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Summary

While the catch-MSY analysis for the Blue-Eye from the eastern seamounts remains highly uncertain, it generates what appears to be a relatively robust estimate of MSY of about 46 - 50 t. The current depletion is estimated to be about 0.33_B_0_ although the uncertainty about that value is extreme.

Currently there is no accepted harvest strategy, or more specifically a harvest control rule (HCR) for such Tier 5 analyses, so generating an acceptable RBC cannot be done until such an HCR is agreed. A constant catch projection of about 40 t over a five year period leads to the predicted mean and median depletion levels staying stable, although the lowest and highest depletion levels continue to diverge. To allow for stock rebuilding, assuming the stock is close to or below the mean depletion level would presumably require a smaller RBC than 40 t, but such details need to be considered in the harvest strategy adopted for Tier 5 analyses.

This analysis assumes that the catch time series reflects changes in depletion of Blue-Eye. However, this may not be the case, as other factors unrelated to abundance can influence this (e.g. management changes - catch limits; marine closures; gear restrictions, fisher behaviour etc.). It also assumes that the fishery dynamics are adequately represented by the underlying model equations.

Fisheries that only have such catch data but that also require management advice are only marginally served by such 'assessment' methods. Such data-poor assessments are not usefully updated by including future catch levels if those catch levels came from the predictions of such an assessment. Rather, the application of such methods is effectively an admission that such a fishery should be classed exploratory. This implies that evidence needs to be gathered concerning any impact the exploratory fishing has upon the stock being fished.

Introduction

The methods used here are described in Haddon *et al* (2018) and relate specifically to the catch-MSY approach (Martell and Froese, 2013). The catch-MSY data-poor stock assessment method requires strong assumptions and a minimum amount and quality of data. If one has insufficient data, or only has data of poor and uncertain quality, then sometimes outcomes from a stock assessment are highly uncertain. The Blue-Eye fishery on the eastern seamounts is a difficult fishery to assess because of this.

Blue-Eye - Eastern Seamounts

Introduction

The array of fishing methods that have been used to catch Blue-Eye (*Hyperoglyphe antarcticus*) off the Australian east coast sea-mounts is diverse and exhibits no stable pattern of exploitation on any particular sea-mount (Haddon, 2014). Over the last five years the average catch was about 51 t with a minium of 25 t and a maximum of 84 t (Table 1).

Table 1: Fishery data for Blue-Eye. That from 1984 - 2016 is from the standard AFMA database, that from 1984 - 1996 derives from Tilzey (1997).

year	catch	year	catch	year	catch
1984	7	1996	16.000	2008	8.100
1985	9	1997	10.975	2009	43.003
1986	38	1998	1.590	2010	69.948
1987	105	1999	21.640	2011	147.192
1988	210	2000	7.258	2012	102.941
1989	174	2001	42.856	2013	43.887
1990	243	2002	48.983	2014	25.297
1991	181	2003	74.978	2015	50.385
1992	60	2004	47.021	2016	84.548
1993	38	2005	14.758	2017	55.603
1994	27	2006	15.431	.	.
1995	19	2007	16.174	.	.

