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The effect of choice of stock recruit model and partial recruitment on reference points in Div. 3LNO American plaice

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Abstract

Currently there is a biomass limit reference point for Div. 3LNO American plaice but no fishing mortality limit. This paper estimates F_{msy} as a candidate F_{lim} for the stock using 4 different stock recruit models and 3 different partial recruitment vectors. Estimates were mainly affected by the choice of stock recruit model with only minor influence of choice of PR. The Loess smoother gave the best fit to the data and the best prediction of recruitment. The F_{msy} based on the Loess smoother and a PR averaged over all years for ages 9-14 was 0.4. This estimate of F_{msy} is consistent with the history of the stock and is suggested as F_{lim} for this stock.

Introduction

The precautionary approach framework of NAFO calls for both biomass and fishing mortality reference points (Fig. 1). For many of the stocks managed by NAFO, the framework has not been fully specified. This is the case for Div. 3LNO American plaice, where a B_{lim} of 50 000 tons of spawning stock biomass (SSB) has been set as a biological limit, but no fishing mortality limit (F_{lim}) has been specified. The default F_{lim} proposed by the United Nations Fish Stocks Agreement (UNFSA) and widely adopted is F_{msy} (Shelton and Sinclair, 2008).

A previous exploration of reference points for this stock was presented in 2005 (Dwyer et al., MS 2005). However, STACFIS was concerned about the sensitivity of estimated reference points to the stock recruit model chosen (previous work had used a smoother) and to the choice of current PR, given that the fishery is not directed but is based on bycatch.

This paper examines the impact of choice of PR and S/R model on estimates of fishing mortality limit reference points for Div. 3LNO American plaice.

Methods

The data used in these analyses were those from the 2007 assessment of this stock (Dwyer et al., MS 2007). Natural mortality was taken to be 0.2 on all ages. The weights and maturities were as used in the projections of stock size in the last assessment and were the average of the last three years prior to that assessment (Table 1).

The F matrix was examined for variation in partial recruitment. Three PR vectors were chosen: the average of the last three years prior to the assessment year as used in the last projections of stock size, the average of all years in the matrix and the average of the years 1997-1999, during which time the PR seemed different from the average. These are shown in Fig. 2 and Table 1. In all cases the PR was rescaled to the average over ages 9-14.

Four S/R models were used. These were the Ricker: $R = \alpha * SSB * e^{-\mathrm{B}*SSB}$;

Beverton-Holt $R = \dfrac{\alpha * SSB}{\mathrm{B} + SSB}$;

Segmented Regression $R = \begin{cases} \alpha * SSB & if\ SSB < \mathrm{B} \\ \alpha * \mathrm{B} & if\ SSB \geq \mathrm{B} \end{cases}$;

And a Loess smoother where the smoothing parameter is chosen by Akaike information criteria and the weighting for the regression is

$$w_i = \frac{32}{5}\left(1 - \left(\frac{d_i}{d_q}\right)^3\right)^3$$

where d_q is the maximum distance for the q points closest to x (with the proportion of points used in the neighbourhood set by the smoothing parameter) and d_i is the distance of a particular point from x, so that the farther a point is from x the less weight it gets in the local regression.

Each PR was used in conjunction with each S/R model to calculate F_{msy}. For the parametric models (Segmented, Ricker and Beverton-Holt) the Sissenwine-Shepherd method was used (Sissenwine and Shepherd, 1987) to determine F_{msy}. For the Loess smoother the fitted smoothing parameter was used in simulations of the population over a 500 year period at a series of F values to determine F_{msy}.

In an attempt to determine which of the four S/R models best predicts recruitment, the model was fitted on a portion of the data and then used to predict the remaining data points. In this exercise, 10% (4 points) of the data were eliminated in the fitting, and then the omitted data points predicted based on the fit to the remaining data. The residual sums of squares for the predicted vs observed values was then compared for the 4 models. The 10% of the data eliminated was the same for each model. This was done only once.

In addition, F_{med} was calculated as a possible reference point. This reference point may be affected by PR and uses the stock-recruit data points, but does not rely on a particular model of S/R. Rather it is based on the median of recruits per spawner.

