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ESTIMATION OF ATLANTIC SKIPJACK FISHERIES' PRODUCTIVITY USING A CATCH BASED METHOD AND HYPOTHESES ON STOCK RESILIENCE

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SUMMARY

Fisheries are managed using biological information of fish stocks, historical catch data and complex numerical models. However, the availability of reliable and complete information of both biological characteristics and fisheries yield is often incomplete, inaccurate or non-available. Therefore, there is a need for simple methods that allow estimating fish stocks productivity using limited data. In this study we use a simple method to investigate the productivity and historical harvest rates applied to four stocks of Atlantic skipjack, a species exploited by several nations and a diversity of gears on the tropical waters of the Atlantic Ocean and managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Our results suggest that historical catch is within the estimated limits of the capacities of these stocks to replace the amount of biomass harvested. However, we also estimate that the probability of the recent catch to be nearby to the estimated upper confidence boundaries of MSY is high. We discuss that these results need to be supported by deeper studies and new data due to the limitations of catch based methods.

RÉSUMÉ

Les pêcheries sont gérées au moyen d'informations biologiques sur les stocks de poissons, de données de prise historique et de modèles numériques complexes. Ceci dit, les informations fiables et complètes sur les caractéristiques biologiques et le rendement des pêches sont souvent incomplètes, imprécises et ne sont pas disponibles. Il est donc nécessaire d'avoir recours à des méthodes simples qui permettent d'estimer la productivité des stocks de poissons au moyen de données limitées. Dans cette étude, nous utilisons une méthode simple afin d'étudier la productivité et les taux de capture historique appliqués à quatre stocks de listao de l'Atlantique, une espèce exploitée par plusieurs pays et une variété d'engins dans les eaux tropicales de l'océan Atlantique et gérée par la Commission internationale pour la conservation des thonidés de l'Atlantique (ICCAT). Nos résultats donnent à penser que la prise historique se situe dans les limites estimées des capacités de ces stocks pour remplacer le volume de biomasse capturée. Néanmoins, nous estimons également qu'il est fort probable que la prise récente se situe à un niveau proche des limites de confiance supérieures estimées de la PME. Nous signalons que ces résultats doivent être étayés par des études plus exhaustives et de nouvelles données compte tenu des limitations des méthodes fondées sur la prise.

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RESUMEN

Las pesquerías se gestionan utilizando información biológica de los stocks de peces, datos de captura históricos y modelos numéricos complejos. Sin embargo, la disponibilidad de información completa y fiable tanto de las características biológicas como del rendimiento de las pesquerías es a menudo incompleta, imprecisa o no está disponible. Por lo tanto, es necesario contar con métodos más simples que permitan estimar la productividad de los stocks de peces utilizando datos limitados. En este estudio, se usa un método simple para investigar la productividad y las tasas de captura históricas aplicadas a cuatro stocks de listado del Atlántico, una especie explotada por varias naciones con diversos artes en aguas tropicales del Atlántico y gestionada por la Comisión Internacional para la Conservación del Atún Atlántico (ICCAT). Nuestros resultados sugieren que la captura histórica se encuentra dentro de los límites estimados de la capacidad de estos stocks para sustituir la cantidad de biomasa capturada. Sin embargo, también estimamos que la probabilidad de que la captura reciente se encuentre cerca de los límites superiores de confianza estimados del RMS es elevada. Se discute que estos resultados deben ser respaldados con estudios más profundos y nuevos datos debido a las limitaciones de los métodos basados en la captura.

KEYWORDS

Atlantic skipjack, Data-poor stocks, Maximum Sustainable Yield, Stock assessment

1. Introduction

The International Commission for the Conservation of Atlantic Tunas (ICCAT) aims for the conservation of tunas and tuna-like species in the Atlantic Ocean and adjacent seas. ICCAT aims for fish stocks that are maintained at levels that can produce the maximum sustainable yield (MSY) and that are within safe biomass limits with high probability. Generally, stocks' MSY and their level of exploitation is estimated using complex stock assessment models fed with comprehensive fishery and fishery-independent data, collected through substantial international effort. However, in some cases, these data are not available or informative and simpler methods that do not require catch rate information are needed. Here, we estimate the productivity of four stocks of Atlantic skipjack using only historical catch series provided by ICCAT secretariat and a method for estimating MSY from catch and resilience (Martell and Froese, 2012). This method is not proposed as a definitive stock assessment procedure but it can yield useful information on stocks' productivity and prior information for more complex stock assessment models.

