

DETAILED ANALYSIS OF THE CATCH-AT-LENGTH AND AGE COMPOSITION DATA TO CHECK RESULTS FOR RECENT YEAR RECRUITMENT ESTIMATES FOR EASTERN ATLANTIC BLUEFIN TUNA

L.E. Ailloud¹, T. Rouyer², A. Kimoto³, R. Sharma⁴, D.S. Butterworth⁵

SUMMARY

A model-free exercise was carried out to determine the plausibility of the high 2004-2007 recruitment estimates that resulted from the VPA base run for Eastern Atlantic bluefin tuna. Information on year class strength from the base run was compared to information on year class strength present in the catch at length data for the Japanese Northeast Atlantic longline fishery and the trap fishery. The analysis revealed inconsistencies: while the VPA results suggest the 2004-2007 cohorts are of near equal strength to the 2003 cohort, the catch at length data suggest that the 2003 cohort was certainly stronger. In addition, the catch at length information was somewhat more compatible with alternative VPA runs that indicate lower recruitment and lower biomass in recent years than the VPA base run does. This analysis suggests applying some assessment approach which will result in a reduction in the size of the 2004-2007 cohorts relative to the 2003 cohort. However, the analysis did not allow a quantification of the extent of change in VPA specifications that would best reflect the available data as a whole.

RÉSUMÉ

Un exercice sans modèle a été effectué pour déterminer la vraisemblance des estimations de recrutement élevé entre 2004 et 2007 qui ont résulté du cas de base de la VPA pour le thon rouge de l'Atlantique Est. Les informations sur la force de la classe d'âge obtenues du scénario du cas de base ont été comparées à l'information sur la force de la classe d'âge présente dans les données de prise par taille de la pêcherie palangrière japonaise opérant dans l'Atlantique Nord-Est et la pêcherie de madragues. L'analyse a révélé des contradictions : alors que les résultats de la VPA suggèrent que les cohortes de 2004-2007 sont de force presque égale à la cohorte de 2003, les données de prise par taille donnent à penser que la cohorte de 2003 était certainement plus forte. De plus, l'information de prise par taille était quelque peu plus compatible avec d'autres scénarios de VPA qui indiquent un recrutement plus faible et une biomasse plus faible au cours de ces dernières années que ne le fait le scénario du cas de base de la VPA. Cette analyse suggère d'appliquer une approche d'évaluation qui se traduira par une réduction de la taille des cohortes de 2004-2007 par rapport à celle de la cohorte de 2003. Cependant, l'analyse n'a pas permis de quantifier l'ampleur du changement dans les spécifications de la VPA qui refléterait au mieux les données disponibles dans leur ensemble.

RESUMEN

Se ha realizado un ejercicio sin modelo para determinar la plausibilidad de las estimaciones de levado reclutamiento en 2004-2007 resultantes del ensayo del caso base del VPA para el atún rojo del Atlántico este. La información sobre la fuerza de la clase anual del ensayo del caso base se comparó con la información de la fuerza de la clase anual presente en los datos de captura por talla para la pesquería japonesa de palangre del Atlántico nororiental y al pesquería de almadraba. El análisis reveló incoherencias: mientras que los resultados del VPA sugieren que las cohortes de 2004-2007 tienen un a fuerza casi igual a la de la cohorte de 2003, los datos de captura por talla sugieren que la cohorte de 2003 era sin duda más fuere. Además, la información

¹lailloud@vims.edu, Virginia Institute of Marine Science, College of William and Mary, P.O. Box 1346, Gloucester Point, VA 23062, USA.

²tristan.rouyer@ifremer.fr, IFREMER, UMR MARBEC, Avenue Jean Monnet, 34203 Sète, France.

³aikimoto@affrc.org, NRIFS, 5-7-1, Orido, Shimizu, Shizuoka, 424-8633, Japan

⁴rishi.sharma@noaa.gov, NWFSC, NOAA-Fisheries, 1201 NE Lloyd Boulevard, Suite 1100, Portland, OR 97232, USA.

⁵doug.butterworth@uct.ac.za, University of Cape Town, Rondebosch 7701, South Africa.

sobre captura por talla era en cierto modo más compatible con ensayos de VPA alternativos, que indican un reclutamiento más bajo y una biomasa más baja en años recientes que los que indicaba el ensayo caso base del VPA. Este análisis sugiere que se aplique un enfoque de evaluación que tenga como resultado una reducción en el tamaño de las cohortes de 2004-2007 con respecto a la cohorte de 2003. Sin embargo, el análisis no permitió una cuantificación de la medida del cambio en las especificaciones del VPA que reflejaría mejor los datos disponibles en su conjunto.

