AN EVALUATION OF DATA POOR APPROACHES FOR THE EVALUATION OF STOCK STATUS IN LARGE ECOSYSTEMS USING ONLY LANDINGS DATA.

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SUMMARY

Ecosystem Based Fisheries Management is challenged by fishing impacts not just on the target stocks but also on by caught, threatened and endangered species, and the associated ecological communities. For example in the case of ICCAT although more than a hundred species are recorded in the statistical database only 15 tuna and billfish stocks are formally assessed. We therefore evaluated a spectrum of data poor methods using SRA+. At the data limited end SRA+ approximates the behaviour of catch-msy, sampling from prior distributions given a catch history do not crash the population and satisfy priors for initial and final depletion. At the data rich end SRA+ is fitted to abundance indices with priors for population growth rate (r) and current and initial depletion. We used the RAM Legacy database,to simulate data poor datasets by removing information. This allowed the Value of theInfomation in the dataset and priors to be evaluated. For example are results determinded by the data or expert knowledege? We showed that catch only methods performed poorly and were highly dependent on expert knowledge rather than the data.

KEYWORDS

Biomass Dynamic; Catch Only; Data Limited; Ecosystem Based Fisheries Management; Stock Assessment.

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Introduction

Regional Fisheries Management Organisations have the responsibility to manage not just the main commercial stocks but also by caught species that may be endangered, threatened and protected. (ETP) Although ICCAT has over 100 species in its statistical database only 15 tuna and billfish stocks have been formally assessed. This is due either to lack of data, capacity or management recommendations. The lack of formal assessments may hamper progress towards Ecosystem Based Fisheries Management (Levi, et al., 2012) which requies as a first step the assessment of the impacts on non-target species, trophic structure and habitat (Hilborn, 2011).

Many fisheries support the livelihoods of people with few other sources of protein (Hall, Hilborn, Andrew, & Allison, 2013), and income from fisheries can be a major contributor to social well-being in coastal and inland communities (FAO, 2016). Thirty one per cent of marine fish stocks globally are over-exploited, however, meaning that their productivity is lower than what could be supported if fishing pressure was reduced (FAO, 2016). In some parts of the world, management regulations have successfully reduced the capacity of fishing fleets and reduced fishing pressure to levels that should enable stock recovery to levels that could support maximum sustainable yield (Bell, Watson, & Ye, 2017; Rosenberg et al., 2017; Worm et al., 2009).

In the case of small scale and artisanal fisheries a growing body of research suggests that despite the lack of traditional top-down management by central governments, many of these fisheries have managed to avoid the "tragedy of the commons" where common-pool resources are inevitably degraded (Feeny et al. 1996; Ostrom et al. 1999). At the same time, recent work on community co-management, a widespread approach to management of small-scale fisheries, has elucidated the characteristics of such systems that lead them to be effective (Gutierrez et al. 2011).

There is currently a lively scientific debate about the global status of marine fisheries. The most recent evaluations suggest that, at a global level, populations of exploited marine fish and invertebrate have declined 38% between 1970 and 2007, but have, on average, been stable since the early 1990s (Hutchings et al. 2010). However, the information base to make these judgements are limited at best and the methodology used are mainly qualitative using expert judgement in evaluating global performance.

The purpose of this paper therefore is to evaluate the impact of commonly made assumptions when attempting to measure trends in overfishing globally or regionally in order to evaluate the value-of-information (VoI) using data poor assessment approaches. To evaluate the robustness of the different approaches for determining stock status, we used the RAM legacy database. a compilation of stock assessment results for commercially exploited marine populations from around the world (https://www.ramlegacy.org). The stocks assessment results in the database have been used extensively in management and many global studies (e.g. Hilborn at al., 2020, Rosseau, et al., 2019) have made extensive use of the database. We use this well studied dataset as a benchmark to evaluate the performnace of techniques currently used to assess data poor fish stocks globally that vary in their data and knowledge requirements.

The use of historical data for simulation testing also provides an objective way of evaluating assessment methdos and provides a scoping exercise by helping to identify scenarios to be used in future simulations and Management Strategy Evalaution.

Material and Methods

We use the RAM legacy database to simulate data poor datasets then used SRA+ to estiamte stock status and referenec points, which can then be compare to the original data rich estimates. This allowed the Value-of-Infomation (VoI) to be evaluated, i.e. which is more important for determining bias and precision, the data or expert knowledge?

SRA+[3] is a R package that can be applied across the "data limited" stock assessment spectrum (Ovando et al., 2019). At the most data limited end the model approximates the behavior of catch-msy, sampling from prior distributions to obtain parameter values that given a catch history do not crash the population and satisfy supplied priors on initial and final depletion. At the data rich end the model can be fitted to an index of relative abundance or catch-per-unit-effort data with priors for population growth rate (r) and current and initial depletion. SRA+ is also able to incorporate priors on recent stock status based on Fisheries Management Index (FMI) scores and swept-area ratio data.

