Assessing the sensitivity of length-indicator methods for resources in the Atlantic waters

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Comentado [MOU1]: Order is provisional in alphabetic order to review at the need, please add your affiliation

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Abstract

Keywords: data-poor; fishery management; LBI; LBSPR; stock assessment

Introduction

The capture production in the Northeast Atlantic (No. 27 fishing area, FAO) accounted for XX% of the world total marine capture in 2017 (Watson, 2017). The management of exploited fishery stocks in this region requires a knowledge of stock status and relevant reference points (RPs) that can be used in formulating fishery management policies. However, this kind of information is usually deficient or inadequate, especially for data-limited stocks (Froese et al., 2012). In recent years, in order to resolve this dilemma, there have been attempts targeting research effort on developing assessment techniques for data-poor fisheries, and a suite of tools is evolving to assess and manage stocks with limited data (Chong et al., 2020). However, many of these methods still require considerable amounts of data from the fishery or the biology of the target species, including a time-series of historical catch, catch-per-unit-effort (CPUE) trends, or information on the age structure of the stock, all of which are difficult to obtain for many data-poor fisheries (Hordyk et al., 2015a).

In this sense, length-frequency data from commercial catches are often the primary data type collected because they are relatively economical and easy to record (Mildenberger et al., 2017). As a result, a number of length-based methods have been developed and applied to estimate biological parameters and to understand the dynamics of fish populations.

Many of these length-based techniques were developed to estimate fish growth and mortality rates without the need to obtain age data, which by comparison are much more expensive and difficult to obtain (Hordyk et al., 2015b). Other size-based techniques aim to use the length structure of the stock to directly estimate its exploitation status and provide management advice (e.g. Klaeret al., 2012).

Among all data-limited length-based methodologies, the International Council for the Exploration of the Seas (ICES) Workshop on the “Development of Quantitative Assessment Methodologies based on Life-history Traits, Exploitation Characteristics and other Relevant Parameters for Data-limited Stocks” (WKLIFE V) (ICES, 2016), identified the length-based indicators (LBI, Froese, 2004) and length-based spawning potential ratio (LBSPR; Hordyk et al., 2015b) as the most appropriate ones for setting plausible RP proxies for stocks with different limitations on data availability.

LBI method consists on a set of length-based indicators selected for analyzing catch/landings–length composition and classify the stocks according to conservation/sustainability, yield optimization and MSY (maximum sustainable yield) considerations. On the other hand, LBSPR method is a length-based model that assesses stock status by comparing the spawning potential as measured through the length composition data to that expected in an unfished stock.

Hordyk (2015b) pointed out the relevance of examining the sensitivity of the model to errors in the input parameters, for LBI and LBSPR methods, respectively. In both cases the accuracy of the model results depends on the precision of the estimates of the life history parameters. The simulation study carried out by Hordyk (2015b) shows that the model was considerably sensitive to the variation/misspecification of the parameters L_∞ (i.e. von Bertalanffy asymptotic average maximum body size) and M/k (ratio of natural mortality to von Bertalanffy growth rate). However, few studies test these sensitive analyses on real data and data-poor stocks.

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With this context, the aim of this study is to quantify accuracy and precision of LBI and LBSPR methods for XX stocks among fish, crustaceans and elasmobranch species (i.e. *Galeus melastomus, Engraulis encrasicolus, Pagellus bogaraveo, Trisopterus luscus, Pollachius pollachius,* and *Nephrops norvegicus*), under various scenarios, testing the sensitivity of the most important parameters.

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Material and methods

Length based indicator (LBI)

Length-based indicator describes length frequencies of catch/landings and are compared to appropriate RPs related to conservation, optimal yield and length distribution relative to expectations under maximum sustainable yield (MSY) assumptions. LBI method requires the following data: length at maturity (L_{mat}, also known as L_{50}, length at 50% of maturity), von Bertalanffy asymptotic average maximum body size (L_∞), ratio of natural mortality to von Bertalanffy growth rate (M/k), catch/landings at length per year, and length–weight relationship parameters (*a* and *b* parameters in $W=aL^b$ being W and L the corresponding weight and length, respectively). Instead of *a* and *b* parameters, the mean weights-at-length per year can be also used as an input data in the model. The length-based indicators $L_{95\%}$ and $L_{max5\%}$ (Table 1) analyse the conservation of large individuals through the comparison of such indicators, which characterize the upper portion of the length frequency distribution, to the reference point L_∞. The corresponding ratios provide information about the degree of truncation of the population length structure that may be caused by fishing, and are expected to be above 0.8, based on a simulation study carried out by Miethe and Dobby (2015). The indicator P_{mega} (Table 1) is the proportion of mega-spawners in the stock (fish larger than the optimum length plus 10%) and follows the idea summarized by Froese (2004) as “Let the mega-spawners live”. Froese (2004) and ICES (2015) concluded that values above 0.3 correspond to health stocks.

