

The p.<page> l.<line> comments refer to a revised manuscript version (in a track changes mode) that we are going to provide. This comment-form says: "do NOT submit here".

Authors Response to Reviewer 2

R2: The paper by Winter et al. develops a novel stock-recruitment function that captures the diversity of density dependencies (compensation, Allee effect) of recruitment production and disentangles the effects of spawner abundance, spawner weight and temperature on recruitment dynamics. The developed model is fitted to empirical time series to identify Allee effects and their potential drivers for Atlantic cod. Overall, the paper contributes to the emerging recognition of dynamic Allee effects that can interact with the environment, and as such, it addresses relevant scientific questions.

Nonetheless, some parts of the paper require careful rewriting or reorganization to make it easier to follow. See my specific comments below.

Authors: Thanks reviewer R2 for the detailed suggestions. In the revised manuscript we worked on rewriting the text, considering all these specific comments, and added the suggested model overall structure scheme.

R2-1: 46 Check spacing after '(SSB)' and before 'the biomass'.

Authors: corrected.

R2-2: 52, 101... (many occasions) Check the use of parentheses in citations throughout.

Authors: thank you, extra parentheses removed throughout the text.

R2-3: Figure 1 & 113-118 It is not usual to include results of an exploratory analysis in the Introduction. Could you motivate the study setup in another way and have these in Materials and Methods or Appendix?

Authors: thanks, we thought of stock assessment data as literature data to be referenced to in the introduction. However, since we base on our own data analysis, it is indeed more logic to place it as a part of our work. We have inserted the following paragraph and the figure 1 in the beginning of the Results section as: "Stock assessment data analysis suggested the highest probability for a decrease in recruitment per capita at below average spawner abundance, indicating patterns of an Allee effect (Fig. 1 a). Interestingly, most stocks have been prevalent in the area of the Allee effect threshold (Fig. 1 a, white area), where SSB degradation can have strong repercussions for population and management. In particular at low spawner

abundance, below the Allee effect threshold, recruitment per capita ratios are accompanied by temperatures above the average experienced SST (Fig. 1 b, red shading), as well as a below average spawner weight (Fig. 1 c, blue shading). This led us to a hypothesis that spawner weight and SST could have effects on recruitment production at low abundance, which is further tested by the developed model.”

While instead in the introduction on p.6 l.120 we say “Based on literature and preliminary stocks data analysis we hypothesize that consideration of spawner abundance, spawner weight and SST as components of the stock-recruitment function, should give insight on Allee effect dynamics in Atlantic cod.”.

R2-4: 101 Also, Fig. A1 could be cited in M&M, instead of citing it in the Introduction.

Authors: on p.4 l.101-102 of the introduction we changed the phrase “The different stocks are located in the North Atlantic Ocean (see Appendix A: Fig. A1)), where direction and intensity..” to “In the North Atlantic Ocean direction and intensity.. ” and moved the citation of Fig.A1 to M&M to p. 7 l.136 as follows “For the 17 Atlantic cod stocks, that are located in the North Atlantic Ocean (see Appendix A: Fig. A1), we extracted time series”.

R2-5: 147-148 I assume the age class is a discrete variable. I would rather say its value belongs to the set $\{1, \dots, A\}$.

Authors: thanks, corrected on p.7 l.152.

R2-6: 155 What does 'R' stand for in eqn. (1)? Is it recruitment (line 257)?

Authors: yes, thanks, on p.7 l.159 the change is made from “recruitment production to be..” to “recruitment production function R to be..”

R2-7: 175-177 Should this rather be included in the Discussion?

Authors:

we have moved this phrase to the end of the discussion on p.31 l.591-593.

R2-8: 168-169 & 178-184 I got confused about the description of the basic demographic component. Line 169 states that 'spnum' stands for the abundance of spawners. But, in lines 182-183 you elaborate whether spnum captures mainly the impact of spawner abundance. Is

the paragraph in lines 178-184 supposed to describe the 'basic demographic component'? Is this basic demographic component given by eqn. (4)? Or is it given by eqn. (5)? Please, make clear what 'spnum', SSB_N and the demographic component are.

Authors:

Sorry for the confusing description. We used words “spnum”, “spwe” and “SST” as short labels for the models (especially needed for the figures) that take into account effects of spawner number, spawner weight, SST, correspondingly.

SSB_N - is a value calculated similar to SSB, using age-specific historical average spawner weights instead of actual weights and is defined by the Eq.4. It is used instead of SSB in the stock-recruitment function to isolate spawner abundance effect from spawner weight effect.