There were 473 stock assessments with catch trends and estimates og biomass/SSB relative to reference points in the RAM legacy database. These stocks were used to assess how well does a biomass dynamic stock assessment perform in estimating historical and recent trends in biomass and current stock status relative to reference points when

- both catch and an index of abundance are provided?
- heuristic estimates of stock depletion are used with only catch data?

Methods

To compare the performance of the approaches we fitted the methods to each stock dataset models; for three scenarios

> **BD**: both catch and an index of relative abundance were used, where it wasassumed that the biomass trend from the Myers database was a "perfect" index of relative abundance;
>
> **BD4:** both catch and and index of relative abundance were used, where we assumed the biomass trend from the Myers database was an index of relative abundance to which we added log normal measurement error with a CV of 40%,
>
> **SRA:** only catch used along with heuristics to set initial and final depletion.

The heuristics used to set depletion are that if catch in the first year is less than 20% of maximum catch, initial depletion is assumed to be between 50% and 90% of carrying capacity, otherwise it is assumed to be between 20% and 60% For final depletion, the heuristic assumes that if final catch is greater than 50% of max catch, final depletion is between 30%-70%, 1%-50% otherwise.

We then compared trends in the estimates of stock biomass and final stock biomass relative to the level that would support the maximum sustainable yield (B_{MSY})

Results

The results are first summarised by exploring the correlations between RAM legacy estimates of biomass and those estimated under the SRA scenarios, scaled by their means to show how well trend are estimated. The correlations between full historical time series of biomass estimates for each stock

[3] https://github.com/DanOvando/sraplus

are shown in Figure 1, the correlations between the trends in the last 10 years in Figure 2, and between the trends in last 5 years in Figure 3.

Quantities of potential use in management, i.e. the ICES 2 over 3 rule,(mean of last 2 years divided by mean in years -5 to -3) is shown in Figure 4, and a comparison of the depeletion estimates in the final year in Figure 5.

The ability of the models to capture the trends in biomass when an informative index is available is good; even large with measurement error. The catch based heuristic approach, however performs poorly particularly for the recent period (10 and 5 years) as shown in Figures 1, 2 and 3.

The 2 over 3 rule of ICES performs well for the estimates of biomass when an index of abundance is available, but poorly for the catch only method (Figure 4).

With respect to categorizing stock status relative to B_{MSY} in the final year (Figure 5), the correlations are reasonable for the methods using the index of abundance but poor for the catch only method. Table 1 summarises the ability to classify the stock as being overfished, which is poor for the catch only method.

Temporal trends in classification and the bias associated with these with the actual criteria based on FAO classification is compared (Figures 6 and 7). Essentially if we have an informative source of data that can be used to assess stock status, we should have the ability to determine the actual status of the stock. Indices of abundance or effort would be a good basis to do so.

Discussion

In general the ability of the models to capture trends is reasonable when an index of abundance is available although poor when only catch data are used. In some cases the model failed to converge and these results were omitted from the analysis and so the performance of the methods is likely to be poorer than in the summary above.

Conclusions

The following conclusions can be drawn from the analysis

- In SRA+ alternative methods are available to infer stock status based on fishery management indices (FMI) or swept area ratios (SAR). The use of informative priors on FMI and SAR are useful only if they cover the stocks examined.
- Expert judgement about current status, i.e. the last point, is informative, if such knowledge actually exists and can be objectively chosen. The catch heuristic is such an objective method that can be tested, however it did not perform well.
- If external estimates of depletion are being used, even with uncertainty, based on a covariate to fix depletion, why not use this to anchor the catch time series?
- Use of catch only methods are not recommended unless external sources of data are available to inform parameters; the following methods, ranging from bad to worse are potentia ways to do this:
    - Use an index of abundance from a survey if available
    - Use a nominal cpue based on regional derived effort data
    - Use length composition data to estimate a F ratio from LBSPR to anchor multiple points.
    - Use expert opinion on harvest rates at different points of the time series, and/or final

depletion with uncertainty.
    - Possibly use an ecosystem index (Ye and Corocci 2018) for an index by region. This could provide some context to the fitting when data is not available.
- Recent trends or the two over three rule could be used as part of a Harvest Control Rule, if they were first simulation tested using Management Strategy Evaluation. Alternatively an index of abundance in an emprical control should also be evaluated.