On the other hand, length indicators $L_{25\%}$ and L_c relate to the conservation of immatures, and follow the principle “Let them spawn” (Froese, 2004). Hence, the ratio of both indicators to the RP L_{mat} is expected to be greater than 1 (Table 1). Finally, other two indicator ratios (L_{mean}/L_{opt} and L_{maxy}/L_{opt}) relate to the optimal yield which follow the principle “Let them grow” (Froese, 2004) and a ratio indicator (L_{mean}/LF=M) focus on MSY considerations since its RP is the length at which F=M and F=M is considered as proxy for MSY.

Length-based spawning potential ratio (LBSPR) method

The original LBSPR model described by Hordyk et al. (2015a, b) is based on a conventional age-structured equilibrium population model. The method uses maximum likelihood methods to find the values of relative fishing mortality (F/M) and selectivity-at-length that minimize the difference between the observed and the expected length composition of the catch, and calculates the resulting SPR. An inconvenient of this model is that the selectivity is age-based not length-based, whereas, selectivity in fish is often length- dependent, which results in differential fishing mortality rates across fish of the same age; an effect known as “Lee’s Phenomenon” (Lee, 1912). The age-structured LBSPR model did not account for Lee’s Phenomenon, and is therefore expected to over-estimate fishing mortality when selectivity is length-dependent. For this reason, in this study we consider an extension of such model proposed by Hordyk et al. (2016) which consists on a length-structured version of the LBSPR model that uses growth-type-groups (GTG) to account for length-based selectivity (known as GTG-LBSPR model).

Throughout the article we make a slight abuse of notation referring to such model simply as LBSPR. The LBSPR model uses length composition to estimate the spawning potential ratio (SPR) for data-limited stocks by developing a computationally efficient length-structured per recruit model that splits the population into a number of sub-cohorts, or growth-type-groups, to account for length-dependent fishing mortality rates.

The LBSPR model requires the following parameters: the ratio M/k and L_∞ (parameters described previously in the LBI method) and knowledge of maturity-at-size (L_{50} and L_{95}, length at 50% and 95% of maturity, respectively), furthermore, it uses data on the length composition of the catch to estimate the SPR. It is worth to mention that SPR estimates in the range of 0.35-0.4 are usually associated to a stock at MSY level; whereas SPR estimates below 0.1-0.15 indicate that the stock is collapsed.

Sensitivity analysis

Firstly, the LBI and LBSPR methods have been applied using the M/k and L_∞ values fixed by the researcher after a literature review and/or the analysis of other reliable information about the stock/species. We refer to such values as M/k^{LIT} and L_∞^{LIT}, and to the corresponding model as reference model. Hence, to analyse the effect of underestimation and overestimation of these parameters the model is recalculated using a lower or upper bound of one of the two parameters instead of the reference value M/k^{LIT} or L_∞^{LIT}. That is, we fitted the models summarized in Table 2.

The upper and lower bounds of parameters M/k^{LIT} or L_∞^{LIT} in Table 2 have been fixed following the ideas of the simulation study carried out by Hordyk (2015b). Furthermore, we have also considered M/k=1.5 since Jensen (1996) suggests that such value can be closed to the optimal one.

After applying each method using each of the parameter configurations/settings described in Table 2 the results of models 2-6 are compared with the results provided by the reference model analysing in this way the effect of underestimation/overestimation of the parameter values M/k or L_∞.

Species data

The sensitive analysis for LBI and LBSPR methods described in the previous section was applied, as we mentioned above, to the following stocks in the Atlantic waters: *G. melastomus*, *E.*

encrasicolus, P. bogaraveo, T. luscus, P. pollachius, and *Nephrops norvegicus* FU25 and FU2627 (Males and Females).

The required data for LBI and LBSPR method (catch/landings at length per year) have been retrieved from the following sources of information: the data comes from (please complete with the required information) for *G. melastomus*, from (please complete with the required information) for *E. encrasicolus*, from (please complete with the required information) for *P. bogaraveo*, from (please complete with the required information) for *T. luscus*, from (please complete with the required information) for *P. pollachius*, from (please complete with the required information) for *N. norvegicus* FU25 and finally from (please complete with the required information) for *N. norvegicus* FU2627.

Table 3 reports the values and sources of the life history parameters (M/k, L_∞, L_{50}, L_{95}, *a* and *b*) of each stock and the value of the parameter BinWidth (i.e. width of length bins) of LBI method for all the stocks.

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Results

LBI

Firstly, the results derived from the sensitive analysis of LBI method have been summarized in Tables 4 and 5. Table 4 reports the results of *N. norvegicus* FU25 and FU2627 (Males and Females), whereas Table 5 provides the information of the remaining stocks (*G. melastomus, E. encrasicolus, P. bogaraveo, T. luscus,* and *P. Pollachius*). Results have been reported respect to the ones derived from the reference model (setting/parameter configuration 1).

