Cape Infanta 2012 when calculating the November 2011 model predicted west stock recruitment. As there was no survey estimate of recruitment east of Cape Infanta in 2012, only the stock-recruitment relationship and autocorrelated error was used to calculate south stock recruitment in November 2011. Due to the mix in the recruitment assumed surveyed west of Cape Infanta under these hypotheses, it was decided to simply calculate the November 2011 recruitment for both the west and south stocks from the stock recruitment relationships. For comparative purposes, therefore, the baseline results shown with Alternative B has been re-run without the information of recruitment west of Cape Agulhas in May 2012.

*Alternative D (Varied Adult Movement)*

This hypothesis assumes some adult west stock sardine migrate to the south stock in addition to the recruits which are modelled to migrate in the November in which they become 1 year olds. The alternatives tested are:

<u>Baseline:</u> Only west stock recruits migrate to the south stock as they turn 1 year old. The proportion migrating is estimated annually from 1994.

<u>D-1:</u> West stock recruits **and 1 year olds** migrate to the south stock as they turn 1 and 2 years old, respectively. The age-independent proportion migrating is estimated annually from 1994.

<u>D-2:</u> West stock sardine of **all ages** migrate to the south stock. The age-independent proportion migrating is estimated annually from 1994.

<u>D-3:</u> West stock recruits **and 1 year olds** migrate to the south stock as they turn 1 and 2 years old, respectively. The proportion migrating is estimated annually from 1994, and the **proportion of 1 year olds is assumed to be half that of the recruits**.

<u>D-4:</u> West stock sardine of **all ages** migrate to the south stock. The proportion migrating is estimated annually from 1994, and the **proportion of adults migrating is assumed to be half that of the recruits**.

**Results and Discussion**

*Alternative A (Effective Spawning Biomasses)*

Figure 1 shows the different model predicted 1+ biomasses for the west and south stocks from results at the joint posterior mode, under the movement hypothesis *MoveAutoC*, while Figure 2 compares the medians of the future projections between the alternative “A” hypotheses. These indicate a faster growth of the 1+ biomass in the short term under A-2 to A-5. The 1+ biomass after 20 years is projected to be 10-20% higher under A-2 to A-5 compared to the baseline and 25% higher under A-1.

Figures 3 and 4 are a repeat of Figures 1 and 2, but for the movement hypothesis *NoMove*, showing little difference between the alternative “A” hypotheses in the south stock projections, but a lower plateau in the increase of west stock 1+ biomass under A-2 to A-5 compared to the Baseline and A-1.

The trajectories based on the posterior distributions show a similar pattern, although the differences between the Baseline and A-1 are smaller for *MoveAutoC* and larger for *NoMove*. Unfortunately, since A-2 to A-5 did not converge at the joint posterior mode, trajectories from posterior distributions of these hypotheses cannot be shown. Thus, although de Moor et al. (2014) suggested A-3 to A-5 would be preferred *a priori* to A-1 and A-2, we cannot currently conclude whether the differences between the Baseline and A-2 to A-5 would be of large consequence.

*Alternative B (Varied Recruit Distributions)*

There is little difference between the model predicted future 1+ biomass of the baseline and Alternative “B” hypotheses from projections from the joint posterior mode (Figures 9, 10, 13, 14). The difference is larger for projections are based on results from the posterior distributions (Figures 11, 12, 15, 16). The recovery of the sardine is slower under B-1 to B-3 compared to the baseline for *MoveAutoC*. The median west stock 1+ biomass at the end of the projection years is 76% (54%) of the Baseline for B-2 (B-3), while the median south stock 1+ biomass at the end of the projection years is 91% (82%) of the Baseline for B-2 (B-3). Recall, however, that de Moor et al. (2014) considered B-3 to be an extreme.

*Alternative D (Varied Adult Movement)*

The projected 1+ biomasses are worse under the alternative “D” hypotheses than the Baseline (Figures 17, 18, 21, 22) for *MoveAutoC*. This may be because even though the proportion moving may be lower than the Baseline, the number of fish moving is higher. Under the *NoMove* hypothesis, the west stock 1+ biomass for D-1 plateaus at a higher level (Figures 19, 20, 23, 24) given the higher west stock carrying capacity for D-1 compared to the Baseline and D-2 to D-4.

**References**

de Moor, C.L. and Butterworth, D.S. 2013. The simulation testing framework used during the development of OMP-13. DAFF Branch Fisheries document FISHERIES/2013/OCT/SWG-PEL/26. 27pp.

de Moor, C.L., Butterworth, D.S., van der Lingen C.D., and Coetzee J.C. 2014. Alternative hypotheses of two mixing stocks of South African sardine: Initial testing. MARAM International Stock Assessment Workshop Report No MARAM/IWS/DEC14/Sardine/P2. 20pp.

