NORTH ATLANTIC SWORDFISH STOCK STATUS AND PROJECTIONS WITH THE STOCK SYNTHESIS AND JABBA ASSESSMENT MODELS

Kimoto A.[1]., Schirripa M.[2], Gillespie K.[3], Parker D.[4], and Ortiz M.[1]

SUMMARY

This document provides the final stock status and projection results for the North Atlantic swordfish from JABBA and Stock Synthesis assuming a multivariate lognormal distribution. The Swordfish Species Group reviewed preliminary projections during the stock assessment meeting and agreed to finalize all results for adoption at the Species Group meeting. All tables and figures followed the recommendation by the Working Group on Stock Assessment Method. The resulting Kobe plot based on the Stock Synthesis and JABBA runs indicated that the current stock is likely not overfished (green quadrant; 63% probability) and overfishing is not occurring. The projections show that the current TAC level catch (13.2 thousand t) is sustainable in the near-term.

RÉSUMÉ

Ce document fait état des résultats finaux de l'état du stock et des projections pour l'espadon de l'Atlantique Nord issus de JABBA et de Stock Synthesis en postulant une distribution lognormale multivariée. Le Groupe d'espèces sur l'espadon a examiné les projections préliminaires lors de la réunion d'évaluation du stock et a convenu de finaliser tous les résultats pour adoption à la réunion du Groupe d'espèces. Tous les tableaux et toutes les figures suivaient la recommandation du Groupe de travail sur les méthodes d'évaluation des stocks. Le diagramme de Kobe en résultant, basé sur les scénarios de Stock Synthesis et de JABBA, indiquait que le stock actuel n'est probablement pas surexploité (quadrant vert ; probabilité de 63%) et ne fait pas l'objet de surpêche. Les projections indiquent que les captures au niveau du TAC actuel (13,2 mille tonnes) sont durables à court terme.

RESUMEN

Este documento proporciona información sobre el estado final del stock y los resultados de las proyecciones para el pez espada del Atlántico norte de JABBA y Stock Synthesis asumiendo una distribución lognormal multivariable. El Grupo de especies de pez espada revisó las proyecciones preliminares durante la reunión de evaluación de stock, y acordó finalizar todos los resultados para su adopción durante la reunión del Grupo de especies. Todas las tablas y figuras siguen la recomendación del Grupo de trabajo sobre métodos de evaluación de stock. El diagrama de Kobe resultante, basado en ensayos de Stock Synthesis y JABBA, indicó que es probable que el stock actual no esté sobrepescado (cuadrante verde; 63 % de probabilidad) y que no se esté produciendo sobrepesca. Las proyecciones muestran que el nivel actual de capturas del TAC (13.200 t) es sostenible a corto plazo.

KEYWORDS

JABBA, North Atlantic Swordfish, Projection, Stock Status, Stock Synthesis

[1] ICCAT Secretariat – International Commission for the Conservation of Atlantic Tunas, SPAIN
[2] NOAA - National Marine Fisheries Service, USA
[3] DFO – Fisheries and Oceans Canada
[4] DFFE – South Africa

1. Introduction

The Swordfish Species Group (SWOSG) reviewed three stock assessment models results (Stock Synthesis, JABBA, and ASPIC) and their preliminary projection results during the Stock Assessment Meeting (Anon., 2022a). The Group decided that the 2022 advice would be based on the equally weighted and integrated outcomes from the base JABBA and Stock Synthesis models, noting that the 2017 Stock Assessment (Anon. 2017) advice for the northern swordfish stock was based on the integrated results from a single Bayesian surplus production model and a Stock Synthesis model. Although ASPIC would not be used in projections, it would be used to describe stock status.

Due to the time constraints, it was not possible to do the projections of Stock Synthesis, nor to generate a joint Kobe distribution for the projected status of the stock during the meeting. It was agreed that this work will be completed intersessionally and will be provided at the 2022 Species Group meetings. This document provides the final stock status and projection results for the North Atlantic swordfish stock.

The Working Group of Stock Assessment Methods (WGSAM, Anon., 2022b) at its meeting recommended that modelers be aware of the time reference that biomass (B) or spawning stock biomass (SSB) and fishing mortality (F) are reported in the SS outputs and ensure that biomass and fishing mortality corresponds to the same reference year in both Kobe plots, matrices, and summary tables. The WGSAM recommended reporting the spawning stock biomass (SSB) at the end of the terminal year (i.e. beginning of the first forecast year) in order to account for landings in the terminal year of the model on biomass estimates. This document follows this recommendation.

2. Data and methods

Stochastic stock status and projections for the Stock Synthesis results were conducted applying the Monte-Carlo Multivariate Lognormal (MVLN) approximation (Walter and Winker (2019)) of the posterior density of the reference case model with 15,000 iterations. For the JABBA model, 15,000 MCMC iterations were extracted from the reference case. For the ASPIC model, 1,000 iterations were conducted for the stochastic stock status. Although the Group recommended using the ASPIC model for the stock status, tentative Kobe phase plots show that the other production model expresses uncertainty better than this model. The authors suggest providing the final stock status and projections by combining Stock Synthesis and JABBA model platforms (30,000 iterations in total).

Following the agreement on the projection specifications during the stock, projections were conducted for the Stock Synthesis and JABBA with 22 constant catch scenarios (0; 9,000 – 16,000 t) for 13 years (2021 to 2033). Projections assumed a fixed catch in 2021 and 2022 of 10,476 t similar to the 2020 Task 1 reported catch, followed by the TAC scenarios starting in 2023. It was assumed also that the relative proportion of catches from the different fleets 2021 onwards were the same as the average proportions of the 2018-2020 period, and that future recruitment is determined by the spawning stock function estimated by the model in Stock Synthesis.

