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PROPOSAL OF IMPLEMENTATION OF LOW-FECUDITY SPAWNER-RECRUITMENT RELATIONSHIP FOR SHORTFIN MAKO IN THE NORTH ATLANTIC

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SUMMARY

This document paper presents the short review of low-fecundity spawner-recruitment relationship (LFSR) to give a motivation of the implementation of the LFSR in the stock synthesis model. The parameter values of the LFSR are also computed using the preliminary value of the steepness for shortfin mako in the North Atlantic.

RÉSUMÉ

Ce document présente un examen succinct de la relation de faible fécondité recrue-recrutement (LFSR) dans le but d'encourager la mise en œuvre de la LFSR dans le modèle de synthèse des stocks. Les valeurs des paramètres de la LFSR sont également calculées en utilisant la valeur préliminaire de l'inclinaison du requin-taupe bleu de l'Atlantique Nord.

RESUMEN

Este documento presenta una breve revisión de la relación reproductor-recluta de baja fecundidad (LSFR) para ofrecer una motivación para la implementación de la LSFR en el modelo Stock Synthesis. Los valores de parámetros de la LFSR se calculan también usando el valor preliminar de la inclinación para el marrajo dientuso del Atlántico norte.

KEYWORDS

LFSR, Steepness, Shortfin mako

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1. Low-fecundity spawner-recruitment relationship (LFSR)

Low-fecundity spawner-recruitment relationship (LFSR) is a survival based spawner-recruitment function (Taylor *et al.* 2013). Recruitment (R_y) in each year is defined as:

$$R_y = S_y B_y, \tag{1}$$

where B_y is the spawning output in year *y* and S_y is the pre-recruit survival given by:

$$S_y = \exp\left(-z_0 + (z_0 - z_{min})\left(1 - \left(\frac{B_y}{B_0}\right)^{\beta}\right)\right), \tag{2}$$

where:

$$z_0 = -\log\left(\frac{R_0}{B_0}\right), \tag{3}$$

where R_0 is the recruitment at equilibrium, resulting from the exponential of the estimated $\log(R_0)$ parameter, and $B_0$is the equilibrium spawning output. $z_{min} = z_0(1 - s_{Frac})$ is the limit of the pre-recruit mortality as depletion approaches 0, parameterized as a function of s_{Frac} (which represents the reduction in mortality as a fraction of z_0); and, Beta (β) is a parameter controlling the shape of density-dependent relationship between spawning depletion and pre-recruit survival. This equation can produce a variety of SR-relationships (**Figure 1**) and pre-recruit survival against pups or spawning biomass (**Figure 2**) (see Rice *et al.* 2014). In the way that the LFSR is set up in SS.

2. Computation of the parameters for the shortfin mako in the north Atlantic Ocean

Cortés (2017) provided a steepness value of 0.345 for shortfin mako shark in the North Atlantic Ocean. Note that the value of steepness is a preliminary. The parameters of LFSR (s_{Frac} and Beta) can be directly estimated using the "optim" function of software R and then $s_{Frac} = 0.263$ and Beta=0.642 were computed respectively. These values can produce the same stock-recruitment relationships as those with steepness = 0.345. However, values of β < 1 have survival increasing fastest at low spawning output (concave decreasing survival). It is unlikely that shortfin mako survival would decrease fastest at low stock size; instead it is reasonable to expect that for a low-fecundity species, offspring survival would decrease faster due to competition when the population approaches carrying capacity (β > 1). The values of β > 1 have the increase in survival occurring fastest closer to the unfished equilibrium (convex decreasing survival) (**Figure 3**).