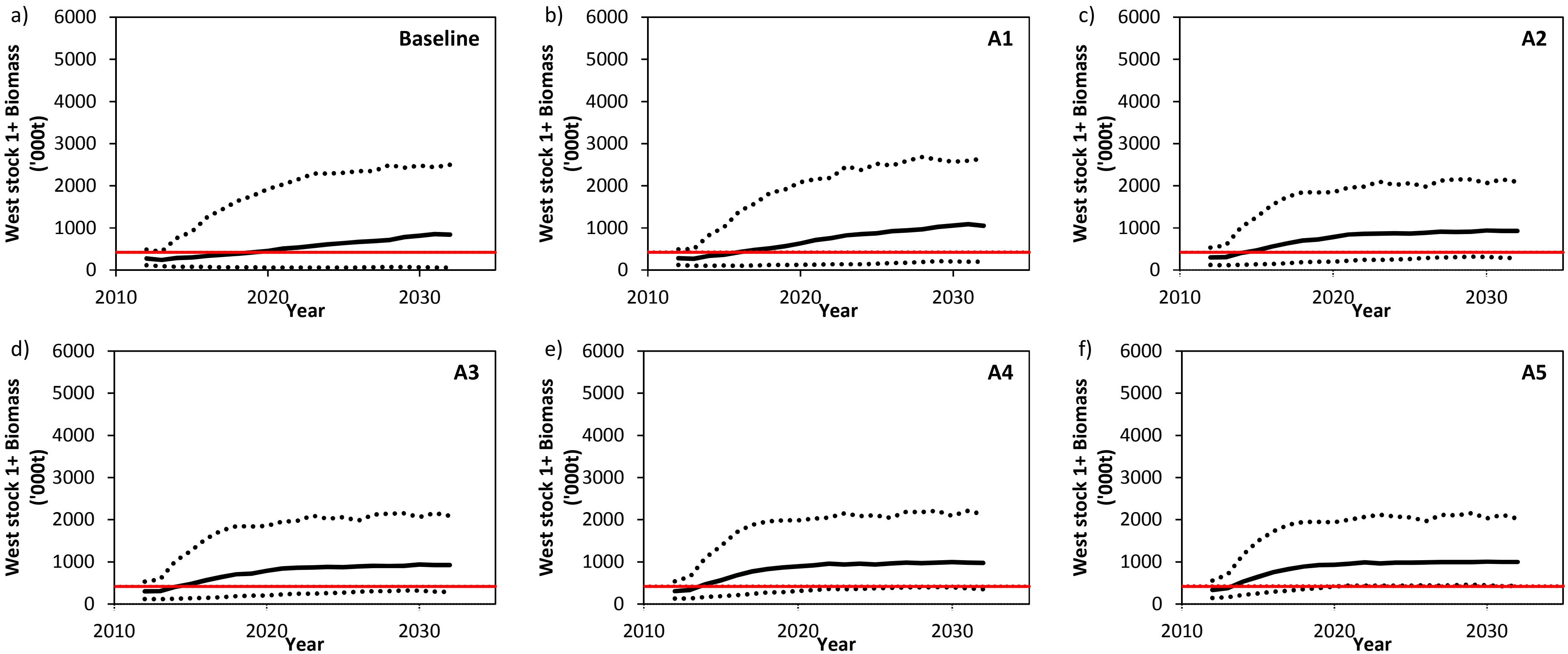


**Figure 1a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **joint posterior mode**.

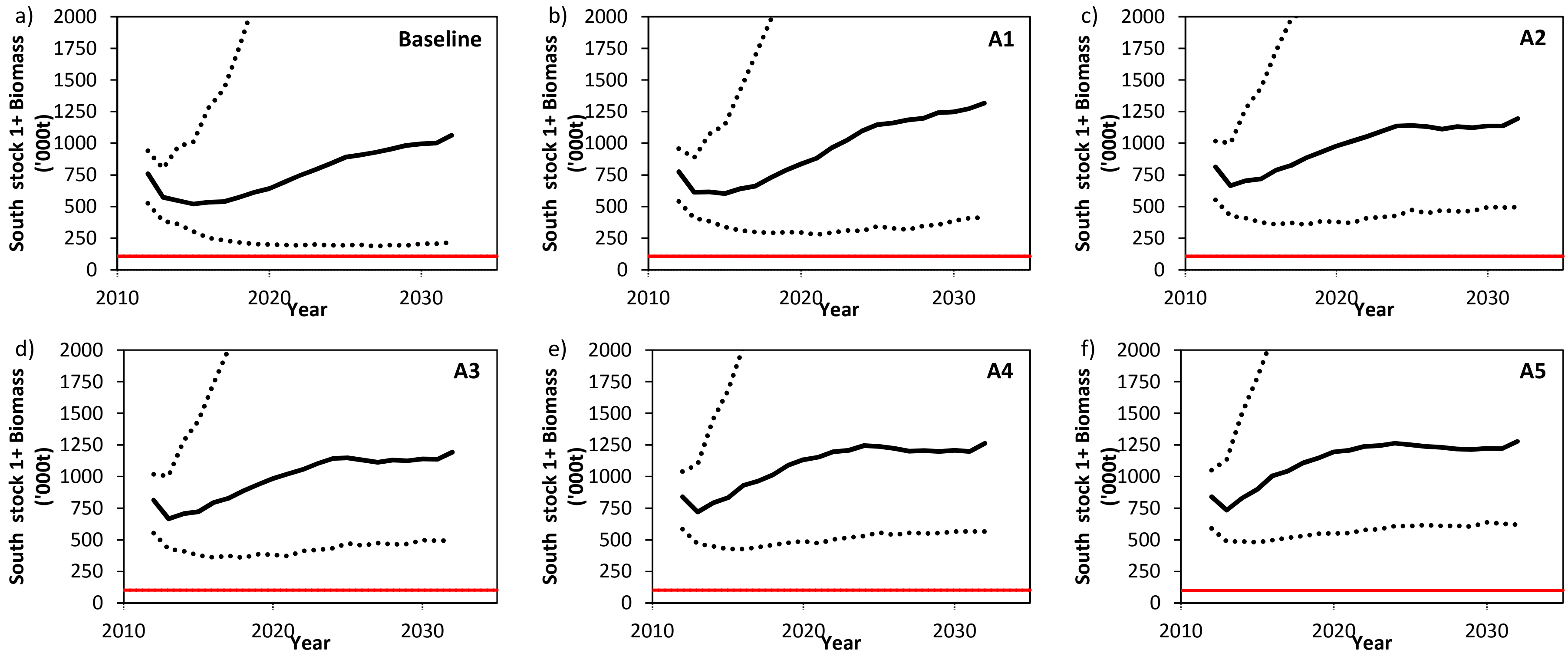


**Figure 1b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **joint posterior mode**.

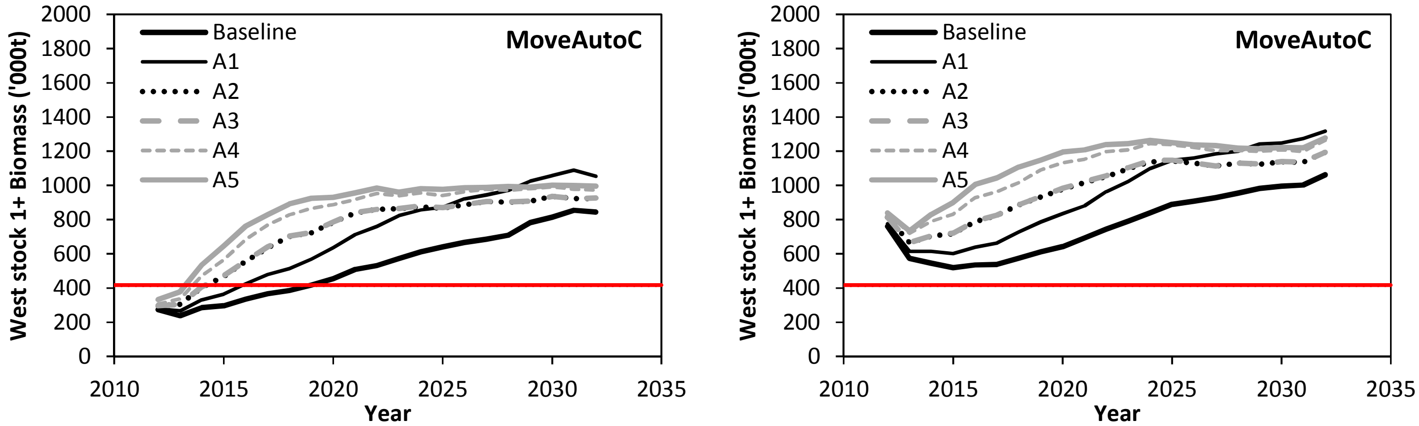


**Figure 2.** The median probability intervals from Figure 1.

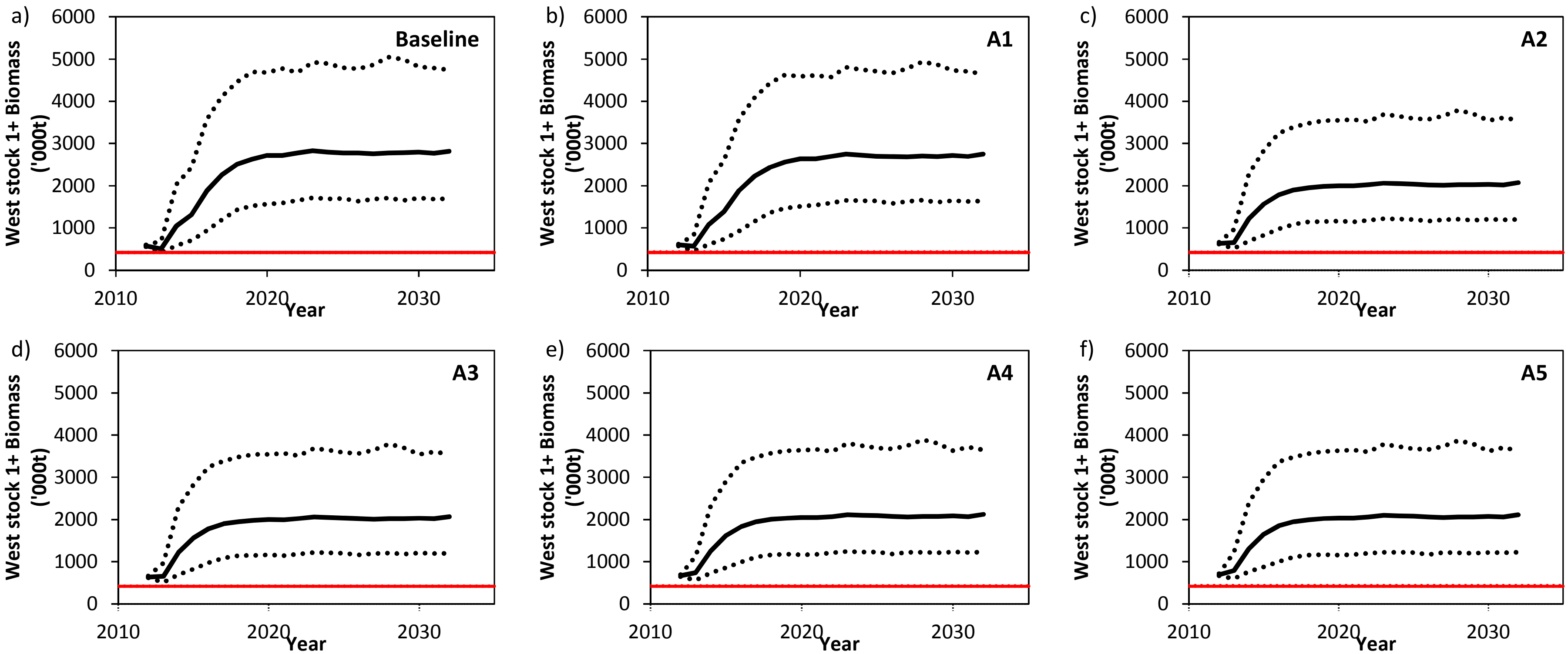


**Figure 3a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **joint posterior mode**.

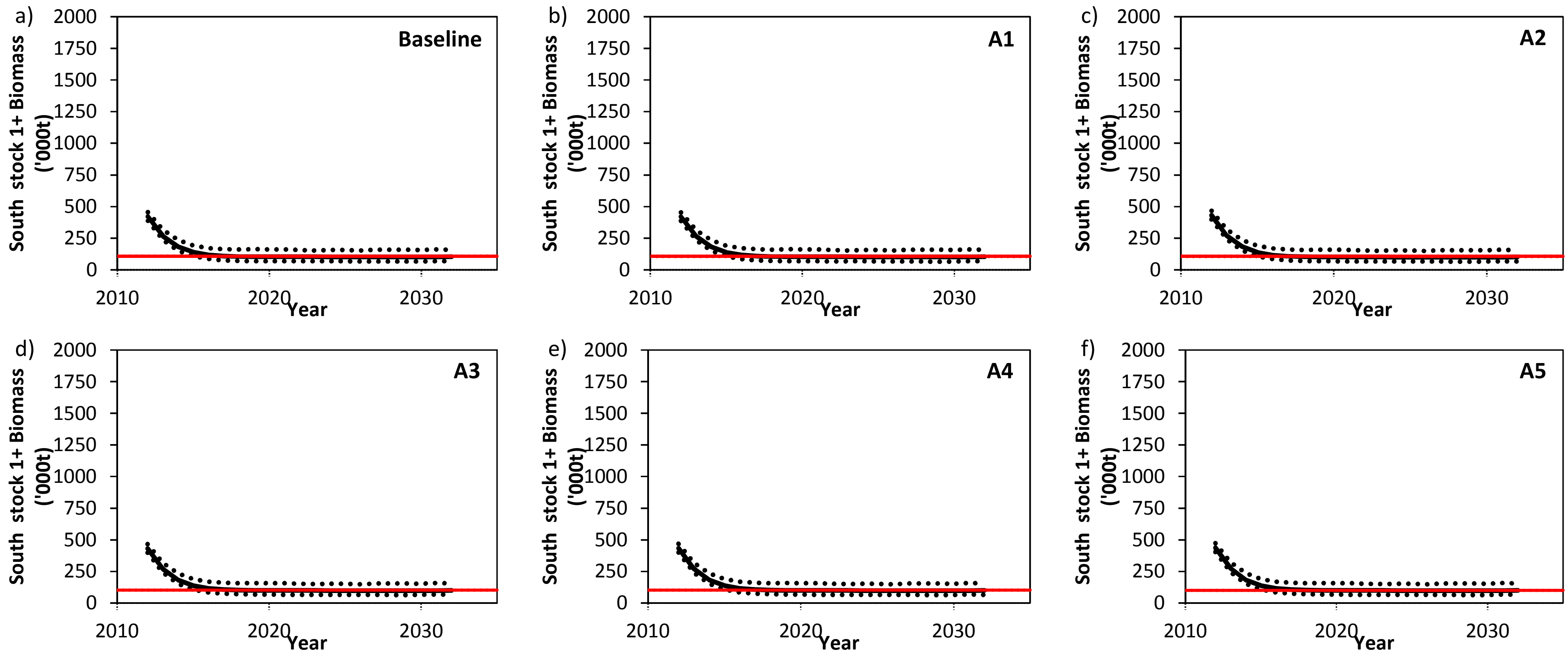


**Figure 3b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **joint posterior mode**.

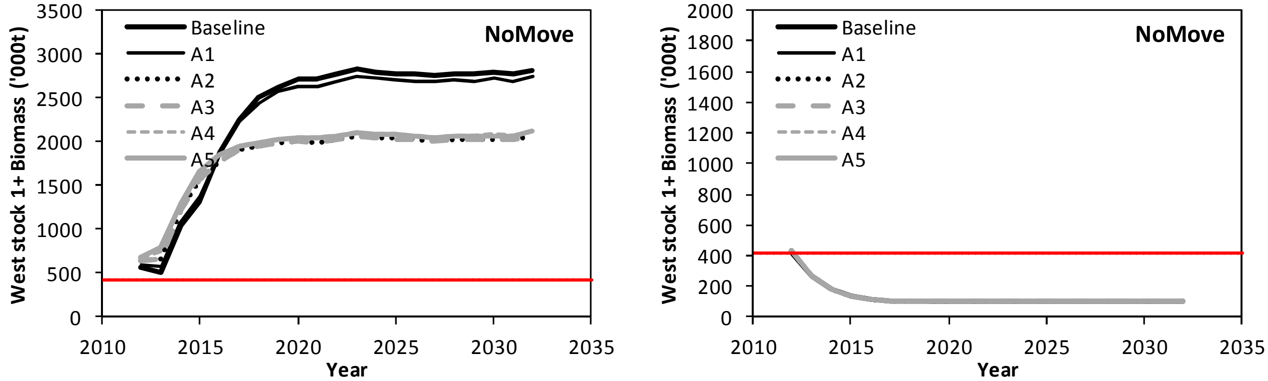