KEYWORDS

Bluefin tuna, recruitment, catch-at-length, cohort strength

1. Introduction

Results from the Virtual Population Analysis (VPA) and Stock Synthesis 3 (SS3) show different patterns of recruitment in recent years for Eastern Atlantic bluefin tuna (EABT), with biomass being estimated to be much higher for the VPA than for SS3. While SS3 results suggest that only the 2003 year class was strong, the VPA suggests year-classes of similar size to 2003 for the next four years (2004-2007). In the VPA, estimates of recent recruitment are very sensitive to the addition of the terminal years of data. In particular, the addition of the 2015 data results in very high 2004-2007 year classes that were not particularly evident in earlier retrospectives, which raises concerns about the plausibility that these high recruitment estimates reflect reality. While SS3 should, in theory, be better informed as the model makes use of both length information and direct age information to estimate age composition (available for only part of the years and ages covered by the assessment), SS3 results may be compromised by seeking a longer period summary of conflicting datasets. To attempt to resolve these differences and assess the plausibility of the high 2004-2007 recruitment estimates, we compare VPA results to information present in the catch-at-length (CAL) data in a model-free way, following the methodology described below.

2. Methods

2.1. Comparing CAL information to the VPA base run results

We compare proportions-at-age estimated from the VPA base run with those provided by the CAL for two fisheries of interest: 1. the Japanese Northeast Atlantic longline fishery and the trap fishery (i.e., Spanish-Morocco trap up to 2011 and Morocco-Portugal trap from 2012 onward). The comparison is made over the years 2006 to 2015 to focus on the 2003 to 2007 cohorts that are of particular interest.

Annual proportions-at-age ($P_{y,a}^{VPA}$) are calculated from VPA estimates of numbers-at-age ($N_{y,a}^{VPA}$) as follows:

$$P_{y,a}^{VPA} = N_{y,a}^{VPA} / \sum_{a=1}^{10} N_{y,a}^{VPA} \quad (1)$$

where y is year and a is age (using a plus group of 10+ in accordance with the base case scenario for the EABT stock assessment).

Proportions-at-age from the CAL data ($P_{y,f,a}^{CAL}$) from each of the two fisheries are calculated by converting length composition (C) to selectivity-corrected length composition (C^*) and then converting the output to age-based results using year-specific estimates of probabilities of age given length ($A_{y,a,l}$) generated using the combined forward-inverse age-length keys (ALKs) developed for EABT (SCRS/2017/179).

Selectivity-corrected length composition by year (y), fishery (f) and length (l) is obtained by dividing the CAL matrices for individual fisheries by the selectivity (S) vectors obtained from SS3 (**Figure 1**), as follows:

$$C_{f,y,l}^* = C_{f,y,l} / S_{f,y,l} \quad (2)$$

Selectivity-corrected length composition is then converted to an age-basis using matrices of probabilities of age given length, $A_{y,a,l}$:

$$C_{f,y,a}^* = \sum_{l=20}^{349} C_{f,y,l}^* A_{y,a,l} \quad (3)$$

Finally, catches are normalized to obtain proportions-at-age:

$$P_{f,y,a}^{CAL} = C_{f,y,a}^* / \sum_{a=1}^{10} C_{f,y,a}^* \quad (4)$$

We select a range of ages, a' , over which to compare proportions-at-age from the VPA base run to those calculated from the CAL, and renormalize over the range of ages to compare results. The range of ages was chosen based on selectivities and the reliability of the ALK conversions. Based on selectivity, ages were truncated on the left at age 3 for the Japanese NE Atlantic longline index until 2009 and age 6 for this index from 2010 onward; similarly truncation was at age 3 for the trap index until 2011 and 4 from 2012 onward – see **Figure 1** for the selectivity curves by fishery and time period. In addition, because of concerns that fish belonging to the plus group 10+ could have been mis-assigned to age 9 in the ALK, the analysis was truncated with age 8 for the oldest age. The difference matrix, $\Delta P_{f,y,a'}^{\square}$, is expected to show a pattern for specific cohorts if, indeed, the CAL data are incompatible with the VPA results:

$$\Delta P_{f,y,a'} = P_{f,y,a'}^{CAL} - P_{y,a'}^{VPA} \quad (5)$$

2.2 Comparing CAL information to alternatively tuned VPA runs

Four alternatively tuned VPA scenarios are presented here (**Appendix 1 Table A1** shows all the configurations that were examined) and the resulting proportions-at-age were compared with the proportions-at-age in the CAL data of the two fisheries of interest following the methodology outlined in 2.1. These alternative runs were not chosen as potential replacements for the current base case VPA, but rather because they are examples which exhibit either or both lesser 2004-2007 recruitments and a subsequent lower recent trend in biomass than the base case run (**Figures 2 and 3**). Detailed descriptions of the alternative runs are listed below.

