# West Greenland bowhead whale candidate SLA

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ABSTRACT
I develop a data based SLA candidate for the hunt of bowhead whales in West Greenland. The procedure has no internal population model, and was tuned for an average need satisfaction of 0.88 across selected evaluation trials, making sure that the population at the end of the hundred year simulation period is larger than at the beginning of the period for the 5th percentile across all evaluation trials.

## INTRODUCTION

I extend on the work in Witting 2013 to produce a simple data based SLA for bowhead whales in West Greenland. The proposed SLA has no internal population dynamic model, so the calculation is relatively simple and easy to understand. As long as this provides acceptable conservation performance and relatively high need satisfaction there seems to be no real reason to extend to larger and more complicated model based procedures.

The procedure was developed from performance on nearly all the evaluation and robustness trials, with some of the easier trials excluded. These are the five year survey interval trials (GB02), and all 2.5% msyr trials except for the base case.

The procedure had to pass the conservation criterion that the 5th percentile of the D10 statistics of relative increase ($P_T/P_0$) was larger than one on all evaluation trials with 1% msyr, i.e., the population at the end of the hundred year simulation period needed to be larger than at the beginning of the period for the 5th percentile.

## SLA DESCRIPTION

With $\tau$ being the year of a strike limit calculation, the SLA candidate makes an interim-SLA-like calculation based on an estimate of abundance ($N_\tau$) with an associated coefficient of variation ($cv_\tau$).

If there are three, or less than three, abundance estimates from surveys available, the measure of abundance is

$$N_\tau = \frac{\sum_t N_t e^{-0.07(\hat{t}-t)}}{\sum_t e^{-0.07(\hat{t}-t)}} \qquad (1)$$

where $N_t$ is the point estimate of abundance in year $t$ and $\hat{t} \leq \tau$ is the year of the last estimate. If instead there are four or more surveys estimates available, the measure of

| Name | $r$ | $p$ | $\gamma$ | $n_u$ | $n_l$ | $s_u$ |
|---|---|---|---|---|---|---|
| p2r0.5 | 0.005 | 2 | 0.8 | 800 | 400 | 2 |
| p2r0.8 | 0.008 | 2 | 0.8 | 800 | 400 | 2 |
| p2r0.9 | 0.009 | 2 | 0.8 | 800 | 400 | 2 |
| p2r1.0 | 0.010 | 2 | 0.8 | 800 | 400 | 2 |
| p2r1.5 | 0.015 | 2 | 0.8 | 800 | 400 | 2 |

Table 1: Names and parameters of candidate SLAs. $r$:production; $p$:percentile; $\gamma$:snap to need level; $n_u$:upper protection abundance; $n_l$:lower protection abundance; $s_u$:strike limit at $n_u$.

abundance is obtained by fitting a straight line

$$n_t = a + bt \tag{2}$$

to the point estimates of the last four abundance estimates, using the Chi-Squares fitting routine *fitab.h* of Press et al. (2007). The abundance estimate that is provided to the SLA is then

$$N_\tau = a + b\hat{t} \tag{3}$$

This measure of abundance was chosen because the use of the last estimate only, as done in the interim procedure, was considered too sensitive to statistical variation in the estimate, and because alternative measures that provide some average over a larger set of abundance estimates do not take the trend in the estimates into account.

Independently of the number of survey estimates available, the estimate of uncertainty in the abundance estimate is

$$cv_\tau = \frac{\sum_t cv_t e^{-0.07(\hat{t}-t)}}{\sum_t e^{-0.07(\hat{t}-t)}} \tag{4}$$

where $cv_t$ is the coefficient of variation of the survey estimate in year $t$.

The strike limit $S_\tau$ is then calculated as

$$\tilde{S}_\tau = r N_\tau e^{-p\, cv_\tau} \tag{5}$$

$$\dot{S}_\tau = \begin{cases} \tilde{S}_\tau & \text{if} \quad \tilde{S}_\tau < \gamma\ \text{need}_\tau \\ \text{need}_\tau & \text{if} \quad \tilde{S}_\tau \geq \gamma\ \text{need}_\tau \end{cases}$$

$$S_\tau = \begin{cases} \dot{S}_\tau & \text{if} \quad N_\tau > n_u \\ \frac{N_\tau - n_l}{n_u - n_l} s_u & \text{if} \quad n_l < N_\tau \leq n_u \\ 0 & \text{if} \quad N_\tau \leq n_l \end{cases}$$

with the total number of strikes for the six year block period being $\min[\text{round}(6S_\tau), 6\text{need}_\tau]$.

This method is quite similar to that proposed last year, except that it is now formulated as a model with parameters ($r$, $p$, $\gamma$, $n_u$, $n_l$, $s_u$) that have to be specified.

| | p2r0.5 | p2r0.8 | p2r0.9 |
|---|---|---|---|
| 50% | 0.678 | 0.843 | 0.877 |
| 5% | 0.488 | 0.585 | 0.594 |

Table 2: Need satisfaction (N9) of SLA candidates that passed the conservation criterion for the selected evaluation trials. N9 is given as the median (50%), and 5th percentile (5%), of the average between the 20 and 100 year period across the selected trials.