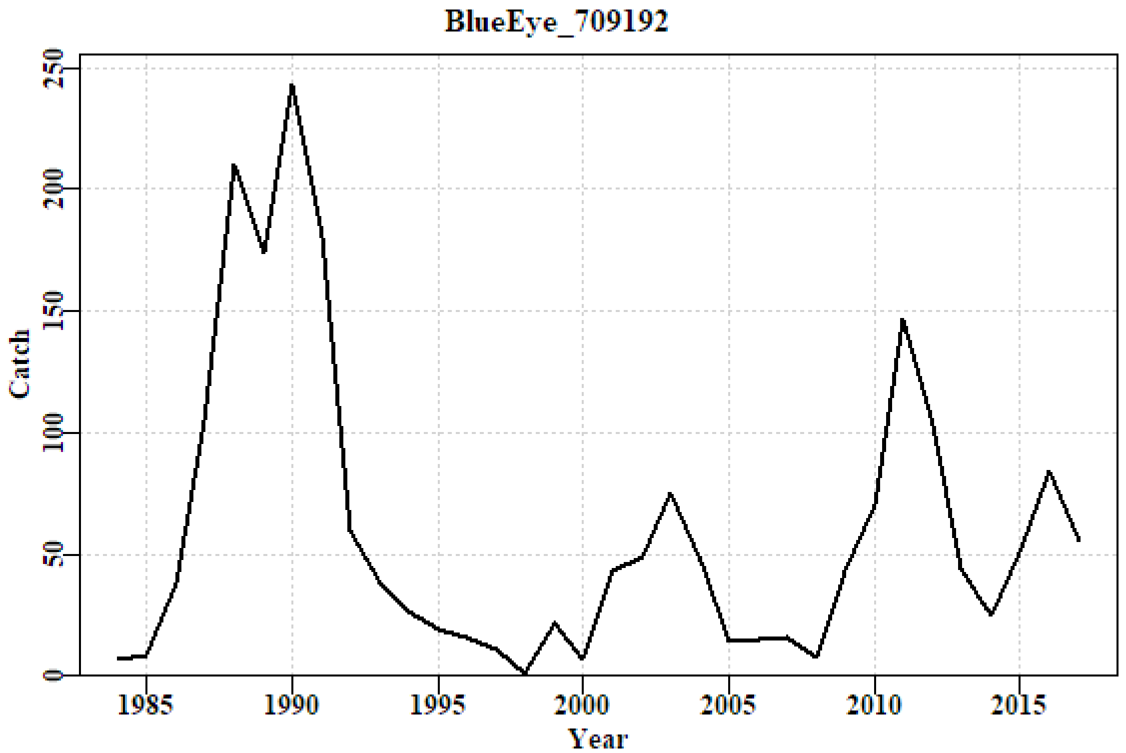


Figure 1: The catch (t) history of the Blue-Eye fishery from the Eastern Seamount fishery.

It is possible to generate a sketch map of the distribution of the catches from the eastern seamounts, at least from 1997 to present.