- i. **FrSplt_NoLarv**
The French aerial survey was split and the larval index removed.
- ii. **NoFrLarJPNLLBB**
The following 4 indices were removed: French aerial survey, larval index, recent part of the Japanese longline NE Atlantic index (JPLL NEATL 2) and recent part of the bait boat index (SPBB2)
- iii. **350Pcent**
Variances associated with the French aerial survey (0.509), larval survey (0.737) and Japanese longline CPUE (0.4151) were increased by 350 percent compared to the base case (2.291, 3.317 and 1.86, respectively) and then used as weighing factors for their respective indices in the VPA.
- iv. **Fratio**
The F-ratios from the first two time periods (1968-1980; 1981-1995), which were estimated separately in the base case (1.401 and 0.684, respectively), were merged and fixed at a value below one (0.75) since appreciable numbers of smaller fish were caught during this period and there seems no reason to believe that the catch of fish of ages 10+ would have been larger than the catch of age 9 fish. The F-ratio for the third period (1996-2007), estimated at 2.632 in the base case, was re-estimated in the new run (2.385). During this period, the French and Spanish purse seine fleets started to develop and move to the spawning grounds, targeting larger animals.

The F-ratio for the last period (2007-2015), which was left to be estimated by the VPA in the base case (1.688), was rather fixed at 1 here.

A sum of squares metric (SS) was calculated for the base run and alternative runs to quantify the differences observed between the information present in the CAL data of the two fisheries of interest and the estimated numbers at age resulting from each VPA run (see **Table A1** of **Appendix 1** for results for all the runs examined). In addition absolute error differences for ages 6 to 8 from year classes 2003-2007 in the catches of the JPN LL NEA fishery and trap fishery can also be examined for the Frario run (**Appendix 1, Figure A1**). Similar figures were examined for all other runs, but we chose to only report the SS statistic below that focuses on the key issue at hand. SS provides a relative measure from which to compare the results from each run and establish which resulted in a catch at age matrix that was most similar to the information present in the CAL data for the two fisheries. The ranges of ages and years chosen for each fishery and time period are detailed in section 2.1.

$$SS_{f,VPAlt} = \sum_y \sum_a (P_{f,y,a'}^{CAL} - P_{f,y,a'}^{VPAalt})^2 \quad (6)$$

3. Results

Table 1 illustrates the discrepancies between the catch at age information present in the CAL data and the VPA base run results. There does not appear to be a systematic/clear-cut pattern of residuals in $\Delta P_{f,y,a'}^{\square}$, but these results do nevertheless appear to indicate that the strength of the 2003 cohort is being underestimated in the VPA base run. This is clearly apparent in the Japanese longline data (**Table 1B**) where the numbers associated with the 2003 cohort (outlined in black) are nearly all highly positive while those numbers associated with the 2004-2007 cohorts are, for the most part negative. The one exception is the strongly positive number assigned to age 3 in 2007 (.27) but this could be a result of the fact that there remains a small positive bias in the ALK for assigning ages to younger fish (due to issues in the otolith age readings where false bands may have occasionally lead to over-counting of bands in young fish). As such, it is likely that some of the fish that were assigned to age 3 in 2007 actually belong to the 2003 cohort. It is unclear why age 8 appears systematically stronger in the CAL data compared to the VPA base case for 2010 to 2015, even though the 2004-2007 cohorts appear systematically weaker in early age stages (**Table 1A**). This result could be due, in part, to the fact that the ALK is more reliably able to assigning ages to younger fish compared to older fish. In the TP fishery (**Table 1A**), the 2003 cohorts appears stronger in the CAL data compared to the VPA base run from 2009 to 2011. Subsequent cohorts do not appear to have such a strong signal from 2010 to 2015. In summary then, use of this approach for the JPN LL data provides qualitative indications that the base case VPA is over-estimating the strength of the 2004-2007 cohorts; the trap data does not provide as clear results, possibly because selectivity there is more variable over time.

All four alternative runs resulted in a lower SS than the base case VPA run (**Table 2**) but the differences in SS between the alternative runs and the base case scenario are relatively small, and hence unfortunately provide little basis for assigning preference.

