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A candidate SLA for fin whales in West Greenland

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In this paper I develop a new candidate SLA for West Greenland fin whales. The new fin whale trials have a huge amount of variation in the point estimates of abundance, and the proposed SLA takes an inverse variance weighed average of the last three estimates as an estimate of abundance. The strike limit is calculated as a growth rate fraction of a lower percentile of the abundance measure, conditional on a trend modifier, a snap to need feature, and a protection level.

The proposed SLA is somewhat simpler than the earlier candidate SLAs that I have developed for fin whales in West Greenland. The earlier SLAs fitted a straight line to the abundance estimates in order to provide a measure of abundance and trend. But these estimates were unreliable due to the highly variable abundance estimates of the trials.

The SLA is proposed in three versions, where the D10 statistics for the 5th percentile of the influx trial F34-1 is tuned to 1.0, 0.9 and 0.8 for the medium (B) need envelope.

SLA DESCRIPTION

With τ being the year of a strike limit calculation, the SLA makes an interim-SLA-like calculation based on an estimate of abundance (N_τ) with an associated coefficient of variation (cv_τ). This estimate

$$N_\tau = \exp\left(\frac{\sum_{i=-2}^{0} \ln N_i/cv_i^2}{\sum_{i=-2}^{0} 1/cv_i^2}\right) \tag{1}$$

and its uncertainty

$$cv_\tau = \left(\frac{1}{\sum_{i=-2}^{0} 1/cv_i^2}\right)^{1/2} \tag{2}$$

is an inverse variance weighted average of the last three abundance estimates (ignoring zero estimates), with $i = 0$ denoting the most recent positive estimate, and cv being the error coefficient of variation.

Trend modifier

Let r be an assumed standard production for the population, and Δr a change in production as a function of a possible trend. Let r_Δ be the allowed maximum to the absolute change, with $-r_\Delta \leq \Delta r \leq r_\Delta$.

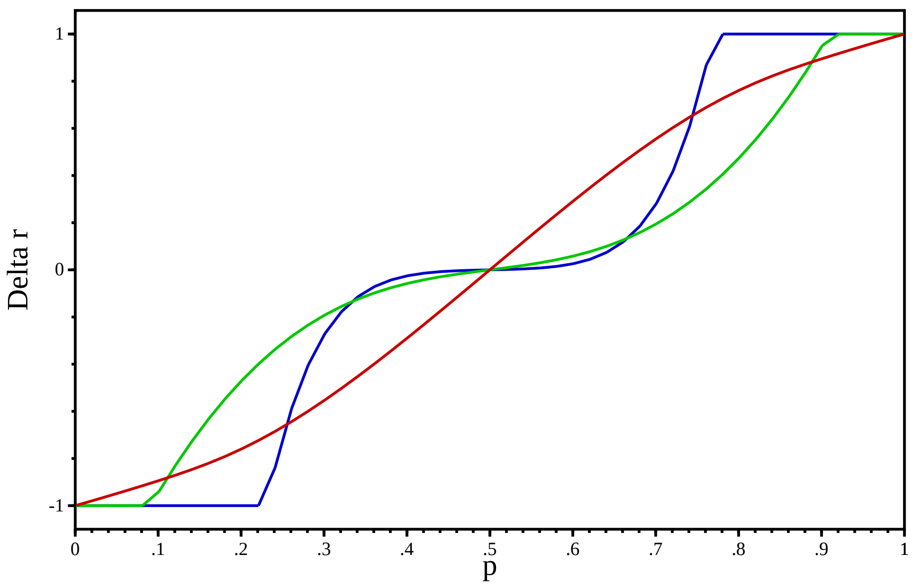

Figure 1: **Trend modifier.** The change in production (Δr, with $r_\Delta = 1$) as a function of the probability p of an increase in population, for three parametrisations: Red:$\gamma = 1$, $\epsilon = 1$, Green:$\gamma = 1.1$, $\epsilon = 5$, Blue:$\gamma = 1.3$, $\epsilon = 10$

