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Further potential SLAs for West Greenland fin whales testing against the agreed evaluation trials

A. Brandao and D.S. Butterworth

INTERNATIONAL WHALING COMMISSION

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A. Brandão and D.S. Butterworth

MARAM (Marine Resources Assessment and Management Group)
Department of Mathematics and Applied Mathematics
University of Cape Town, Rondebosch 7701, South Africa

ABSTRACT

This paper presents improved variants of two SLAs for which results were reported at the 2015 Scientific Committee meeting in San Diego. Candidate *SLA*s are presented ranging from providing complete satisfaction of the conservation performance criterion for all evaluation trials, to alternatives that sacrifice performance on this count to increasing extents for improved need satisfaction. Need is satisfied over the first 20 years, but not over 100 years for the two new *SLA*s in these trials.

INTRODUCTION

This paper provides further results from the application of the software developed by Andre Punt for the West Greenland fin whale trials, as reported in IWC (2015), to two additional potential *SLA*s. For comparison, results from two previous *SLA*s considered in Brandão and Butterworth (2015) are also given here, as well as results for the interim *SLA* (*SLA*1).

The *SLA*s considered here are tuned to all 53 evaluation trials to achieve the conservation performance and need satisfaction criteria.

*SLA*s CONSIDERED

Five *SLA*s are considered in this paper. One of these, the interim *SLA*, formed part of the 'reference *SLA*s' as given in IWC (2012). Results for some *SLA*s described below (*SLA* 2 and 3) are not given here (see Brandão and Butterworth (2015) for these results), but the details of these *SLA*s are given here as the present *SLA*s are variants of previous *SLA*s considered, which need to be included to allow the new *SLA*s to be described. As such the *SLA*s are numbered in sequence from those reported in Brandão and Butterworth (2015).

*SLA*1: Interim *SLA* which sets the *Strike Limit* as the lesser of need and $0.02\hat{N}e^{-1.645CV}$
where $\hat{N}$ is the most recent estimate of abundance and *CV* is the coefficient of variation of $\hat{N}$.

*SLA*2: Weighted-average interim *SLA* which uses all the abundance estimates and replaces $\hat{N}$ and *CV* in *SLA*1 by:

$$\hat{N} = \exp\left[\sum_i \frac{0.9^{t_i} \ln N_i}{CV_i^2} \Big/ \sum_i \frac{0.9^{t_i}}{CV_i^2} \right] \quad (1)$$

$$CV = \sqrt{\sum_i \frac{0.9^{2t_i}}{CV_i^2}} \Big/ \sum_i \frac{0.9^{t_i}}{CV_i^2} \quad (2)$$

where N_i is the *i*th estimate of abundance, CV_i is the coefficient of variation of N_i, and t_i is the time (in years) between when the *i*th estimate of abundance was obtained and the first year of the block for which a *Strike Limit* is needed.

*SLA*3: Variant of *SLA*2 described above. This variant adjusts the 0.02 multiplier applied to $\hat{N}$ as in *SLA*2 by a function of the observed trend of the abundance indices, so that the *Strike Limit* is set as the lesser of need and $\varphi f\left(\beta^*\right)\hat{N}e^{-1.645CV}$, where

$$f\left(\beta^*\right) = \alpha + (1-\alpha)\frac{1}{1+e^{\left(\beta^*-\bar{\beta}\right)/\delta}},$$

where

$\beta^* = \hat{\beta} - \lambda s_{\hat{\beta}}$, where $\hat{\beta}$ is the negative of the slope of the log-linear regression applied to the abundance indices, $s_{\hat{\beta}}$ is the standard error of the slope coefficient and λ is a control parameter, and

$\alpha, \bar{\beta}, \varphi$ and δ are further control parameters.

For this variant the following values are chosen for the control parameters:

$\alpha = 0.1, \bar{\beta} = 0.003, \delta = 0.005/3, \varphi = 0.03$ and $\lambda = 3$. The function $f\left(\beta^*\right)$ is calculated only if there are more than three abundance indices, otherwise it is set to 1.

*SLA*5: Variant of *SLA*3 described above. In this variant the control parameters are set to:

$\alpha = 0.7, \bar{\beta} = 0.005, \delta = 0.008, \varphi = 0.014$ and $\lambda = 3$.