4. Discussion

Results are not clear-cut (due to issues remaining in the ALK and potential mismatch between the selectivity vectors estimated and true selectivities of the fisheries which may not be constant over time as assumed) but **Table 1** suggests that the 2003 cohort was certainly stronger than the 2004-2007 cohorts (which conflicts with what the VPA base run indicates). The VPA base run recruitment estimates for the more recent years (2004-2007) are likely to be too high, but the extent to which they have been overestimated is unclear. With the alternative runs there is some improvement in SS but these improvements are not considerable.

Hence this analysis suggests applying some approach (e.g. an alternative F-ratio formulation, or down-weighting in the VPA fit of at least some of the indices showing recent upward trends) which will reduce the size of the 2004-2007 cohorts relative to the 2003 cohort, compared to their near equality in the base case VPA run. However this analysis in isolation is unable to quantify the extent of change in VPA specifications that would best reflect the available data (both abundance index and size structure) as a whole.

Table 1. Difference matrices, $\Delta P_{f,y,a'}^{\square}$, illustrating the differences in proportions-at-age between the CAL information and the VPA base run for A. the trap fishery and B. the JPN LL NEA fishery. The 2003 cohort is outlined in black, with a lower outline indicating the span of the 2004-2007 cohorts. Colder colors/negative numbers indicate that the age group in question appears weaker in the CAL data than in the VPA base case in that specific year, while warmer colors/positive numbers indicate that the age group in question appears stronger in the CAL data than in the VPA base case in that specific year.

A

| YEAR/AGE | 3 | 4 | 5 | 6 | 7 | 8 |
|----------|-------|-------|-------|-------|-------|-------|
| 2006 | -0.41 | -0.20 | 0.04 | 0.22 | 0.18 | 0.16 |
| 2007 | -0.34 | -0.24 | 0.13 | 0.27 | 0.10 | 0.08 |
| 2008 | -0.33 | -0.24 | -0.10 | 0.03 | 0.18 | 0.47 |
| 2009 | -0.35 | -0.21 | -0.05 | 0.24 | 0.28 | 0.08 |
| 2010 | -0.21 | -0.28 | -0.14 | 0.01 | 0.33 | 0.29 |
| 2011 | -0.15 | -0.15 | -0.18 | -0.01 | 0.00 | 0.50 |
| 2012 | - | -0.16 | -0.08 | 0.07 | 0.05 | 0.12 |
| 2013 | - | 0.39 | 0.08 | -0.13 | -0.20 | -0.13 |
| 2014 | - | -0.06 | 0.28 | -0.09 | -0.11 | -0.02 |
| 2015 | - | -0.06 | 0.34 | -0.11 | -0.08 | -0.09 |

B

| YEAR/AGE | 3 | 4 | 5 | 6 | 7 | 8 |
|----------|-------|-------|-------|-------|-------|-------|
| 2006 | -0.15 | 0.29 | -0.07 | -0.04 | -0.03 | -0.01 |
| 2007 | 0.27 | 0.01 | -0.08 | -0.11 | -0.05 | -0.03 |
| 2008 | -0.19 | -0.20 | 0.20 | 0.13 | 0.02 | 0.04 |
| 2009 | -0.24 | -0.16 | -0.12 | 0.19 | 0.33 | 0.01 |
| 2010 | - | - | - | -0.13 | 0.19 | -0.06 |
| 2011 | - | - | - | -0.02 | -0.23 | 0.25 |
| 2012 | - | - | - | -0.22 | 0.15 | 0.07 |
| 2013 | - | - | - | -0.16 | -0.10 | 0.26 |
| 2014 | - | - | - | -0.18 | -0.17 | 0.35 |
| 2015 | - | - | - | -0.34 | -0.10 | 0.44 |

Table 2. SS metric calculated for the 4 alternative runs and the base case scenario for the trap fishery and the JPN LL NEA fishery. The abbreviations for the alternative runs are explained in the text.

| Alternative run | TP | | JPN LL NEA | |
|-----------------------|------|-------------------|------------|-------------------|
| | SS | %change from base | SS | %change from base |
| Fratio | 2.46 | 0.12 | 1.34 | 0.06 |
| NoFrLarJPNLLBB | 2.50 | 0.11 | 1.35 | 0.06 |
| 350Pcent | 2.55 | 0.09 | 1.36 | 0.05 |
| Frsplt_nolarv | 2.65 | 0.06 | 1.38 | 0.03 |
| Base | 2.81 | 0.00 | 1.43 | 0.00 |