**Figure 4.** The median probability intervals from Figure 3, and projections from the **joint posterior mode**.

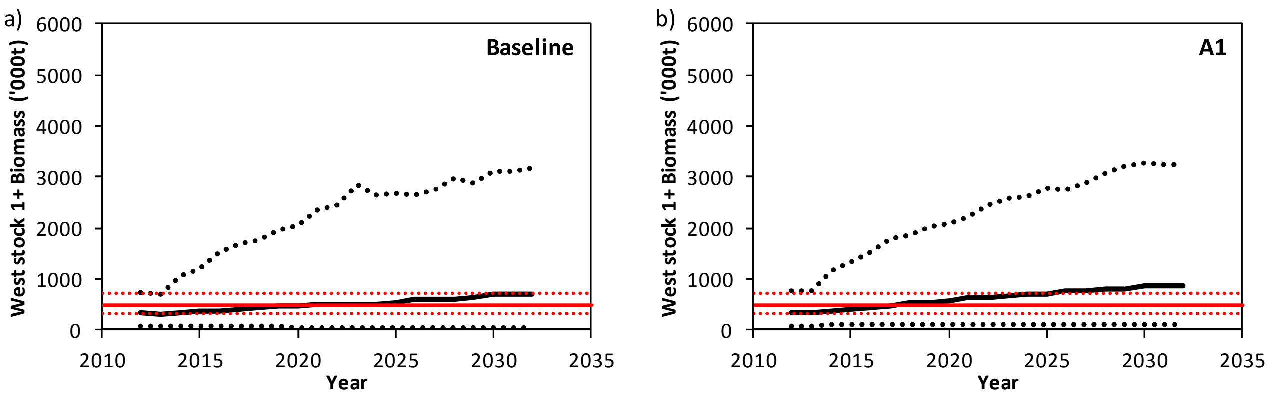


**Figure 5a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **posterior distribution**.

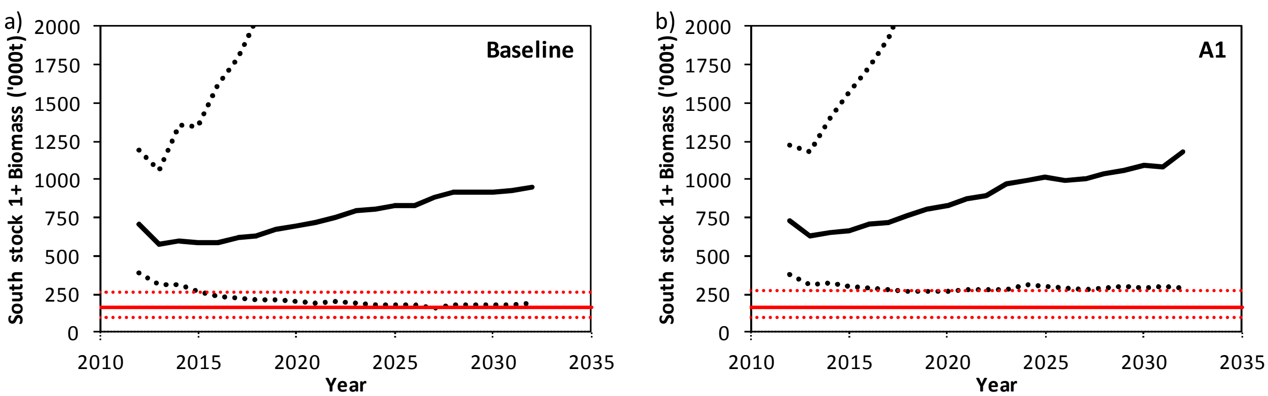


**Figure 5b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **posterior distribution**.

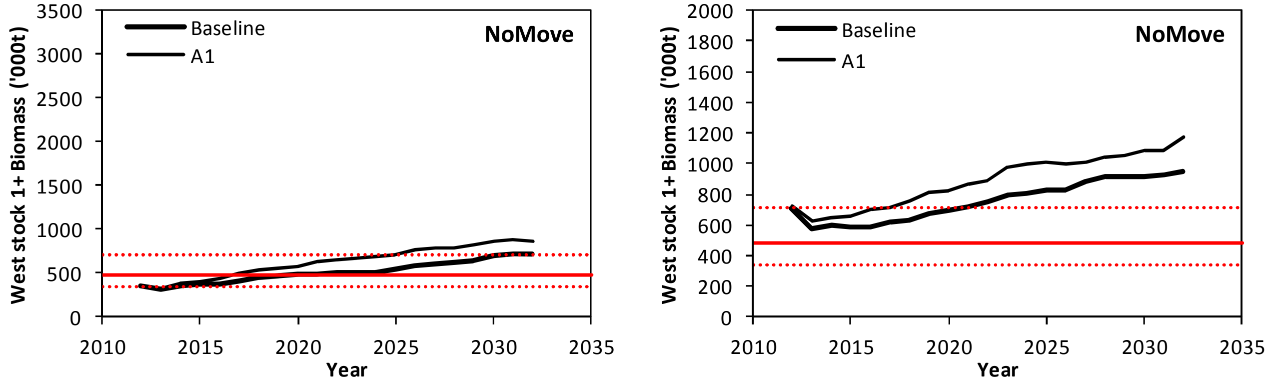


**Figure 6.** The median probability intervals from Figure 5.

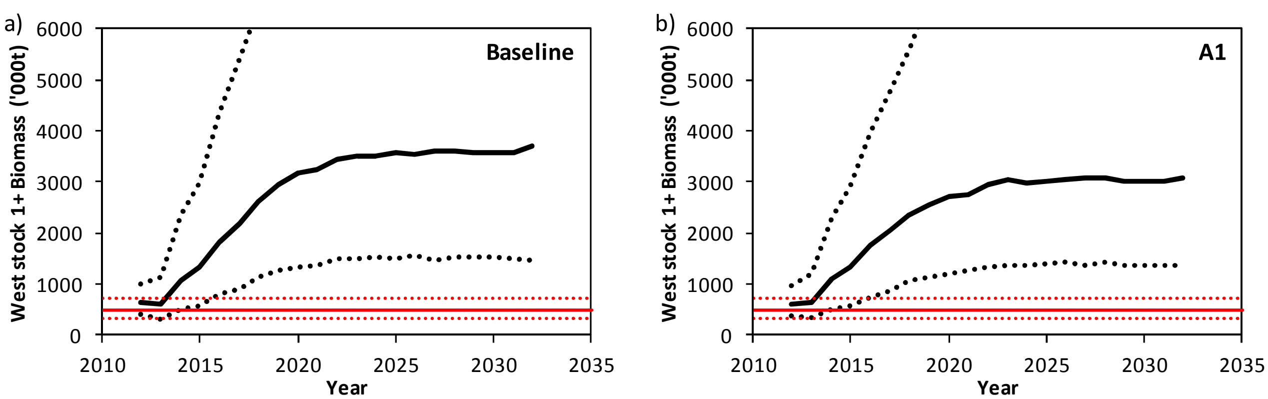


**Figure 7a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **posterior distribution**.

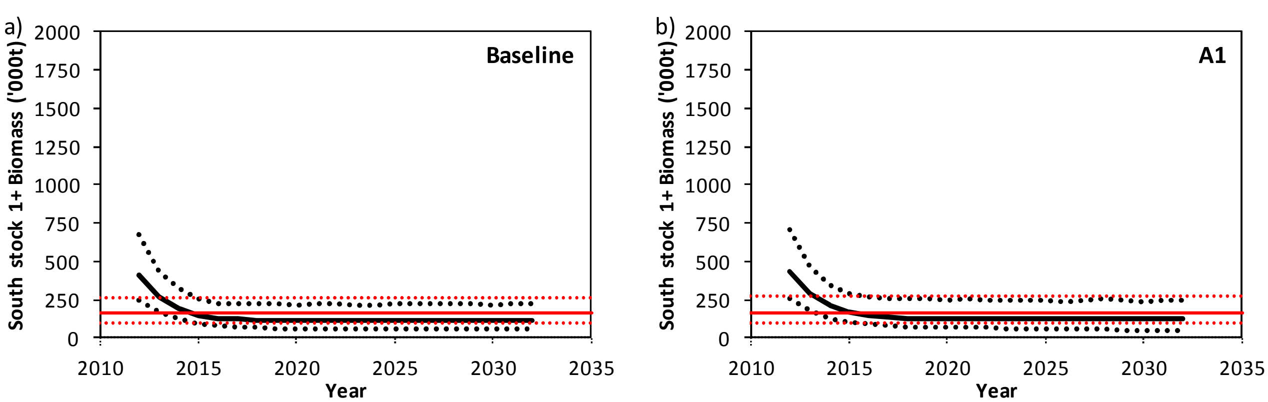


**Figure 7b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "A" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **posterior distribution**.