The estimation of the parameters inside the model is not recommended because it is a task harder than estimating steepness due to the extra parameter involved (Rice *et al.* 2014). If the value of Beta is given, the values of s_{frac} can be computed using the information of steepness presented in Cortés (2017) and the following equation (Taylor *et al.* 2013):

$$s_{frac} = \log(5 * h)/(z_0 * (1 - 0.2^{\beta})). \tag{4}$$

The values were summarized in **Table 1** and the relationships between biomass and recruitment, and the relationships between biomass and survival were shown in **Figure 4**. These values match the steepness of the Beverton and Holt model with h = 0.345.

In the implementation of the LFSR for the actual stock synthesis model, the most consistent values with the life history information available for shortfin mako sharks are chosen as a reference case. However, it is necessary to examine the impacts of the other parameters (s_{Frac} and Beta) on the outputs of the stock assessment. Even if the output from the BH model in the SS is almost similar to that of LFSR, LFSR is more suitable than BH model to use in SS due to the perspective of the biological interpretation for such a low-fecundity shark as we mentioned above. Therefore, we recommend to use the LFSR for the stock assessment of the shortfin mako in the North Atlantic.

References

Cortés, E. (in press). Estimates of maximum population growth rate and steepness for Shortfin makos in the North and South Atlantic Ocean. ICCAT, Document SCRS/2017/126.

Rice, J., Harley, S., and Kai, M. 2014. Stock assessment of blue shark in the North Pacific Ocean using stock synthesis. WCPFC-SC10-2014/SA-WP-08.

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Table 1. Estimates of *S*frac for each value of *β*.

Scenario	Parameters of LFSR	
	β	S_{frac}
1	0.642	0.263
2	1	0.212
3	2	0.176
4	3	0.171