*SLA*6: Variant of *SLA*3 described above. In this variant the control parameters are set to:

$\alpha = 0.7, \bar{\beta} = 0.005, \delta = 0.008, \varphi = 0.007$ and $\lambda = 3$.

*SLA*7: Variant of *SLA*3 described above. In this variant the control parameters are set to:

$\alpha = 0.6, \bar{\beta} = 0.005, \delta = 0.008$ and $\lambda = 3$. For this *SLA*, the control parameter φ has been defined as

$$\varphi = \begin{cases} 0.02 & \text{on or before 2038} \\ 0.016 & \text{after 2038} \end{cases}.$$

*SLA*8: Variant of *SLA*3 described above. In this variant the control parameters are set to:

$\alpha = 0.6, \bar{\beta} = 0.005, \delta = 0.008$ and $\lambda = 3$. For this *SLA*, the control parameter φ has been defined as

$$\varphi = \begin{cases} 0.02 & \text{on or before 2038} \\ 0.007 & \text{after 2038} \end{cases}.$$

RESULTS AND DISCUSSION

Table 1 gives a summary of the results in terms of conservation performance (defined by the D10 statistic: relative increase of 1+ population size: P_T/P_0, where P is the size of the total 1+ population) and need satisfaction criteria (defined by the N9 statistic: Average need satisfaction given by $\frac{1}{T}\sum_{t=0}^{T-1}\frac{C_t}{Q_t}$, where C is catch and Q is the need) in the same manner as reported in IWC (2014) for the evaluation trials for the *SLAs* considered. A further statistic is reported in Table 1 that was not given previously: the proportion of times that each *SLA* achieves need satisfaction (N9 over 20 and 100 years) above 0.75 at the lower 5%-ile for these fin whale evaluation trials. Note that Appendix A gives details of all the trials and need envelopes considered.

Both *SLA*7 and *SLA*8 were selected as alternatives to *SLA*5 and *SLA*6 respectively, to improve need satisfaction without sacrificing conservation performance. *SLA*s 6 and 8 were selected so that the requisite conservation performance would be achieved for all the evaluation trials. However, this is achieved at the expense of meeting need satisfaction, with a worse performance for need satisfaction over a 100 year period. Both *SLA* 7 and 8 meet need satisfaction over a 20 year period. *SLA*s 5 and 7 achieve better need satisfaction with a slight decrease in conservation performance. However, the required conservation performance is achieved for $MSYR_{1+}$=2.5% and 4% evaluation trials.

Figure 1 shows the proportion of times that each *SLA* meets the conservation performance criteria *vs* the mean need satisfaction (over 20 and 100 years) for various *SLA*s for the $MSYR_{1+}$=2.5% evaluation trials, while Figure 2 shows these results for the $MSYR_{1+}$=4% evaluation trials . For all variants, need satisfaction tends to be better for the first 20 years compared to a longer period.

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Table 1. Proportion of times that each *SLA* meets the conservation performance and need satisfaction (over 20 and 100 years) criteria for various subsets of the 53 evaluation trials for West Greenland bowhead whales, and the mean of the lower 5%-ile need satisfaction (over 20 and 100 years).

(a) Results by MSY rate

	Interm Interm	SLA 5	SLA 6	SLA 7	SLA 8
MSYR1+ = 1% (12 trials)					
Conservation performance	0.17	0.75	1.00	0.75	1.00
Mean Need satisfaction 20 yrs	0.85	0.80	0.64	0.83	0.83
Mean Need satisfaction 100 yrs	0.74	0.57	0.36	0.58	0.39
Proportion Need satisfaction 20 yrs	1.00	1.00	0.00	1.00	1.00
Porportion Need satisfaction 100 yrs	0.42	0.08	0.00	0.08	0.00
MSYR1+=2.5% (21 trials)					
Conservation performance	1.00	1.00	1.00	1.00	1.00
Mean Need satisfaction 20 yrs	0.99	0.85	0.66	0.91	0.91
Mean Need satisfaction 100 yrs	0.96	0.84	0.56	0.86	0.60
Proportion Need satisfaction 20 yrs	1.00	0.90	0.00	1.00	1.00
Porportion Need satisfaction 100 yrs	1.00	0.81	0.10	0.86	0.19
MSYR1+=4% (17 trials)					
Conservation performance	0.94	1.00	1.00	1.00	1.00
Mean Need satisfaction 20 yrs	1.00	0.96	0.73	1.00	1.00
Mean Need satisfaction 100 yrs	0.98	0.91	0.61	0.92	0.65
Proportion Need satisfaction 20 yrs	1.00	1.00	0.35	1.00	1.00
Porportion Need satisfaction 100 yrs	1.00	0.94	0.12	1.00	0.18
MSYR1+ = 7% (3 trials)					
Conservation performance	0.00	0.00	1.00	0.00	1.00
Mean Need satisfaction 20 yrs	1.00	0.88	0.68	0.93	0.93
Mean Need satisfaction 100 yrs	0.93	0.75	0.45	0.78	0.49
Proportion Need satisfaction 20 yrs	1.00	1.00	0.00	1.00	1.00
Porportion Need satisfaction 100 yrs	1.00	0.33	0.00	0.67	0.00