Demographic component of the stock-recruitment function is the function - $H(SSB_N)$ defined by the Eq. 5.

In the revised version we use these short abbreviations only for labeling the models to designate combinations of analyzed effects. We have revised the section 2.3 “Stock-recruitment function with separable effects” to make the description clear.

R2-9: 196 the effect 'of'?

Authors: corrected.

R2-10: 203 Introduce eqn. (6) earlier and not separate from the text. For example, 'The second factor, spwe, captures the effect of deviations in average spawner weight on recruitment production and is defined by $F(y) = (SSB(y)/SSBN(y))$ (6).'

Authors: thank you, the equation introduced as suggested earlier in p.9. 1.212.

R2-11: 204 Similarly, introduce the equation for the Lorentz function immediately after first mention.

Authors: corrected, Lorentz function introduced on p.9. 1.227 after its first mention.

R2-12: 211-217 (at least) If these are findings after model fitting and not data preprocessing, should they be reported in the Results section instead?

Authors: yes, indeed. We moved this paragraph to p.14 1.318-325 of the Results.

R2-13: 222 Please include in the text and introduce earlier. What was SST₀? You're talking about T₀ in the text above eqn. (7).

Authors: this was a typo, on p.1. “T₀” changed to “SST₀”.

R2-14: 211 Given that there seem to be only two parameters for G, why not introduce both of them in the main text.

Authors: We have added right after the equation 7 on p.10 1.228 both parameters with the following “where SST₀ is a SST optimum value, and b – sensitivity to SST.”.

R2-15: 226-227 Often, one prefers not to start a sentence by a symbol. Consider throughout the paper.

Authors: thank you, corrected throughout the text.

R2-16: 240-242 Please modify in a similar way as suggested above.

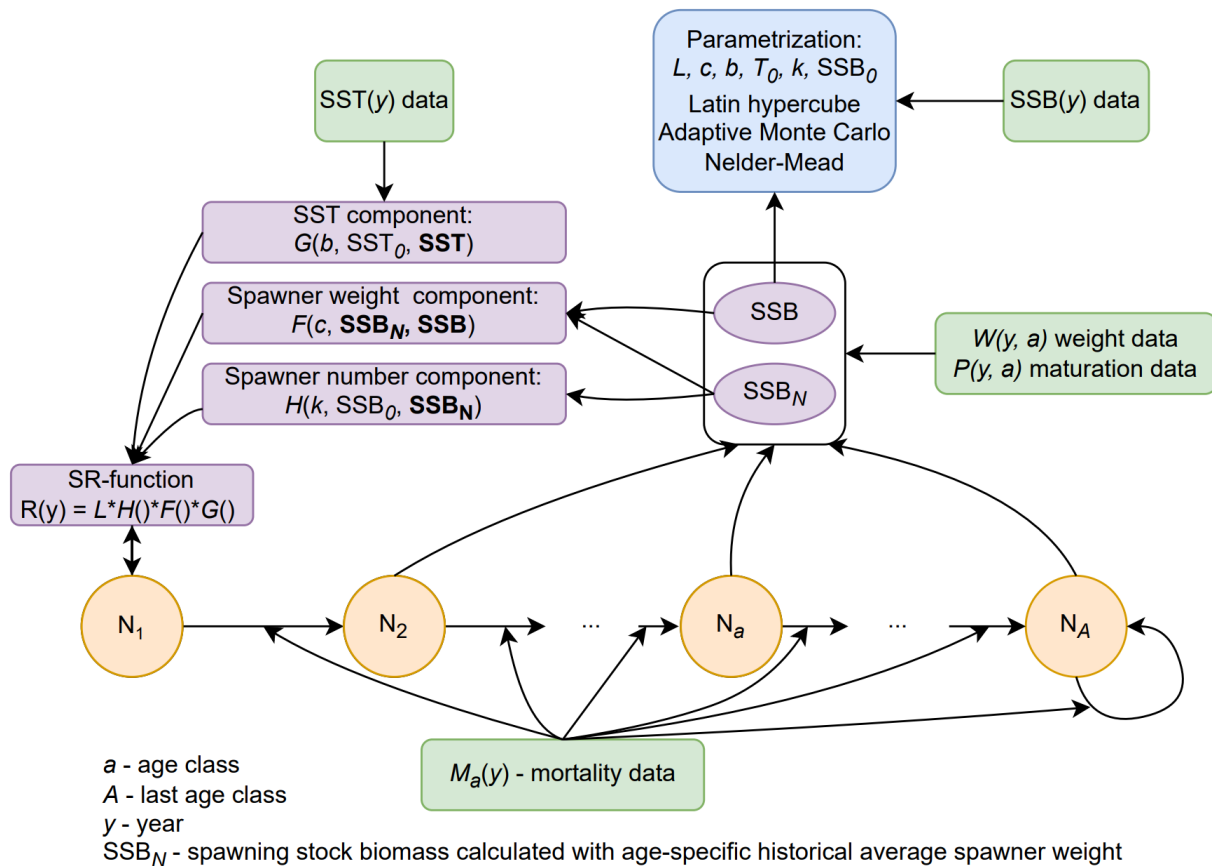
Authors: done.