2. Material and Methods

The simplest model-based methods for estimating MSY are production models such as that of Schaefer (1954), only require a time series of relative or absolute abundance and of removals to estimate two model parameters: the carrying capacity, *K*, and the maximum rate of population increase, *r*, for a stock (Martell and Froese, 2012). Abundance estimates can be difficult and costly to obtain and therefore, methods that require only a time series of removals are sometimes necessary. Without abundance estimates, Schaefer models output a range of *r*-*K* combinations which can be used to approximate MSY (Martell and Froese, 2012). We applied this method to obtain plausible MSY estimates and other biological parameters from catch only data, based on assumptions on resilience (corresponding to the intrinsic growth rate *r* in the stock production model) and the plausible range of relative stock sizes at the beginning of the time series (Martell and Froese 2012). We used a medium resilience range and high resilience ranges as defined by Martell and Froese (2012), *i.e*. medium resilience of $0.2<r<1$, high resilience of $0.6<r<1.5$ (Fishbase estimate for skipjack), and an initial (in 1950) relative stock size range of 50 to 90% of carrying capacity *K* or pristine biomass. The identification of pairs of *r*-*K* values compatible with the catch time series and the above assumptions was performed using the R-code for batch processing made publicly available in http://www.fishbase.de/rfroese/CatchMSY_2.r. For each plausible *r*-*K* pair, an estimate is obtained as $MSY=1/4\ r\ K$. This MSY estimation algorithm has been validated against analytical fish stock assessment estimates of MSY (Martell & Froese, 2012). We ran the model for four geographical areas based on the geographical coordinates agreed in the ICCAT East and West Atlantic Stock Assessment held in Dakar (Senegal, June 23 to July 1, 2014): East, West, Southwest and Southeast (see **Figure 1** and SCRS document 2014/073). We used catch information from CatDis data made available by the ICCAT Secretariat for the 2014 assessment. The total catch for each of the purported stocks considered in this study are shown in **Figure 2**.

3. Results

Figures 3 and **4** show the graphical output of the catch-MSY method as applied to purported 4 Atlantic skipjack stocks using the two hypotheses on their resilience. The catch based model outputs a probabilistic estimation of the maximum sustainable yield and the intrinsic growth rate (*r*) and carrying capacity (*K*) parameters of the logistic surplus production model. **Figures 3** and **4** show the estimated MSY (median and upper-lower confidence intervals) together with historical catches of each of the stocks considered and the probabilistic distribution of the estimated parameters MSY, *r* and *K.* In these figures, recent catch is within the confidence intervals of the estimated MSY for all stocks except for the southeastern stock under the high resilience hypothesis. For all but the western stock in the high resilience hypothesis, the most recent catch is above the estimated MSY median. At the right side of the historical catch and MSY boundaries, the posterior densities of *r, K* and MSY are shown.

The impact of the prior of the intrinsic growth rate for "medium" and "high" resilience of the stock could modify the perception of stocks' state of exploitation. For both assumptions, the estimated MSY is similar for all stocks, but the estimated *r-K* pairs are substantially different. For the "medium" resilience hypothesis, we would be considering skipjack a larger but less productive stock than for the "high" resilience runs. Although the MSY may not change, the estimated fishing mortality that will lead to this MSY will be different, and so will be the time for the stock to recover from potential overexploitation.

In order to investigate if the catch increase observed in the last two years of the series could bias the MSY estimates, we tried the catch-based method retrospectively: We ran the model for the eastern and southern areas for alternative data series starting in 1951 and ending in 1990, 2000, 2003, 2004-2012, and compared the resulting parameters with those estimated using the complete catch data. The retrospective analyses were run with different priors for skipjack resilience ("high" $0.6<r<1.5$ and "medium" $0.2<r<1$).