Following the recommendation by the WGSAM, all figures for Stock Synthesis were produced with biomass (B) or spawning stock biomass (SSB) at the end of the year *t* that is equal to the beginning of the year *t*+1.

3. Results and conclusions

Figure 1 shows trajectories of B/B_{MSY} and F/F_{MSY} from three different stock assessment model platforms (**Figure 1a** shows same results as Figure 45 at the stock assessment). Kobe phase plots for the three different stock assessment platforms are provided in **Figure 2**. Although the Group recommended using the ASPIC model for the stock status, the Kobe plots for production models show that JABBA model captures uncertainty better and includes the results of ASPIC. The authors suggest providing the final stock status and projections by combining Stock Synthesis and JABBA model platforms.

The joint Kobe phase plot from the two stock assessment model platforms (Stock Synthesis and JABBA) (**Figures 3** and **4**) shows that JABBA model results provide wider range of uncertainty than the Stock Synthesis results. Based on the median of the entire uncertainty (**Table 1**), the North Atlantic swordfish stock in 2020 was not overfished (median B_{2020}/B_{MSY} = 1.08 and 95% CI of 0.71 and 1.33) and was not undergoing overfishing (median F_{2020}/F_{MSY} = 0.80 and 95% CI of 0.64 and 1.24). The average of MSY was estimated as 12,819 t with 95% CI of 10,864 and 15,289. Probabilities of the stock being in each quadrant of the Kobe plot (**Figure 3**) are 63% in the green (not overfished not subject to overfishing), 22% in the yellow (overfished but not subject to overfishing)

and 15% in the red (overfished and subject to overfishing). In summary, the results point to a stock status of not overfished (37% probability of overfished status), with no overfishing (15% probability of overfishing taking place).

In the projection results from mostly JABBA runs, some iterations were predicted with exceptionally small biomass, which results in extremely high F, indicating the potential for stock collapse. Therefore, probability of biomass being less than 10% or 20% of the biomass that supports MSY was calculated for each projection year and catch scenario (**Table 2**). The probability increased with higher catch levels and in the later projected years. Trajectories of B/B_{MSY} and F/F_{MSY} in projections were provided for each model (**Figures 5** and **6**) and for the joint results (**Figure 7**). The combined projections show that 13,200 t constant catch, which is the current TAC level (Rec. 21-02), will maintain more than 60% probability of being in green quadrant through 2033 (**Table 3**).

References

Anonymous. 2017. Report of the 2017 ICCAT Swordfish Stock Assessment Meeting. Madrid, Spain 3-7 July 2017. Collect. Vol. Sci. Pap. ICCAT, 74(3): 729-840.

Anonymous. 2022a. Report of the 2022 ICCAT Atlantic Swordfish Stock Assessment. (Online, 20-28 June 2022).

Anonymous. 2022b. Report of the 2022 Intersessional meeting of the working group on stock assessment methods. (Online, 31 May – 3 June 2022)

Walter J., and Winker H. 2019. Projections to create Kobe 2 strategy matrix using the multivariate log-normal approximation for Atlantic yellowfin tuna. Collect. Vol. Sci. Pap. ICCAT, 76 (6): 725-739. SCRS/2019/145

Table 1. Estimates (average or median, and 95% confidence intervals) of B_{MSY}, F_{MSY}, MSY, B_{2020}/B_{MSY} and F_{2020}/F_{MSY} based on the Stock Synthesis and the JABBA results.

	Average or Median	*LCI (95%)***	*UCI (95%)***
MSY	12,819	10,864	15,289
B_{MSY}	57,919	23,666	153,156
F_{MSY}	0.15	0.08	0.23
B_{2020}/B_{MSY}*	1.08	0.71	1.33
F_{2020}/F_{MSY}*	0.80	0.64	1.24

* B_{2020}/B_{MSY} and F_{2020}/F_{MSY} are the median or 95% confidence intervals of 30,000 iterations.
** Confidence intervals for MSY, B_{MSY} and F_{MSY} are the maximum range of the 95% confidence intervals of the two model platforms.

Table 2. Percent of the model runs based on 30,000 iterations of the MVLN approximation for Stock Synthesis and JABBA MCMC iterations that resulted in SSB or B levels <= 10% or 20% of SSB_{MSY} or B_{MSY} during the projection period for a given catch level for the North Atlantic swordfish stock.

Probability of Stock Depletion (B < 10% of B_{MSY})

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9000t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
10000t	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%
11000t	0%	0%	0%	0%	0%	0%	0%	1%	1%	2%	2%
12000t	0%	0%	0%	0%	0%	0%	1%	1%	2%	3%	3%
12500t	0%	0%	0%	0%	0%	1%	1%	2%	2%	3%	4%
12600t	0%	0%	0%	0%	0%	1%	1%	2%	2%	3%	4%
12700t	0%	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%
12800t	0%	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%
12900t	0%	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%
13000t	0%	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%
13100t	0%	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%
13200t	0%	0%	0%	0%	0%	1%	1%	2%	3%	4%	6%
13300t	0%	0%	0%	0%	0%	1%	1%	2%	3%	5%	6%
13400t	0%	0%	0%	0%	0%	1%	2%	2%	3%	5%	6%
13500t	0%	0%	0%	0%	0%	1%	2%	3%	4%	5%	6%
13600t	0%	0%	0%	0%	0%	1%	2%	3%	4%	5%	7%
13700t	0%	0%	0%	0%	0%	1%	2%	3%	4%	5%	7%
13800t	0%	0%	0%	0%	0%	1%	2%	3%	4%	6%	7%
14000t	0%	0%	0%	0%	0%	1%	2%	3%	4%	6%	8%
15000t	0%	0%	0%	0%	1%	2%	3%	5%	7%	9%	11%
16000t	0%	0%	0%	0%	1%	2%	4%	6%	9%	11%	14%