Next Steps

Although using the RAM Legacy database was an informative exercise, the details of the stock assessments, i.e. how well they fitted the data, the model structure and what parameters were fixed, are difficult determine. Therefore further studies should be developed where assess stock status is evaluated for a set of stock assessments that the analysts are familiar with (i.e. ICCAT datasets). This approach allows the ability of the data limited methods to capture trends as well as assess catch only methods and the benefits of alternative datasets, priors and heuristics. For example using priors based on the production function and the impact of process error.. Therefore examining data limited methods using alternative formation of reality based on either a surplus production based or integrated assessments should be performed and what knowledge is required to correctly identify trend and status.

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Tables

Table 1: Contingency tables for classification of stock as being overfished (i.e. $B/B_{MSY}<1$)

BD

	FALSE	TRUE
FALSE	221	82
TRUE	15	72

BD4

	FALSE	TRUE
FALSE	211	97
TRUE	12	63

SRA

	FALSE	TRUE
FALSE	109	51
TRUE	157	116

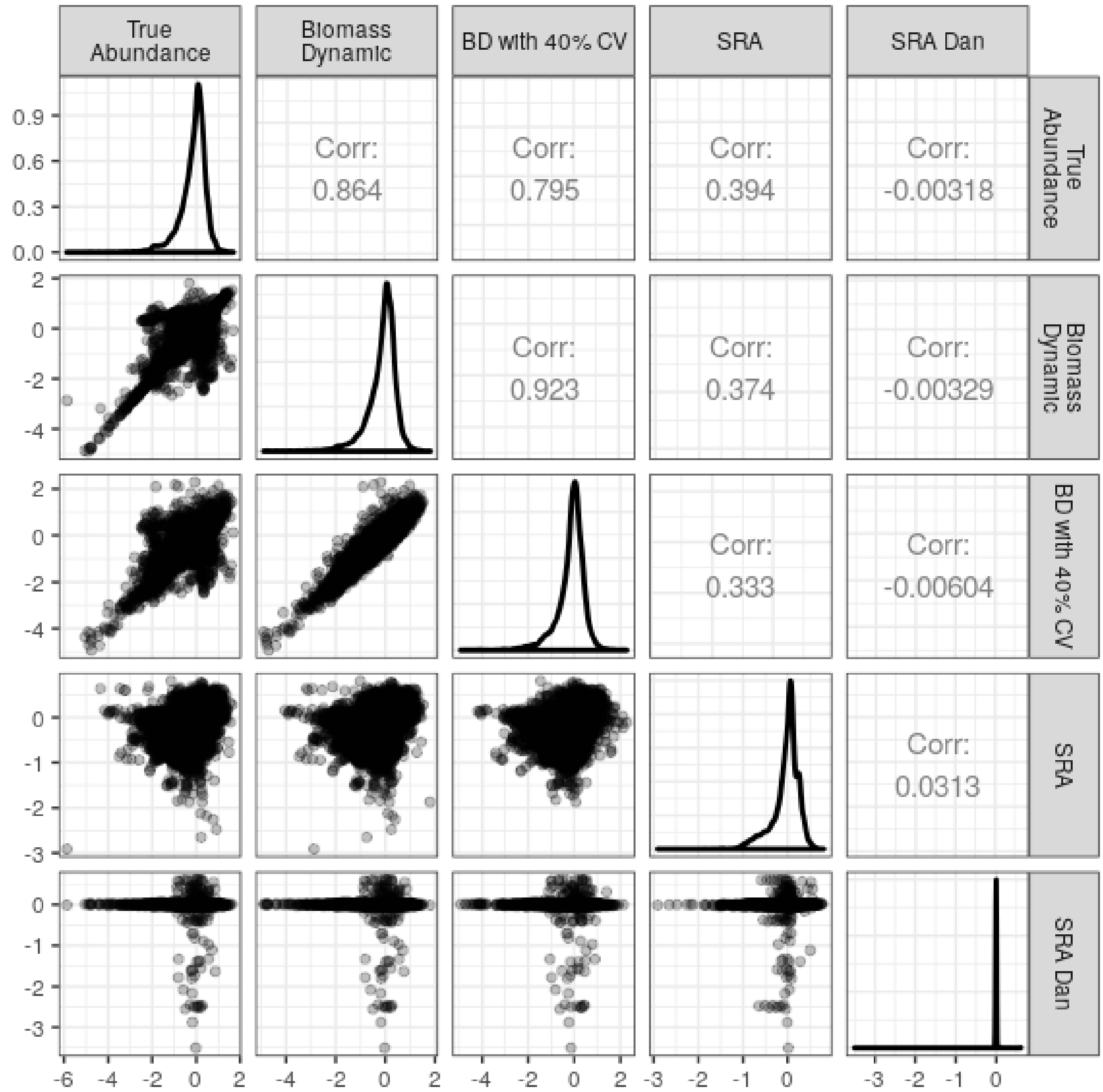

Figure 1 Correlations between trends over entire series.