Figure 5 shows that the estimates with data series ending at different years would produce variations on the MSY for the eastern (black) stock (from ~ 100,000 t if estimated in 1990 to 180,000 t estimated using the complete series). This may indicate that this stock is more productive than what may have been thought in the 1990 assessment with this method, or, that the sustainable levels of harvest have been exceeded for the last 30 years, which seems unlikely. However, these conclusions require the support of additional studies. In contrast, for the western (grey) stock this variation is insignificant (29,000-31,000 t). For the southwestern stock, the appreciable increase in catch could be related to the expansion of the Brazilian fishery. This point needs to be confirmed with further studies as well.

Finally, for the medium resilience hypothesis, we estimated the probability of the historical catch to be within the estimated MSY range (**Figure 6**). According to this figure, despite most of the historical catch falls within or below MSY ranges (**Figure 3**), the probability of recent catches exceeding MSY is high for three of the stocks (SKJ-E, SKJ-SE, SKJ-SW). In other words, recent catch is close to the upper limit of the MSY estimates, with high probability of the catch being above MSY, as the probability of MSY being that of the upper tail of the distribution is low.

4. Discussion

The method used here allows a very simple estimation of the productivity of fish stocks and is similar to that previously used by the Skipjack Working Group (after Vasconcellos and Cochrane, 2005; see Rosenberg *et al*, 2014). However, the key question is how well this method compares with the estimates yielded by full stock assessments and .and to those previously used by the Skipjack Working Group (after Vasconcellos and Cochrane 2005; see Rosenberg *et al.*, 2014). In the paper by Martell and Froese (2012), a comparison using stocks evaluated within the International Commission for the Exploration of the Sea (ICES) and from the RAM legacy database (Ricard *et al.*, 2011) shows that the results obtained with this method are not significantly different to those obtained from full stock assessments (R^2=0.986). In addition, the RAM legacy database contains information from many tuna and tuna-type stocks that were used for the comparison, including bigeye, yellowfin, skipjack, swordfish, albacore stocks from the Atlantic, Indian and Pacific Oceans. However, this method does have limitations and caveats that need to be discussed.

A key assumption in this approach is the ability to define reasonable prior ranges for the parameters of the Schaefer model. For example, in developing fisheries, or fisheries that have not reached or exceeded their MSY and have not gone through overexploitation phases, the time series of catches do not contain sufficient information about productivity (Martell and Froese, 2012). This may be the case for the stocks analyzed here, especially for the east Atlantic. The retrospective analysis shows that using the most recent data produces higher MSY estimates. Since the maximum recorded catch is the most recent there has been no time elapsed to observe a decay which may indicate the maximum productivity of the stock and that it has been exceeded. For these stocks, using this method we cannot predict if the current catch increase has exceeded MSY and resulted in overexploitation or that the stock is more productive than what shorter catch series may have indicated. However, it is known that fishing effort has both increased and become more efficient with increasing use of FADs for catching skipjack. The future yields of the fisheries exploiting these stocks will be critical in assessing if MSY has been exceeded and if the stock is undergoing overexploitation. Close monitoring of yields and fishing effort will be of high importance in supporting future assessments.

The Schaefer model used in this study does not consider environmental effects on the productivity of the stocks, as it does not allow for change in the parameters over time. Fish stocks, especially pelagic fish, can be highly vulnerable to environmental variability (Barange *et al.*, 2009; Hsieh *et al*., 2009), which are hypotheses that are generally considered in ICCAT and other Tuna Regional Management Organizations full stock assessments. Future evaluations could take on such hypotheses, if supporting evidence for such systematic change can be identified.

These types of simple methods are suitable for data poor fisheries only if additional data are not available. For the cases where more complex methods are used, this method can be used to generate priors or provide robustness tests in support of the overall stock assessment.