Probability of Stock Depletion (B < 20% of B_{MSY})

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9000t	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%
10000t	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	2%
11000t	0%	0%	0%	0%	0%	1%	1%	1%	2%	2%	3%
12000t	0%	0%	0%	0%	0%	1%	1%	2%	3%	3%	4%
12500t	0%	0%	0%	0%	1%	1%	2%	2%	3%	4%	5%
12600t	0%	0%	0%	0%	1%	1%	2%	3%	3%	4%	5%
12700t	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%	6%
12800t	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%	6%
12900t	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%	6%
13000t	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%	6%
13100t	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%	7%
13200t	0%	0%	0%	0%	1%	1%	2%	3%	4%	6%	7%
13300t	0%	0%	0%	0%	1%	1%	2%	3%	5%	6%	7%
13400t	0%	0%	0%	0%	1%	2%	2%	3%	5%	6%	7%
13500t	0%	0%	0%	0%	1%	2%	2%	4%	5%	6%	8%
13600t	0%	0%	0%	0%	1%	2%	3%	4%	5%	7%	8%
13700t	0%	0%	0%	0%	1%	2%	3%	4%	5%	7%	8%
13800t	0%	0%	0%	0%	1%	2%	3%	4%	5%	7%	9%
14000t	0%	0%	0%	0%	1%	2%	3%	4%	6%	7%	9%
15000t	0%	0%	0%	0%	1%	3%	5%	7%	10%	13%	16%
16000t	0%	0%	0%	1%	2%	4%	6%	8%	11%	14%	16%

Table 3. Joint probabilities of the North Atlantic swordfish stock being below F_{MSY} (overfishing not occurring), above B_{MSY} (not overfished) and above B_{MSY} and below F_{MSY} (green zone) in a given year for a given catch level based on 30,000 iterations of the MVLN approximation for Stock Synthesis and JABBA MCMC iterations.

Probaility $F<F_{MSY}$

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0t	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
9000t	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%
10000t	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
11000t	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
12000t	79%	79%	79%	79%	79%	80%	80%	80%	79%	79%	79%
12500t	76%	76%	76%	76%	76%	76%	76%	76%	76%	76%	76%
12600t	75%	75%	75%	75%	75%	75%	75%	76%	75%	75%	75%
12700t	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%
12800t	74%	73%	73%	73%	73%	73%	73%	73%	73%	73%	73%
12900t	73%	72%	72%	72%	72%	72%	72%	72%	71%	71%	71%
13000t	72%	71%	71%	71%	71%	70%	70%	70%	69%	69%	68%
13100t	71%	70%	70%	69%	69%	68%	68%	67%	66%	66%	65%
13200t	70%	69%	69%	68%	67%	66%	65%	64%	63%	62%	61%
13300t	69%	68%	67%	66%	65%	63%	62%	61%	59%	58%	56%
13400t	68%	66%	65%	64%	62%	60%	59%	57%	55%	53%	51%
13500t	66%	65%	63%	61%	59%	57%	55%	53%	51%	48%	46%
13600t	65%	63%	61%	59%	56%	54%	51%	49%	46%	43%	41%
13700t	63%	61%	59%	56%	53%	50%	47%	44%	41%	38%	36%
13800t	62%	59%	56%	53%	50%	46%	43%	40%	37%	34%	32%
14000t	58%	55%	51%	47%	43%	39%	35%	32%	29%	27%	25%
15000t	38%	31%	25%	21%	25%	32%	32%	31%	31%	30%	29%
16000t	20%	15%	12%	11%	10%	10%	10%	9%	9%	9%	9%

Probability $B>B_{MSY}$

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0t	75%	84%	90%	94%	96%	97%	98%	98%	99%	99%	99%
9000t	75%	78%	80%	82%	83%	84%	85%	86%	86%	87%	87%
10000t	75%	77%	79%	80%	81%	82%	83%	83%	83%	84%	84%
11000t	75%	76%	77%	78%	79%	79%	80%	80%	81%	81%	81%
12000t	75%	75%	76%	76%	77%	77%	77%	77%	77%	77%	77%
12500t	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
12600t	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
12700t	75%	75%	74%	74%	74%	74%	74%	74%	74%	74%	74%
12800t	75%	74%	74%	74%	74%	74%	74%	74%	74%	73%	73%
12900t	75%	74%	74%	74%	73%	73%	73%	73%	73%	72%	72%
13000t	75%	74%	74%	73%	73%	73%	72%	72%	72%	71%	71%
13100t	75%	74%	73%	73%	72%	72%	72%	71%	70%	70%	69%
13200t	75%	74%	73%	72%	72%	71%	71%	70%	69%	68%	67%
13300t	75%	74%	73%	72%	71%	70%	69%	68%	67%	66%	65%
13400t	75%	74%	73%	72%	70%	70%	68%	67%	65%	64%	62%
13500t	75%	74%	72%	71%	70%	68%	67%	65%	63%	61%	59%
13600t	74%	74%	72%	71%	69%	67%	65%	63%	61%	58%	55%
13700t	74%	73%	72%	70%	68%	66%	64%	61%	58%	55%	52%
13800t	74%	73%	71%	70%	67%	65%	62%	59%	55%	52%	48%
14000t	74%	73%	71%	68%	65%	62%	58%	54%	50%	45%	41%
15000t	74%	71%	66%	59%	47%	44%	42%	41%	39%	38%	36%
16000t	74%	69%	59%	48%	36%	27%	21%	18%	16%	15%	14%