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More precisely, each row on Tables 4 and 5 reports the information of one of the 9 stocks addressed in the current study, whereas columns report the changes in term of conclusions for models 2-6 respect to model 1 (reference model/parameter configuration; see Table 2). Hence, information in column *i* is the following:

1. If the relation between an indicator ratio and the corresponding expected value in model 1 remains in model *i*, for all years, then such indicator ratio is not mentioned in column *i*.

2. If an indicator ratio is below the corresponding expected value in model 1 whereas in model *i* the opposite result is obtained then such indicator ratio is typed in green in column *i* with the percentage of the years in which this change has occurred.
3. Analogous to point 2, if an indicator ratio is above the corresponding expected value in model 1 whereas in model *i* the opposite result is obtained then such indicator ratio is typed in red in column *i* with the percentage of the years in which this change has been observed.

According with the above explanation, the conclusion derived from an indicator changes from one model to another when the value of such indicator in one model is above (below) the expected value whereas, for the other model, we obtain the opposite relation among both quantities. Minor changes in the indicator values (changes which do not lead to different conclusions) are not relevant in this study.

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Tables 4 and 5 shows, as expected, that variation (underestimation/overestimation) of the parameter M/k leads to changes in the conclusions derived from the indicator ratios L_{mean}/L_{opt}, $L_{mean}/L_{F=M}$ and P_{mega}. Such indicators relate to the optimal yield, MSY and conservation of large individuals' properties, respectively. Overestimation of M/k (model 3 of Table 2) leads to a more optimistic perception of the state of stock, since as we can see in Tables 4 and 5, the values of the indicator ratios changes from below to the expected value (model 1, reference setting) to above it. Whereas the opposite behavior is detected in the setting underestimation of M/k (model 2 of Table 2). The conclusions on setting M/k=1.5 (model 6 of Table 2) depend on whether M/k^{LIT} is less than or greater than 1.5 and therefore if we are in a particular case of underestimation overestimation of such parameter.

It is important to mention that changes in the conclusions derived from L_{mean}/L_{opt} and $L_{mean}/L_{F=M}$ indicators arise in 74% of the 27 performed models whereas for P_{mega} such value is 33%. Hence for our stocks it seems that underestimation or overestimation of M/k has more effect on the conclusions derived from L_{mean}/L_{opt} and $L_{mean}/L_{F=M}$ than from those obtained from P_{mega}. To wit, changes in the values of M/k have a relevant effect on the conclusions related to MSY and OY properties.

Note that the percentages (of years for which the conclusion derived from the indicator changes respect to the one obtained using the reference model) in Tables 4 and 5 are below 50% except in 6 cases corresponding to *N. norvegicus* FU2627 Females (M/k=1.5 setting), *G. melastomus* (underestimation and overestimation settings), *E. encrasicolus* (underestimation setting) and *P. bogaraveo* (overestimation setting).

Finally, it is worth to mention that *T. luscus* is the unique stock for which no changes in the conclusions have been detected.

For the underestimation and overestimation of L_∞ Tables 4 and 5 show that such settings lead to changes (respect to the reference setting) in the conclusions derived from the indicator ratios L_{mean}/L_{opt}, $L_{mean}/L_{F=M}$, P_{mega} and $L_{max5\%}/L_\infty$. Such indicators relate to the optimal yield, MSY and conservation of large individuals, respectively. Underestimation of L_∞ (model 4 of Table 2) leads to a more optimistic perception of the state of stock, since as we can see in Tables 4 and 5 the values of the indicator ratios changes from below to the expected value (reference model) to above it. Whereas the opposite behavior is detected under overestimation of L_∞ (model 5 of Table 2).

Taking into account that 2 different models varying the value of parameter L_∞ has been applied for each of the 9 stocks; 18 different models to assess the sensitivity of LBI method to the variation of L_∞ has been considered. Changes in the conclusions derived from P_{mega} and $L_{max5\%}/L_\infty$ indicators arise in 66% of the models whereas for L_{mean}/L_{opt} and L_{mean}/LF=M such value is 88% and 83%, respectively. Hence, for our stocks, it seems that underestimation or overestimation of L_∞ has more effect on the conclusions related to optimal yield and MSY properties. Although the effect on the conclusions related to conservation of large individuals is also remarkable.

Note that for all stocks (except *N. norvegicus* FU2627 Males) at least for one indicator the percentage (of years for which the conclusion derived from the indicator changes respect to model 1, Tables 4 and 5) is above 50%. Finally, it is worth to mention that stock *T. luscus* is the unique species for which no changes in the conclusions have been detected in spite of overestimation of L_∞, however for this stock the model has also not been robust to the underestimation of such parameter.

Conclusions above support that LBI methodis more sensitive to the variation/misspecification of L_∞ than to the variation/misspecification of M/k. However, we have verified that both parameters have a strong influence on the final conclusions and that the method is clearly sensitive to the variation/misspecification of both parameters.

LBSPR

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The results of the sensitivity analysis carried out for LBSPR method has been summarized in Figures 1 and 2, which shows the SPR and F/M estimates and their smoother lines for all the 6 parameter configurations/settings in Table 2. Figure 1 reports such information for *N. norvegicus* FU25 and FU2627 (Males and Females), whereas Figure 2 contains such information of the remaining stocks (*G. melastomus, E. encrasicolus, P. bogaraveo, T. luscus, and P. pollachius*).