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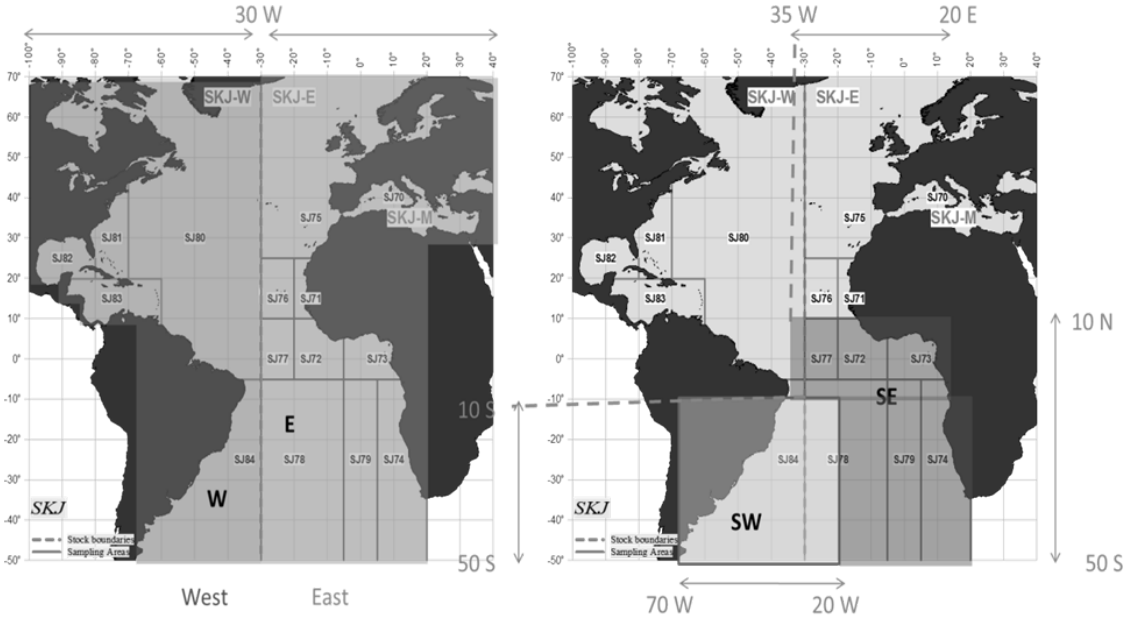

Figure 1. Geographical boundaries of alternative stock structure assumptions: (A) Two stocks: East and West separated by the 30 West Meridian, and (B) metapopulation representation of numerous stocks. Shaded areas were considered for the stock assessment models.

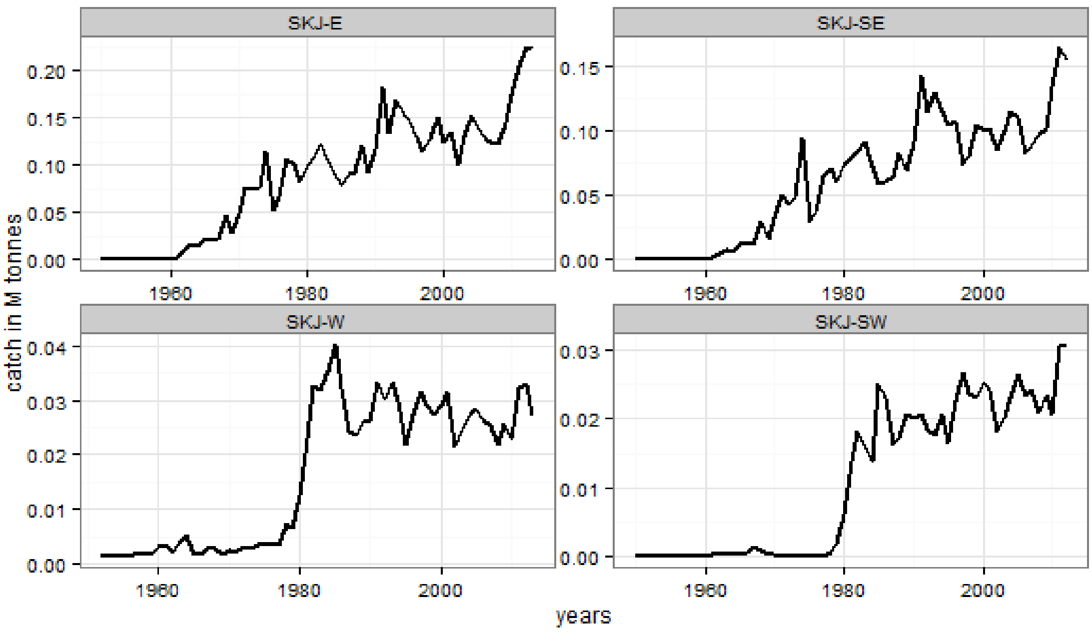

Figure 2. Catch data for the East (SKJ-E), Southeast (SKJ-SE), West (SKJ-W) and Southwest (SKJ-SW) stocks.