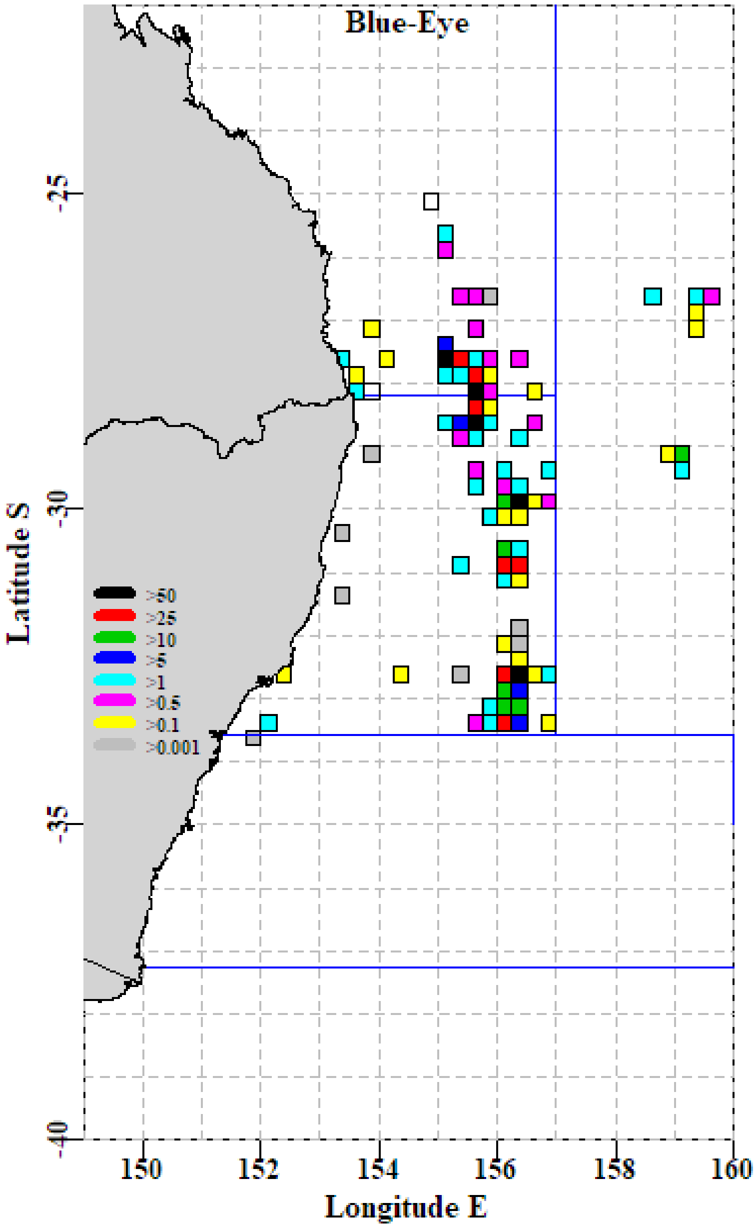


Figure 2: Schematic map of all Blue-Eye catches since 1997 off the east coast (zones 70, 90, and 91. The grid scale is 1.0 and 0.25 degree and the catch scale is in tonnes.

Catch by Gear

Table 2: The catch by gear across the zones 90, 91, and 70 (the east coast above Barrenjoey and the eastern Seamounts). AL - auto-line, BL - bottom-line, DL - drop-line, HL - hand-line, LDR - unknown, LLP - pelagic long-line, PL - pole-line, RR - rod-reel, TL - trot-line, and TW - otter trawl.

	AL	BL	DL	HL	LDR	LLP	PL	RR	TL	TW
1997	.	.	5.503	.	.	.	.	.	5.47	0.002
1998	.	.	1.590	.	.	.	.	.	.	.
1999	10.120	.	11.520	.	.	.	.	.	.	.
2000	1.330	.	0.520	.	.	.	.	.	.	5.408
2001	.	.	7.986	.	.	.	.	.	.	34.870
2002	2.100	.	44.114	.	.	.	.	.	.	2.769
2003	7.230	.	54.380	.	.	.	.	.	.	13.368
2004	6.080	.	5.165	.	.	.	.	.	.	35.776
2005	0.011	1.55	11.120	.	.	.	.	.	.	2.077
2006	5.555	.	9.860	.	.	0.016	.	.	.	.
2007	.	.	2.700	0.400	.	.	.	.	.	13.074
2008	.	.	8.100	.	.	.	.	.	.	.
2009	4.585	.	25.560	.	.	.	3.138	7.550	.	2.171
2010	.	.	13.160	.	.	.	.	56.788	.	.
2011	40.196	.	27.013	17.091	.	.	.	59.934	.	2.957
2012	36.777	.	16.179	21.171	.	.	.	14.782	.	14.031
2013	3.853	.	0.529	24.083	.	.	.	14.125	.	1.296
2014	4.505	.	0.510	19.932	.	.	.	0.350	.	.
2015	4.322	.	45.384	.	0.679	.	.	.	.	.
2016	5.308	.	69.647	4.000	5.593	.	.	.	.	.
2017	1.294	1.20	40.585	8.502	4.022	.	.	.	.	.

Methods

Modified Catch-MSY

The Catch-MSY method (Martell and Froese, 2013) could be termed a 'model-assisted' stock assessment method. It only requires a time-series of catches and a set of strong assumptions to conduct a stock assessment. As only a brief description of how it is considered to work is given here, it is recommended that users read the original paper to gain an understanding of what the method does and how it does it.

The underlying stock dynamics are described by the simple model used, which in the case implemented here is a Schaefer surplus production model with parameters *r*, the population growth rate, and *K*, the population carrying capacity or unfished biomass. The model uses ratios of the initial and final catches relative to the maximum catch to set up arrays of potential values for the initial and final depletion levels as well as for the potential range of *r* and *K* values (all of which are now modifiable by the user). The method sequentially steps through the years of the fishery by randomly selects pairs of *r*-*K* values from the wide initial ranges, which defines the initial biomass, subtracting the catches, and moving the population dynamics forward each year using the predictions from the simple model. Essentially this is a stock reduction that removes catches from a known set of dynamics. However, the very many *r*-*K* pairs used (at least 20000) are combined with a fixed set of initial depletion levels (about 20 steps between the minimum and maximum initial depletion set) to generate often 100,000s of possible stock reduction trajectories. Criteria are included (e.g. no trajectory is kept if it predicted zero biomass or biomass above *K*) that lead to numerous potential trajectories being rejected. Those that are left after all criteria for acceptance have been completed constitute the set of trajectories deemed to be consistent with the known catches. The implications of these successful trajectories are used to produce an assessment of the possible status of the stock.