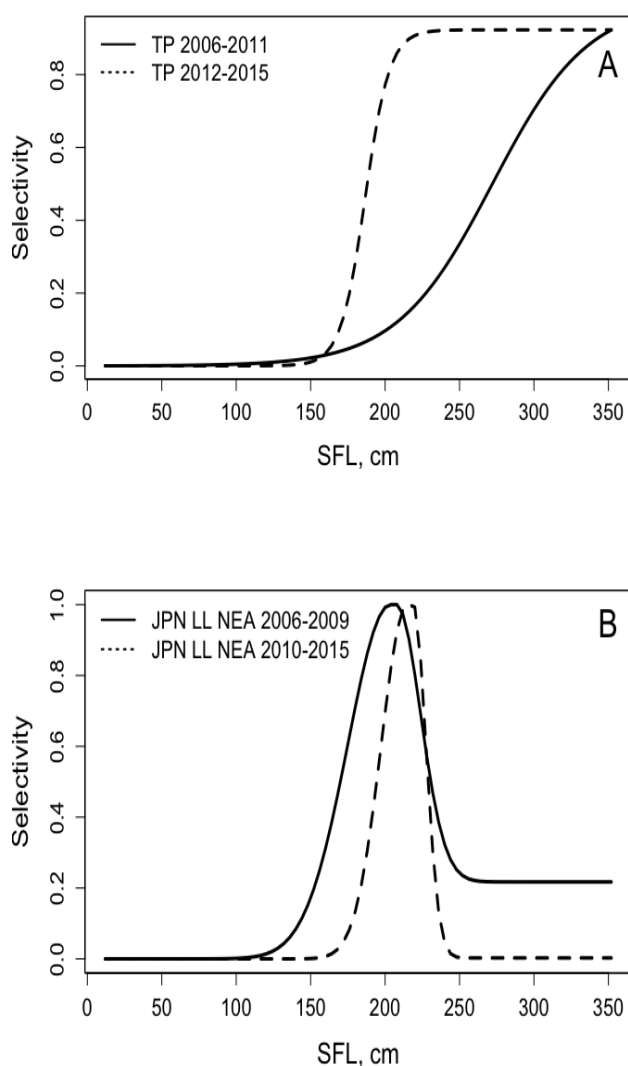


Figure 1. Selectivity curves for **A.** the trap fishery and **B.** the Japanese longline fishery in the NE Atlantic. Note that only the earlier periods shown are utilized for the comparisons reported in the main text.