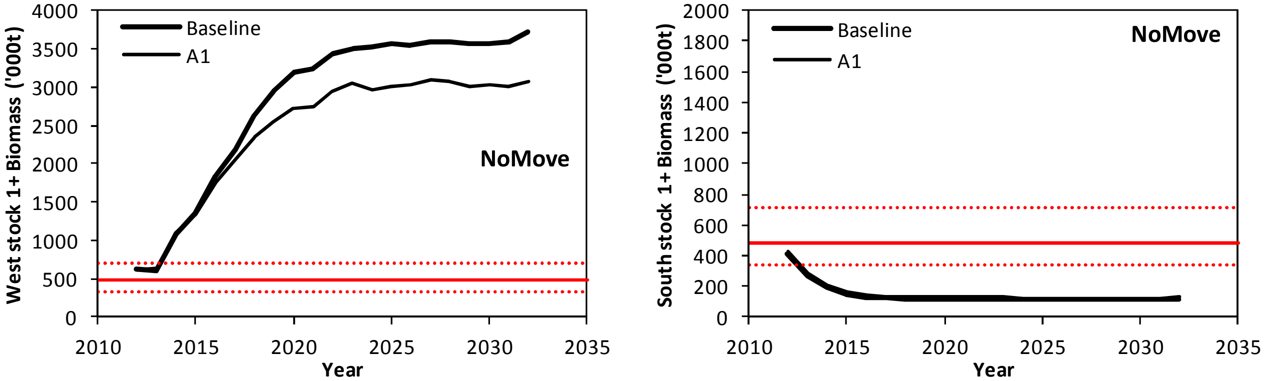


**Figure 8.** The median probability intervals from Figure 7.

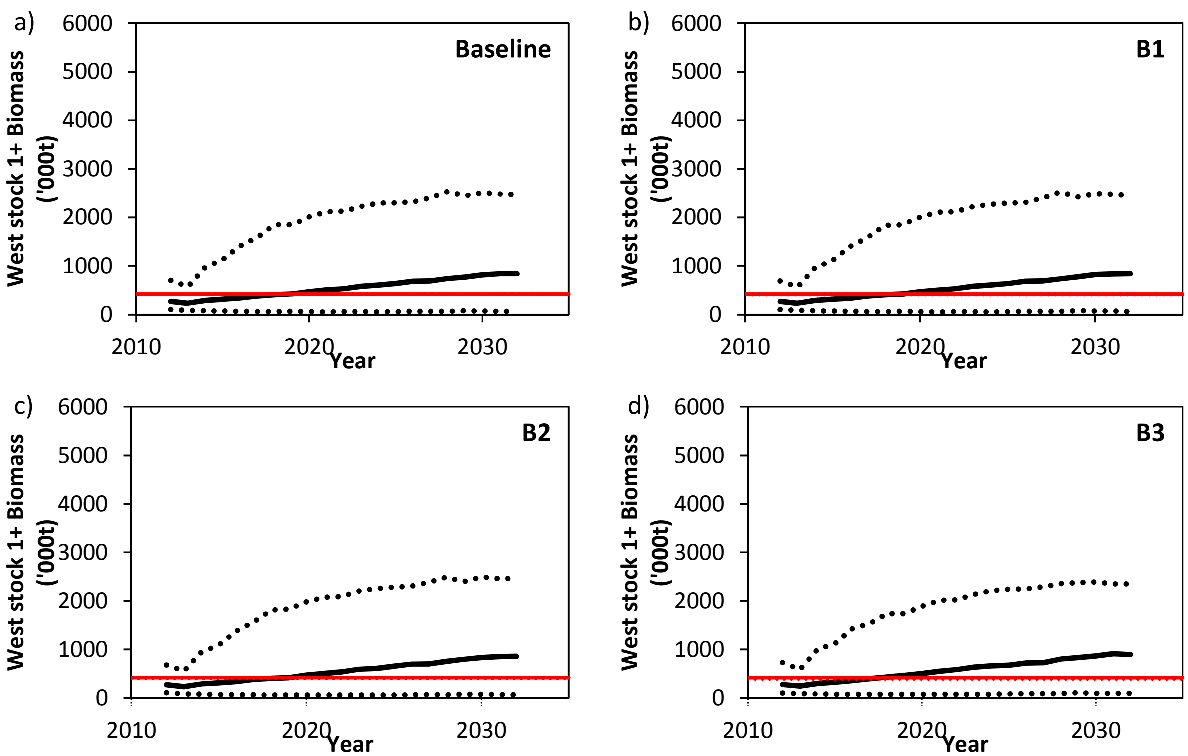


**Figure 9a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **joint posterior mode**.

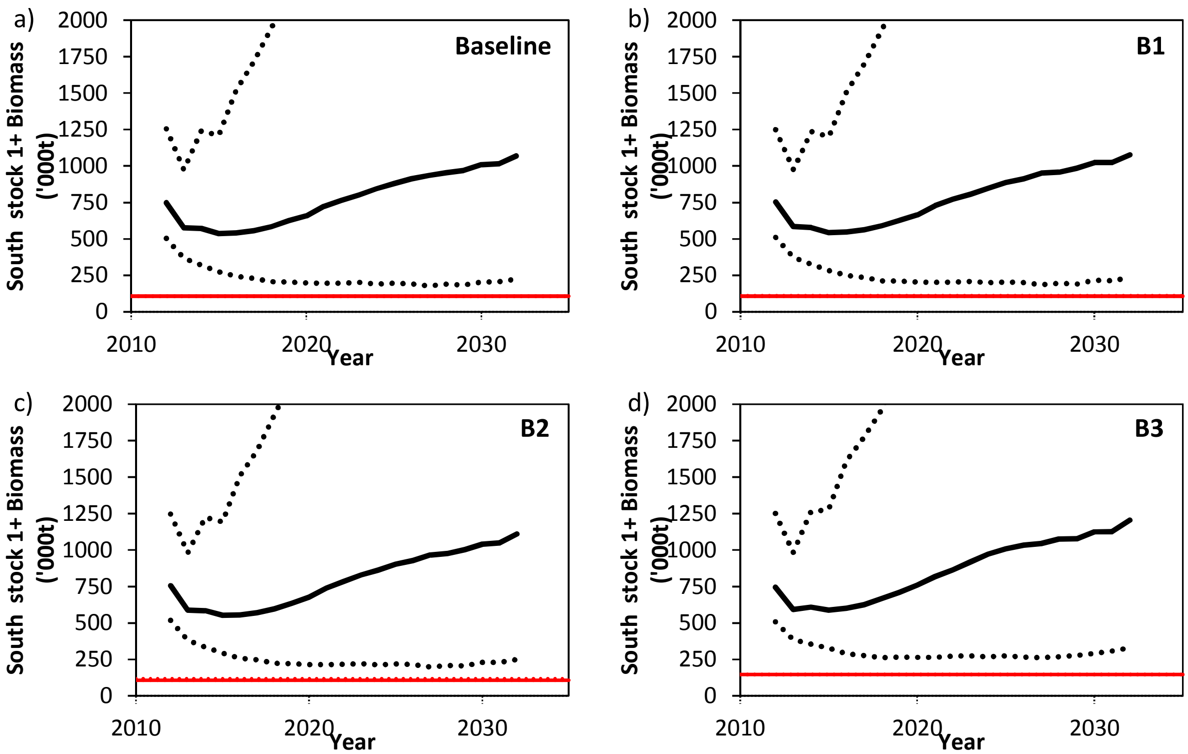


**Figure 9b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **joint posterior mode**.

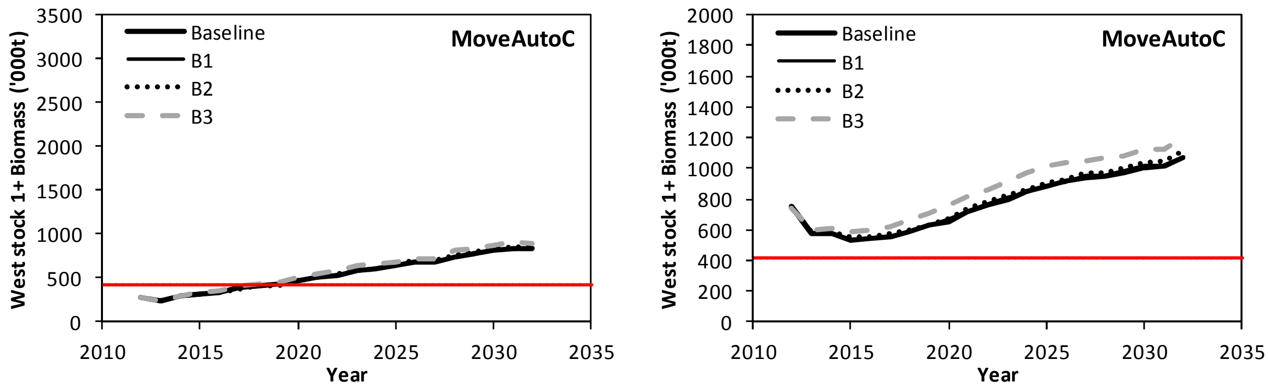


**Figure 10.** The median probability intervals from Figure 9.

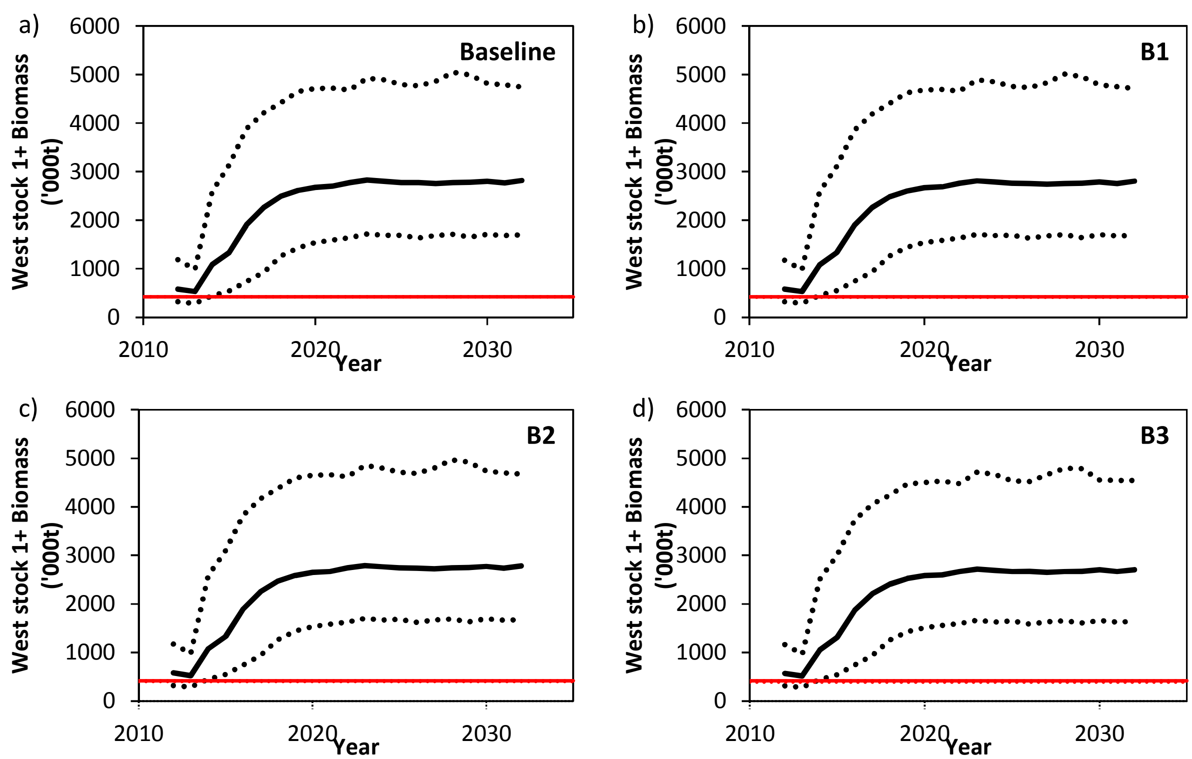


**Figure 11a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **joint posterior mode**.

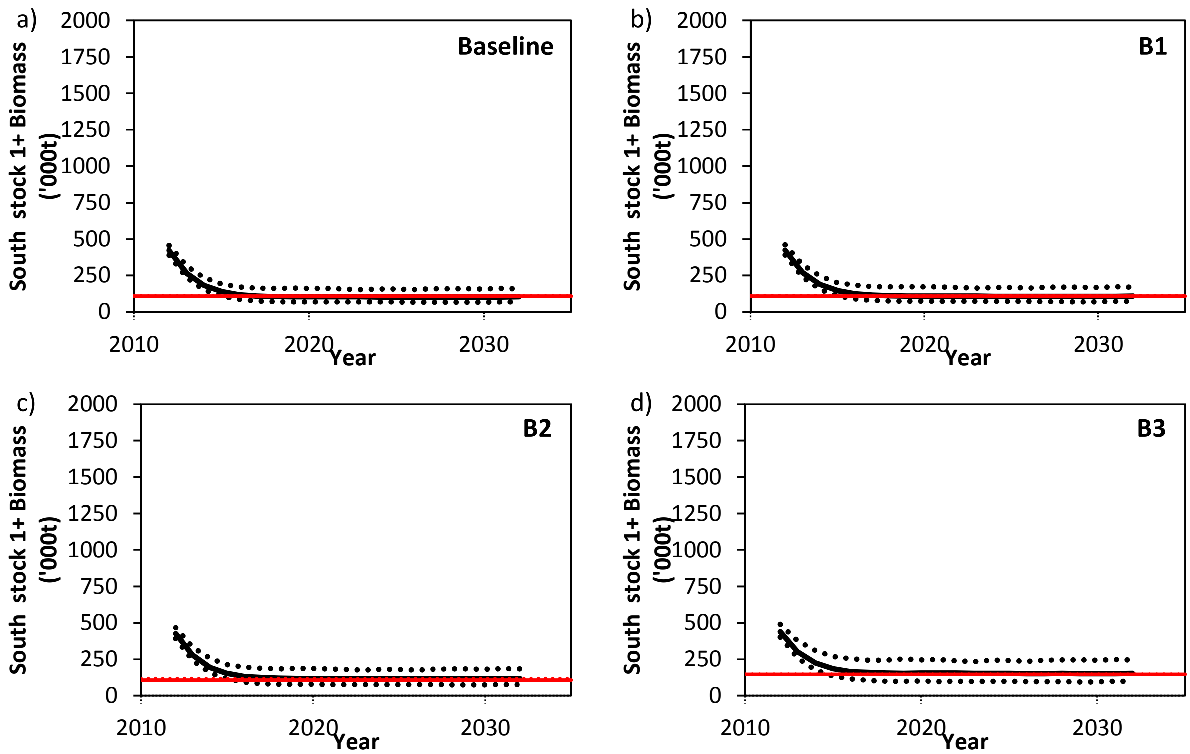


**Figure 11b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **joint posterior mode**.

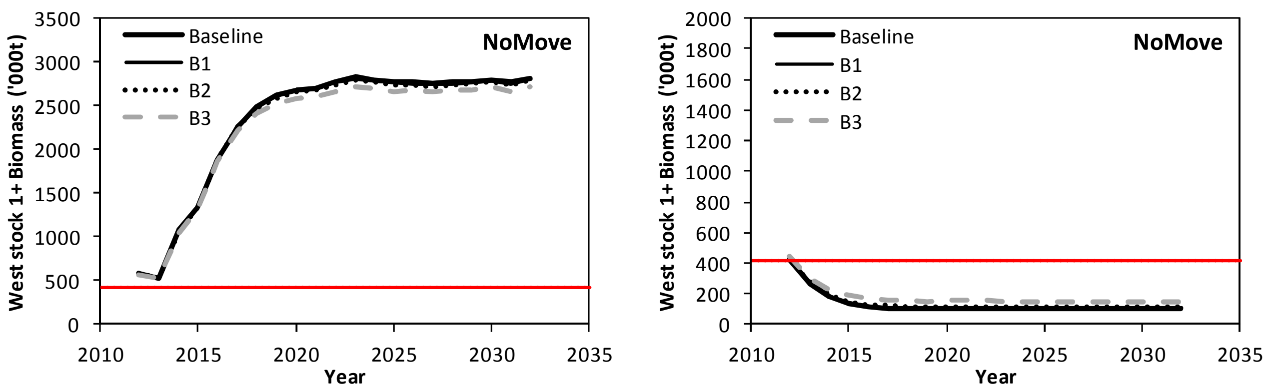