## SELECTION

My starting point was one of my recommended SLAs from last year, with parameters $r = 0.01$, $p = 1.96$, $\gamma = 0.80$, $n_u = 800$, $n_l = 400$, and $n_u = 2$.

I maintained the protection level, increased $\gamma$ from 1.96 to 2, and searched over $r$ in minimum steps of 0.1% for the SLA with the highest need satisfaction that passed the conservation criterion. The tested SLAs are listed in Table 1, with need satisfaction statistics listed in Table 2 for the SLAs that passed the conservation criterion. Figures 1 to 2 show more performance statistics across trials and SLAs, including also the interim procedure (Inte) and strike equals to need (Need). Neither of the latter two procedures passed the conservation criterion.

With an average need satisfaction of 0.88, and 5th percetile saticfaction of 0.59, the p2r0.9 procedure performed best, and is proposed here as a candidate.

REFERENCES

Press, W. H., S. A. Teukolsky, W. T. Vetterling and B. P. Flannery 2007. *Numerical recipes. The art of scientific computing.* 3rd ed. Cambridge University Press, Cambridge.

Witting, L. 2013. Candidate SLAs for the hunt of bowhead whales in West Greenland. *IWC/SC/65a/AWMP05. Available from the International Whaling Commission (http://www.iwcoffice.org/)* .