The Catch-MSY method described here can be regarded as a model-assisted data-poor method. It uses a form of stock reduction analysis where the productivity of a given stock (its unfished biomass and its reproductive rate) is characterized within the parameters of a simple mathematical model, and how that modelled stock responds to the history of known catches (a stock reduction analysis) forms the basis of the alternative methods used to characterize productivity in management useable terms.

The Catch-MSY method (Martell and Froese, 2013) uses the relatively simple Schaefer surplus production model as the basis for describing the dynamics of the stock being described.

Equ. 1: $$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{K}\right) - C_t$$

where B_t represents the stock biomass in year *t*, *r* represents a population growth rate that includes the balance between recruitment and natural mortality, *K* is the maximum population size (the carrying capacity), and C_t being the catch in year *t*. The $\left(1 - \frac{B_t}{K}\right)$ represents a density dependent term that trends linearly to zero as B_t tends towards *K*.

Importantly, for our purposes, one of the properties of the discrete Schaefer surplus production model is that MSY can be estimated very simply from the parameter estimates:

Equ. 2: $$MSY = \frac{rK}{4}$$

which reflects the symmetric production function implied by the model dynamics. A relatively simple future possible development would be to include the option of using Fox model dynamics instead of the Schaefer.

There are many fisheries within Australia that may only have a time-series of catches with only limited information related to a useable index of relative abundance. In addition, such catch time-series may not be available from the beginning of the fishery, which means that methods such as Depletion-Based Stock Reduction Analysis (Dick and MacCall, 2011) cannot be validly applied (although, as shown in Haddon et al, 2015, if sufficient years of catches are present (perhaps >25) then the method can still provide approximate estimates of management related parameters). Under such data-limited situations other catch-only based assessment methods can provide the required estimates of management interest.

Stock Reduction Analyses

As with many of the more capable catch-only data-poor approaches the Catch-MSY method evolved from the stock reduction analyses of Kimura and Tagart (1982), Kimura et al. (1984), and eventually Walters et al. (2006). It uses a discrete version of the Schaefer surplus production model (Schaefer, 1954, 1957) to describe the stock dynamics in each case. The Catch-MSY requires a time-series of total removals, prior ranges for the *r* and *K* parameters of the Schaefer model, and possible ranges of the relative stock size (depletion levels) in the first and last years of the time-series. As described by Martell and Froese (2013) the range of initial depletion levels can be divided into a set of initial values, and a stock reduction using the known total removals, applied to each of these multiple initial depletion levels combined with pairs of *r*-*K* parameters randomly drawn from uniform distributions across the prior ranges of those parameters. Each of these parameter pairs plus each of the initial depletion levels are projected using the total catch trajectory leading to a stock biomass trajectory which is either accepted or rejected depending on whether the stock collapses or exceeds the carrying capacity, and whether the final depletion level falls within the assumed final range.

The initial and final depletion ranges can be relatively broad. Other criteria can be included to further constrain the biomass trajectories if extra evidence is available. Such additional constraints are still under development. For example, in some of the examples you will notice that the annual harvest rates for some accepted trajectories can be very high (> 0.5), which for many (though not all) Australian species can be considered to be implausible. Now it is possible to conduct a sensitivity analysis where trajectories implying some pre-defined harvest rate will also be rejected. These high fishing mortality trajectories are only possible for the more productive parameter combinations so removing such trajectories will likely reduce the predicted MSY (maximum productivity).