R2-17: 244 Now there's also SSB₀ to optimize. Should it also be listed earlier (line 228)?

Authors: Thank you, we forgot to list this parameter. This is corrected now on p.10 1.253.

R2-18: Sections 2.2-2.3 A schematic figure of the overall structure of your model would be nice.

Authors: We have added the scheme of overall model structure as Appendix C: Fig. C2. instead of the extra duplicating text about the model. Former Fig.C2 became Fig.C3.



R2-19: 258 I didn't find figure D4 in the Appendix. The last 25 years here mean..?

Authors: thanks, the deletion of one figure in D caused the shift in cited numbers, on p.47 1.766 “Fig. D2-4” is changed to “Fig. D1-3”.

We changed the phrase “Within the last 25 years, all stocks experienced strong declines in SSB” to “All of the stocks cod experienced strong declines in SSB with their historical minima observed after 1990 except for NEA cod stock.”.

R2-20: Figure 2 The figure is great, but the font size could be bigger and, especially, the resolution of the graphics should be higher.

Authors: Unfortunately the figures lost quality because of introducing them into word docx file. All figures are now reinserted into docx file in svg/emf vector format to preserve the best quality of original figures. Each figure will be provided for publication as vector images in a pdf format to provide the best quality. We have increased text font size on Figure 2.

R2-21: 265 But for many of the stocks in Fig A2, the average SST seems to be over 11? For example, Flemish Cap, Georges Bank.

Authors: Very true, corrected. Should be “Average ambient sea surface temperature ranges between 3 °C and 15 °C (Appendix A: Fig. A2, Appendix B: Figure B1.i)...”

R2-22: 266 There is no Figure A1 in Appendix B. However, Fig. B1 illustrates trends and p values for individuals stocks over the whole time series, should you refer to it later (in line 267)?

Authors: yes, the reference to figure B1 is corrected on p.14 l.311.

R2-23: 276-277 I'm not sure if I understood your reasoning. Please, expand/say in another words.

Authors: we improved this paragraph on p.15 l 328-332 as follows: “For example, when fishing pressure of the NEA cod started to decline as part of a management plan, the ocean water was also cooler (triangles symbols, Fig. 2) and thus the stock growth temperature component had the highest value (Appendix C: Fig. C2). This could be the reason behind the increase and recovery of its SSB. Further decline in fishing mortality happened concurrently with ocean warming and likely overweighted the negative response to SST, and the stock continued to grow.”

R2-24: 291 Check consistency with the description in Section 2.3.

Authors: we have made it consistent through out the text designations of the 3 components of SR-function - H(), G(), L() functions and corresponding model designations by significant effects (spnum, spwe, SST).

R2-25: 308-310 Describe the symbols of your figure in the legend instead. Refer here only to your model (components)?

Authors: we have changed this to “We consider that spnum component of SR-function should reflect the inherent density-dependence regulation”.

R2-26: Overall, the text should be readable without the figures and the figures should be described in their legends. For example, instead of 'A high goodness of fit for total biomass

(TB) and recruitment (R) time series is shown in Appendix D: Fig. D2-4).' (lines 257-258), could you say 'We obtained a high goodness of fit for total biomass (TB) and recruitment (R) time series (Figs D2-4).'?

Authors: thanks for the suggestion, we corrected accordingly on p.11.1.261-262, p.14 1.318-319, and header of table D1, captions of Fig.2, 3, C2, D1-3.

R2-27: Since the Allee effect threshold SSB_0 plays an important role in your results, should you give it more space in Section 2.3?