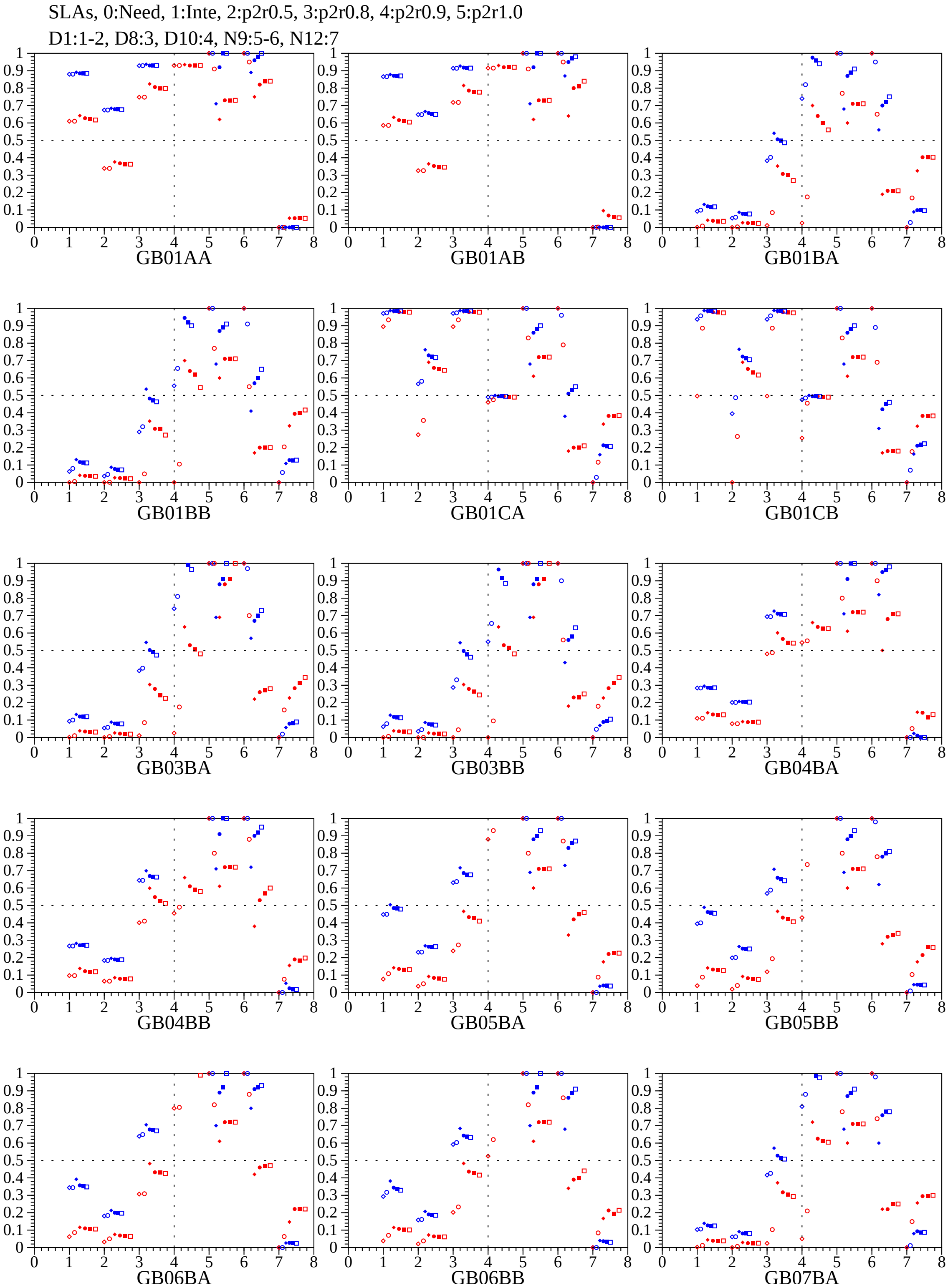


Figure 1: Performance of p2r0.5, p2r0.8, p2r0.9 and p2r1.0 (relative to Need and Inte) over trials GB01AA to GB07BA, with blue showing the median and red the 5th percentile of different statistics ($D10$ is rescaled as $D10/2$, and red gives the 95% percentile for $N12$).

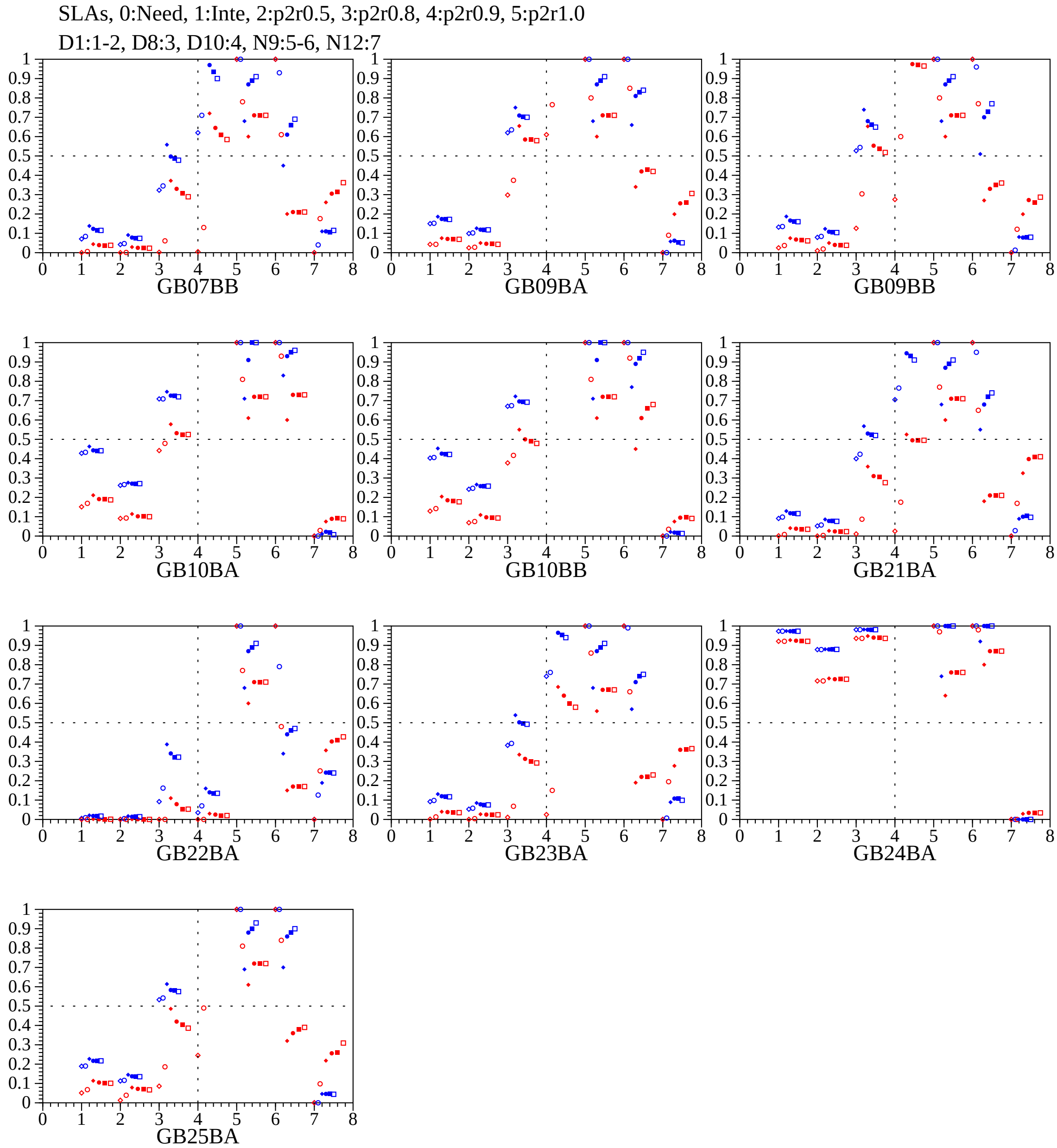


Figure 2: Performance of p2r0.5, p2r0.8, p2r0.9 and p2r1.0 (relative to Need and Inte) over trials GB07BB to GB25BA, with blue showing the median and red the 5th percentile of different statistics ($D10$ is rescaled as $D10/2$, and red gives the 95% percentile for $N12$).