Before proceeding to discuss the information in Figures 1 and 2, some details about them must be clarified. In Figure 1, for *N. norvegicus* FU2627 Males the dark blue line (M/k=1.5, setting) does not appear on the corresponding graph, since it overlaps with the red line ($0.75 \cdot M/k^{LIT}=0.75 \cdot 2=1.5$). In Figure 2, for *G. melastomus* the dark blue line (M/k=1.5, setting) is also missed, in this case it overlaps with the black line (reference model) since M/k^{LIT} is 1.5. Finally, in Figure 2 we observe an unexpected high F/M estimate (≈150) for *E. encrasicolus*.

Figures 1 and 2 show that, as expected, the variation on parameters M/k and L_∞ has an effect on the final conclusions concerning the stock status.

In general, as mentioned above for LBI method, overestimation of M/k leads to a more optimistic perception of the state of stock, since as we can see in Figures 1 and 2 the smoother line of SPR estimates is always above to the corresponding one for the reference model, which lead to the opposite behavior in the F/M estimates plot. Whereas the contrary behavior is detected under underestimation of M/k. As in the LBI method, the conclusions for setting M/k=1.5 depend on whether M/k^{LIT} is less than or greater than 1.5, and therefore, if we are in a particular case of underestimation or overestimation.

In the setting $0.75 \cdot M/k^{LIT}$, we conclude that the stock is collapsed with SPR estimates below 0.10 or 0.15 almost for all stock (except *P. pollachius*, *N. Norvegicus* FU2627 and *N. Norvegicus* FU25 Females). Although the SPR estimates derived from the reference model for such stocks are larger the final conclusion about the stock status is the same. For *P. pollachius* the SPR estimates (in both settings) are above 0.15 but below 0.35 hence we conclude that the stock is not collapsed but below the MSY level. The same holds for *N. norvegicus* FU25 Females whereas for *N. norvegicus* FU2627 both settings lead to conclude that the stock in the last years at MSY level.

On the other hand in the setting $1.25 \cdot M/k^{LIT}$, we can see that the conclusions for almost all the species (except *T. luscus*, and *N. norvegicus* FU25 Females) are the same as the ones derived from the reference model in spite that the SPR estimates are larger in the setting $1.25 \cdot M/k^{LIT}$. For *T. luscus*, we can see that overestimation of M/k^{LIT} leads to conclude that the stock is not collapsed although below MSY level whereas the reference model concludes that the stock is collapsed. Finally, for *N. norvegicus* FU25 females the stock is at MSY level in setting $1.25 \cdot M/k^{LIT}$ whereas below it the reference model.

After analyzing the sensitivity of LBSPR method to variations on M/k, we now address the analysis of setting 4 and 5 of Table 2 (underestimation and overestimation of L_∞). Figures 1 and 2 show that underestimation of L_∞ leads to a more optimistic perception of the state of stock, since the smoother line of SPR estimates is always above to the corresponding one for the reference model. Whereas the opposite behavior is detected under underestimation of L_∞. This general behavior matches the one described in LBI discussion.

It is important to stand out that for all species (except *T. luscus*) the setting $0.75 \cdot L_\infty^{LIT}$ lead to conclude that the stock in the last years is above the MSY level when for all species (except *N. norvegicus* FU2627) such conclusion is not derived from the reference model which states that the stock is below the MSY level. Note that for *N. norvegicus* FU2627 the conclusion is the same for both models, the stock is above the MSY level. Conclusions for *T. luscus* are: the stock is collapsed (reference model) whereas the stock is almost at MSY level for setting $0.75 \cdot L_\infty^{LIT}$.

Important changes in the conclusions about the state of the stock appears in the setting $1.25 \cdot L_\infty^{LIT}$ in relation to the ones reported by the reference model. For species *N. norvegicus* FU25, *E. encrasicolus*, *P. bogaraveo*, and *P. pollachius* the setting $1.25 \cdot L_\infty^{LIT}$ lead to conclude that the stock is collapsed when the estimates of SPR derived from the reference model in the last years are above to the 0.15. On the other hand for *G. melastomus* and *T. luscus* we can see that the reference model conclude that the stock is collapsed since the SPR estimates are in the interval or close to it (0.10-0.15) whereas the same conclusion is derived when L_∞^{LIT} overestimated but the difference is that for this model the SPR estimates are below (and far) to the lower limit for such interval. Finally, for *N. norvegicus* FU2627 the reference model leads to conclude that the stock is in an extreme positive situation (in the last years) since the SPR estimates are above 0.40 whereas under the overestimation of L_∞^{LIT} the SPR estimates are below to 0.35 or in the interval (0.35-0.40).

The above comments/discussion indicate that although the variation/misspecification of both parameters (M/k and L_∞) has an effect on the results of LBSPR method, this effect is more significant in the case of L_∞ parameter concluding that such parameter is crucial.