(b) Results by need envelope

	Interm	SLA 5	SLA 6	SLA 7	SLA 8
Need Scenario A (21 trials)					
Conservation performance	0.81	0.90	1.00	0.90	1.00
Mean Need satisfaction 20 yrs	0.97	0.91	0.70	0.95	0.95
Mean Need satisfaction 100 yrs	0.98	0.92	0.67	0.93	0.69
Proportion Need satisfaction 20 yrs	1.00	1.00	0.29	1.00	1.00
Porportion Need satisfaction 100 yrs	1.00	0.86	0.19	0.86	0.33
Need Scenario B (21 trials)					
Conservation performance	0.76	0.90	1.00	0.90	1.00
Mean Need satisfaction 20 yrs	0.97	0.88	0.68	0.93	0.93
Mean Need satisfaction 100 yrs	0.92	0.79	0.47	0.81	0.52
Proportion Need satisfaction 20 yrs	1.00	0.95	0.00	1.00	1.00
Porportion Need satisfaction 100 yrs	0.86	0.76	0.00	0.81	0.00
Need Scenario C (11 trials)					
Conservation performance	0.55	0.82	1.00	0.82	1.00
Mean Need satisfaction 20 yrs	0.92	0.82	0.63	0.86	0.86
Mean Need satisfaction 100 yrs	0.78	0.59	0.35	0.62	0.40
Proportion Need satisfaction 20 yrs	1.00	0.91	0.00	1.00	1.00
Porportion Need satisfaction 100 yrs	0.64	0.09	0.00	0.27	0.00