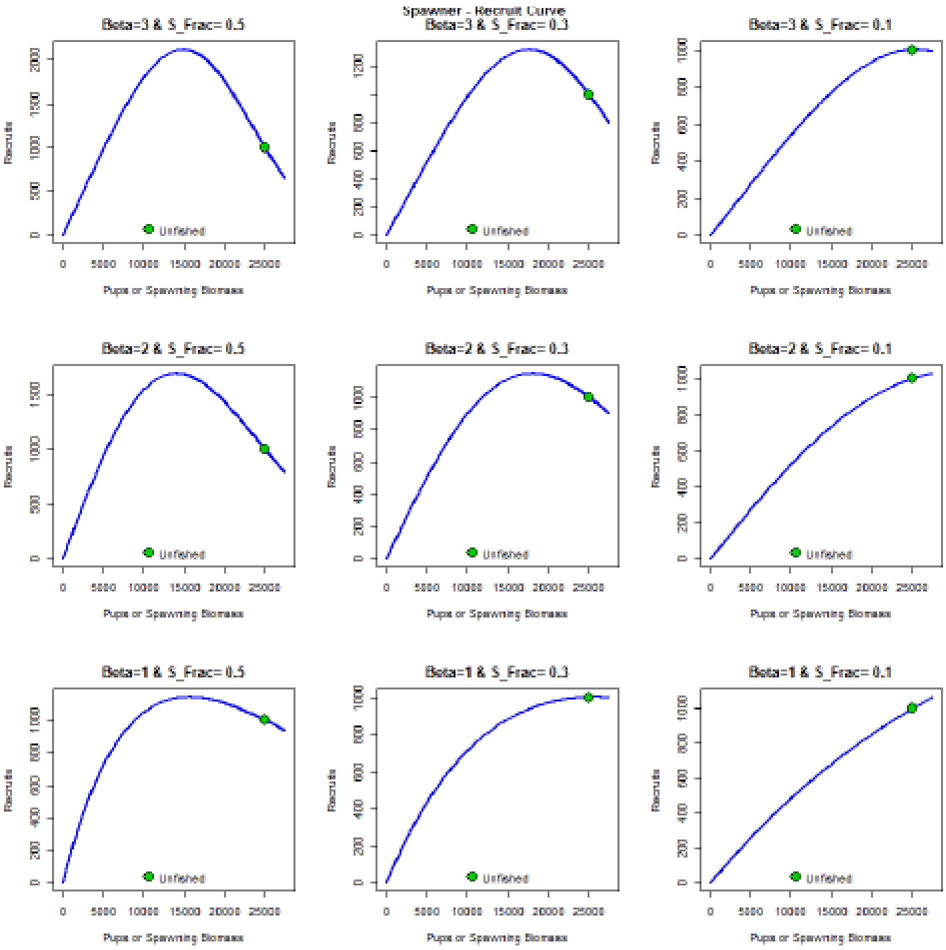

Figure 1. Spawner-recruit curves for the nine low-fecundity spawner recruitment (LFSR) curves considered in the assessment of blue sharks in the north Pacific. The value of 1000 and 25000 are given as unfished recruitment and spawning biomass (green filled circle) (see **Figure 4** in Rice *et al.*, 2014).

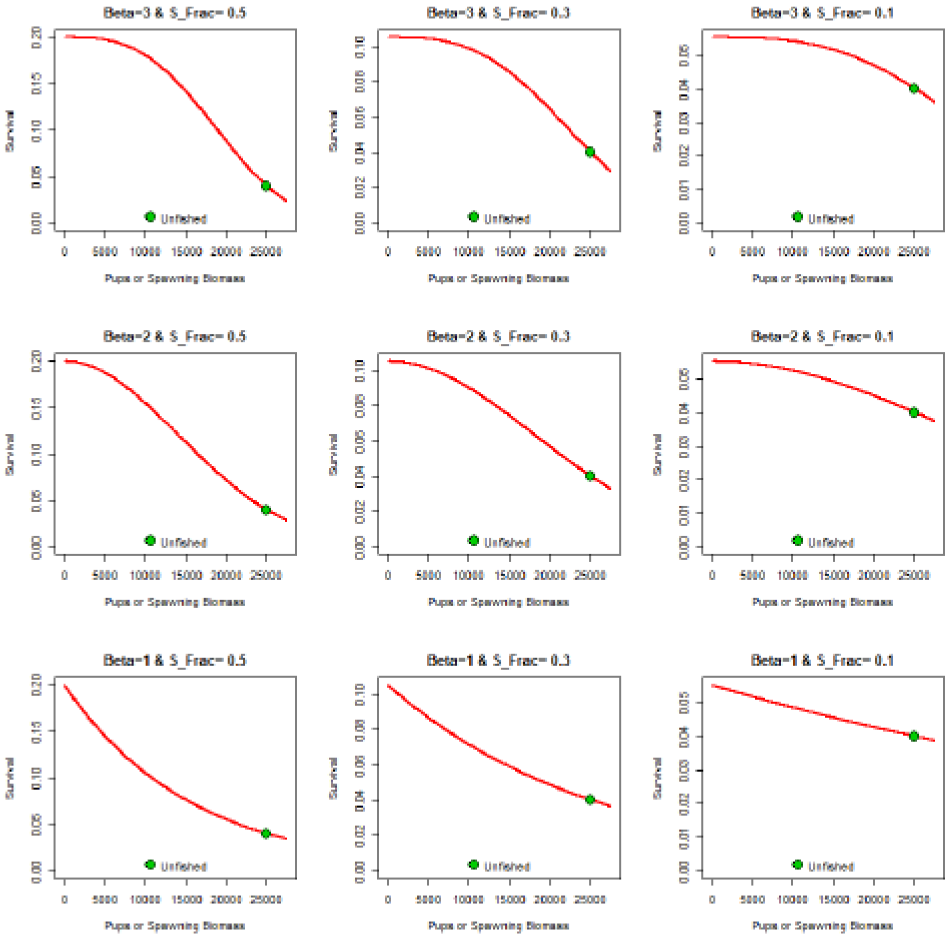

Figure 2. Pre-recruitment survival for the nine low-fecundity spawner recruitment (LFSR) curves. The value of 1000 and 25000 are given as unfished recruitment and spawning biomass. (see **Figure 5** in Rice *et al.*, 2014)