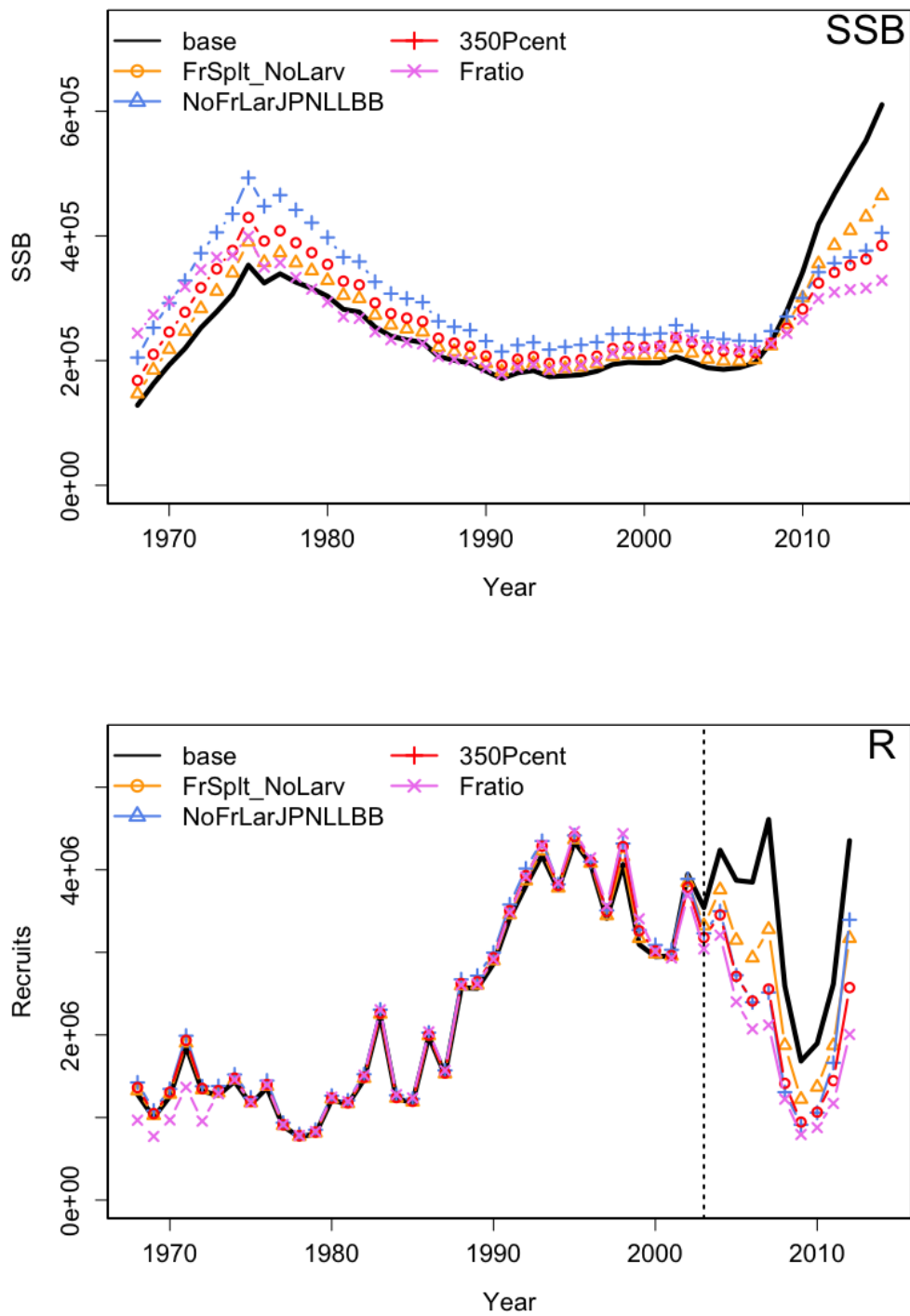


Figure 2. Spawning stock biomass (SSB) and recruitment estimates (R) resulting from the 4 alternative runs compared to the base case scenario. The 2003 cohort is indicated by the dotted line on the lower recruitment plot.