Now let N_0 and cv_0 be the inverse variance weighted estimate of the four abundance estimates from 1987 to 2015, and let t_0 and t_τ be the average years of the estimates in N_0 and N_τ. The Δr-function is then based on an estimate of trend, where

$$r_{max} = \frac{2}{t_\tau - t_0} \frac{e^{\ln N_\tau + z\, cv_\tau} - e^{\ln N_0 - z\, cv_0}}{e^{\ln N_\tau + z\, cv_\tau} + e^{\ln N_0 - z\, cv_0}} \tag{3}$$

and

$$r_{min} = \frac{2}{t_\tau - t_0} \frac{e^{\ln N_\tau - z\, cv_\tau} - e^{\ln N_0 + z\, cv_0}}{e^{\ln N_\tau - z\, cv_\tau} + e^{\ln N_0 + z\, cv_0}} \tag{4}$$

with z being a parameter that defines the percentiles of the abundance measures N_0 and N_τ that go into the estimates of r_{min} and r_{max}.

A probability-like measure of an increasing population is then given as

$$p = \frac{\max(r_{max}, 0)}{\max(r_{max}, 0) - \min(r_{min}, 0)} \tag{5}$$

Relative measures of increase ($m_\uparrow$), and decrease ($m_\downarrow$), that takes values of one when an increase or decrease is certain, and values of zero when an increase or decrease is highly uncertain, are then obtained as

$$\begin{aligned} m_\uparrow &= e^{-\gamma \max\left(\frac{1}{p} - \epsilon, 0\right)} \\ m_\downarrow &= e^{-\gamma \max\left(\frac{1}{1-p} - \epsilon, 0\right)} \end{aligned} \tag{6}$$

with the estimated change in the production rate given as

$$\Delta r = r_\Delta (m_\uparrow - m_\downarrow) \tag{7}$$

where γ and ϵ are the shape parameters (Fig. 1) that determine Δr as a function of the probability of a positive trend (p).

SLA

The strike limit S_τ is calculated as

$$\tilde{S}_\tau = (r + \Delta r) N_\tau e^{-q\, cv_\tau} \tag{8}$$

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

$$S_\tau = \begin{cases} \dot{S}_\tau & \text{if} \quad N_\tau > 2n \\ \frac{N_\tau - n}{n} \dot{S}_\tau & \text{if} \quad n < N_\tau \leq 2n \\ 0 & \text{if} \quad N_\tau \leq n \end{cases}$$

with the total number of strikes for a six year block period being $6S_\tau$.

SLA parameters

The parameters of the three variant are

SLA	d10	r	r_Δ	q	s	n	z	γ	ϵ
lF08	0.8	0.012	0.006	1.7	0.8	500	2.9	1.1	5
lF09	0.9	0.012	0.006	3.3	0.8	500	2.9	1.1	5
lF10	1.0	0.012	0.006	6.1	0.8	500	2.9	1.1	5

(9)

with d10 being the value of the 5th percentile of performance statistics D10 for the influx trial with a msyr of 1% and need envelope B (trial GF34-1B).

RESULTS AND DISCUSSION

Figs. 2 to 6 show SLA performance in relation to zero strikes, strikes equals need, and Interim (inte). The tuning of Interim matches lF0.8, with the 5th percentile of D10 for GF34-1B being 0.8.

For conservation (D10) there is really not much of a difference, not even between zero strikes and strikes equals need. It is only for the influx model (trials GF34-36) that we see real differences, especially on GF34-1B and C. D10 is here about equal for Interim and lF0.8, and slightly better for lF0.9 and lF1.0 as expected by their tunings. D10 median is larger than one for all runs, expect for strike equals need on GF34-1C.

As expected, need satisfaction (N9) is smalles for lF1.0 and then lF0.9, with a median need satisfaction across all trials (20 and 100 years periods combined) of 0.77 and 0.97, and lower 5th percentiles of 0.49 and 0.70. Need satisfaction for Interim and lF0.8 are somewhat higher, with median values of 0.988 and 0.995, and lower 5th percentiles of 0.84 and 0.82.