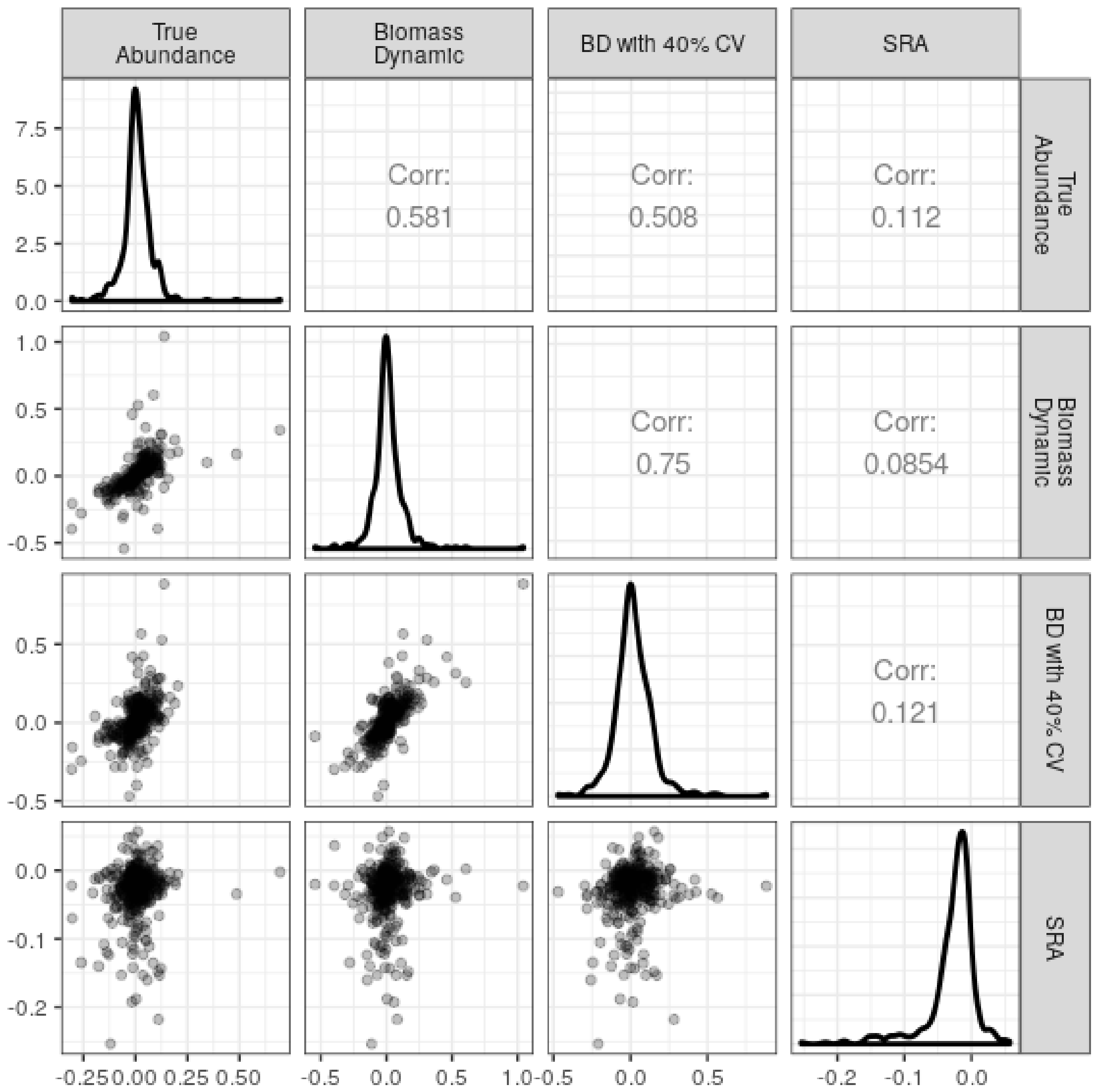

Figure 2 Correlations between trends in last 10 years.