Results and Discussion

The fit of the four S/R models is given in Fig. 3. The model predicted recruitment is fairly similar for the Ricker, Beverton-Holt and Loess. Also, the sums of squares of the residuals do not vary greatly among model fits, although the smallest value is for the Loess smoother. The sums of squares are numerically large because the model fits are for tons of SSB and thousands of recruits.

The estimated F_{msy} varied from 0.19 to 1.03, however this variation was mainly the result of the difference in the S/R curve. For a given S/R model there was little variation across PR with regard to F_{msy} (Table 2).

Since most of the variation was due to the choice of S/R model, an attempt was made to determine which model gave the best prediction, beyond just looking at the residual sums of squares. When the models were fit with 10% of the data missing, the Loess smoother did the best at predicting the missing four data points. The sums of squares for the residuals from the prediction of the four missing data points was 1.0×10^{10} for the Loess smoother, 1.1×10^{10} for the Ricker model, 1.3×10^{10} for the Beverton-Holt and 1.5×10^{10} for the Segmented regression. This should possibly be explored more thoroughly through a cross validation procedure before making a final decision about which model provides the best prediction of recruitment.

The estimation of F_{med} uses the S/R data but does not rely on a model fit. The estimated value of F_{med} was not greatly affected by the choice of PR. The PR derived from the most recent 3 years gave an F_{med} of 0.75, for the PR averaged over all years the F_{med} was 0.72 and for the PR averaged over the years 1997-1999 F_{med} was 0.73.

The stock trajectory may help in deciding on an appropriate level for F_{lim}. Figure 5 shows average F over ages 9-14 plotted against SSB in tons. In only 2 years was the estimated F above 0.7, yet the stock declined to well below B_{lim}. Thus the estimates for F_{med} seem too high to be used as a limit reference point. In most years when the F was below 0.2, increases in SSB were observed. In most (but not all) years when F was above 0.4, SSB decreased. The F_{msy} calculated using a Loess smoother and a PR averaged over all years was 0.41. This should be considered as a candidate F_{lim}. It is derived from the S/R curve which gives the best prediction of recruitment in the initial test and is consistent with the stock history.

In conclusion, PR had little impact on the estimation of the F limit reference point F_{msy} but different S/R models had a large impact. Preliminary investigations indicate that the Loess smoother gives the best fit to the S/R data and F_{msy} using this model ranged from 0.41 to 0.47. Estimates of F_{med} were also not affected greatly by the choice of PR but were much higher than F_{msy}, ranging from 0.72 to 0.75. Estimates of F_{med} are too high to serve as a limit reference point, given the stock history. F_{msy} derived from a Loess S/R curve estimate (F=0.4) should be considered as F_{lim} as it consistent with UNFSA, is derived from the S/R curve giving the best model fit and prediction of recruitment and is consistent with the stock history. The stock trajectory with the suggested F_{lim} is shown in Figure 5.

Acknowledgements

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References

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Table 1. Weights-at-age, maturity-at-age, and partial recruitment vectors used in the study. PR 1 is the average of the last 3 years, PR 2 is the average over all years 1960-2006, and PR 3 is the average of the years 1997-1999.

Age	weight	maturity	PR 1	PR 2	PR 3
5	0.141	0.03	0.015	0.035	0.006
6	0.255	0.15	0.07	0.103	0.0465
7	0.38	0.5	0.18	0.244	0.193
8	0.489	0.82	0.39	0.417	0.497
9	0.582	0.95	0.79	0.625	0.767
10	0.699	0.99	0.99	0.767	0.898
11	0.863	1	1.13	0.969	1.333
12	1.001	1	1.07	1.145	1.289
13	1.213	1	1.05	1.206	1.132
14	1.493	1	0.96	1.288	0.58
15	1.908	1	0.96	1.288	0.58

Table 2. F_{msy} estimates using 3 different PR and 3 different S/R. The PR used are rescaled to the average of ages 9-14.