These statistics indicate that there may not be much of a difference in the performance of Interim and lF0.8. Yet, the largest difference lies in the stability of the strike limit. With the strike limit of Interim being calculated only from the last abundance estimate, the strike limit of Interim is more fluctuating that the strike limit of lF0.8, as evident from N12 in Figs. 2 to 6. If we take, e.g., trials GF01-1B and GF34-1B the median value for N12 is 205% and 180% larger for Interim than for lF0.8.

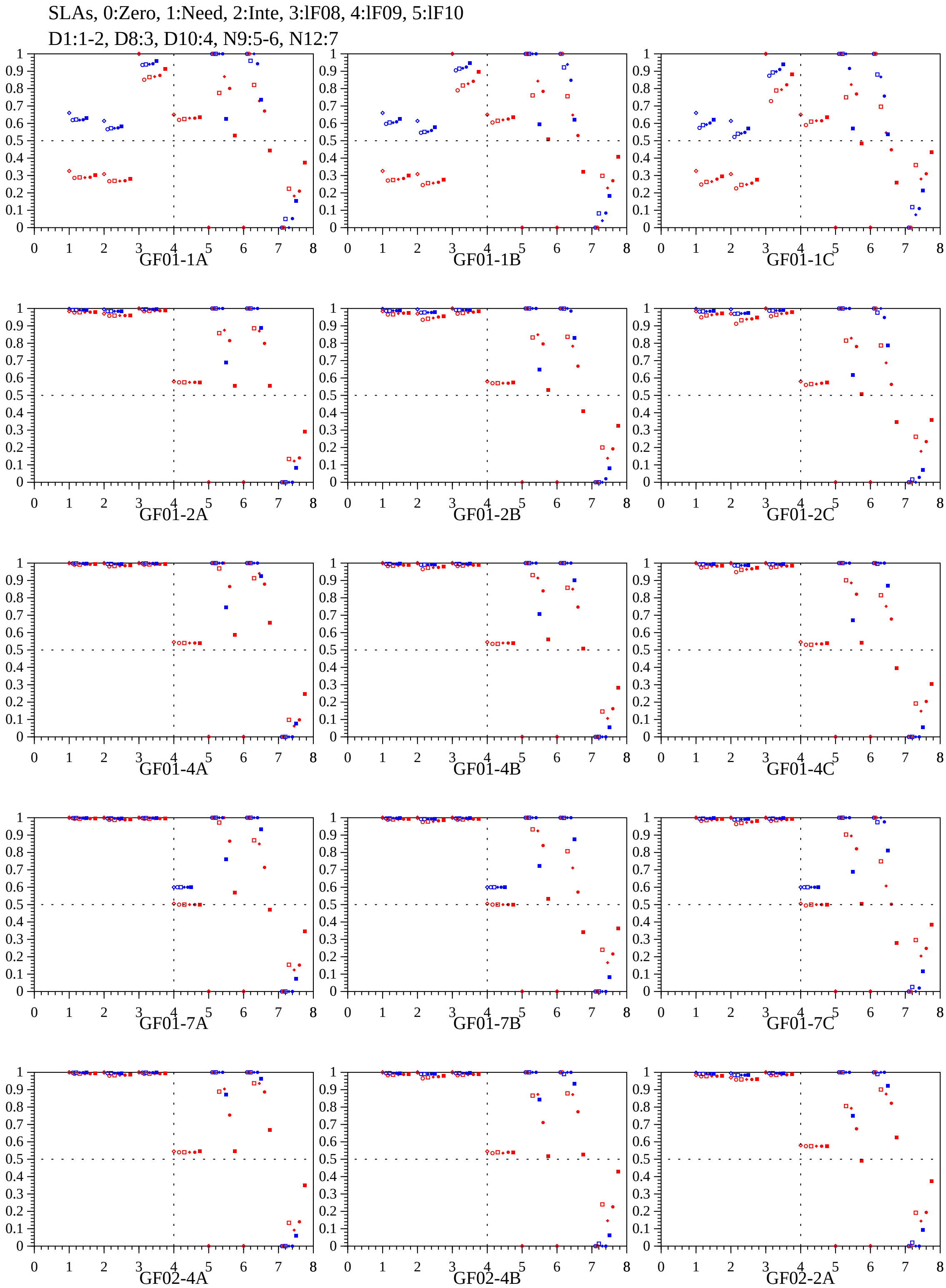

Figure 2: Performance of SLAs, with blue showing the median and red the 5th percentile of different statistics ($D10$ is rescaled as $D10/2$, and $N12$ as $2N12$ with red giving the 95% percentile for $N12$).