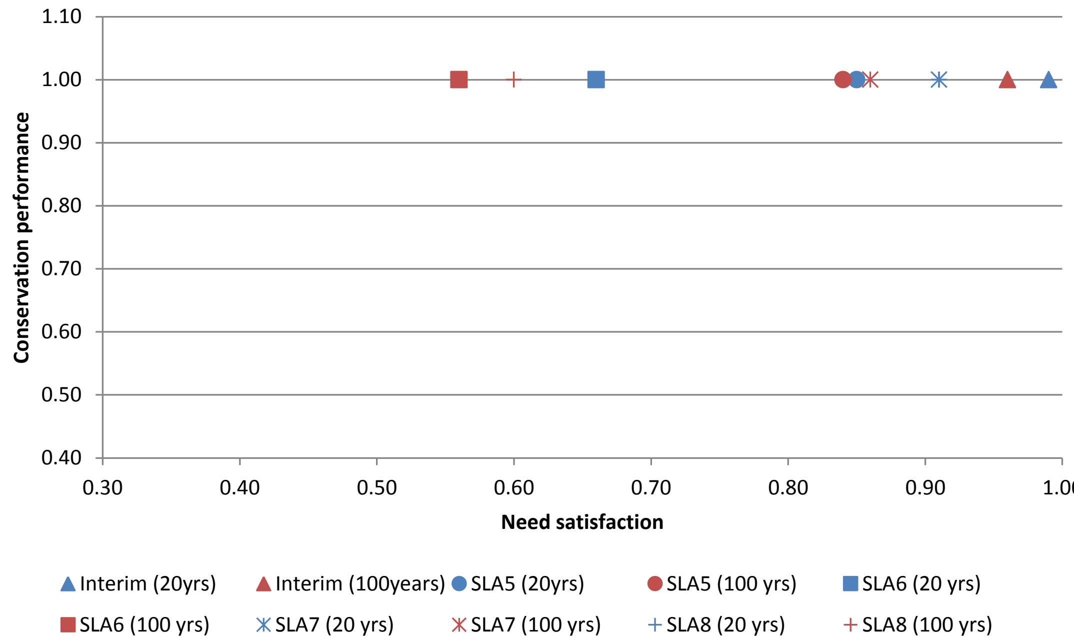

Figure 1. Proportion of times that each *SLA* meets the conservation performance criteria vs mean need satisfaction over 20 (shown in **blue**) and over 100 years (shown in **red**) for various *SLA*s for the $MSYR_{1+}$=2.5% evaluation trials for West Greenland fin whales.

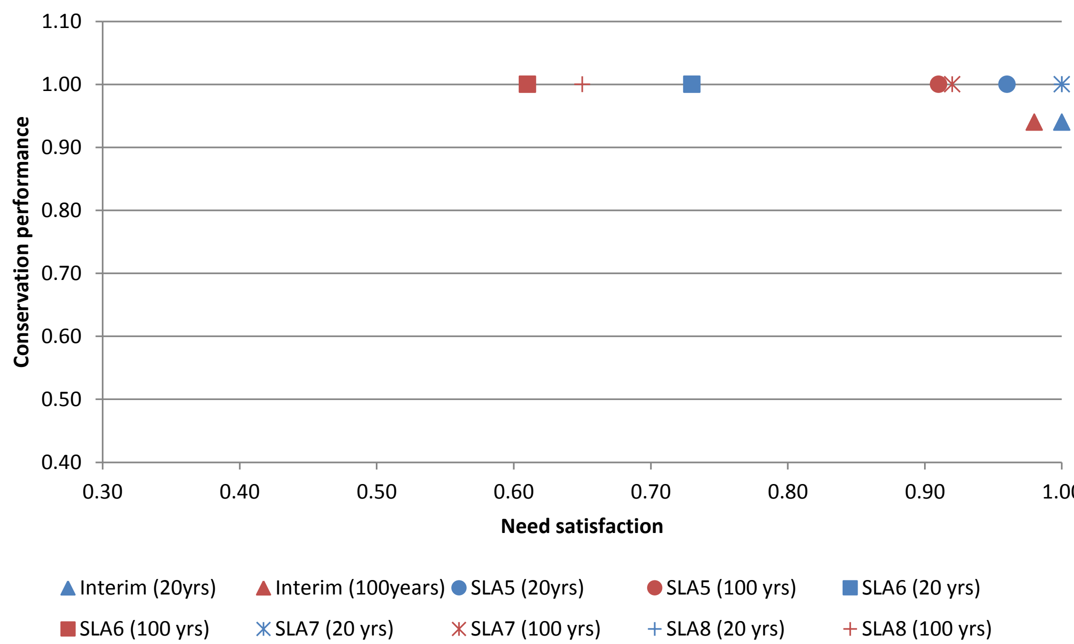

Figure 2. Proportion of times that each *SLA* meets the conservation performance criteria vs mean need satisfaction over 20 (shown in **blue**) and over 100 years (shown in **red**) for various *SLA*s for the $MSYR_{1+}$=4% evaluation trials for West Greenland fin whales.

APPENDIX A

List of evaluation trials (see IWC, 2015a, Table 7)