Authors: we improved the description of SSB_0 and parameter k related to SSB_0 on p.9 1.201-204 by changing “ SSB_0 is the position of the inflection point, where the rate of recruitment production is highest, and k is the function’s steepness at SSB_0 ” to the following “Parameter SSB_0 is the position of the inflection point of the recruitment abundance function. Parameter k is the steepness of the curve at point SSB_0 , which defines the type of recruitment production function, which can be either purely compensatory ($k < 2$) or with a depensatory region ($k > 2$). In the latter case corresponding recruitment per capita function ($H(SSB_N)/SSB_N$) would have a minimum, that indicates the presence of Allee effect with SSB_0 in this case being an Allee effect threshold”.

R2-28: 673 Use Equ./Eq. consistently.

Authors: all made consistent with “Eq”.

R2-29: 680 What does 'q' stand for?

Authors: q stands for log-likelihood of the model for which AIC is calculated and is given by the Eq. D1.

R2-30: Figure A1 This is a great illustration. However, it is somewhat challenging to distinguish the alphabets and arrows from the background. Could you use a color for the symbols?

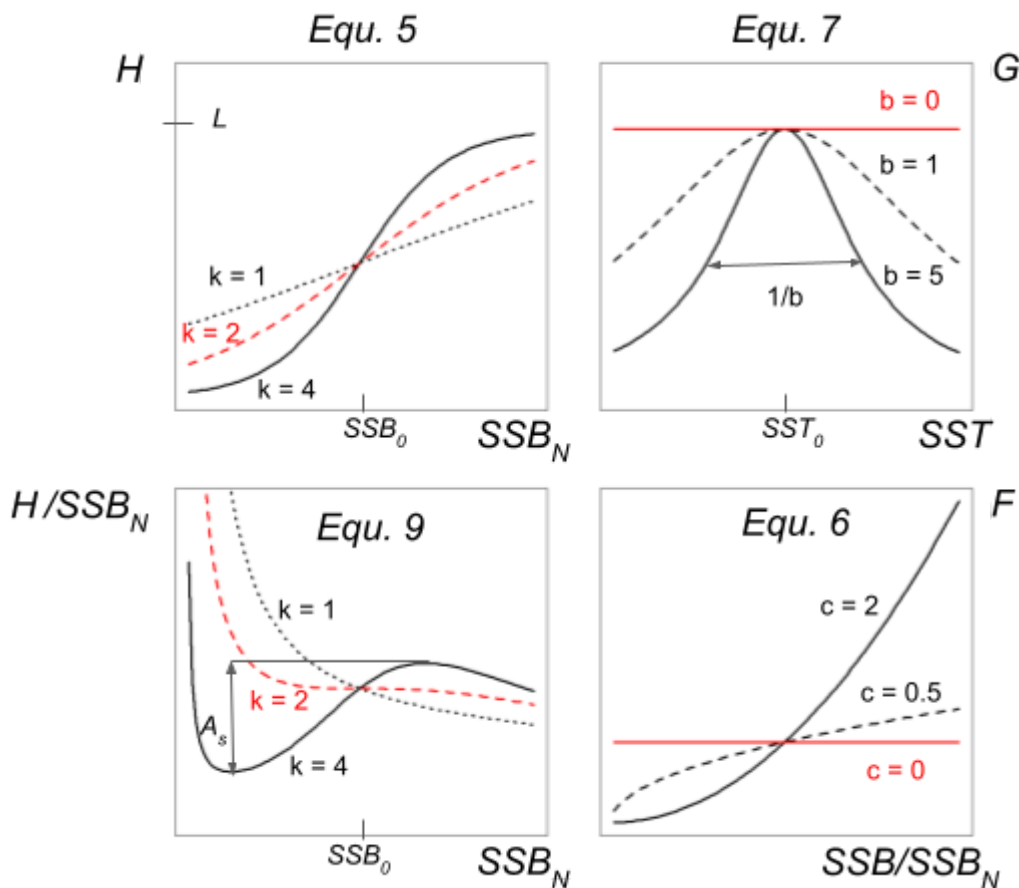
Authors: Thank you for the suggestion. The colors have been changed.

R2-31: 565 'The' --> 'the'

Authors: corrected.

R2-32: Figure C1: This is a nice illustration. However, please tell in all subplots, to which parameter values the different curves correspond, similar to the subplot on the right lower corner.

Authors: The scheme is improved with parameter values corresponding to different curves.



R2-33: Figure D2: What are N, NFT etc. abbreviations of?

Authors: These were the intermediate model abbreviations, which were changed later to spnum, spwe and SST. Thank you for noticing, we have corrected Figure D2 with corresponding abbreviations.