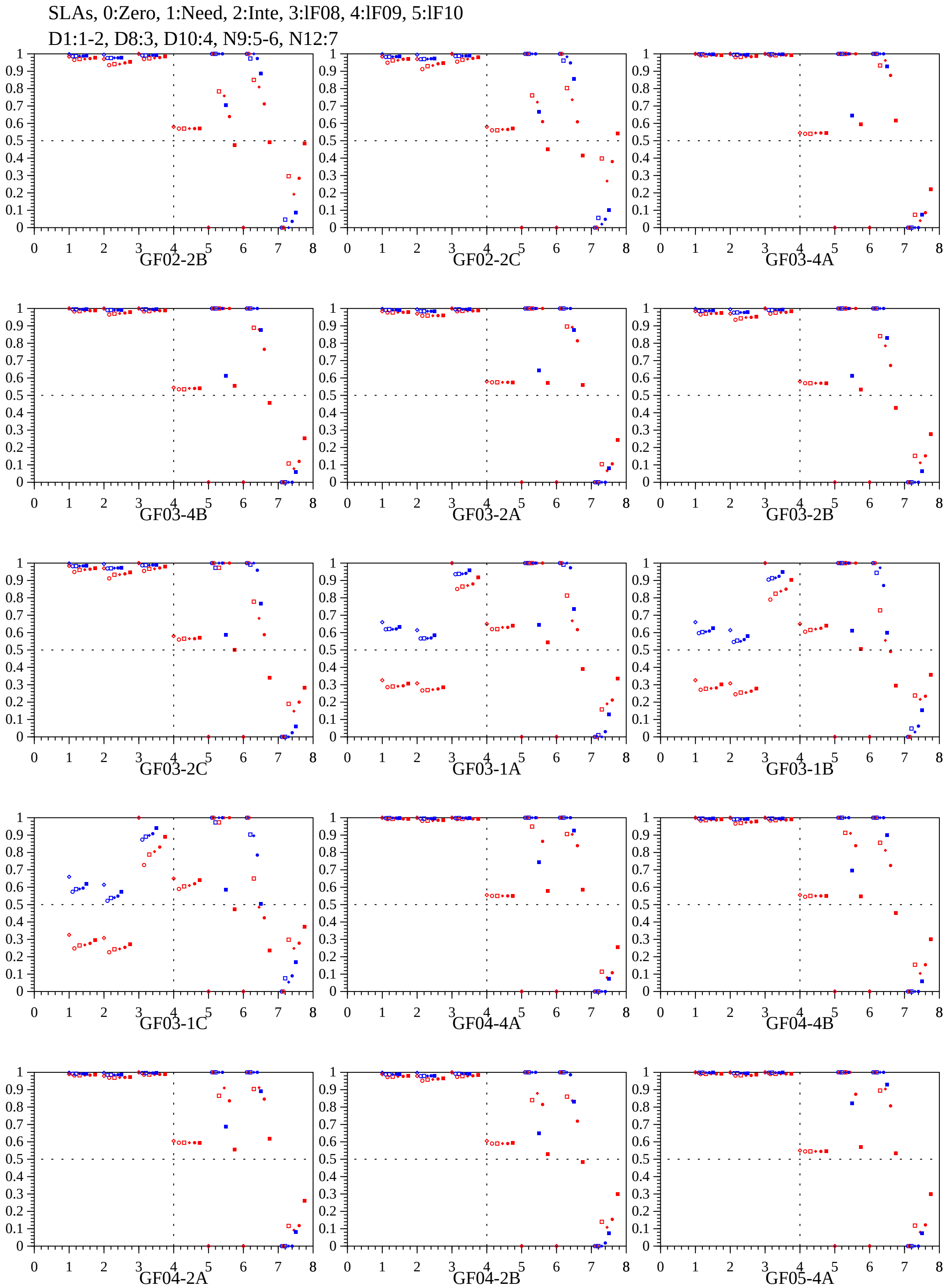

Figure 3: Performance of SLAs, with blue showing the median and red the 5th percentile of different statistics ($D10$ is rescaled as $D10/2$, and $N12$ as $2N12$ with red giving the 95% percentile for $N12$).