Discussion

Acknowledgments

This study is a contribution to the project IMPRESS (RTI2018-099868-B-I00), ERDF, Ministry of Science, Innovation and Universities - State Research Agency and also of GAIN (Xunta de Galicia), GRC MERVEX (nº IN607-A 2018-4).

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Tables

Table 1: Set of length-based indicators, their references, the corresponding indicator ratios and their expected values grouped in terms of conservation/sustainability, optimal yield and MSY considerations.

Indicator	Calculation	Reference	Indicator ratio	Expected value	Property
$L_{max5\%}$	Mean length of largest 5%	L_∞	$L_{max5\%}/L_\infty$	>0.8	Conservation (large individuals); CL
$L_{95\%}$	95th percentile	L_∞	$L_{95\%}/L_\infty$	>0.8	Conservation (large individuals); CL
P_{mega}	Proportion of individuals above L_{opt} + 10%	0.3-0.4	P_{mega}	>0.3	Conservation (large individuals); CL
$L_{25\%}$	25th percentile of length distribution	L_{mat}	$L_{25\%}/L_{mat}$	>1	Conservation (immatures); CI
L_c	Length at first catch (length at 50% of mode)	L_{mat}	L_c/L_{mat}	>1	Conservation (immatures); CI
L_{mean}	Mean length of individuals > L_c	$L_{opt}=3L_\infty/(3+(M/k))$	L_{mean}/L_{opt}	≈1	Optimal yield; OY
L_{maxy}	Length class with maximum biomass in catch	$L_{opt}=3L_\infty/(3+(M/k))$	L_{maxy}/L_{opt}	≈1	Optimal yield; OY
L_{mean}	Mean length of individuals > L_c	$L_{F=M}=(1-a)L_c+aL_\infty$ $a=1/(2(M/k)+1)$	$L_{mean}/L_{F=M}$	≥1	MSY

Table 2: Description of the 6 different parameter configurations consider to assess the robustness/sensitivity of LBI and LBSPR methods to variation/misspecification of parameters M/k and L_∞.

Model	L_∞ value	M/k value
1: Reference model	L_∞^{LIT}	M/k^{LIT}
2: Underestimated M/k	L_∞^{LIT}	$0.75 \cdot M/k^{LIT}$
3: Overestimated M/k	L_∞^{LIT}	$1.25 \cdot M/k^{LIT}$
4: Underestimated L_∞	$0.75 \cdot L_\infty^{LIT}$	M/k^{LIT}
5: Overestimated L_∞	$1.25 \cdot L_\infty^{LIT}$	M/k^{LIT}
6: M/k=1.5	L_∞^{LIT}	1.5

Table 3: Values of the life history parameters (M/k, L∞, L_{50}, L_{95}, *a* and *b*) for each stock and source. In addition, the parameter BinWidth (width of length bins) of LBI method is also reported for all the stocks.

Stock	L_∞^{LIT}	M/k^{LIT}	L_{50}	L_{95}	a; b	BinWidth	Source
N. norvegicus FU25 Males	86mm	1.9	25mm	28.75mm	0.00043; 3.16	1mm	Please complete
N. norvegicus FU25 Females	71mm	1.9	28mm	32.2mm	0.00043; 3.16	1mm	Please complete
N. norvegicus FU2627 Males	80mm	2	28mm	32.2mm	0.00043; 3.16	2mm	Please complete
N. norvegicus FU2627 Females	65mm	2.5	26mm	29.9mm	0.00043; 3.16	2mm	Please complete
G. melastomus	75cm	1.5	54.2cm	58cm	Please complete	2cm	Please complete
E. encrasicolus	18.95cm	1.44	11.2cm	13.3cm	Please complete	2cm	Please complete
P. bogaraveo	62cm	1.42	33cm	35cm	Please complete	2cm	Please complete
T. luscus	46.7cm	1.76	19.2cm	21.43cm	0.01303439; 2.969518	1cm	Please complete
P. pollachius	98.2cm	1.65	42.3cm	59cm	Please complete	4cm	Please complete

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Table 4: Summary of the results derived from the sensitive analysis carried out for LBI method applied to *N. norvegicus* FU25 and FU2627 (Males and Females).