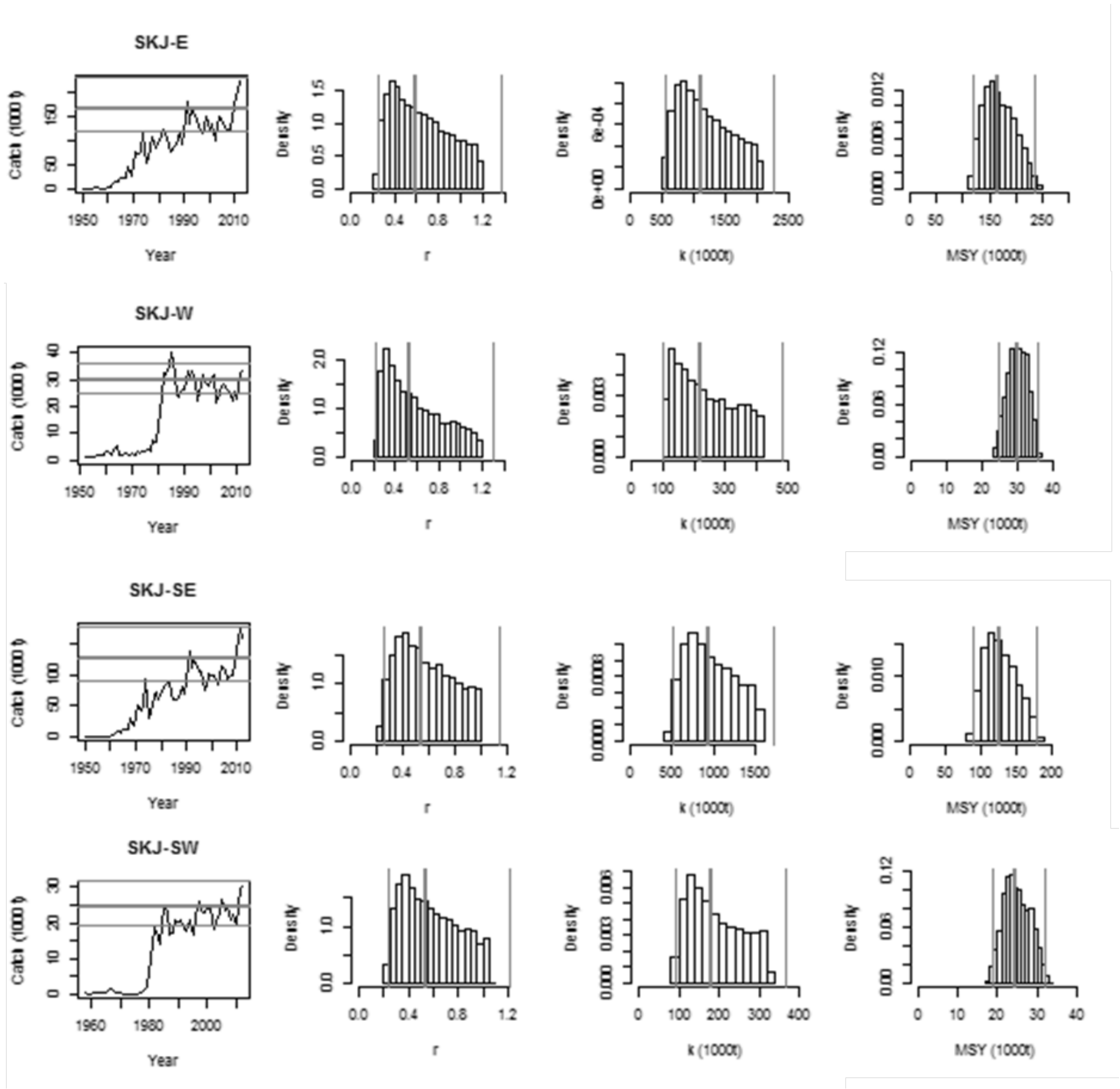

Figure 3. Medium resilience catch only model results for the East (SKJ-E) and West (SKJ-W) Atlantic skipjack (upper) and Southeast (SKJ-SE) and Southwest (SKJ-SW) under the metapopulation structure.