PR/SR	Loess	Ricker	Beverton-Holt	Segmented
Recent 3 years	0.42	0.31	0.20	1.03
All years	0.41	0.30	0.19	0.93
1997 to 1999	0.47	0.32	0.21	1.01

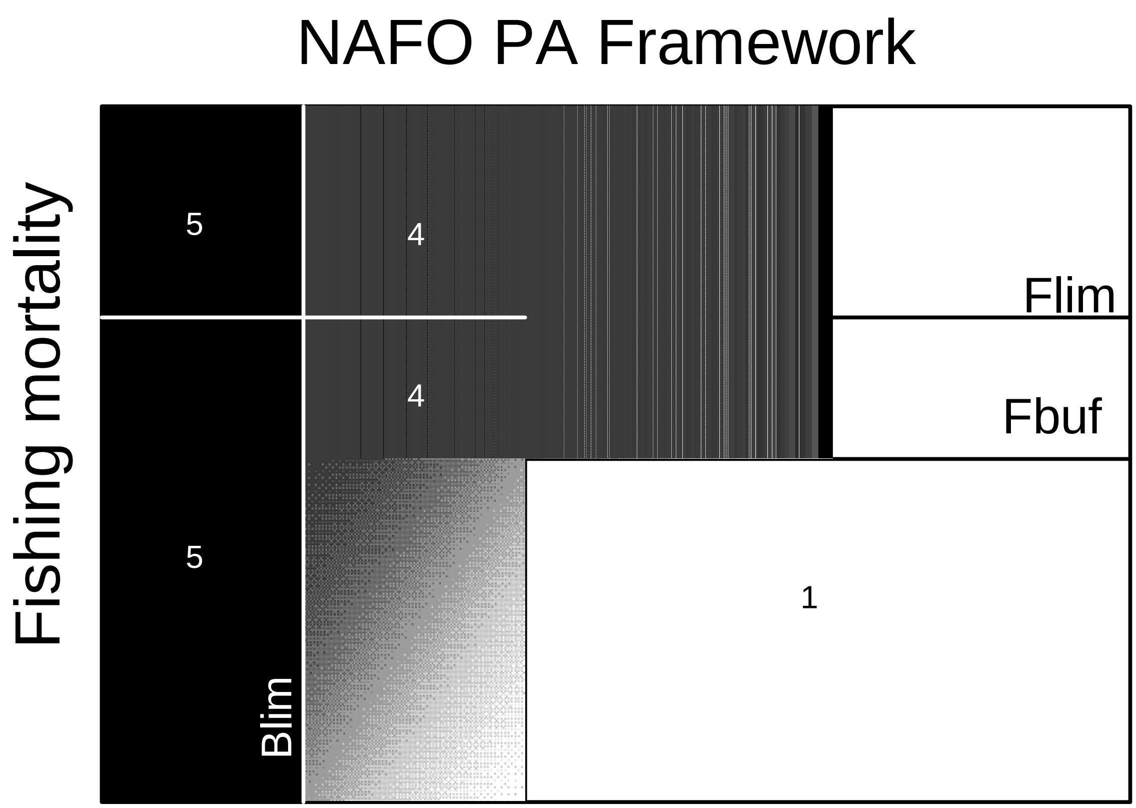

Figure 1. The NAFO precautionary approach framework.