Stock	$0.75 \cdot M/k^{LIT}$	$1.25 \cdot M/k^{LIT}$	$0.75 \cdot L_{\infty}^{LIT}$	$1.25 \cdot L_{\infty}^{LIT}$	M/k=1.5
N. norvegicus FU25 Males	**OY:** L_{mean}/L_{opt} (3%) **MSY:** $L_{mean}/L_{F=M}$ (5%)	**OY:** L_{mean}/L_{opt} (18%) **MSY:** $L_{mean}/L_{F=M}$ (8%)	**CL:** $L_{max5\%}/L_{\infty}$ (58%) P_{mega} (32%) **OY:** L_{mean}/L_{opt} (92%) **MSY:** $L_{mean}/L_{F=M}$ (63%)	**OY:** L_{mean}/L_{opt} (3%) **MSY:** $L_{mean}/L_{F=M}$ (5%)	**OY:** L_{mean}/L_{opt} (3%) **MSY:** $L_{mean}/L_{F=M}$ (5%)
N. norvegicus FU25 Females	**OY:** L_{mean}/L_{opt} (32%) **MSY:** $L_{mean}/L_{F=M}$ (8%)	**CL:** P_{mega} (3%) **OY:** L_{mean}/L_{opt} (47%) **MSY:** $L_{mean}/L_{F=M}$ (21%)	**CL:** $L_{max5\%}/L_{\infty}$ (100%) P_{mega} (89%) **OY:** L_{mean}/L_{opt} (68%) **MSY:** $L_{mean}/L_{F=M}$ (84%)	**OY:** L_{mean}/L_{opt} (32%) **MSY:** $L_{mean}/L_{F=M}$ (8%)	**OY:** L_{mean}/L_{opt} (32%) **MSY:** $L_{mean}/L_{F=M}$ (8%)
N. norvegicus FU2627 Males	**CL:** P_{mega} (16%) **OY:** L_{mean}/L_{opt} (25%) **MSY:** $L_{mean}/L_{F=M}$ (16%)	**CL:** P_{mega} (12%) **OY:** L_{mean}/L_{opt} (12%) **MSY:** $L_{mean}/L_{F=M}$ (16%)	**CL:** $L_{max5\%}/L_{\infty}$ (44%) P_{mega} (47%) **OY:** L_{mean}/L_{opt} (41%) **MSY:** $L_{mean}/L_{F=M}$ (38%)	**CL:** $L_{max5\%}/L_{\infty}$ (47%) P_{mega} (19%) **OY:** L_{mean}/L_{opt} (41%) **MSY:** $L_{mean}/L_{F=M}$ (34%)	**CL:** P_{mega} (16%) **OY:** L_{mean}/L_{opt} (25%) **MSY:** $L_{mean}/L_{F=M}$ (16%)
N. norvegicus FU2627 Females	**CL:** P_{mega} (38%) **OY:** L_{mean}/L_{opt} (19%) **MSY:** $L_{mean}/L_{F=M}$ (31%)	**CL:** P_{mega} (9%) **OY:** L_{mean}/L_{opt} (9%) **MSY:** $L_{mean}/L_{F=M}$ (9%)	**CL:** $L_{max5\%}/L_{\infty}$ (47%) P_{mega} (38%) **OY:** L_{mean}/L_{opt} (16%) **MSY:** $L_{mean}/L_{F=M}$ (12%)	**CL:** $L_{max5\%}/L_{\infty}$ (47%) P_{mega} (53%) **OY:** L_{mean}/L_{opt} (53%) **MSY:** $L_{mean}/L_{F=M}$ (50%)	**CL:** P_{mega} (53%) **OY:** L_{mean}/L_{opt} (44%) **MSY:** $L_{mean}/L_{F=M}$ (50%)

Comentado [MOU9]: Marta yo creo que el problema d elas tabla es por libre office, intenta pegar aquí las cosas y creo que tabla 4 y 5 se pueden unir