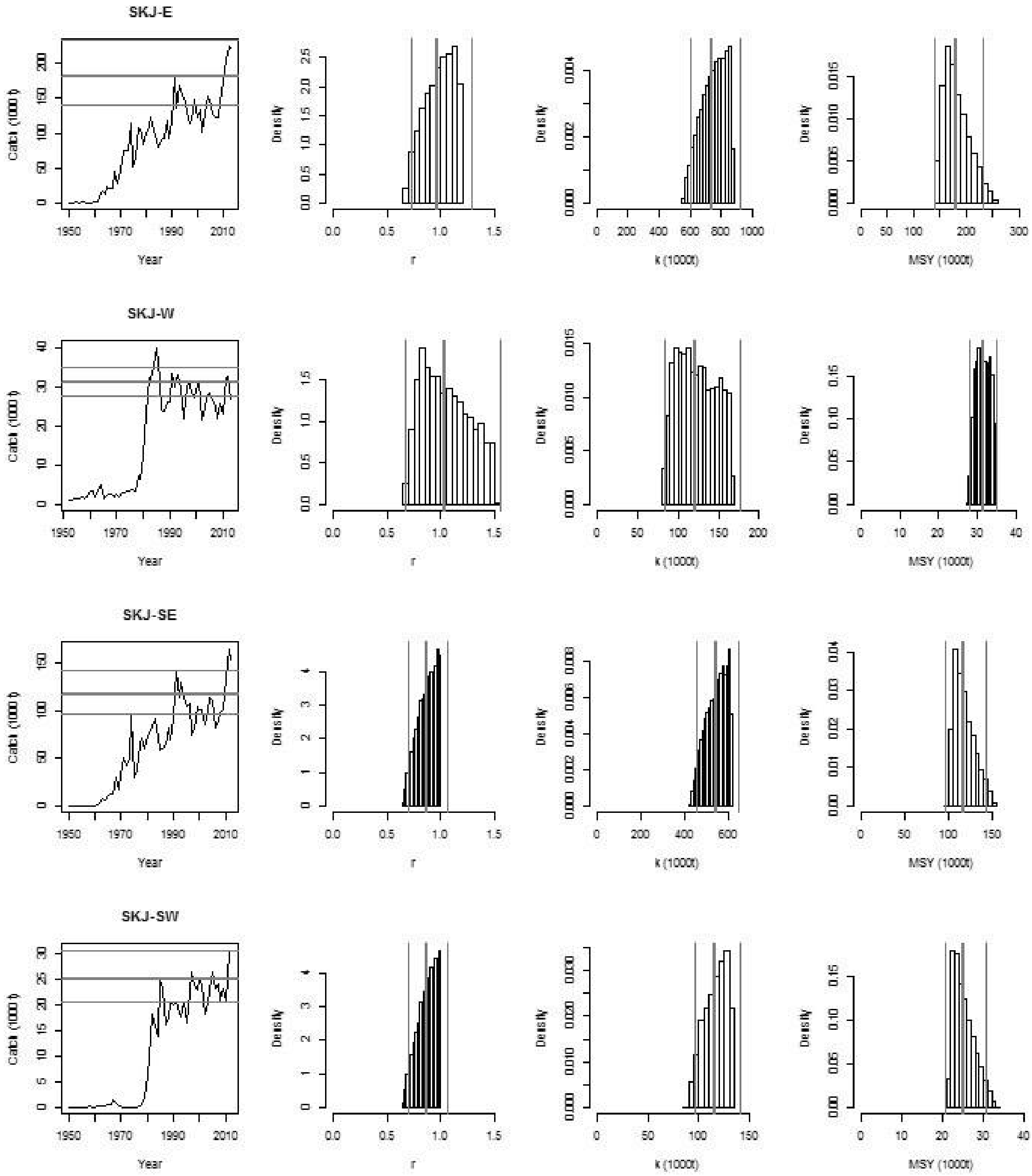

Figure 4. High resilience catch only model results for the East (SKJ-E) and West (SKJ-W) Atlantic skipjack (upper) and Southeast (SKJ-SE) and Southwest (SKJ-SW) under the metapopulation structure.