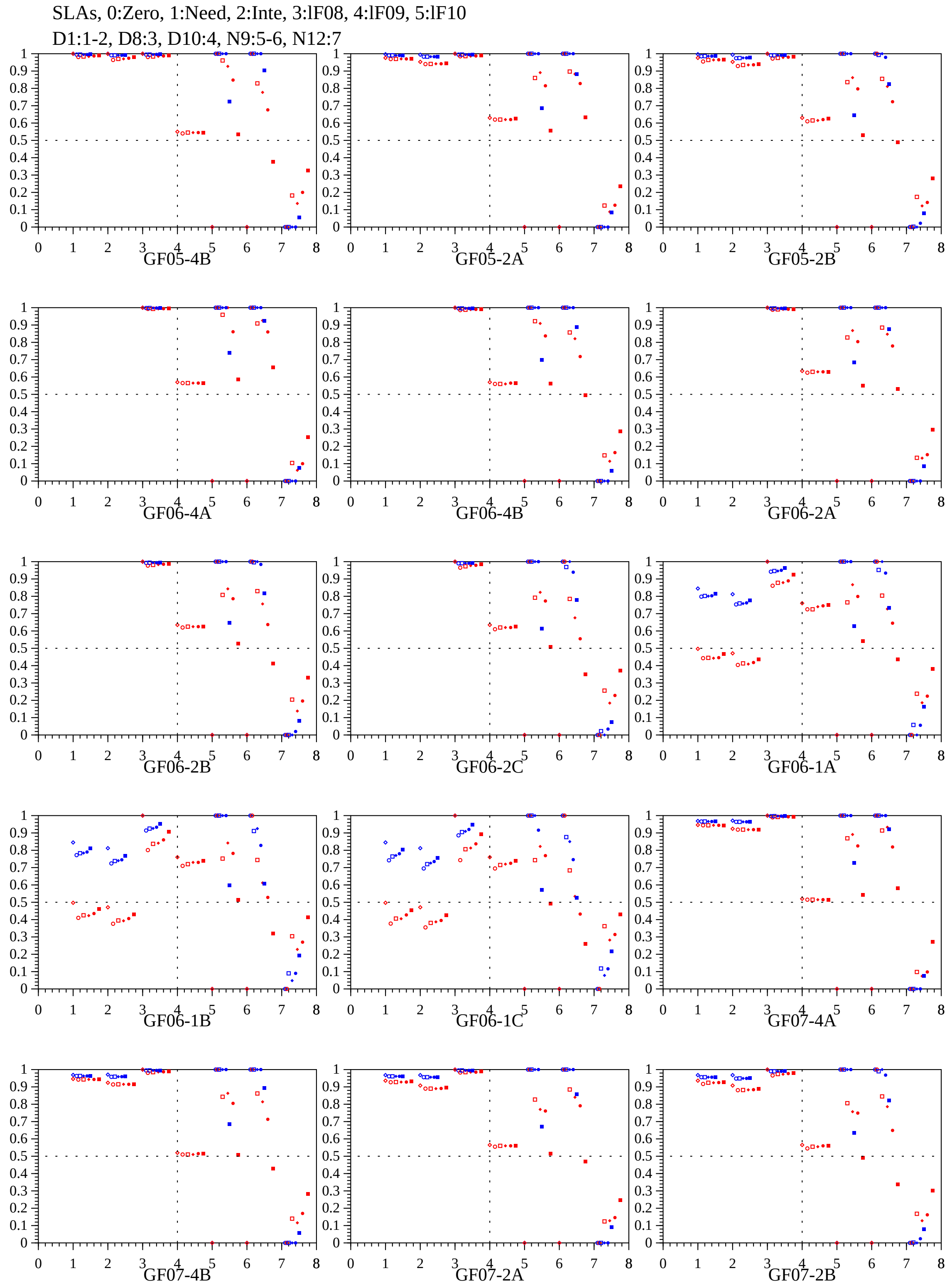

Figure 4: Performance of SLAs, with blue showing the median and red the 5th percentile of different statistics ($D10$ is rescaled as $D10/2$, and $N12$ as $2N12$ with red giving the 95% percentile for $N12$).