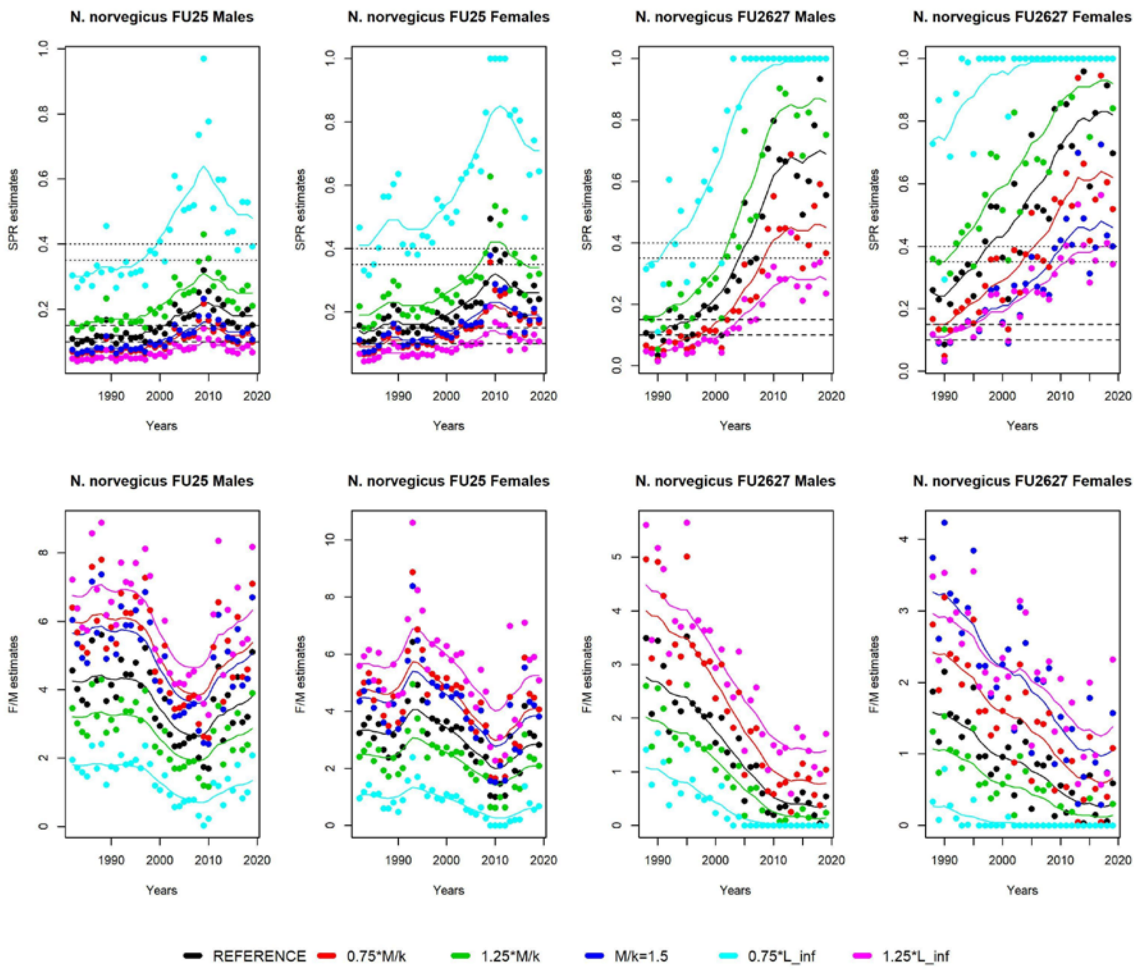
Table 5: Summary of the results derived from the sensitive analysis carried out for LBI method applied to *G.melastomus*, *E. encrasicolus*, *P. bogaraveo*, *T. luscus*, and *P. pollachius*.

Stock	0.75·M/k^{LIT}	1.25·M/k^{LIT}	0.75·L_∞^{LIT}	1.25·L_∞^{LIT}	M/k=1.5
G. melastomus	**CL:** P_{mega} (50%)	**CL:** P_{mega} (50%)	**CL:** P_{mega} (50%) **MSY:** $L_{mean}/L_{F=M}$ (100%)	**CL:** P_{mega} (50%) $L_{max5\%}/L_\infty$ (100%) **OY:** L_{mean}/L_{opt} (100%)	
E. encrasicolus	**OY:** L_{mean}/L_{opt} (56%) **MSY:** $L_{mean}/L_{F=M}$ (6%)	**OY:** L_{mean}/L_{opt} (22%) **MSY:** $L_{mean}/L_{F=M}$ (19%)	**CL:** $L_{max5\%}/L_\infty$ (81%) P_{mega} (97%) **OY:** L_{mean}/L_{opt} (31%) **MSY:** $L_{mean}/L_{F=M}$ (75%)	**CL:** $L_{max5\%}/L_\infty$ (19%) **OY:** L_{mean}/L_{opt} (66%) **MSY:** $L_{mean}/L_{F=M}$ (6%)	**MSY:** $L_{mean}/L_{F=M}$ (3%)
P. bogaraveo	**OY:** L_{mean}/L_{opt} (17%) **MSY:** $L_{mean}/L_{F=M}$ (4%)	**OY:** L_{mean}/L_{opt} (78%) **MSY:** $L_{mean}/L_{F=M}$ (22%)	**CL:** $L_{max5\%}/L_\infty$ (22%) P_{mega} (100%) **OY:** L_{mean}/L_{opt} (83%) **MSY:** $L_{mean}/L_{F=M}$ (91%)	**CL:** $L_{max5\%}/L_\infty$ (74%) **OY:** L_{mean}/L_{opt} (17%) **MSY:** $L_{mean}/L_{F=M}$ (4%)	**OY:** L_{mean}/L_{opt} (35%) **MSY:** $L_{mean}/L_{F=M}$ (4%)
T. luscus			**CL:** $L_{max5\%}/L_\infty$ (80%) P_{mega} (5%) **OY:** L_{mean}/L_{opt} (100%) **MSY:** $L_{mean}/L_{F=M}$ (40%)		
P. pollachius	**OY:** L_{mean}/L_{opt} (22%) **MSY:** $L_{mean}/L_{F=M}$ (11%)	**OY:** L_{mean}/L_{opt} (33%) **MSY:** $L_{mean}/L_{F=M}$ (33%)	**CL:** $L_{max5\%}/L_\infty$ (89%) P_{mega} (56%) **MSY:** $L_{mean}/L_{F=M}$ (56%) **OY:** L_{mean}/L_{opt} (67%)	**OY:** L_{mean}/L_{opt} (22%) **MSY:** $L_{mean}/L_{F=M}$ (22%) **CL:** $L_{max5\%}/L_\infty$ (11%)	**OY:** L_{mean}/L_{opt} (11%)