Results Catch-MSY

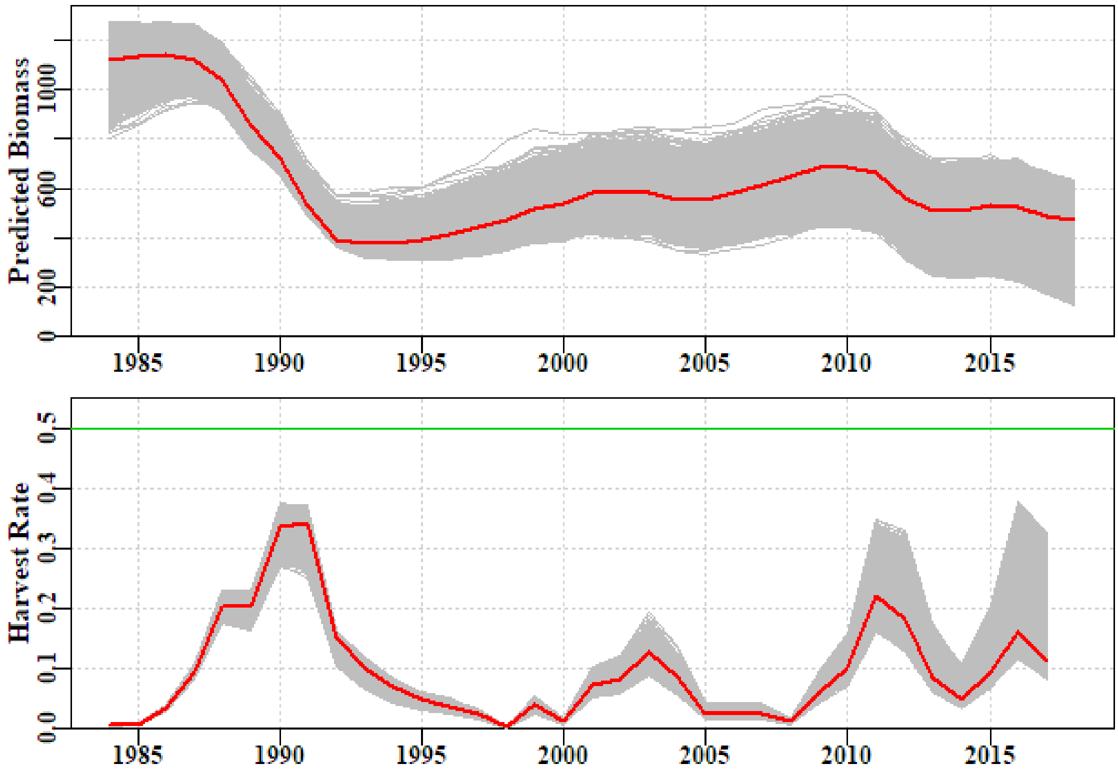


Figure 3: The estimated stock biomass and the implied harvest rates for the successful stock reduction analyses from the catch-MSY analysis for Blue-Eye on the eastern Seamounts. The maximum harvest rate in any one year is limited to 0.5, implying no more than 50% of exploitable Blue-eye could be taken in any single year (bottom plot). The top plot is of the successful biomass trajectories and the red line is the mean in each year.