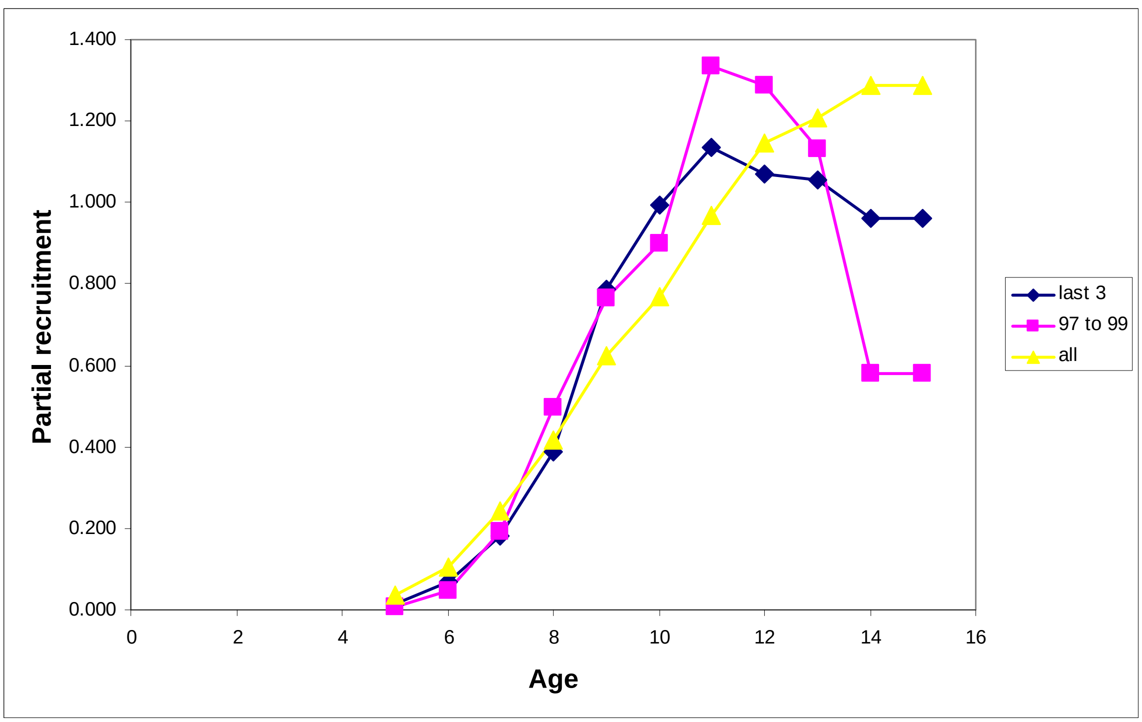

Figure 2. Partial recruitment vectors used in the study.