**Figure 12.** The median probability intervals from Figure 11.

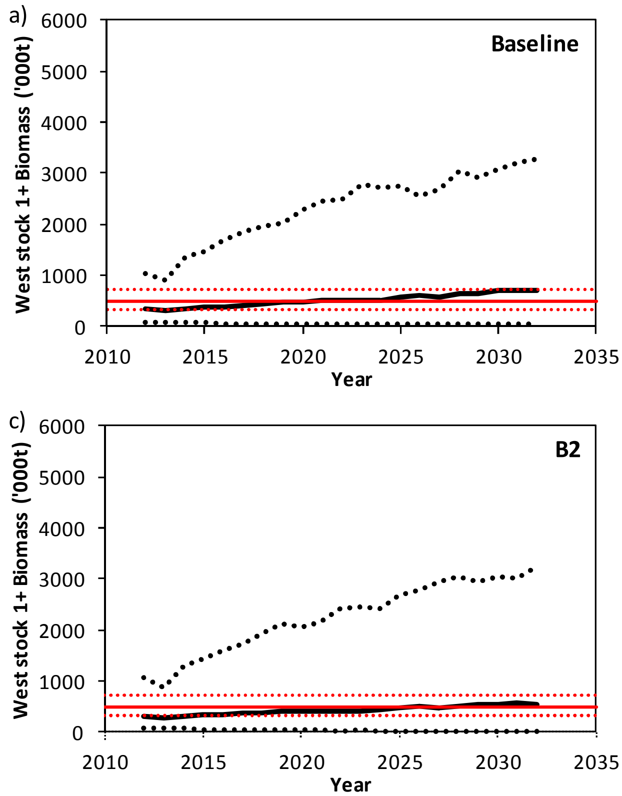


**Figure 13a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **posterior distribution**.

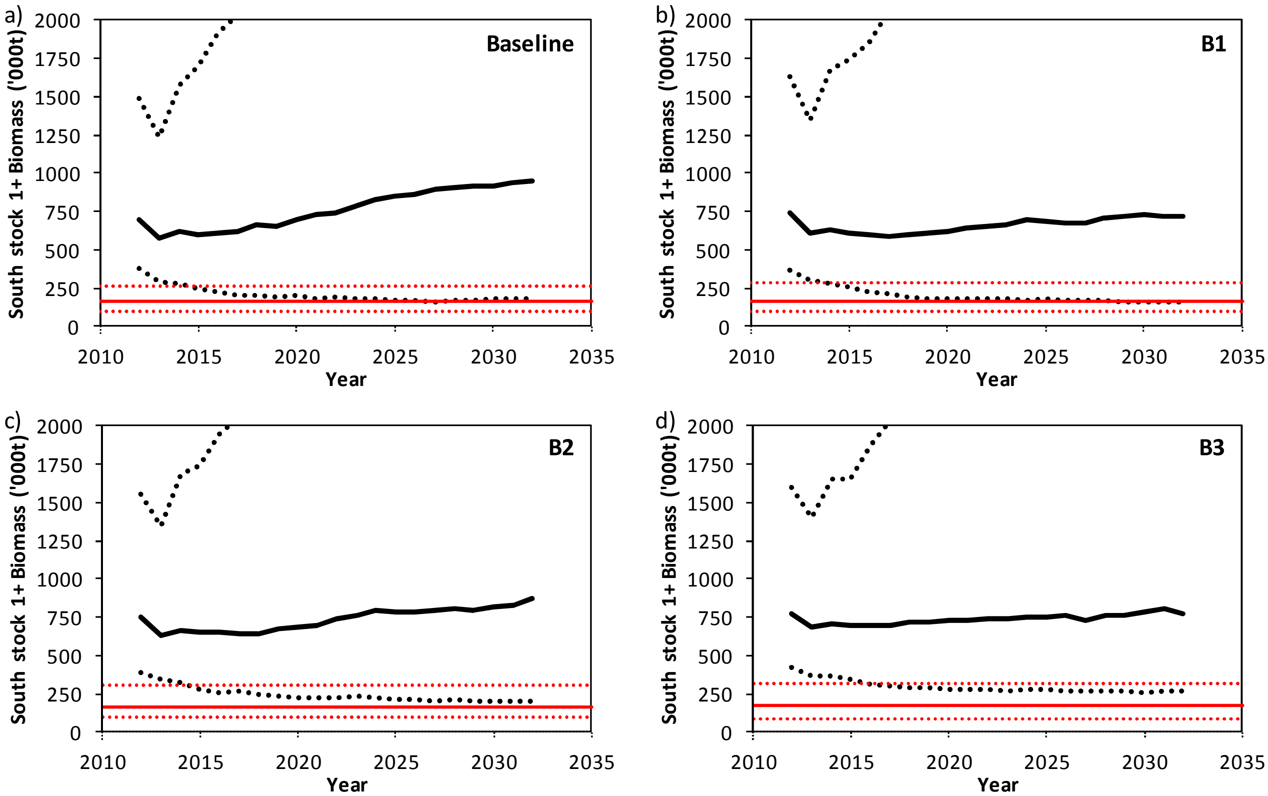


**Figure 13b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **posterior distribution**.

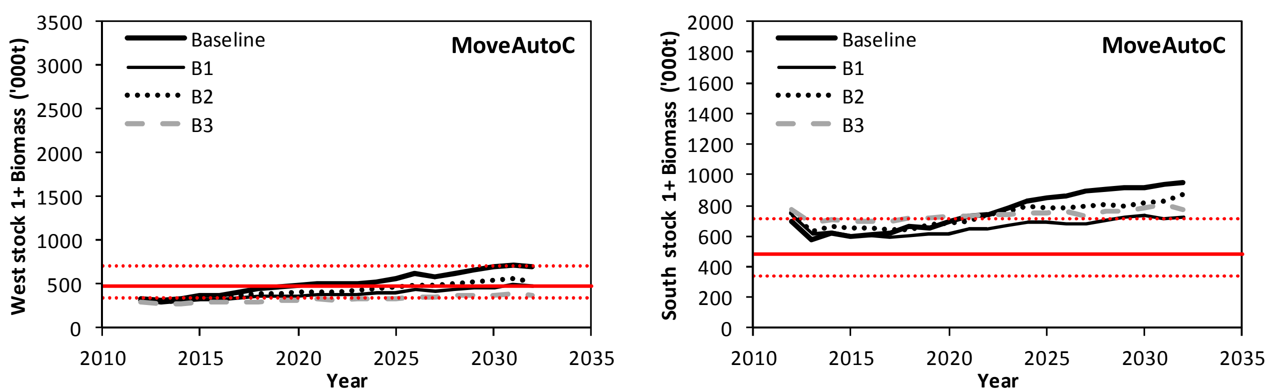


**Figure 14.** The median probability intervals from Figure 13.

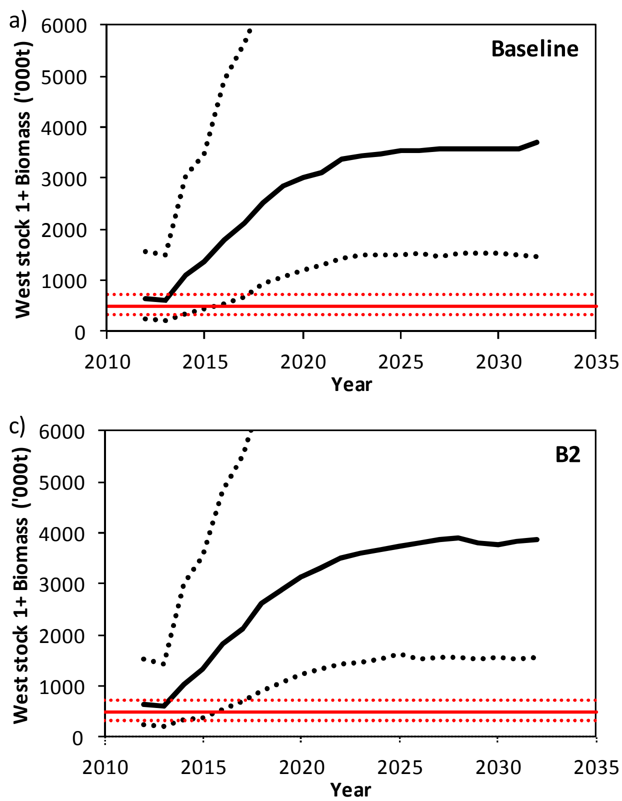


**Figure 15a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **posterior distribution**.

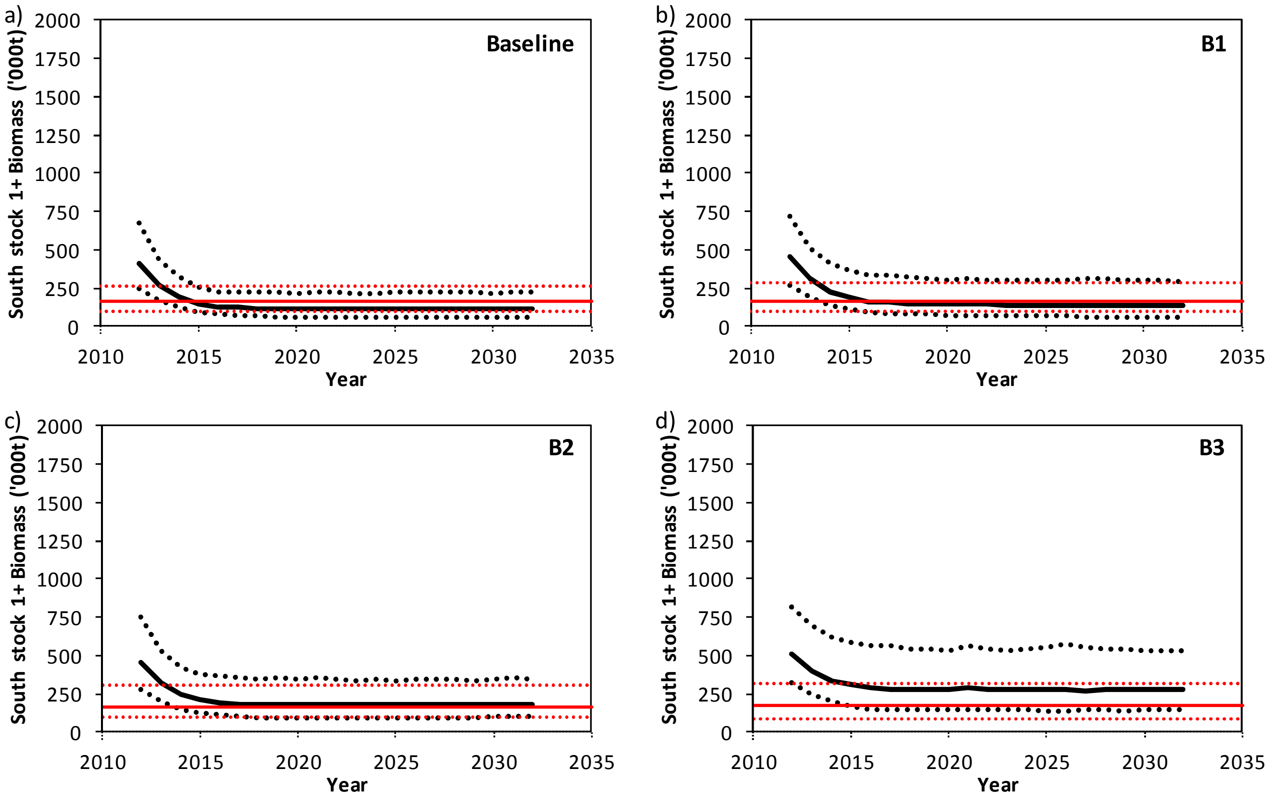


**Figure 15b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "B" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **posterior distribution**.