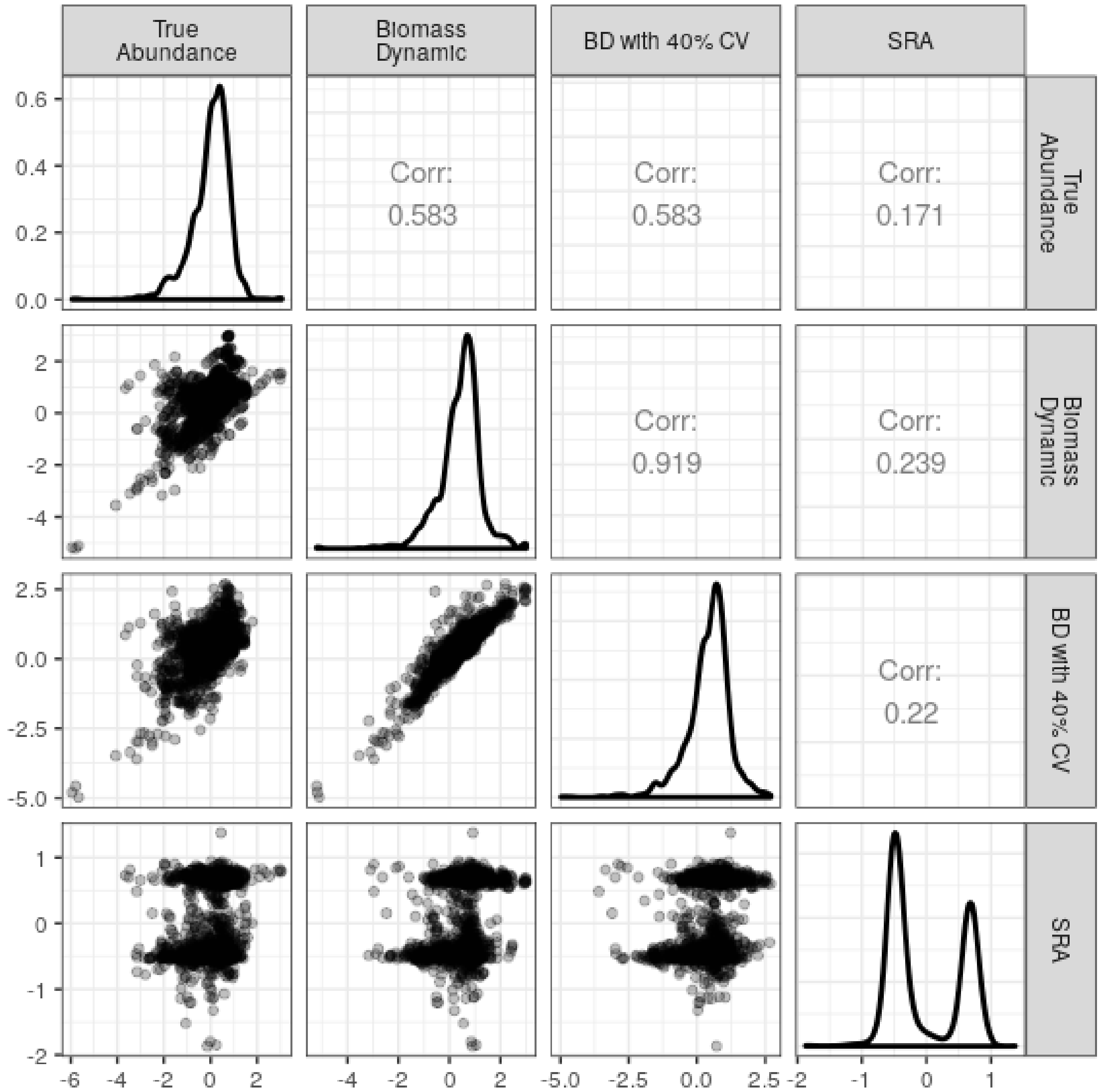

Figure 3 Correlations between trends in last 5 years.