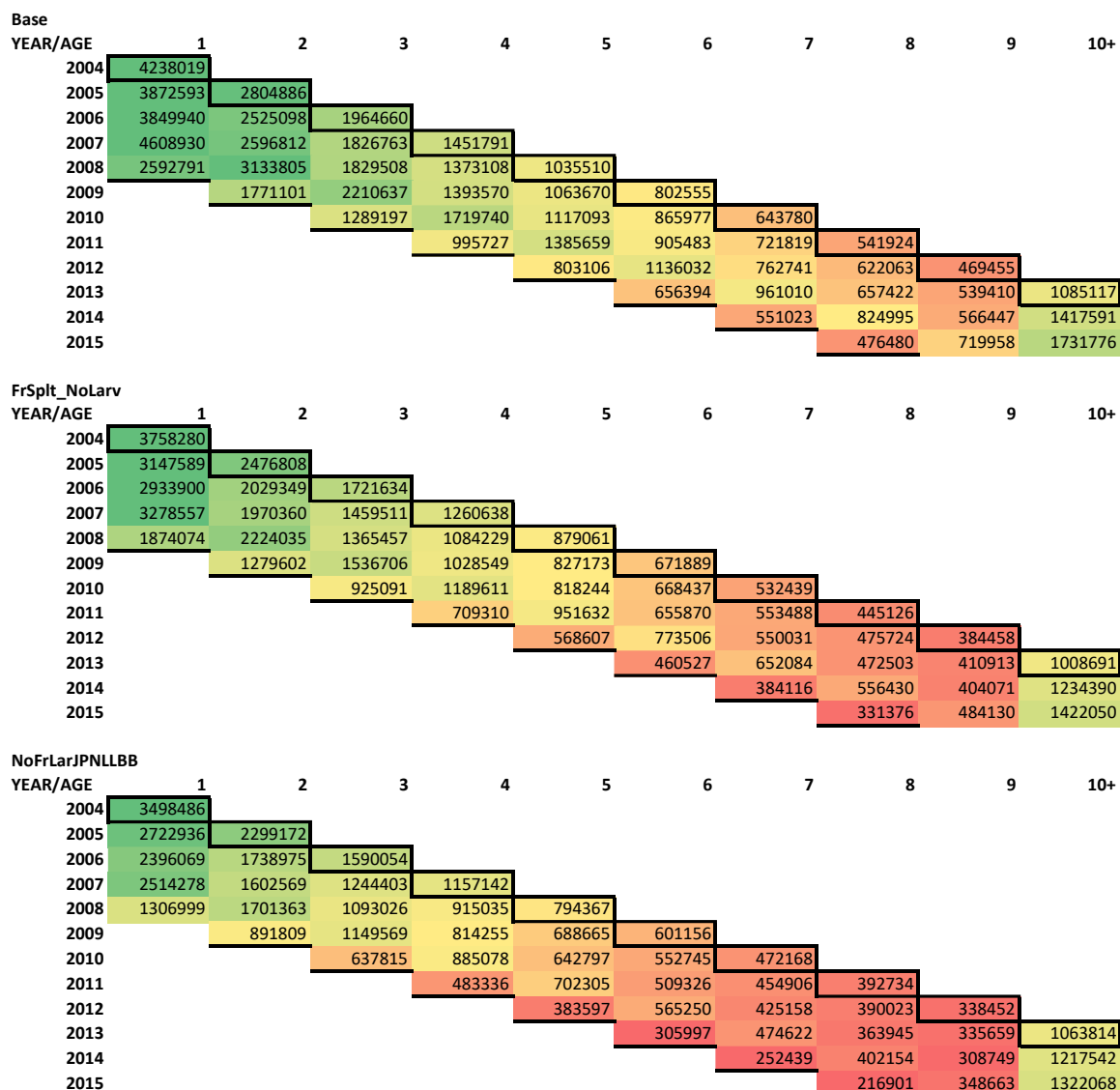


Figure 3. Numbers-at-age estimates from the base run and four alternative VPA runs. The abbreviations for the alternative runs are explained in the text. Green colors indicate higher numbers and red colors lower numbers. The 2003 cohort is outlined in black, with a lower outline indicating the span of the 2004-2007 cohorts.

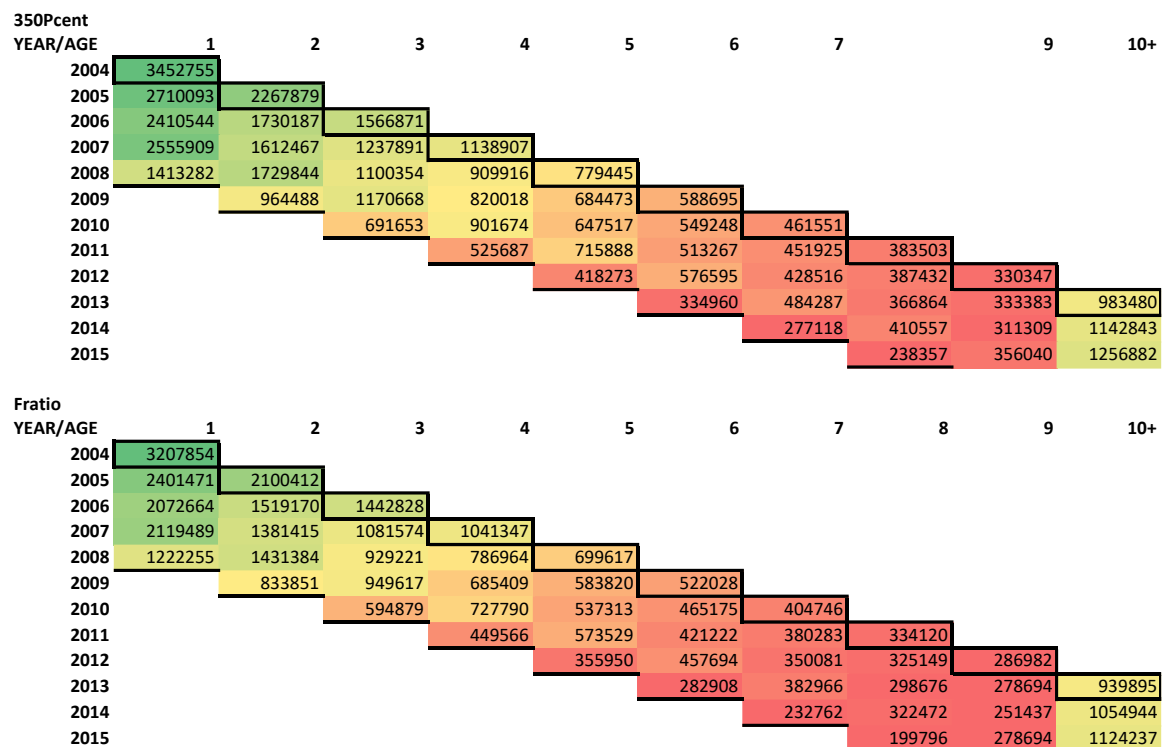


Figure 3 continued. Numbers-at-age estimates from the base run and four alternative VPA runs. The abbreviations for the alternative runs are explained in the text. Green colors indicate higher numbers and red colors lower numbers. The 2003 cohort is outlined in black, with a lower outline indicating the span of the 2004-2007 cohorts.