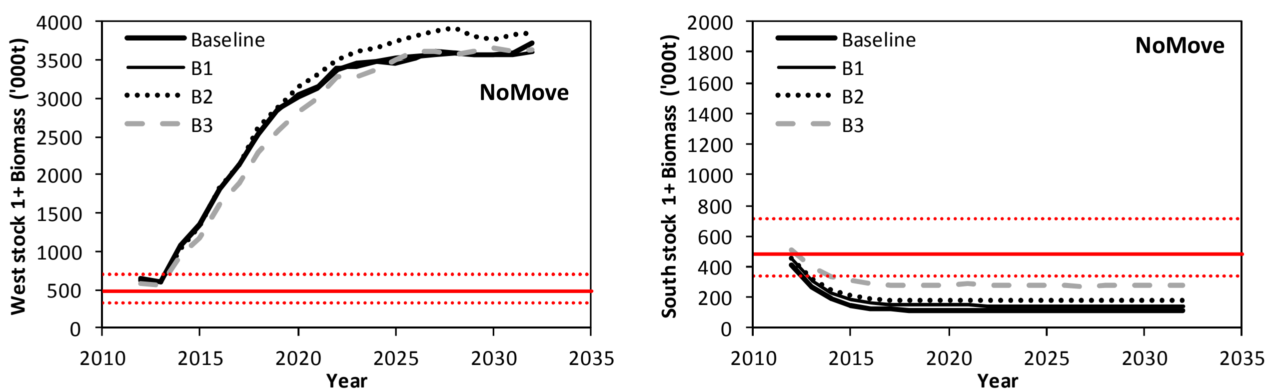


**Figure 16.** The median probability intervals from Figure 15.

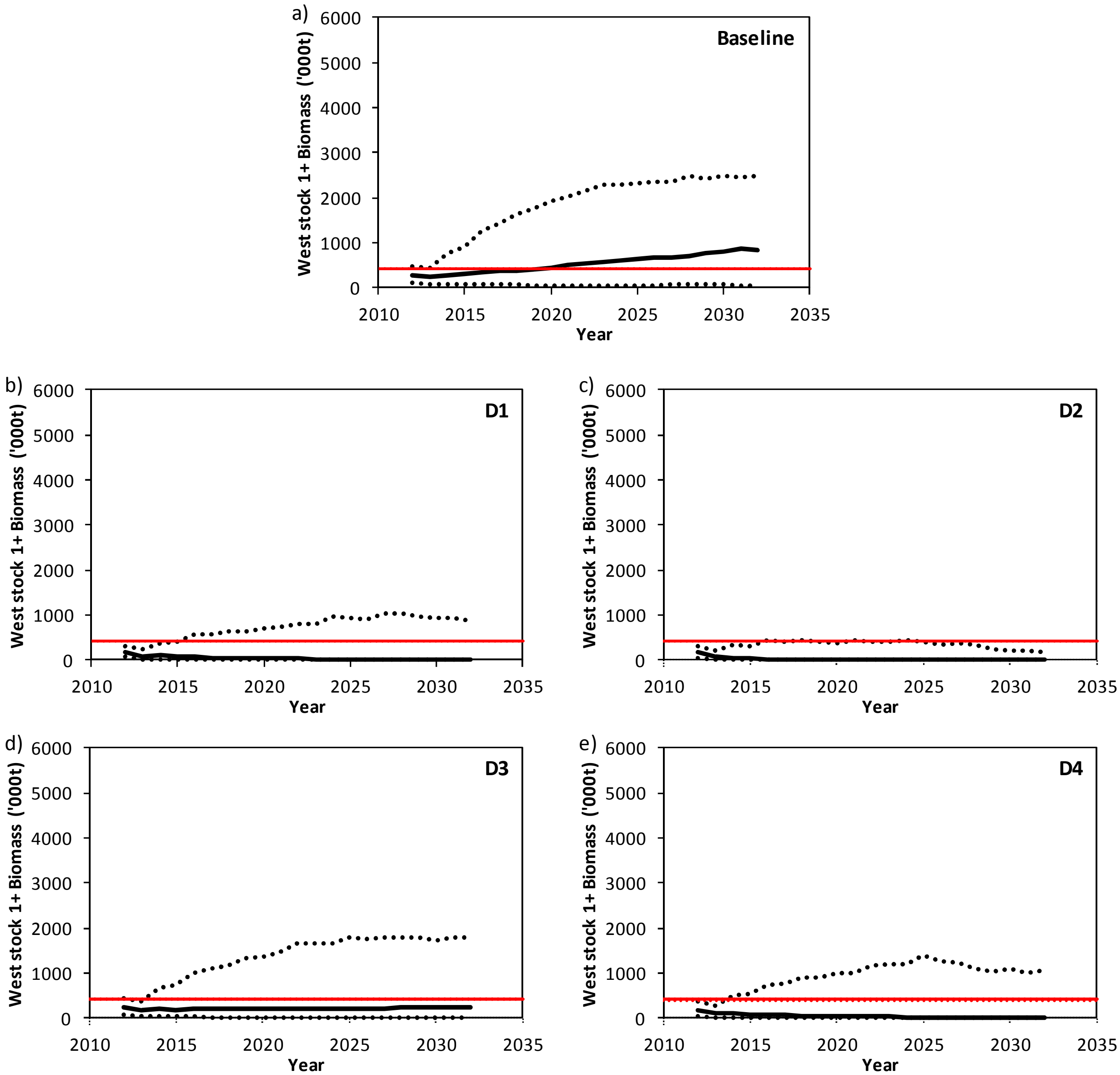


**Figure 17a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **joint posterior mode**.

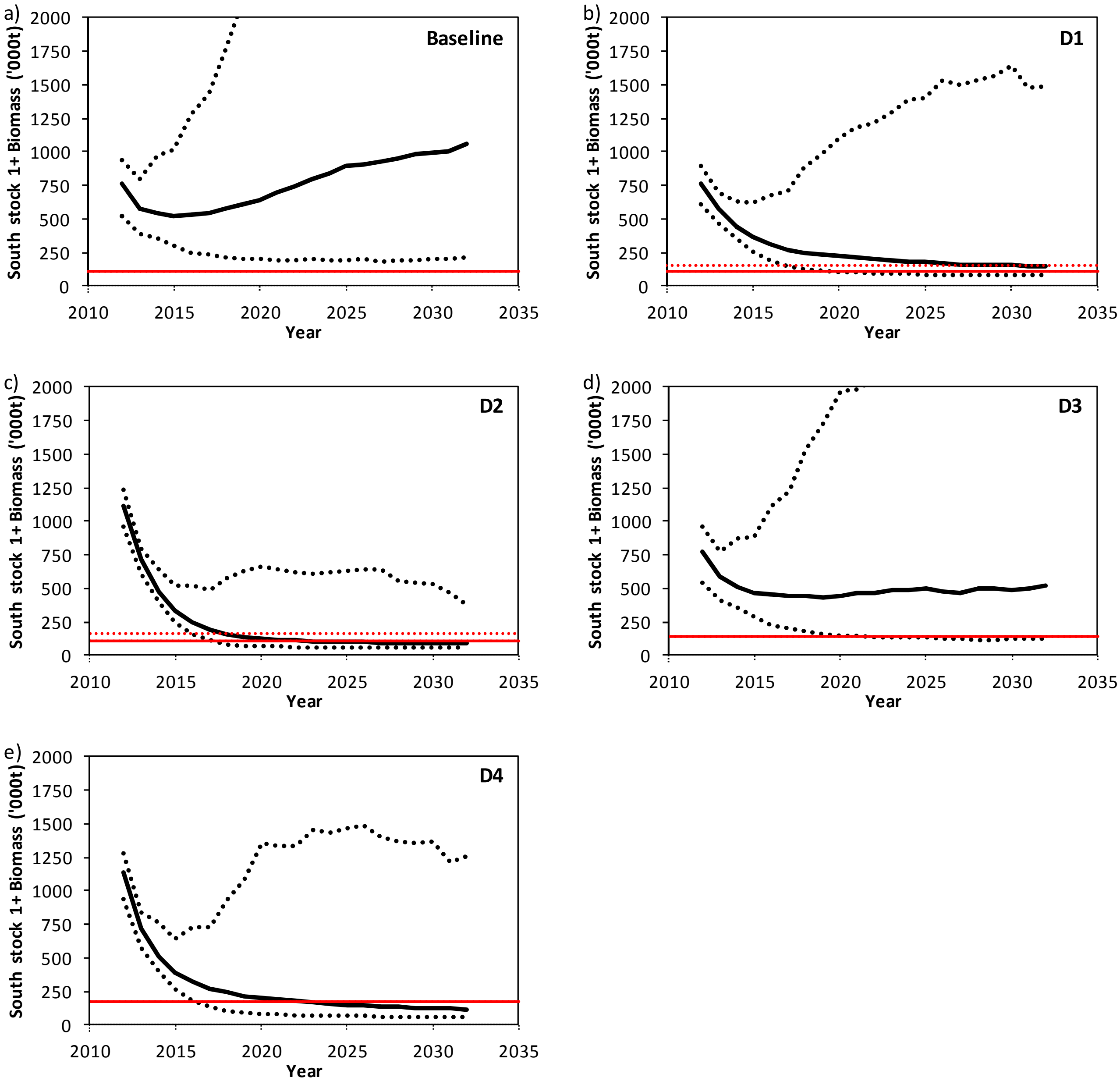


**Figure 17b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **joint posterior mode**.

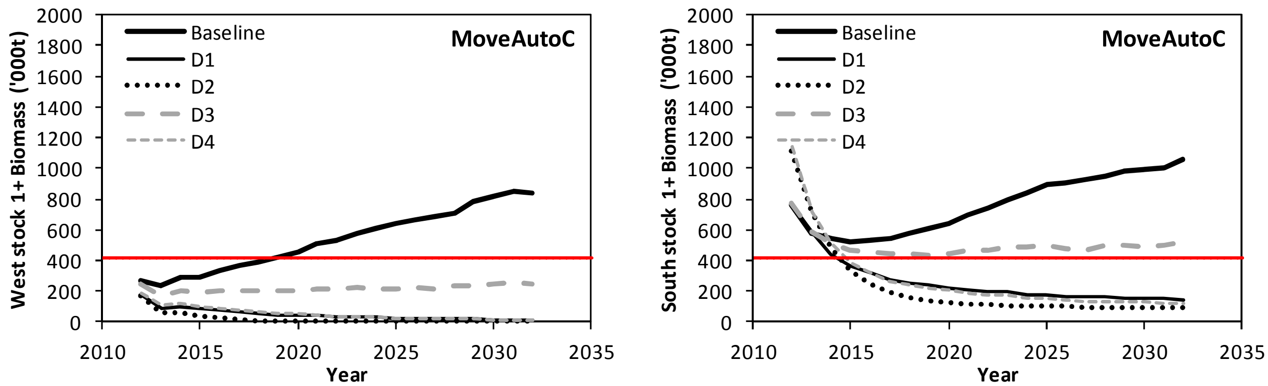


**Figure 18.** The median probability intervals from Figure 17.

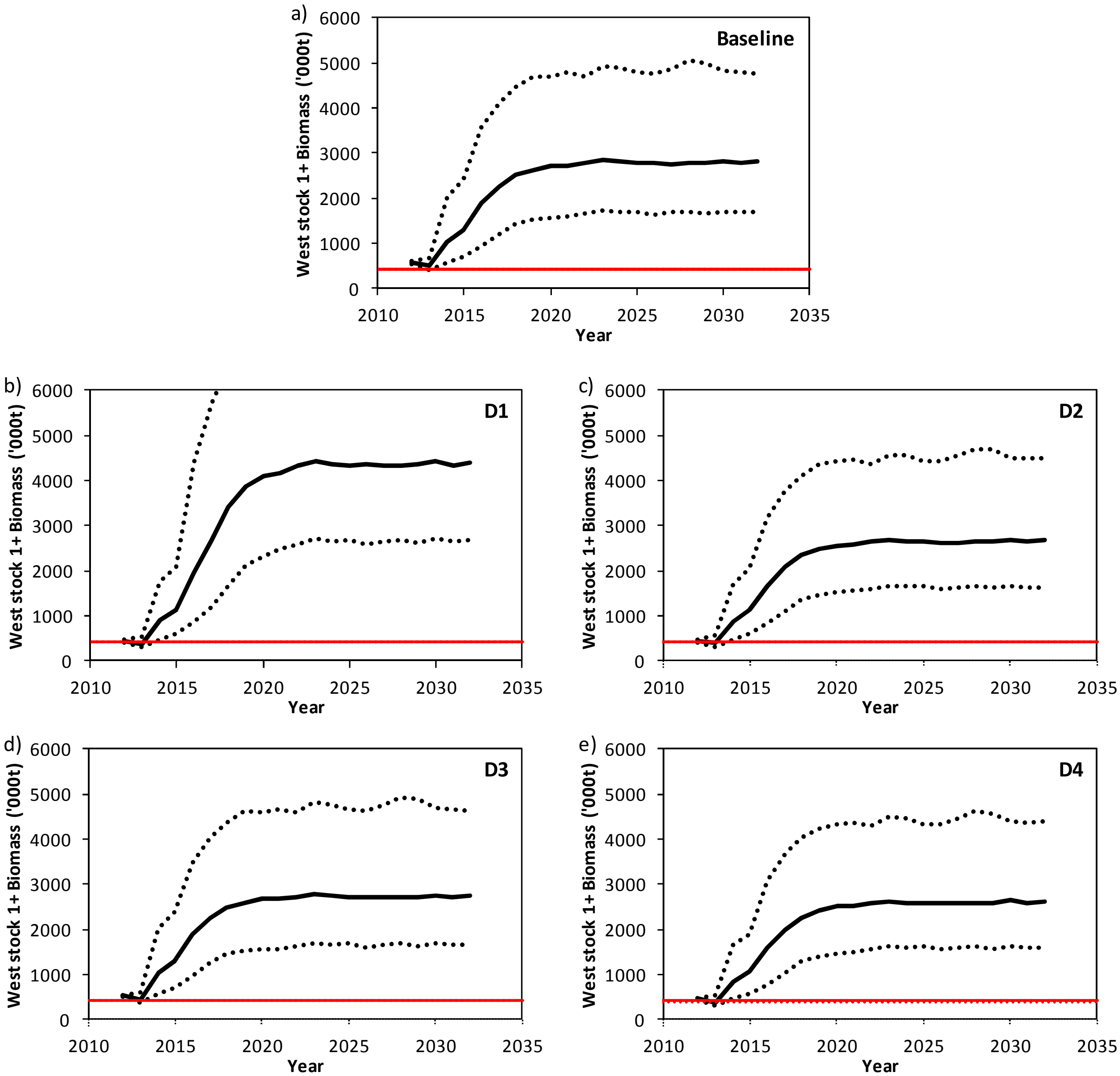


**Figure 19a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **joint posterior mode**.

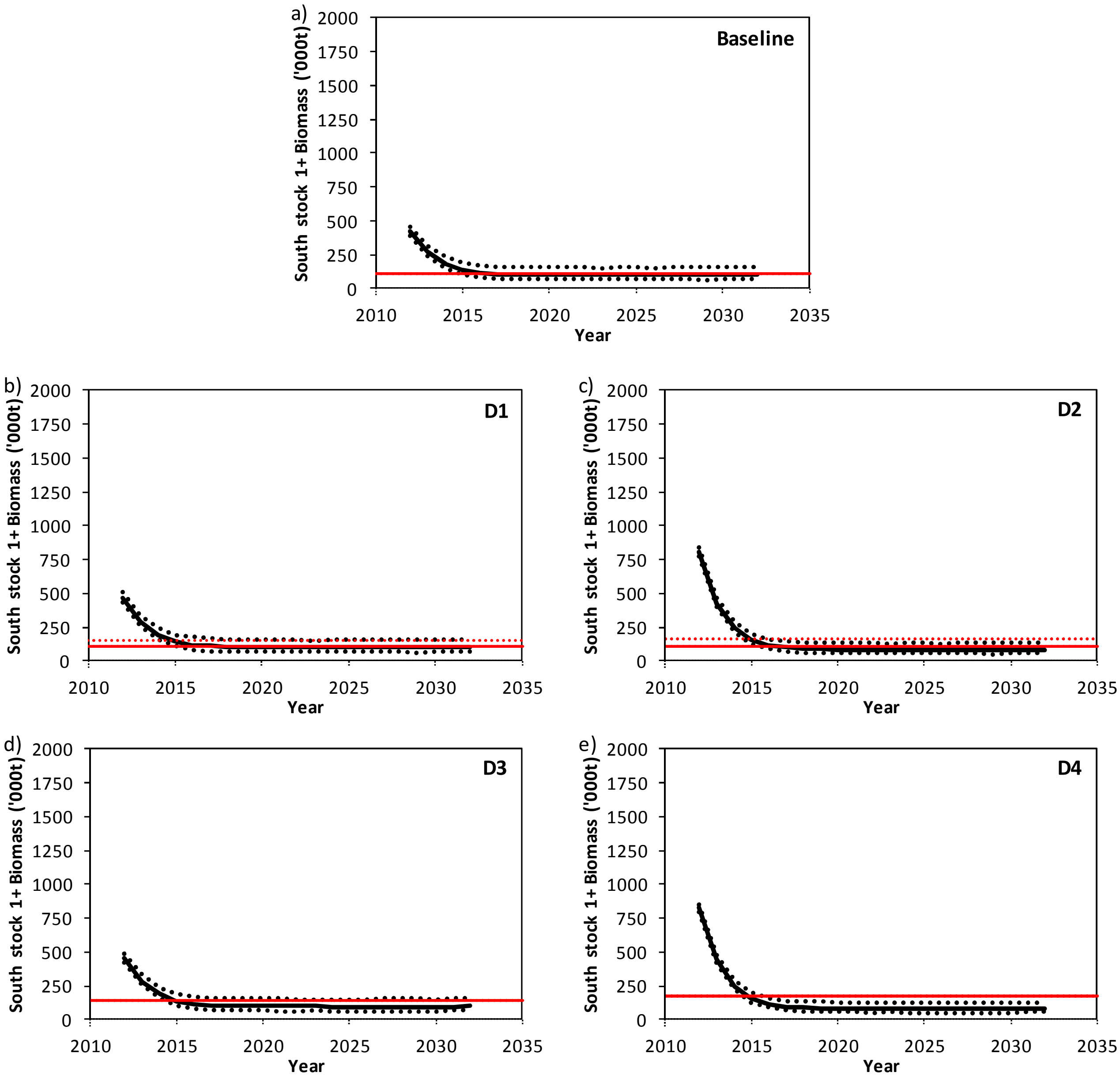