Probability $F<F_{MSY}$ and $B>B_{MSY}$

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0t	75%	84%	90%	94%	96%	97%	98%	98%	99%	99%	99%
9000t	75%	78%	80%	82%	83%	84%	85%	86%	86%	87%	87%
10000t	75%	77%	79%	80%	81%	82%	83%	83%	83%	84%	84%
11000t	75%	76%	77%	78%	79%	79%	80%	80%	80%	81%	81%
12000t	74%	75%	75%	76%	76%	76%	77%	77%	77%	77%	77%
12500t	73%	73%	74%	74%	74%	74%	74%	75%	75%	75%	75%
12600t	73%	73%	73%	73%	74%	74%	74%	74%	74%	74%	74%
12700t	72%	72%	73%	73%	73%	73%	73%	73%	73%	73%	73%
12800t	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%
12900t	71%	71%	71%	71%	71%	71%	71%	71%	70%	70%	70%
13000t	70%	70%	70%	70%	70%	69%	69%	69%	68%	68%	67%
13100t	70%	69%	69%	69%	68%	67%	67%	66%	66%	65%	64%
13200t	69%	68%	68%	67%	66%	65%	64%	63%	62%	61%	60%
13300t	68%	67%	66%	65%	64%	63%	61%	60%	59%	57%	56%
13400t	67%	66%	64%	63%	61%	60%	58%	56%	54%	53%	51%
13500t	66%	64%	62%	61%	59%	57%	55%	53%	50%	48%	46%
13600t	64%	62%	60%	58%	56%	53%	51%	48%	46%	43%	40%
13700t	63%	61%	58%	55%	53%	50%	47%	44%	41%	38%	36%
13800t	61%	59%	56%	53%	49%	46%	43%	40%	37%	34%	32%
14000t	58%	55%	51%	47%	43%	39%	35%	32%	29%	27%	25%
15000t	38%	31%	25%	21%	22%	32%	30%	29%	27%	26%	25%
16000t	20%	15%	12%	11%	10%	10%	10%	9%	9%	9%	9%

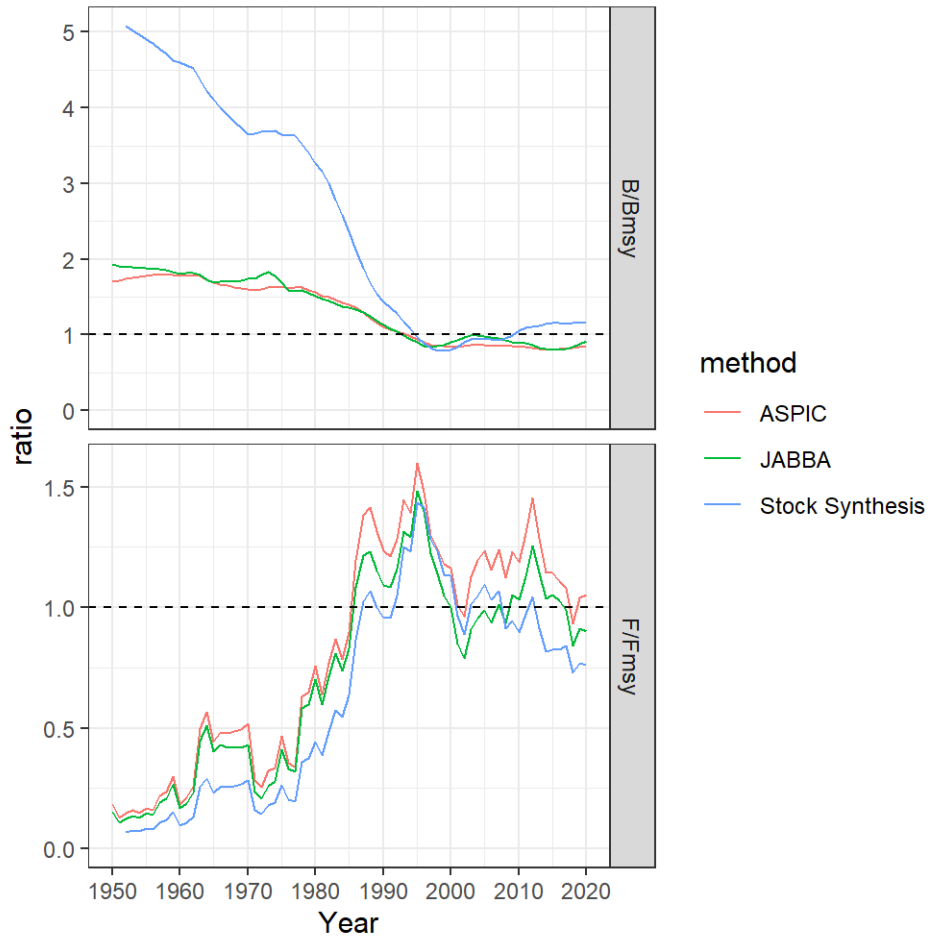


Figure 1a. Trajectories of B/B$_{MSY}$ (top panel) and F/F$_{MSY}$ (bottom panel) using Stock Synthesis (blue), ASPIC (red) and JABBA (green). (Figure 45 in Anon., 2022a)