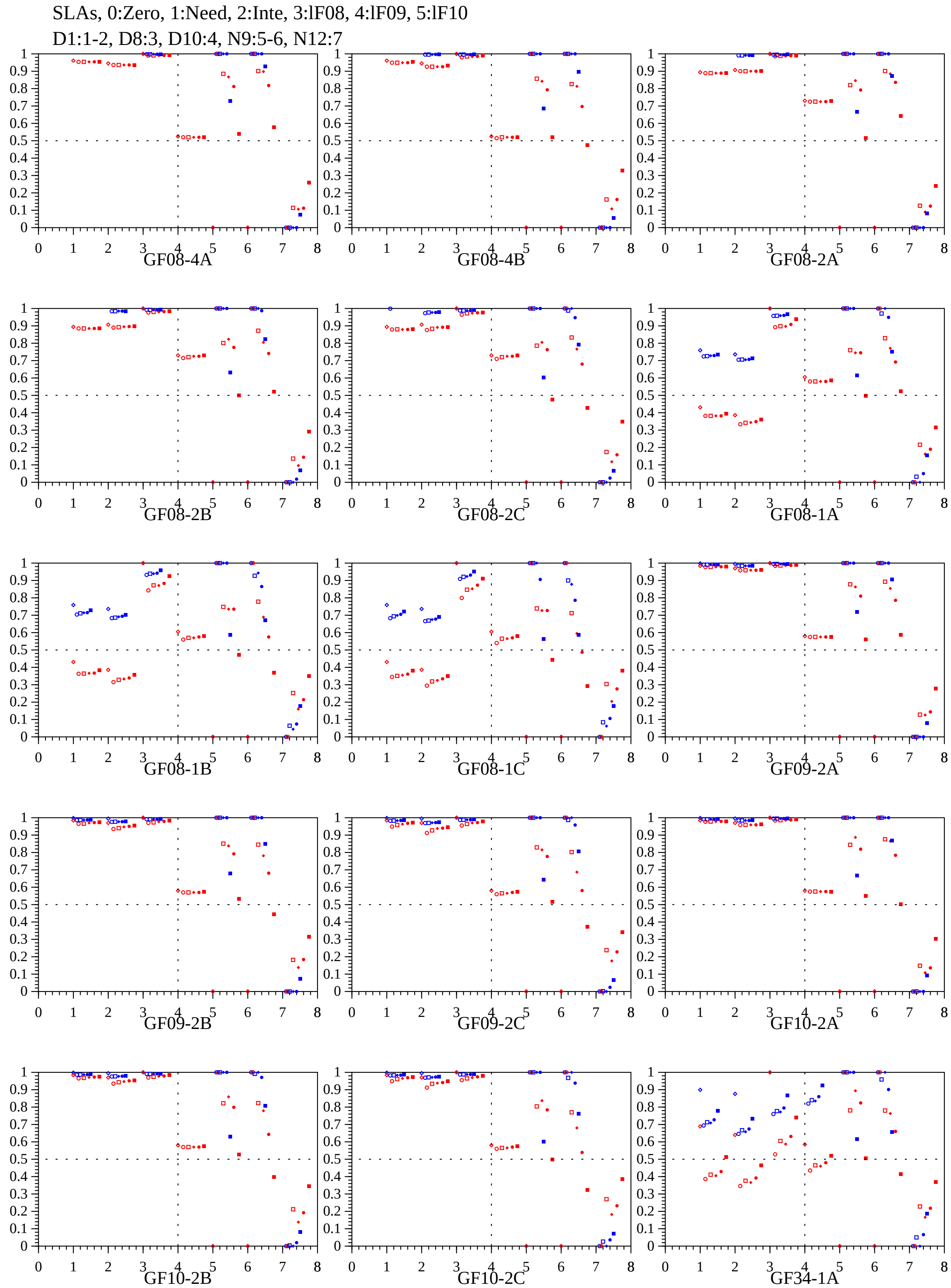

Figure 5: Performance of SLAs, with blue showing the median and red the 5th percentile of different statistics ($D10$ is rescaled as $D10/2$, and $N12$ as $2N12$ with red giving the 95% percentile for $N12$).