**Figure 19b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **joint posterior mode**.

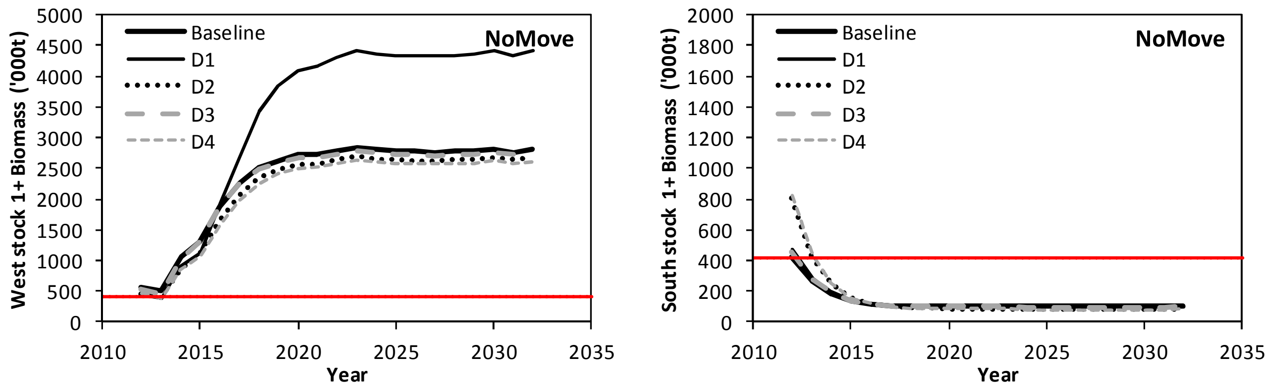


**Figure 20.** The median probability intervals from Figure 19.

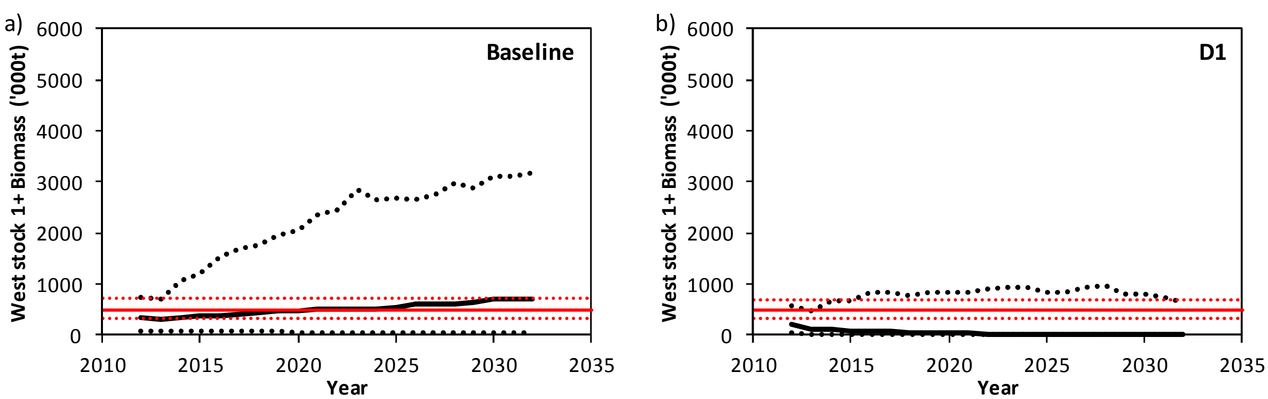


**Figure 21a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **posterior distribution**.

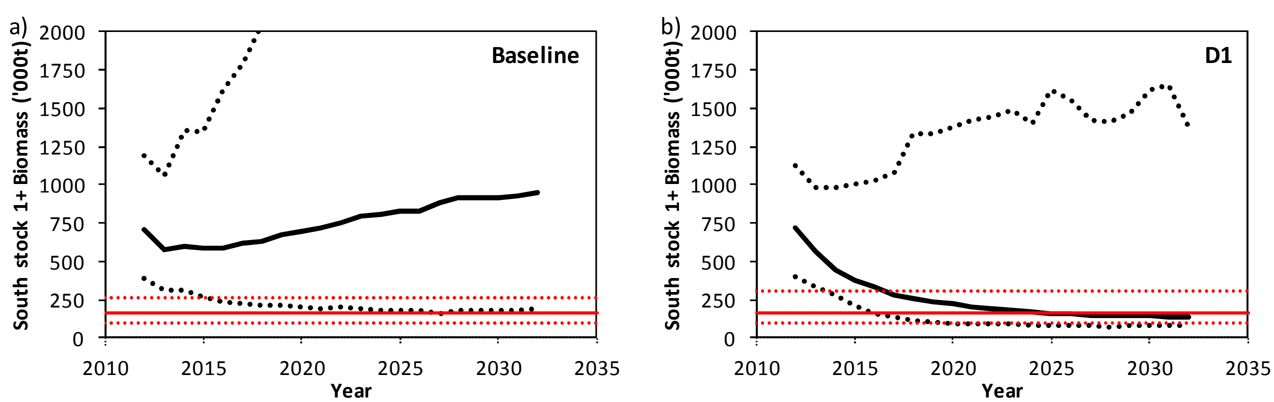


**Figure 21b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***MoveAutoC***, and projections from the **posterior distribution**.

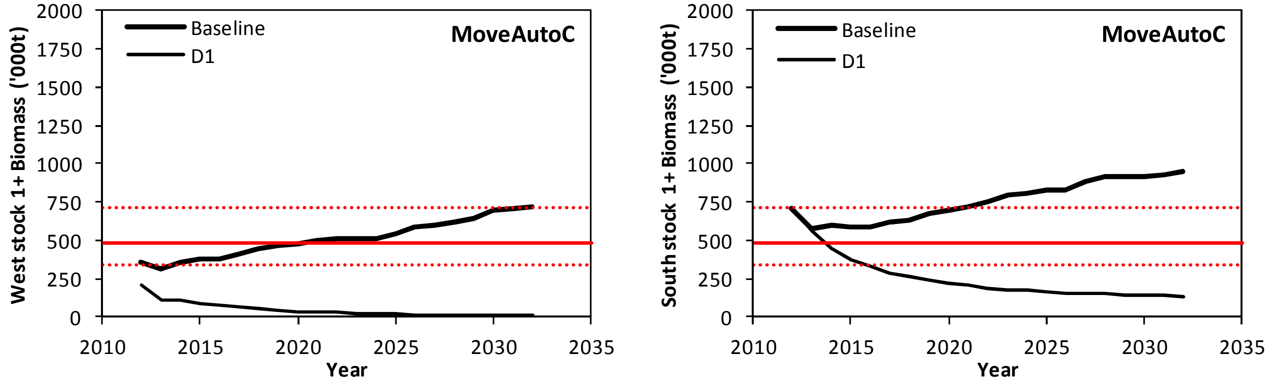


**Figure 22.** The median probability intervals from Figure 21.

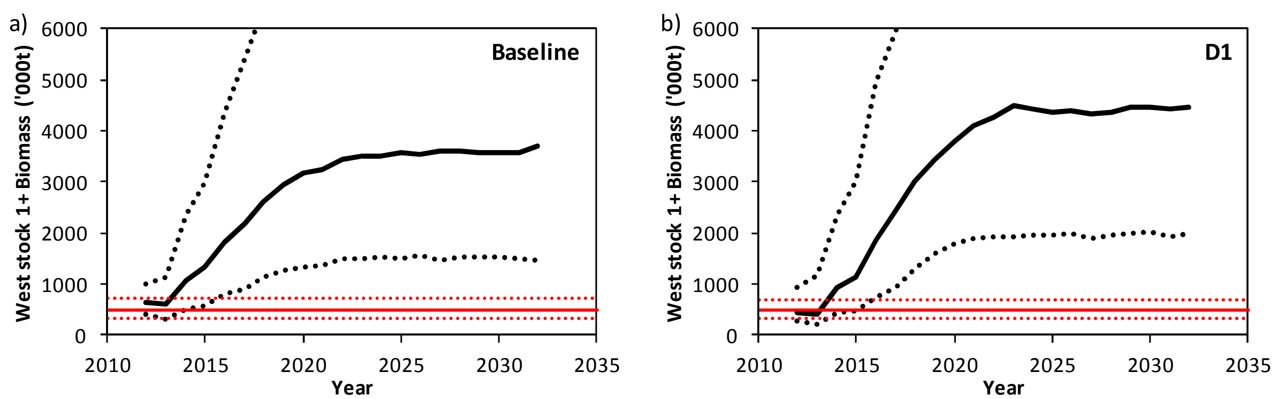