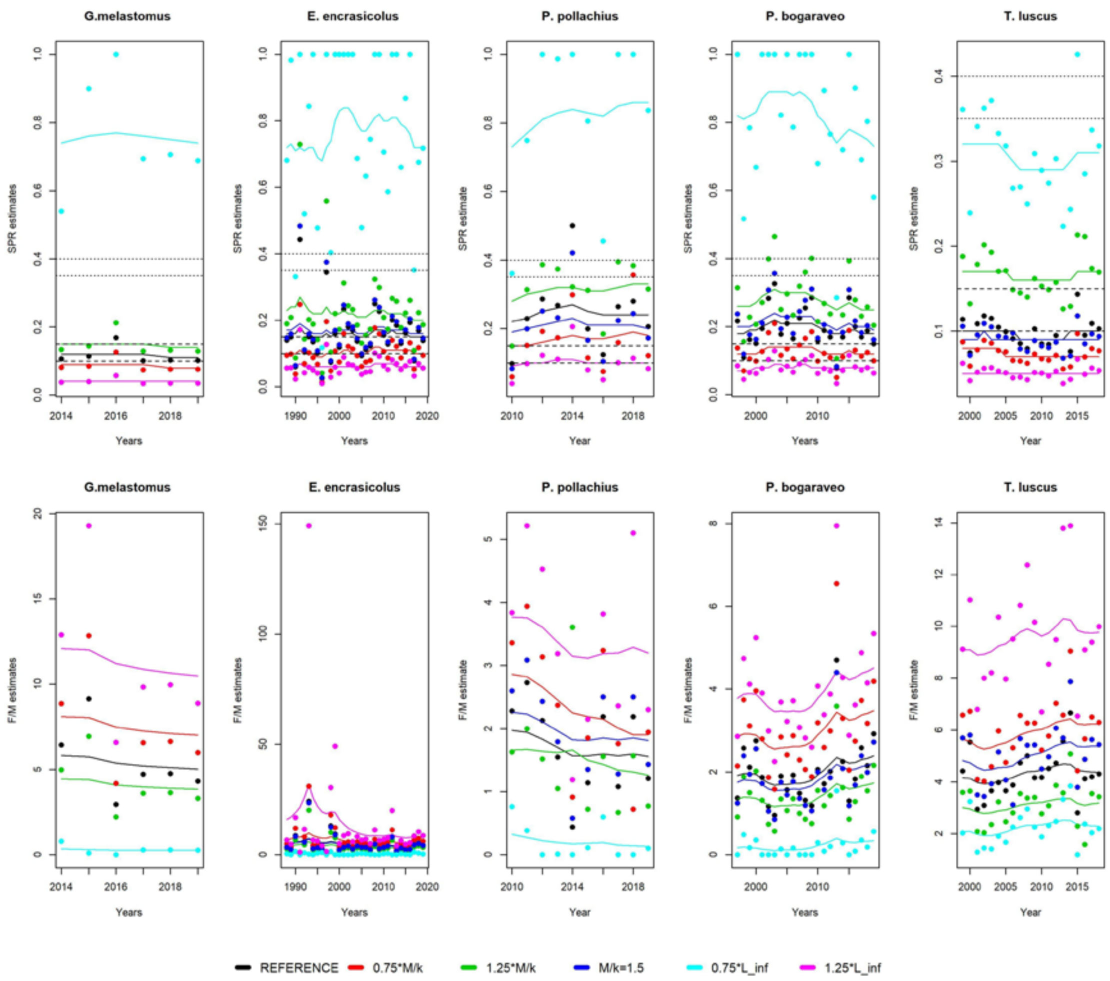
Figures

Figure 1: Plots of the SPR and F/M estimates and their smoother derived from the sensitivity analysis carried out for LBSPR method applied to *N. norvegicus* FU25 and FU2627 (Males and Females). Horizontal dotted lines delimit the range where the stock is considered at MSY level, whereas horizontal dashed lines show the levels below which the stock is considered collapsed.

Figure 2: Plots of the SPR and F/M estimates and their smoother derived from the sensitivity analysis carried out for LBSPR method applied to *G.melastomus, E. encrasicolus, P bogaraveo, T. luscus,* and *P. Pollachius.* Horizontal dotted lines delimit the range where the stock is considered at MSY level, whereas horizontal dashed lines



N. norvegicus FU25 Males
N. norvegicus FU25 Females
N. norvegicus FU2627 Males
N. norvegicus FU2627 Females
SPR estimates
F/M estimates
Years
REFERENCE
0.75*M/k
1.25*M/k
M/k=1.5
0.75*L_inf
1.25*L_inf


G.melastomus
E. encrasicolus
P. pollachius
P. bogaraveo
T. luscus
SPR estimates
SPR estimate
F/M estimates
F/M estimate
Years
Year
REFERENCE
0.75*M/k
1.25*M/k
M/k=1.5
0.75*L_inf
1.25*L_inf