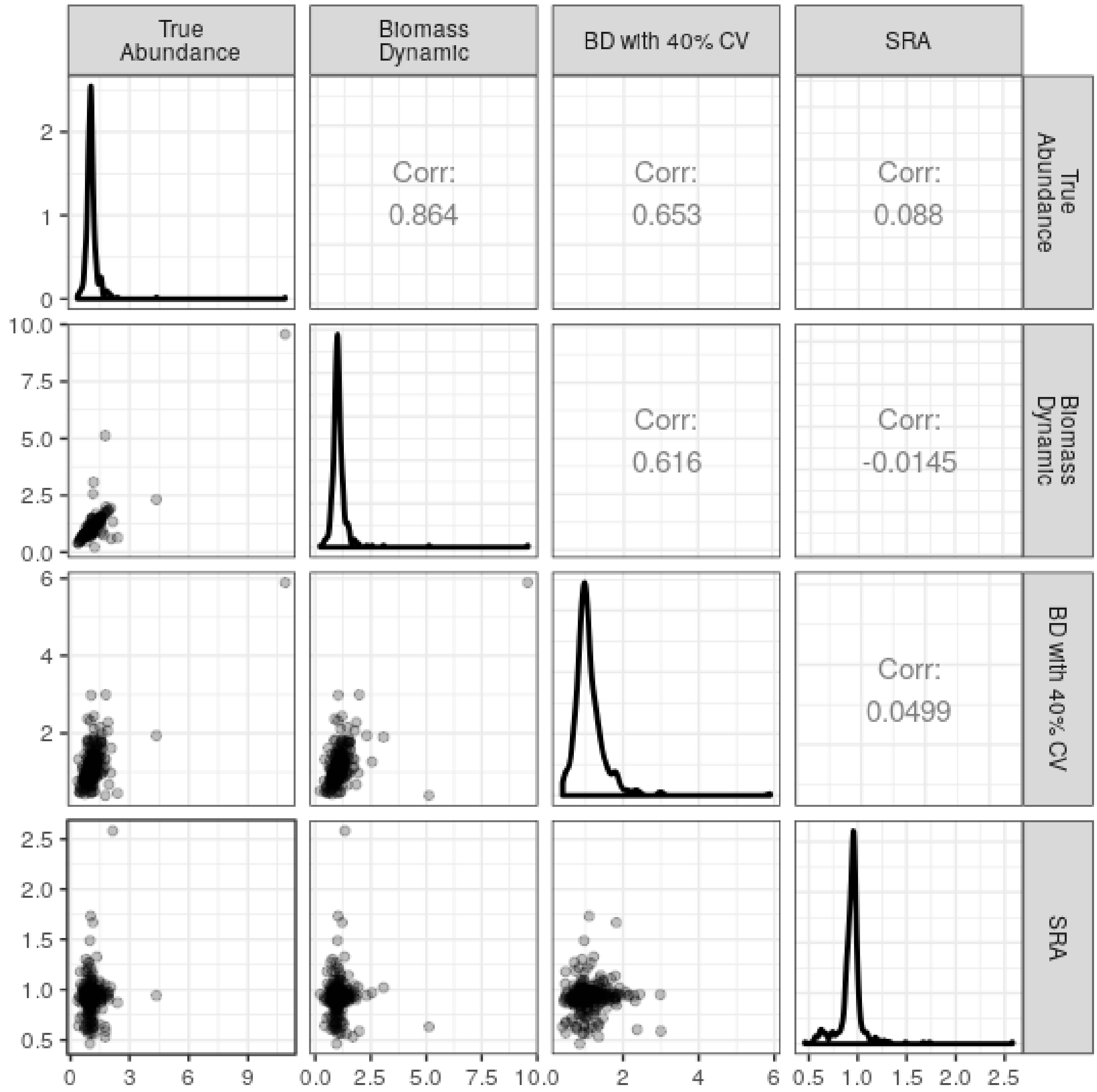

Figure 4 Comparison of ICES 2 over 3 rule, i.e. mean of last 2 years divided by mean in years -5 to -3.