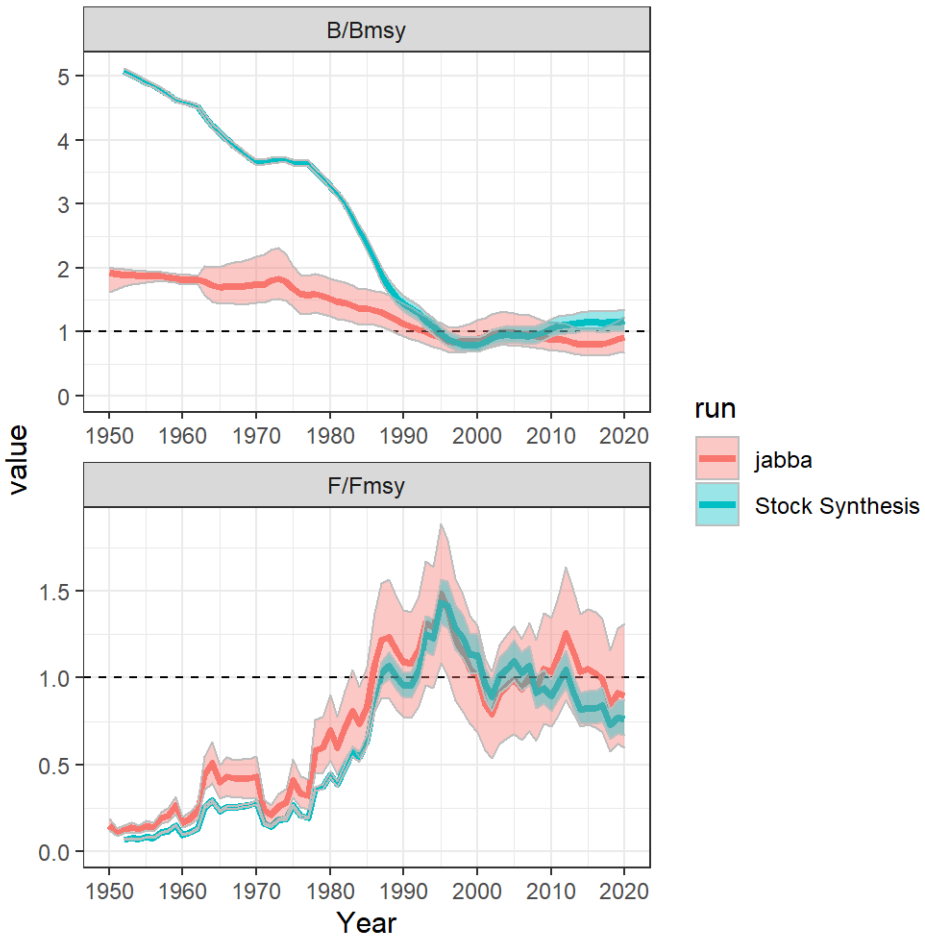
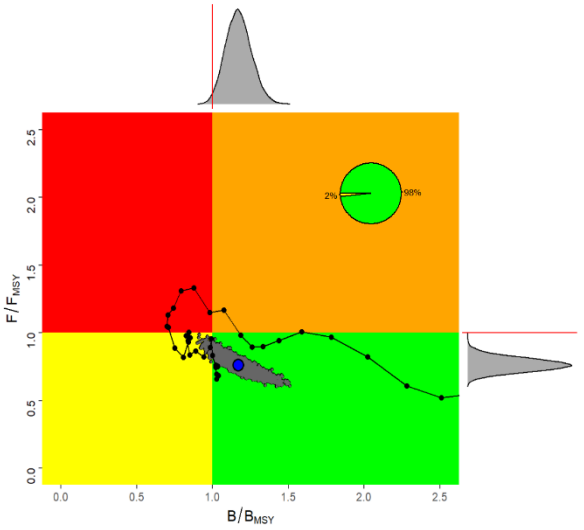
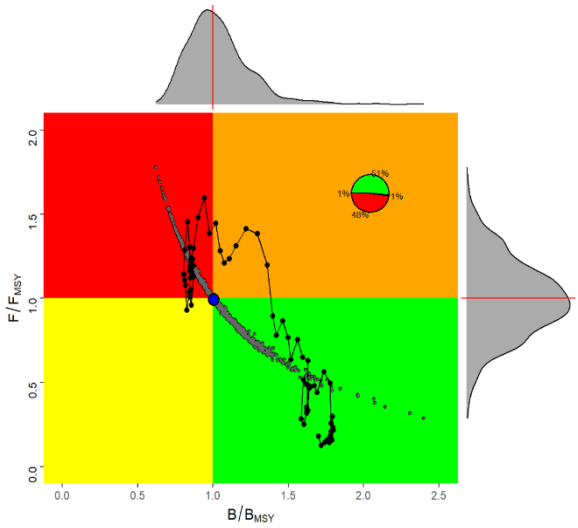


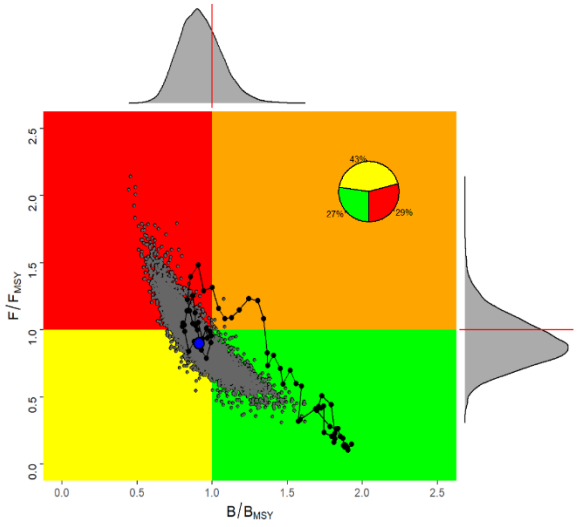
Figure 1b. Trajectories of B/B$_{MSY}$ (top panel) and F/F$_{MSY}$ (bottom panel) using Stock Synthesis (blue), and JABBA (red) with 95% credibility intervals.