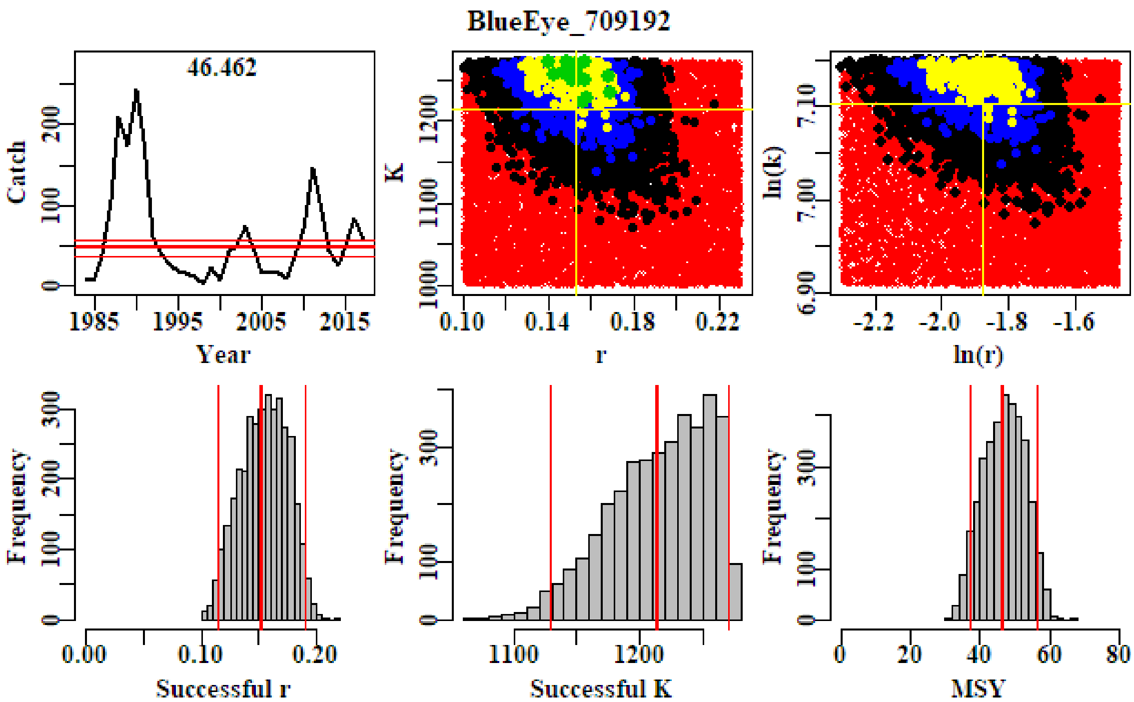


Figure 4: The catch-MSY analysis for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91). The ~46t is the approximate estimate of the MSY of the stock.

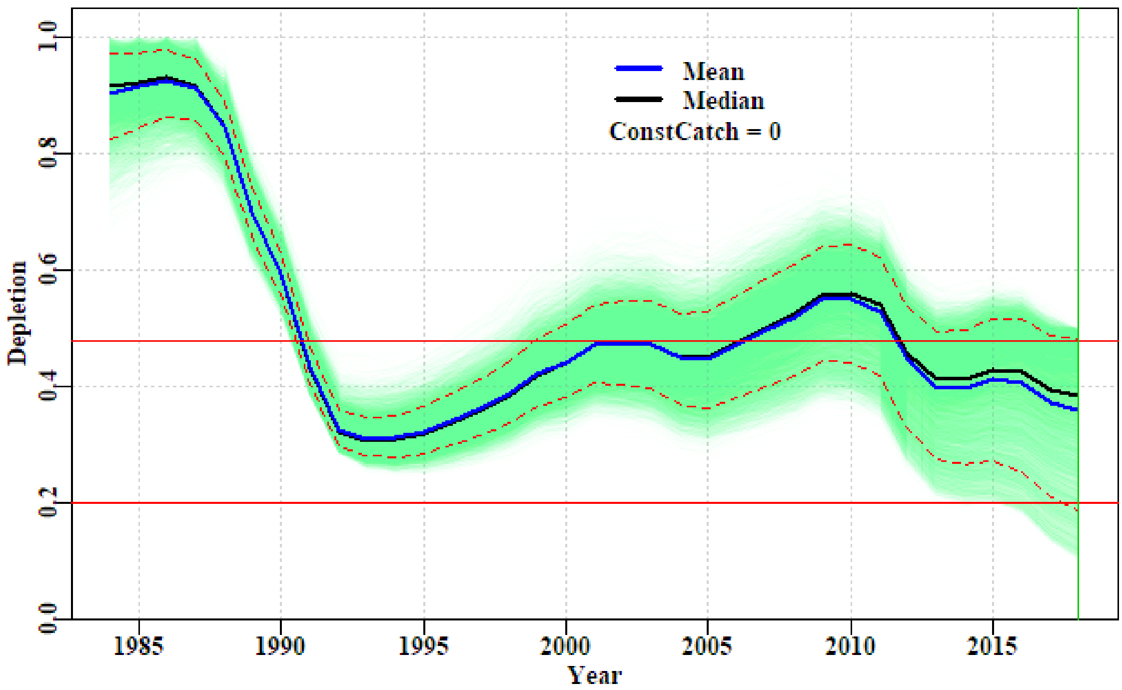


Figure 5: The catch-MSY analysis of stock depletion for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91). A plot of the successful depletion trajectories with the mean and median annual depletion marked with the density of trajectories represented by different intensity of colour. The lower red line is the default 0.2B0 limit reference point, while the upper is the input target reference point. Red dashed lines correspond to the 10% and 90% percentiles.

Conduct some forward projections under the assumed productivity from the catch-MSY analysis.