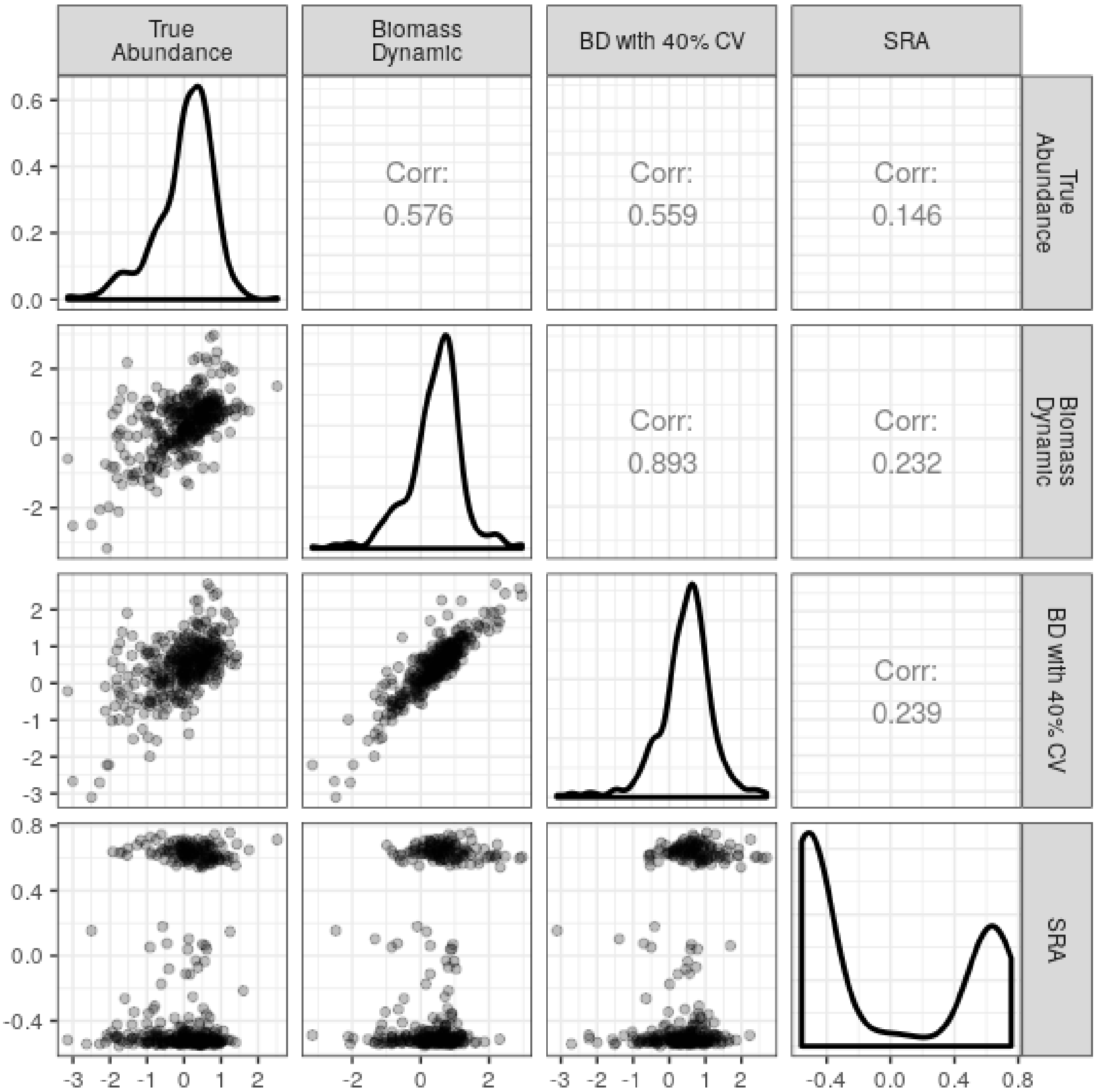

Figure 5 Comparison of depletion estimates in final year.