Trial	Description	Conditioning
GF01AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 12; historic survey bias = 1	Yes [1A]
GF01AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 12; historic survey bias = 1	1A
GF01AC	$MSYR_{1+}$ = 4%; need scenario C; survey frequency = 12; historic survey bias = 1	1A
GF01BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 12; historic survey bias = 1	Yes [1B]
GF01BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 12; historic survey bias = 1	1B
GF01BC	$MSYR_{1+}$ = 2.5%; need scenario C; survey frequency = 12; historic survey bias = 1	1B
GF01CA	$MSYR_{1+}$ = 1%; need scenario A; survey frequency = 12; historic survey bias = 1	Yes [1C]
GF01CB	$MSYR_{1+}$ = 1%; need scenario B; survey frequency = 12; historic survey bias = 1	1C
GF01CC	$MSYR_{1+}$ = 1%; need scenario C; survey frequency = 12; historic survey bias = 1	1C
GF01DA	$MSYR_{1+}$ = 7%; need scenario A; survey frequency = 12; historic survey bias = 1	Yes [1D]
GF01DB	$MSYR_{1+}$ = 7%; need scenario B; survey frequency = 12; historic survey bias = 1	1D
GF01DC	$MSYR_{1+}$ = 7%; need scenario C; survey frequency = 12; historic survey bias = 1	1D
GF02AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 6; historic survey bias = 1	1A
GF02AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 6; historic survey bias = 1	1A
GF02BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 6; historic survey bias = 1	1B
GF02BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 6; historic survey bias = 1	1B
GF02BC	$MSYR_{1+}$ = 2.5%; need scenario C; survey frequency = 6; historic survey bias = 1	1B
GF03AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 18; historic survey bias = 1	1A
GF03AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 18; historic survey bias = 1	1A
GF03BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 18; historic survey bias = 1	1B
GF03BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 18; historic survey bias = 1	1B
GF03BC	$MSYR_{1+}$ = 2.5%; need scenario C; survey frequency = 18; historic survey bias = 1	1B
GF03CA	$MSYR_{1+}$ = 1%; need scenario A; survey frequency = 18; historic survey bias = 1	1C
GF03CB	$MSYR_{1+}$ = 1%; need scenario B; survey frequency = 18; historic survey bias = 1	1C
GF03CC	$MSYR_{1+}$ = 1%; need scenario C; survey frequency = 18; historic survey bias = 1	1C
GF04AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 12; historic survey bias = 0.8	Yes [4A]
GF04AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 12; historic survey bias = 0.8	4A
GF04BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 12; historic survey bias = 0.8	Yes [4B]
GF04BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 12; historic survey bias = 0.8	4B
GF05AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 12; historic survey bias = 1.2	Yes [5A]
GF05AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 12; historic survey bias = 1.2	5A
GF05BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 12; historic survey bias = 1.2	Yes [5B]
GF05BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 12; historic survey bias = 1.2	5B
GF06AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 12; historic survey bias = 1; 3 episodic events	1A
GF06AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 12; historic survey bias = 1; 3 episodic events	1A
GF06BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 12; historic survey bias = 1; 3 episodic events	1B
GF06BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 12; historic survey bias = 1; 3 episodic events	1B
GF06BC	$MSYR_{1+}$ = 2.5%; need scenario C; survey frequency = 12; historic survey bias = 1; 3 episodic events	1B
GF06CA	$MSYR_{1+}$ = 1%; need scenario A; survey frequency = 12; historic survey bias = 1; 3 episodic events	1C

GF06CB	$MSYR_{1+}$ = 1%; need scenario B; survey frequency = 12; historic survey bias = 1; 3 episodic events	1C
GF06CC	$MSYR_{1+}$ = 1%; need scenario C; survey frequency = 12; historic survey bias = 1; 3 episodic events	1C
GF07AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 12; historic survey bias = 1; stochastic events every 5 years	1A
GF07AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 12; historic survey bias = 1; stochastic events every 5 years	1A
GF07BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 12; historic survey bias = 1; stochastic events every 5 years	1B
GF07BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 12; historic survey bias = 1; stochastic events every 5 years	1B
GF08AA	$MSYR_{1+}$ = 4%; need scenario A; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	Yes [1A,8A]
GF08AB	$MSYR_{1+}$ = 4%; need scenario B; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	8A
GF08BA	$MSYR_{1+}$ = 2.5%; need scenario A; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	Yes [1B,8B]
GF08BB	$MSYR_{1+}$ = 2.5%; need scenario B; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	8B
GF08BC	$MSYR_{1+}$ = 2.5%; need scenario C; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	8B
GF08CA	$MSYR_{1+}$ = 1%; need scenario A; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	Yes [1C,8C]
GF08CB	$MSYR_{1+}$ = 1%; need scenario B; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	8C
GF08CC	$MSYR_{1+}$ = 1%; need scenario C; survey frequency = 12; historic survey bias = 1; asymmetric environmental stochasticity (depletion = 0.3)	8C

Description of the different need scenarios (see IWC, 2015b, Table 5) for fin whales off West Greenland.

Need scenario	Description
A	19 -> 19 over 100 years
B	19 -> 38 over 100 years
C	19 -> 57 over 100 years