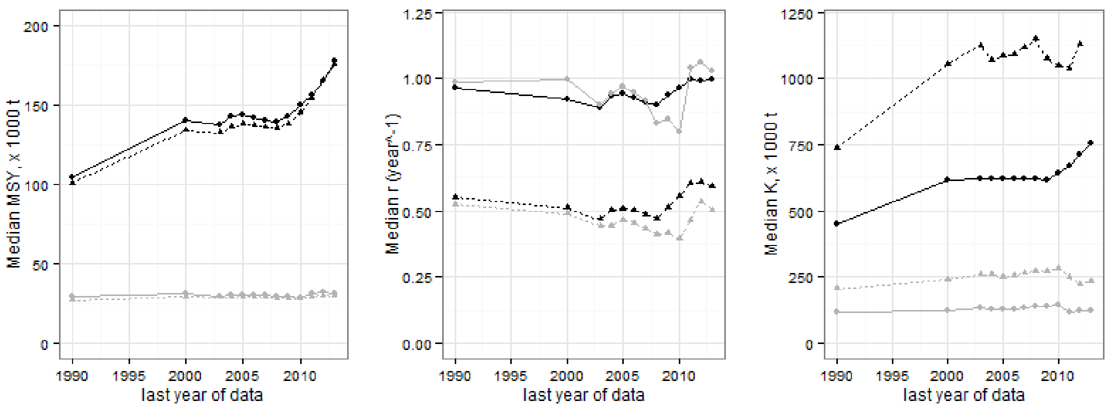

Figure 5. Estimates of MSY, r and K for the catch only models of East (black) and West (gray) Atlantic skipjack. Continuous line (high resilience) and dashed line (medium resilience) hypotheses.

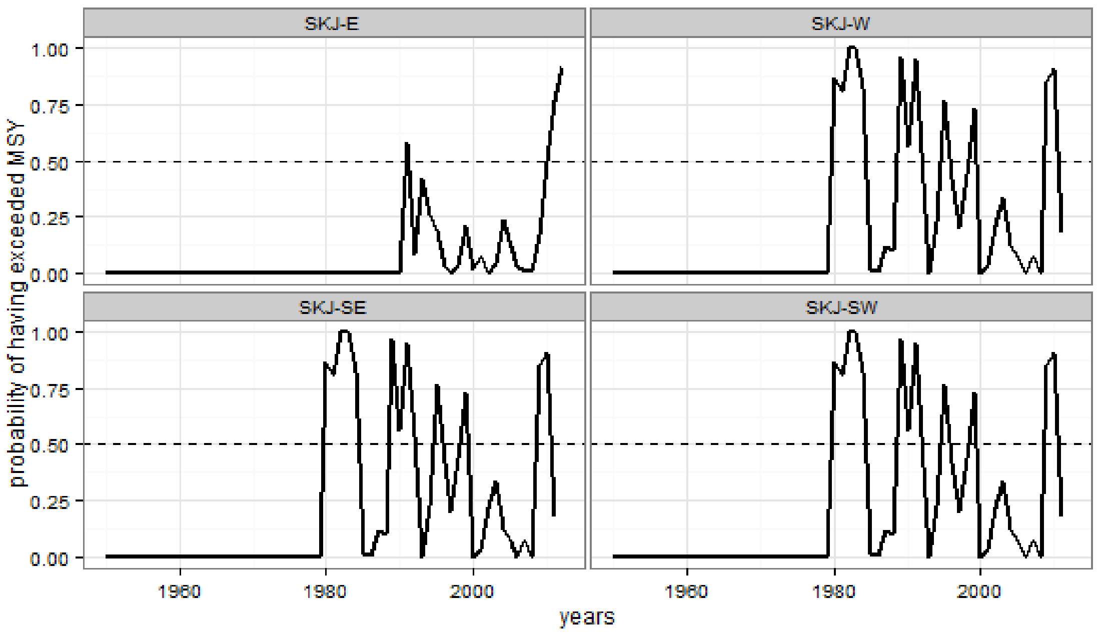

Figure 6. Historical probability of exceeding the estimated MSY for each of the stocks and resilience hypotheses.