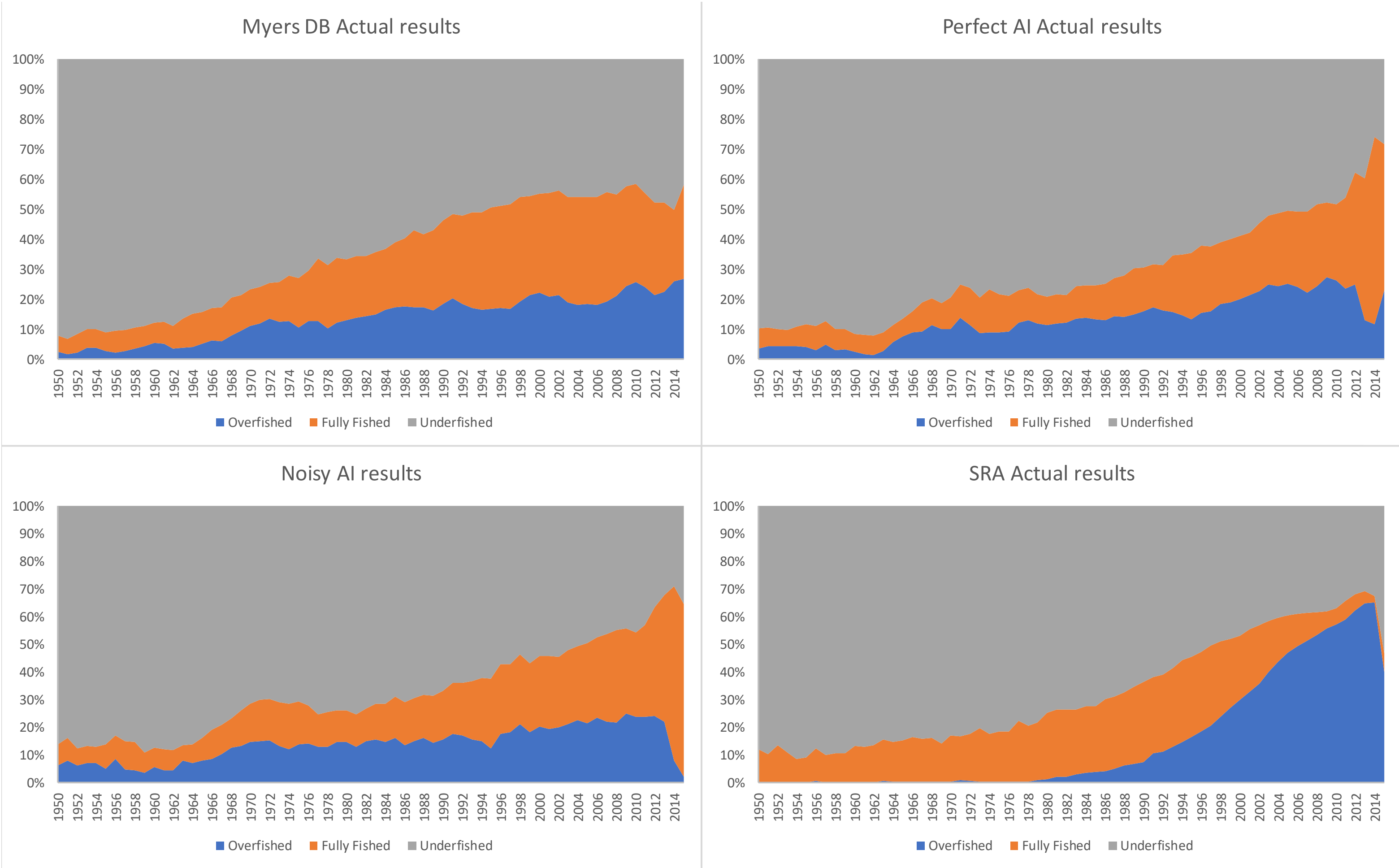

Figure 6: Comparisons of stock status using FAO criteria for the different approaches

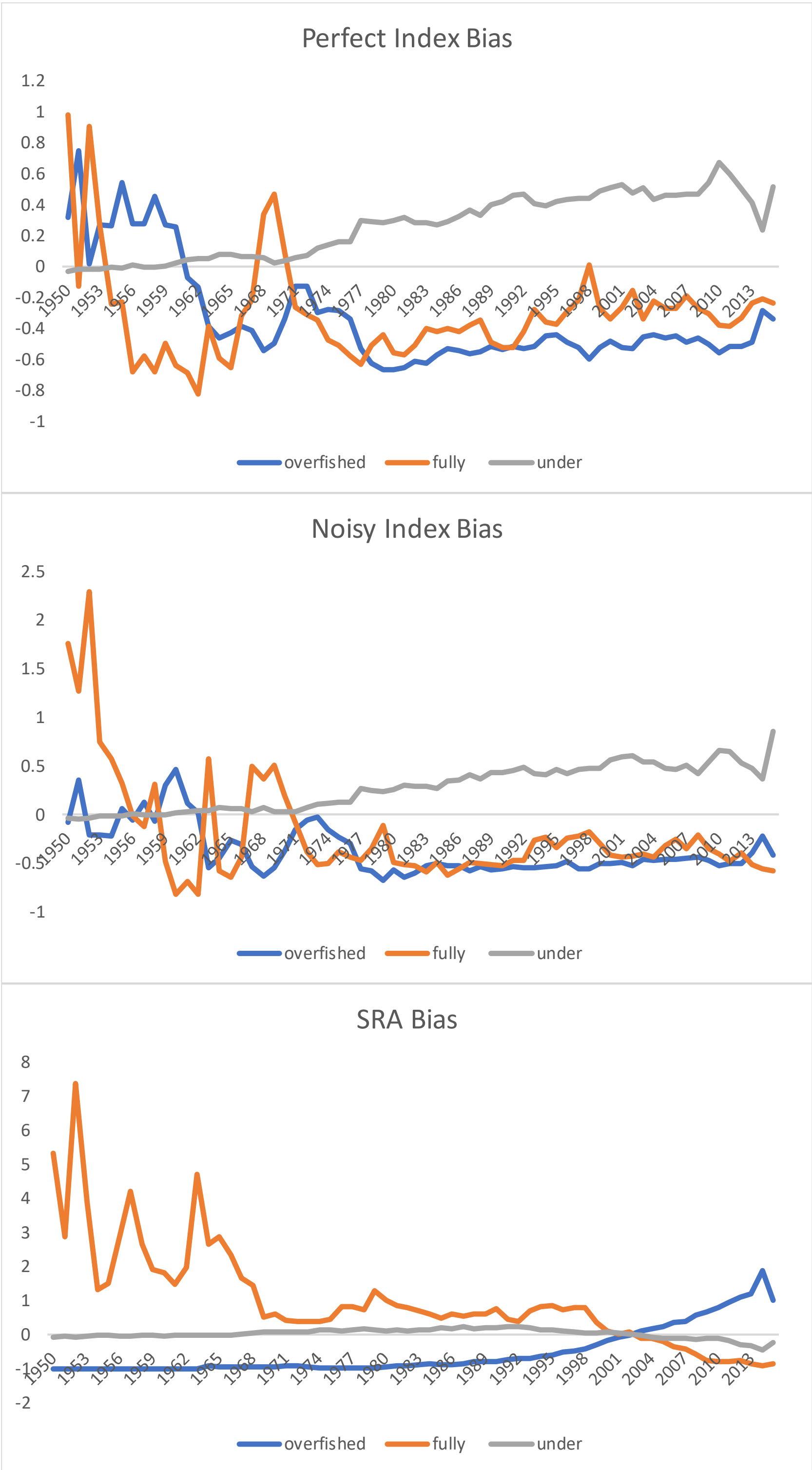

Figure 7: Bias on the different methods