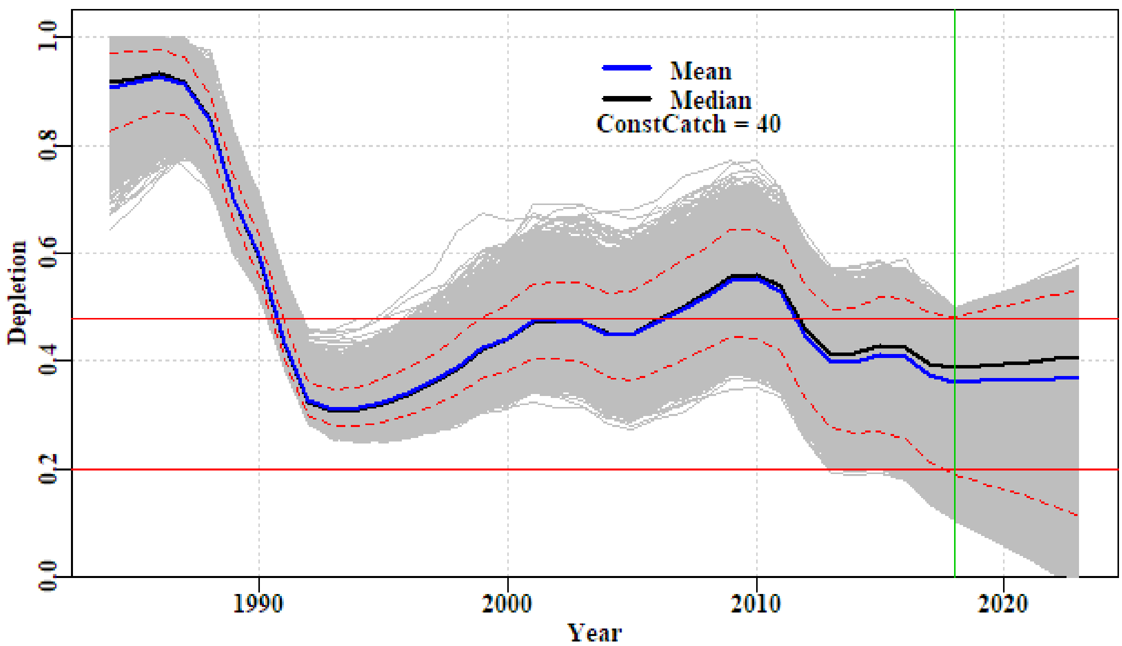
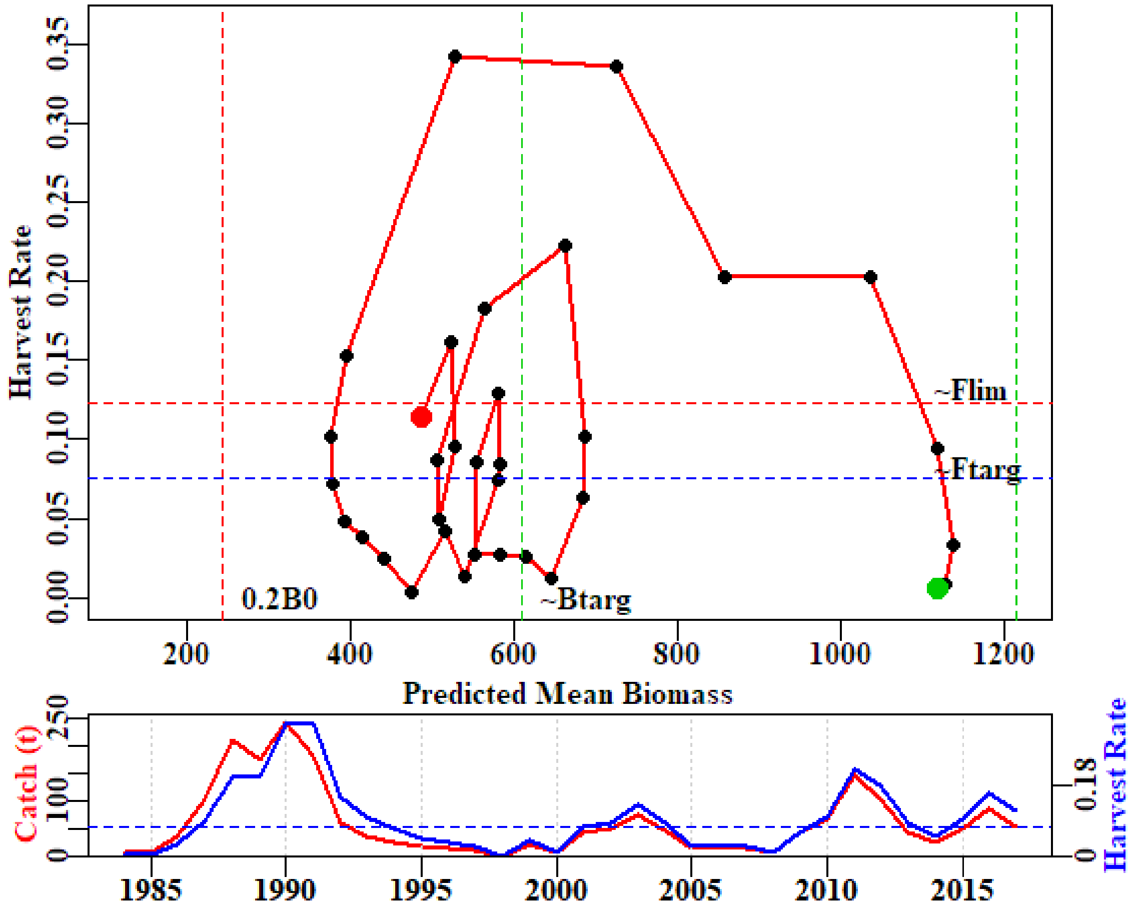