Stock Synthesis



ASPIC



JABBA

Figure 2. Kobe phase plot for the three different stock assessment platforms (Stock Synthesis (top), ASPIC (middle) and JABBA (bottom, same as Figure 43 in Anon., 2022a)) of the North Atlantic swordfish stock.

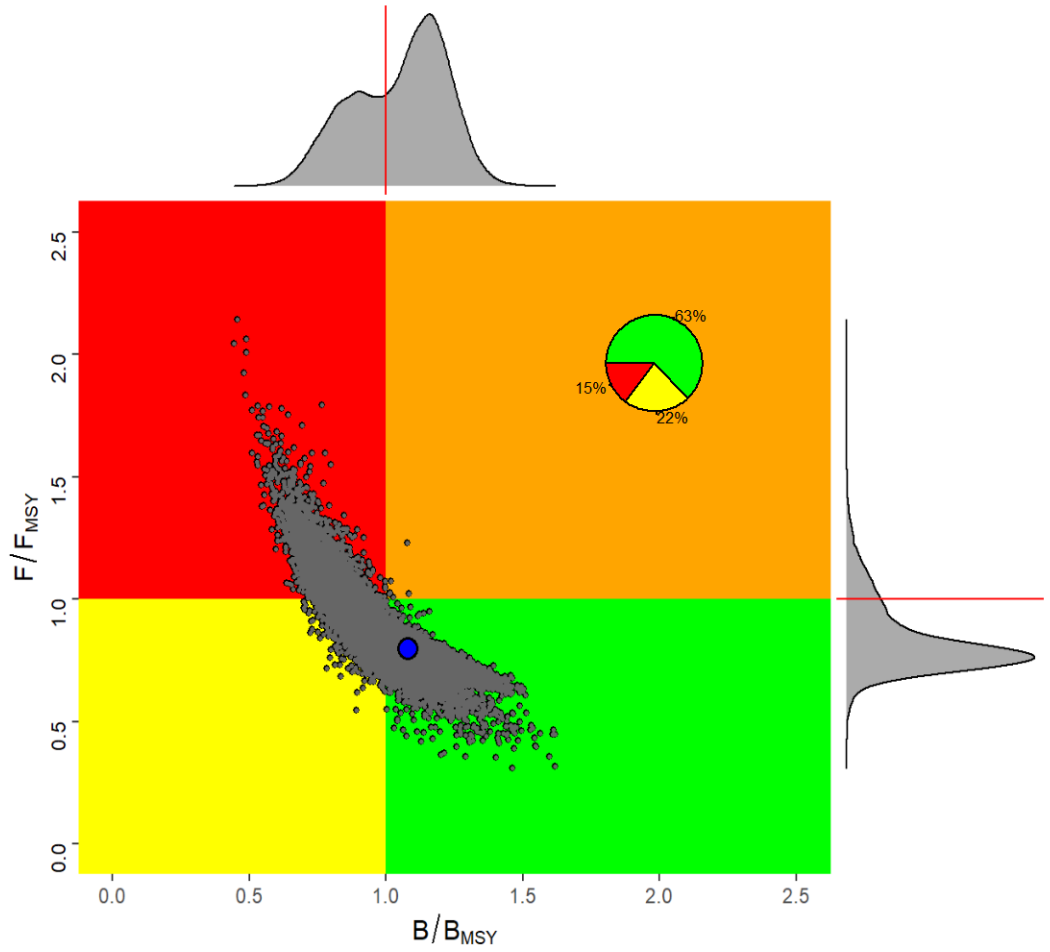


Figure 3a. Joint Kobe phase plot for the Stock Synthesis and the JABBA reference case models for the North Atlantic swordfish stock. For the Stock Synthesis run, the benchmark is calculated from the year-specific selectivity and fleet allocations, and based on 15000 MVLN iterations for Stock Synthesis and 15000 MCMC iterations for JABBA. The blue point shows the median of 30,000 iterations for SSB_{2020}/SSB_{MSY} or B_{2020}/B_{MSY} and F_{2020}/F_{MSY} for the entire iterations from Stock Synthesis and JABBA. Grey points represent the 2020 estimates of relative fishing mortality and relative spawning stock biomass for 2020 for each of the 30,000 iterations. The upper graph represents the smoothed frequency distribution of SSB_{2020}/SSB_{MSY} or B_{2020}/B_{MSY} estimates. The right graph represents the smoothed frequency distribution of F_{2020}/F_{MSY} estimates. The inserted pie graph represents the percentage of each 2020 estimate that fall in each quadrant of the Kobe plot. All SSB for Stock Synthesis showed the values at the end of years.