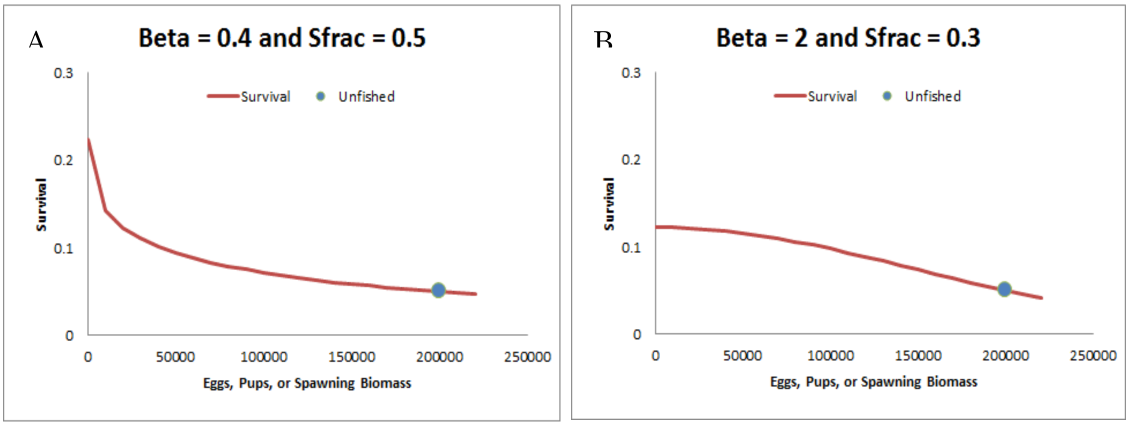

Figure 3. Examples of Pre-recruitment survival for the Low Fecundity Spawner Recruitment (LFSR) pre-recruit survival curves implemented in Stock Synthesis (see page 59 of Stock Synthesis User Manual 3.24S).

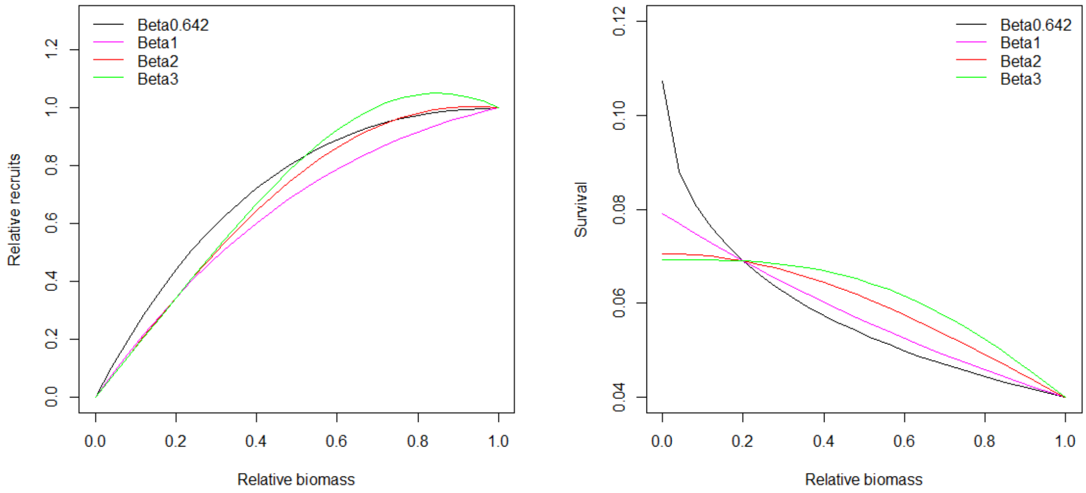

Figure 4. A relationship between biomass and recruits (left), and a relationship between biomass and survival for four different value of Beta (Beta =0.642, 1, 2, 3).