Appendix 1: Summary of all models examined

Table A1. SS of all models examined using A. the Trap fishery and B. the JPN LL NEA fishery. The four runs of interest are shown in bold and the base run is highlighted in grey. Abbreviations for the alternative runs are explained below.

| A. TP | | B. JPN LL NEA | |
|-----------------------|------|-----------------------|------|
| RUN | SS | RUN | SS |
| Fratio | 2.46 | Fratio | 1.34 |
| NoFrLarJPNLLBB | 2.50 | NoFrLarJPNLLBB | 1.35 |
| NoFrLarJPNLLTPBB | 2.53 | 350Pcent | 1.36 |
| 350Pcent | 2.55 | NoFrLarJPNLLTPBB | 1.36 |
| NoFrLarNoJPNLL | 2.58 | NoFrLarJPNLL | 1.37 |
| NoFrLarNoJPNLLTP | 2.61 | NoFrLarJPNLLTP | 1.37 |
| NoFrLarNoBB | 2.63 | NoFrLarBB | 1.38 |
| Frsplt_nolarv | 2.65 | Minus55Pcent3series | 1.38 |
| FrAndLarvSplit* | 2.66 | Frsplt_nolarv | 1.38 |
| Minus55Pcent3series | 2.66 | FrAndLarvSplit* | 1.39 |
| NoFrLar | 2.68 | Minus75Pcent3series | 1.39 |
| Minus75Pcent3series | 2.68 | Minus150Pcent3series | 1.39 |
| Minus150Pcent3series | 2.68 | NoFrLar | 1.39 |
| Minus150Pcent2series | 2.69 | Minus150Pcent2series | 1.39 |
| Minus350Pcent2series | 2.69 | Minus350Pcent2series | 1.39 |
| Minus55Pcent2series | 2.72 | Minus55Pcent2series | 1.40 |
| Minus25Pcent3series | 2.73 | Minus35Pcent3series | 1.40 |
| Minus35Pcent3series | 2.74 | Minus25Pcent3series | 1.40 |
| Minus75Pcent2series | 2.74 | Minus75Pcent2series | 1.41 |
| Minus35Pcent2series | 2.75 | Minus35Pcent2series | 1.41 |
| Minus25Pcent2series | 2.80 | Minus25Pcent2series | 1.42 |
| Base | 2.81 | Base | 1.43 |

Indice abbreviations:

JPNLL = recent part of the Japanese longline NE Atlantic index (JPLL NEATL 2)

BB = recent part of the bait boat index (SPBB2)

TP = Combined Morocco – Spain and Morocco – Portugal index

Fr = French aerial survey

Lar = Larval index in the western Mediterranean

NoXX = the XX indices listed in the run names were removed from the VPA for that run.

MinusXXPcent3series = Variances associated with Fr, Lar and JPNLL were increased by XX% compared to the base case and used as weighing factors for downweighing their respective indices in the VPA.

MinusXXPcent2series = Variances associated with Fr and Lar were increased by XX% compared to the base case and used as weighing factors for their respective indices in the VPA.

*Fr and Lar series were split.

A

| YEAR/AGE | 6 | 7 | 8 |
|----------|-----|-----|-----|
| 2009 | -14 | 51 | -28 |
| 2010 | -64 | 35 | 95 |
| 2011 | -58 | -55 | 170 |
| 2012 | -10 | -9 | 30 |
| 2013 | 2 | -6 | 8 |
| 2014 | -58 | -47 | 61 |
| 2015 | -36 | -32 | 61 |

B

| YEAR/AGE | 6 | 7 | 8 |
|----------|-----|-----|-----|
| 2009 | -19 | 89 | -64 |
| 2010 | -27 | 54 | -31 |
| 2011 | -5 | -68 | 98 |
| 2012 | -48 | 49 | 28 |
| 2013 | -55 | -23 | 89 |
| 2014 | -76 | -56 | 77 |
| 2015 | -91 | -38 | 121 |

Figure A2. Percent error calculated from the difference matrices ($\Delta P_{f,y,a}$ -- equation 5) comparing **A.** the trap fishery and **B.** the JPN LL NEA fishery to the current VPA base run over ages 6 to 8. The 2003 cohort is outlined in black, with a lower outline indicating the span of the 2004-2007 cohorts.