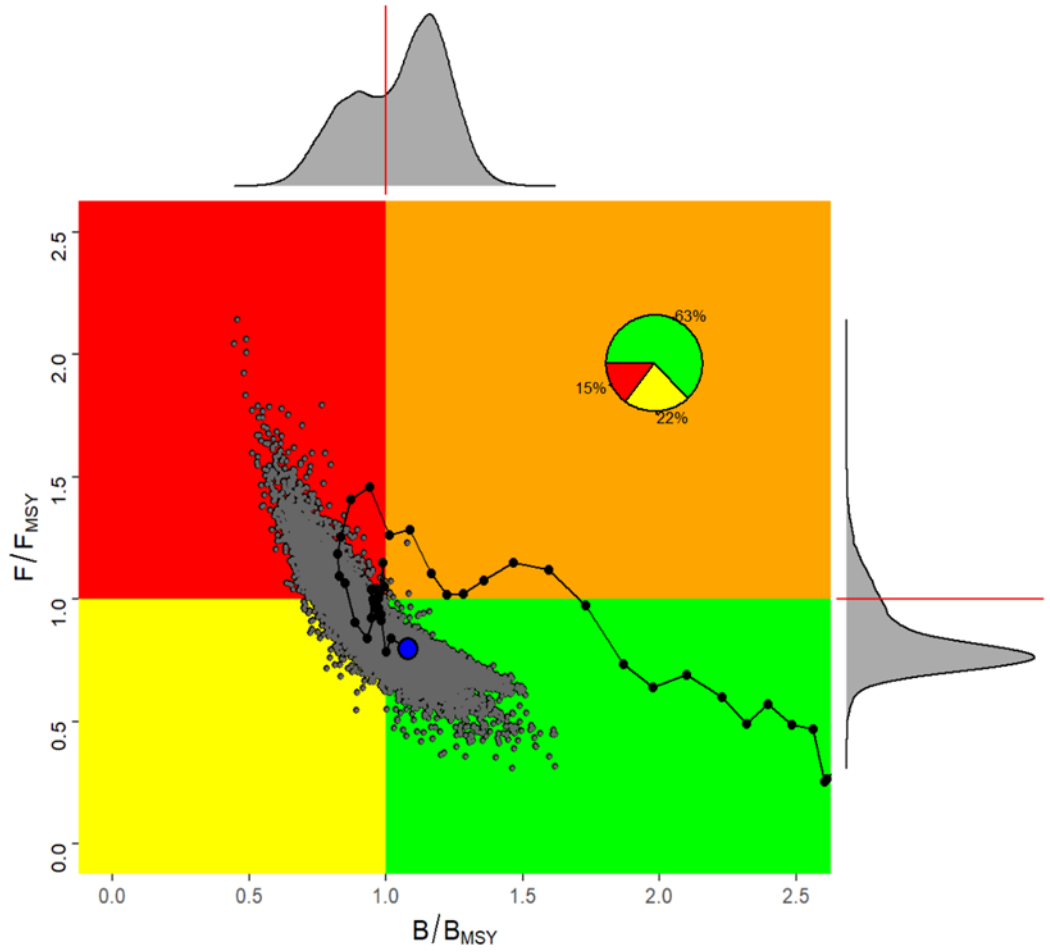


Figure 3b. Joint Kobe phase plot for the Stock Synthesis and the JABBA reference case models for the North Atlantic swordfish stock. The historical trajectory was calculated using the median of the Stock Synthesis deterministic model and JABBA model. The projection settings are the same as **Figure 3a**.

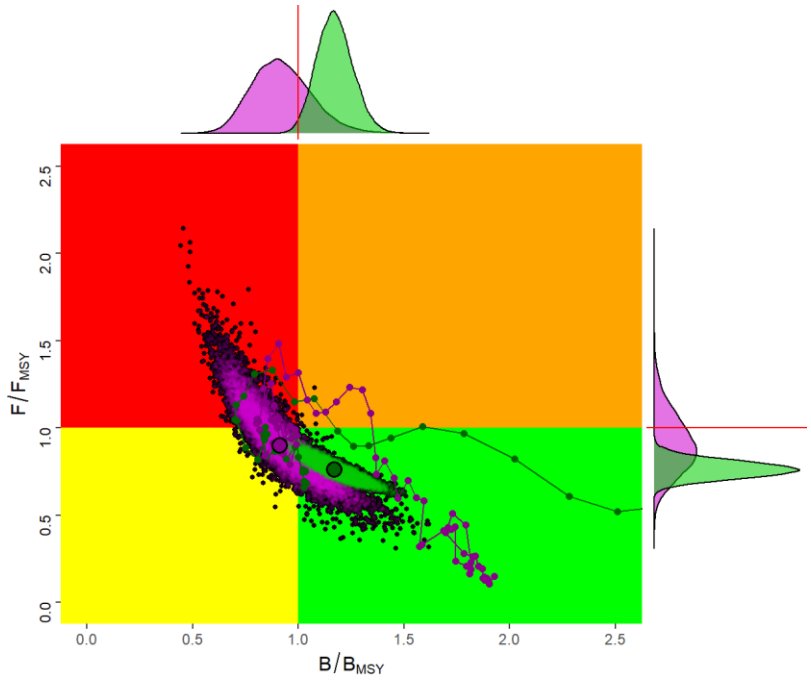


Figure 4. Overlayed Kobe phase plot for the Stock Synthesis (green) and the JABBA (pink) reference case models for the North Atlantic swordfish stock.