**Figure 23a.** The median and 90% probability interval of future projected sardine 1+ biomass for the west stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **posterior distribution**.

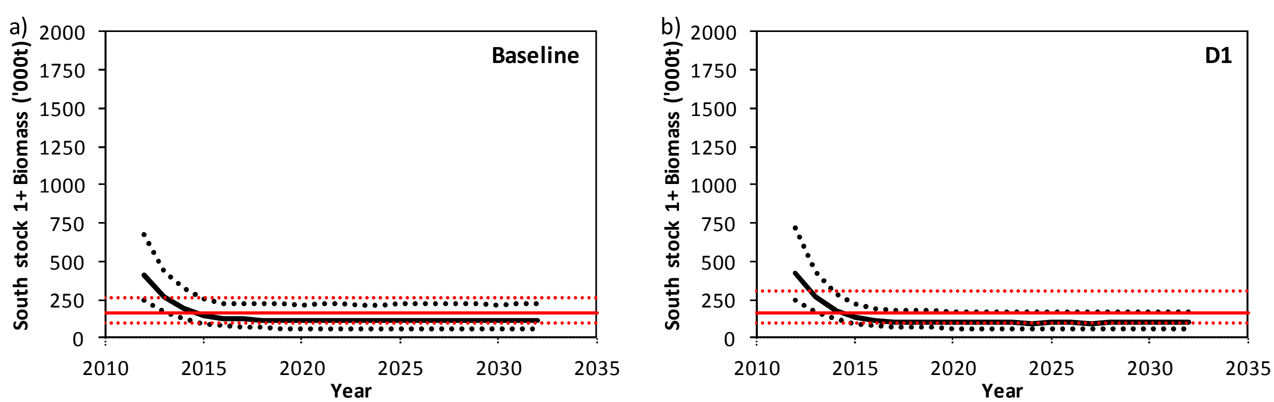


**Figure 23b.** The median and 90% probability interval of future projected sardine 1+ biomass for the south stock under a no catch scenario and **alternative "D" hypotheses**, with the movement hypothesis ***NoMove***, and projections from the **posterior distribution**.

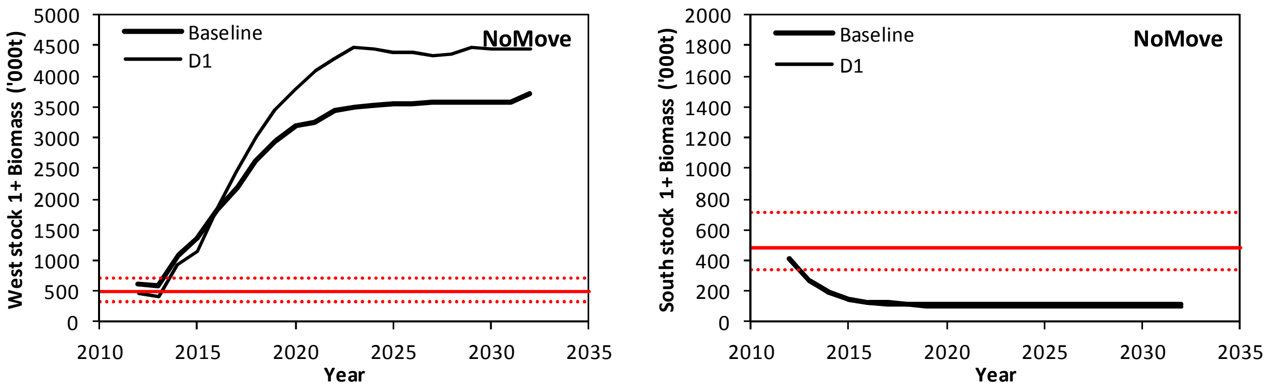


**Figure 24.** The median probability intervals from Figure 23.