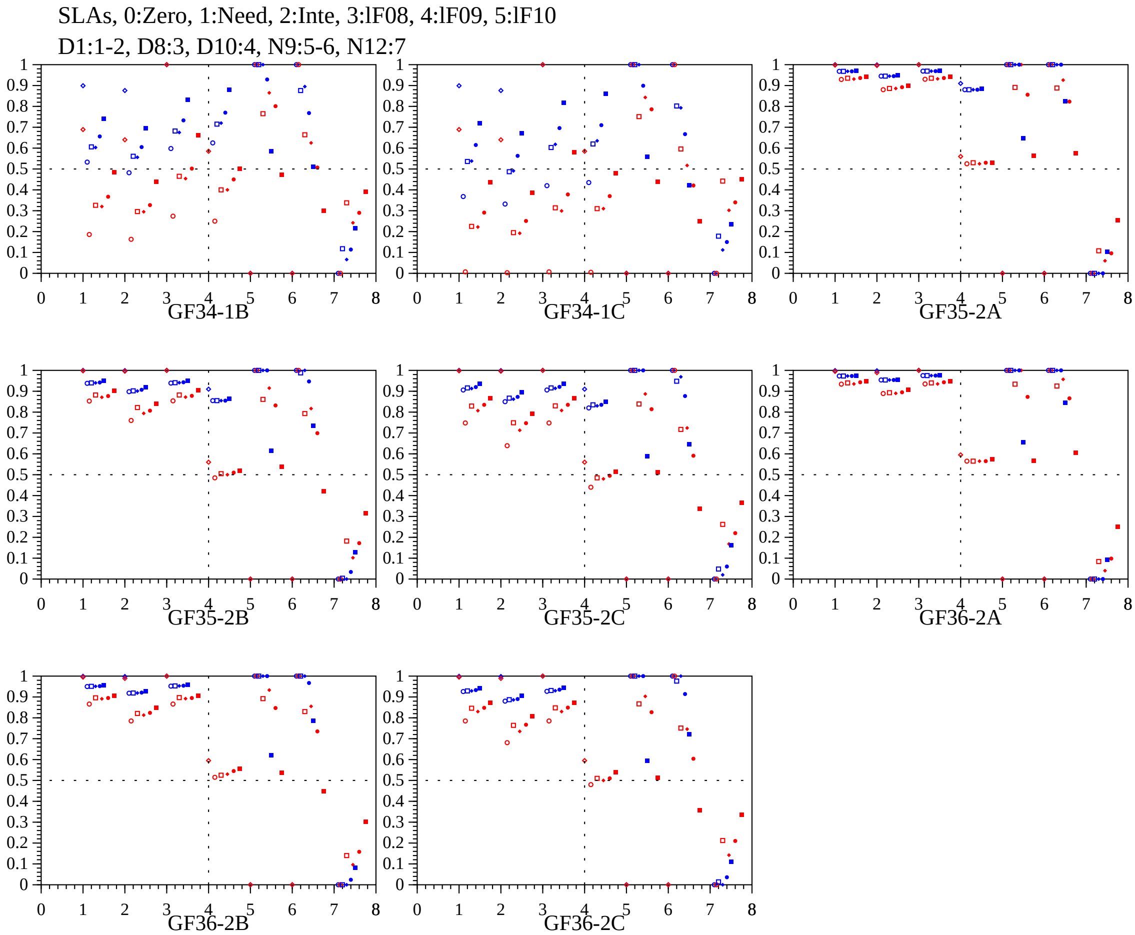

Figure 6: Performance of SLAs, with blue showing the median and red the 5th percentile of different statistics ($D10$ is rescaled as $D10/2$, and $N12$ as $2N12$ with red giving the 95% percentile for $N12$).