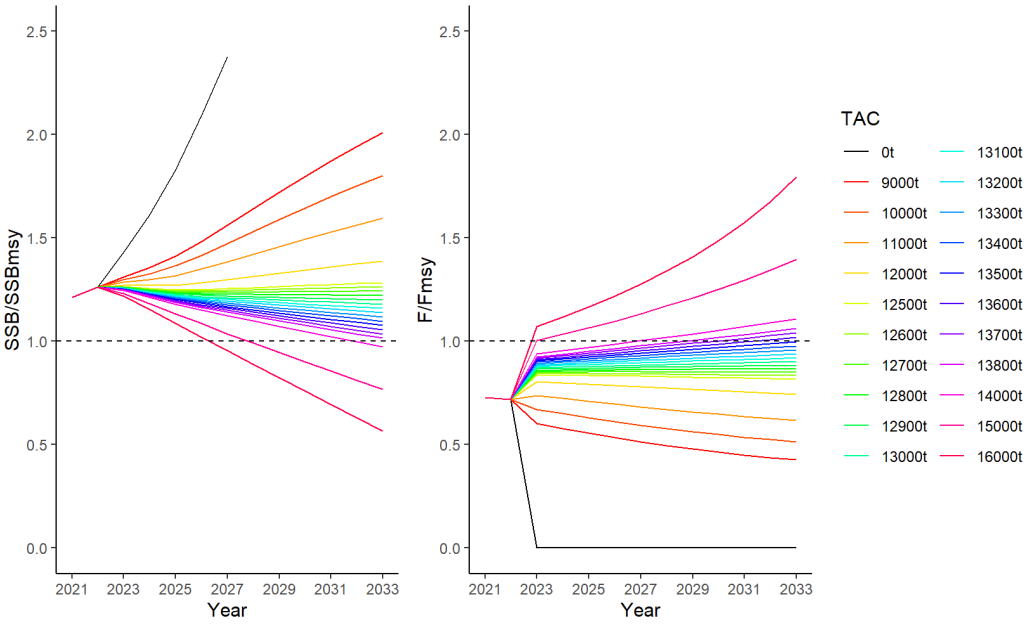


Figure 5. Projections from Stock Synthesis of spawning stock biomass at 0, 9-160 thousand mt constant TACs for the North Atlantic swordfish stock.

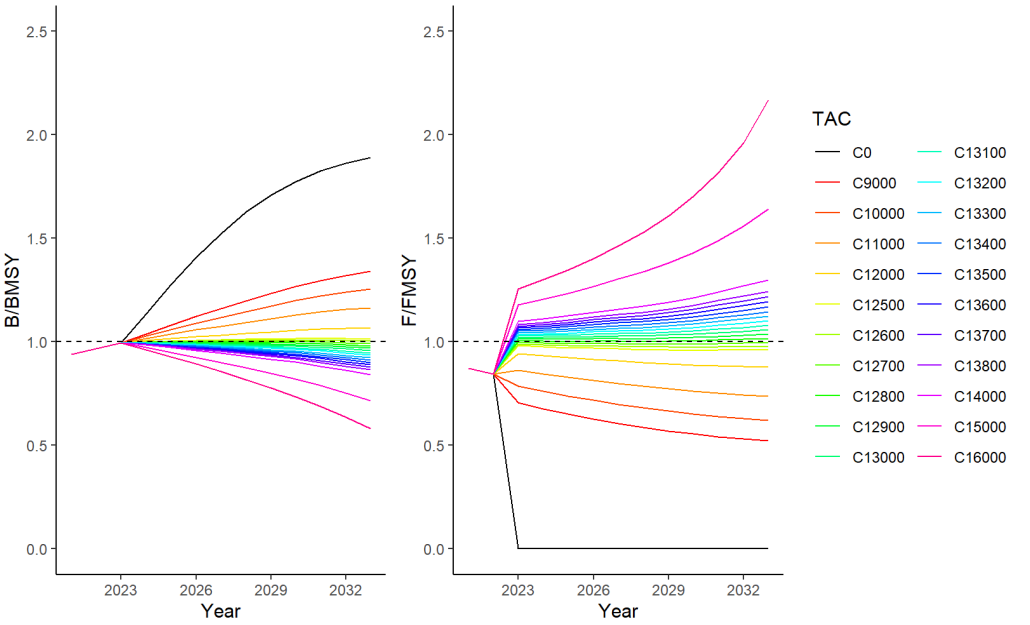


Figure 6. Projections from JABBA of biomass at 0, 9-160 thousand mt constant TACs for the North Atlantic swordfish stock.

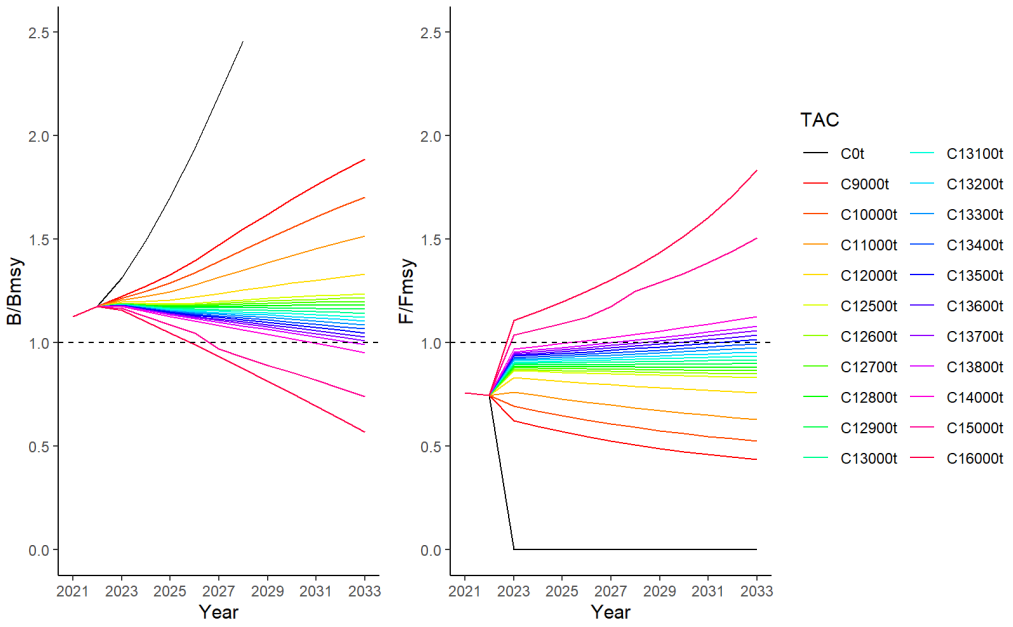


Figure 7. Joint projections from Stock Synthesis and JABBA of biomass (or spawning stock biomass) at 0, 9-160 thousand mt constant TACs for the North Atlantic swordfish stock.