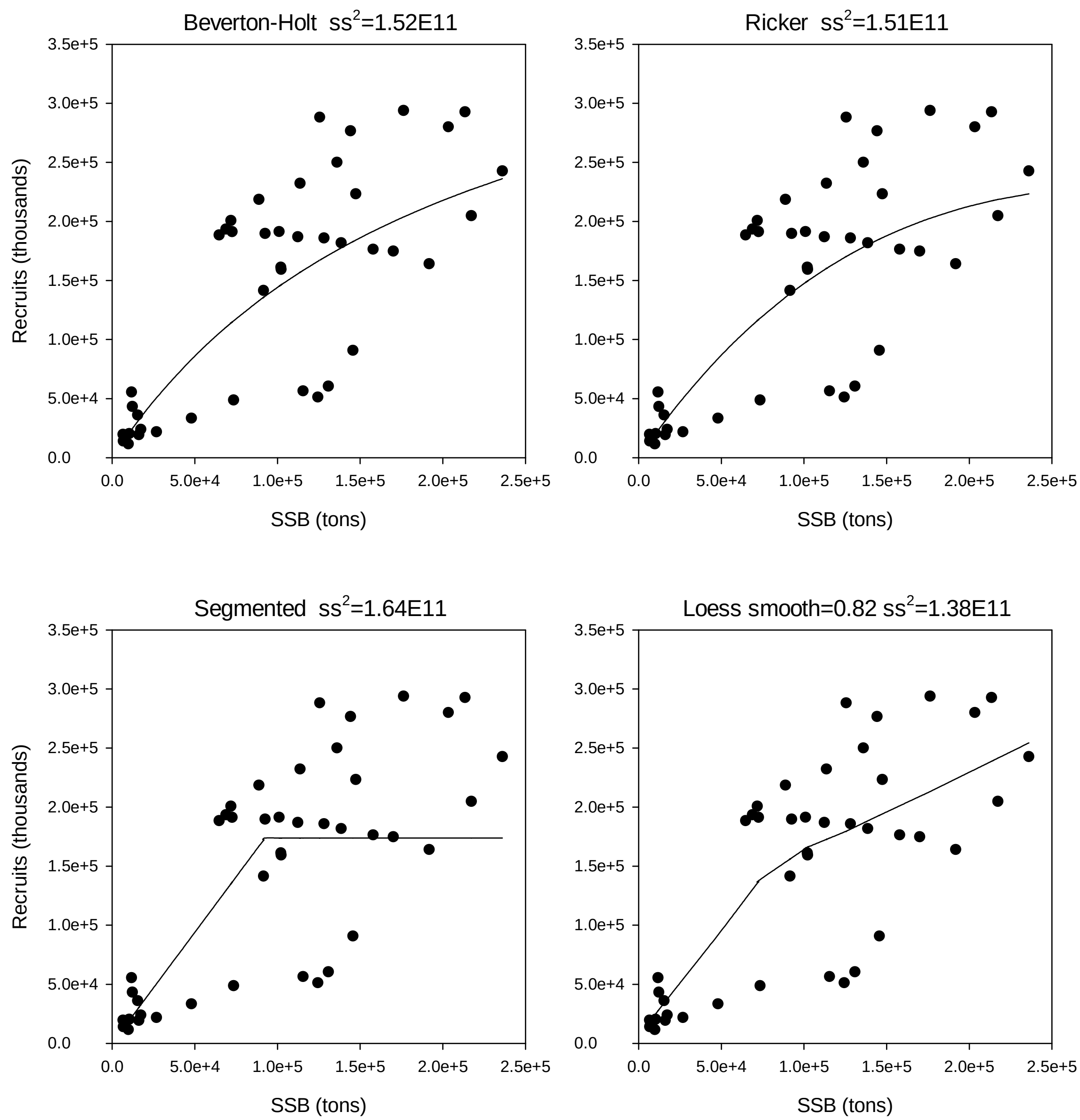

Figure 4. Spawning stock biomass (tons) and recruits (thousands of 5 year olds) with 4 different S/R model fits to the data. The sums of squares of the residuals is given for each model fit.

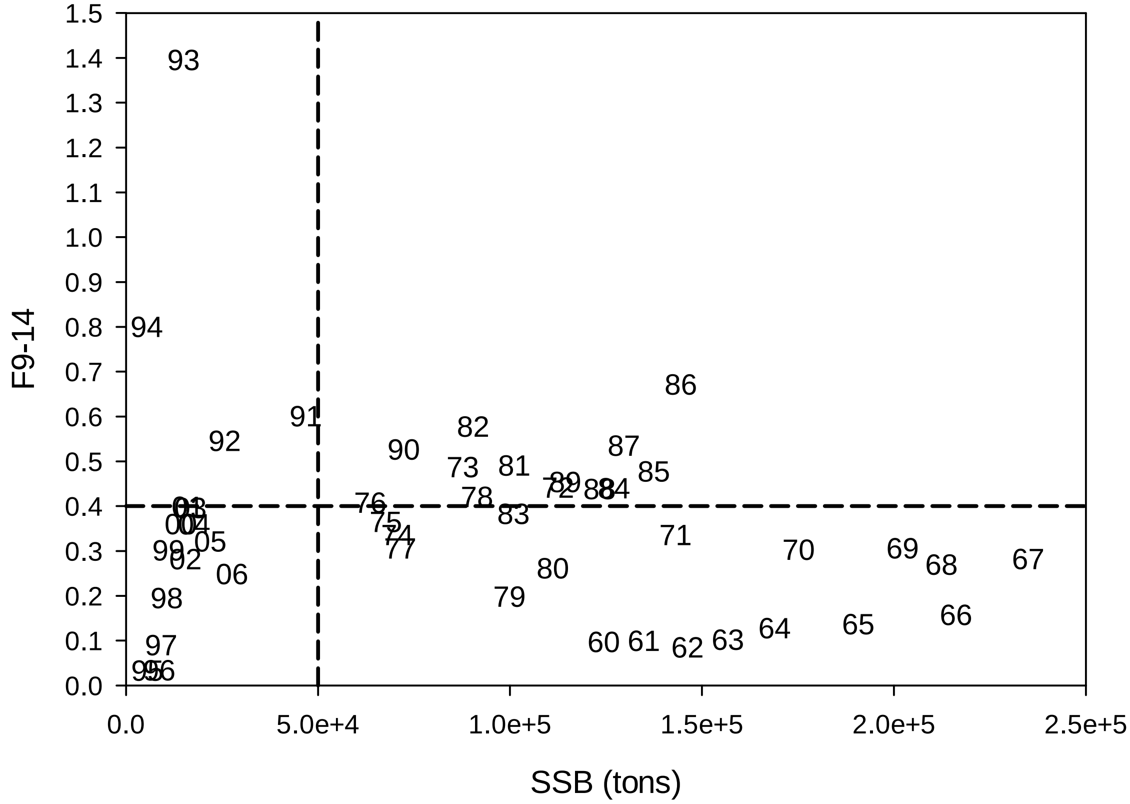

Figure 5. Average F over ages 9-14 plotted against SSB (tons) for Div. 3LNO American plaice. The symbols give the year. The vertical line is B_{lim} and the horizontal line is F_{lim}.