Figure 6: The catch-MSY analysis for Blue-Eye on the eastern seamounts (Zones 70, 90, and 91), with a projection forward for five years under a constant catch of 40 tonnes. The lower red line is the default 0.2B0 limit reference point, while the upper is the input target reference point 0.48B0. The green line denotes the end of the final year in which data are available.

Phase Plot

By plotting the predicted mean harvest rate against the mean biomass a phase plot providing a visual representation of the status of the stock is generated. While this looks convincing the high levels of uncertainty in this analysis must not be forgotten. The first year of data is a green point and the last a red point.



Discussion

Without extra information, such as some form of index of relative abundance, or estimate of abundance through time, the default assumptions of the catch-MSY lead to highly uncertain outcomes. In the base-case here it has been assumed that harvest rates never rose above 0.5 in any single year which adds a constraint to the analysis. This leads to an estimate of *MSY* of about 46t (Figure 4) and a maximum harvest rate in any one year of about 0.4. Because of the increased level of depletion implied by the catches, the harvest rates in 1990 and 1991 are about the same as in 2011 and 2012 and 2016 and 2017, despite the catches involved being rather smaller than those in the 1990s (Figure 3).

The predicted trajectory of stock depletion exhibits a strong decline in the late 1980s and early 1990s as a response to the relatively large catches taken at that time. Following that from about 1994 to 2010 the stock is predicted to have undergone some recovery such that the mean and median depletion rose above the target reference point of 0.48_B_0, *but then the catches from 2010 - 2012 and then in 2016 - 2017 decreased the stock size down to about 0.33_B_0*, with widely spread plausible trajectories and 90% percentile bounds from about 0.2 - 0.48_B_0_ (Figure 5).

Projecting the remaining trajectories forward under a constant catch of 40t leads to predicted stability in the mean and median depletion level (Figure 6). Currently, there is no accepted harvest strategy or harvest control rule for Tier 5 analyses but given the uncertainty of the analysis and the Commonwealth Harvest Strategy Policies objective of managing primary commercial stocks to a proxy of 0.48_B_0_ then presumably some level of catch less than 40t would need to be recommended. Once the SESSF RAG has recommended a harvest control rule then specific Recommended Biological Catch values could be estimated.

Sensitivities

The effect of assuming a maximum annual harvest rate of 0.5 is to lower the *MSY*, although only by between 6 - 7 t (see Appendix). The maximum harvest rate is approximately 0.6 when rather than about 0.4. Even the notion of the fishery taking 40% of all available Blue-Eye from all seamounts in particular years seems implausible for such a long lived species.

Many other sensitivities are possible (see Appendix), for example by changing the initial depletion of the seamount stock to somewhere between 0.9 and 1.0_B_0_ leads only to a slight decrease in productivity and no major change to the final depletion.

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Appendix: Additional Sensitivities

No maximum Harvest Rate

The base-case assumes a maximum annual harvest rate of 0.5. A sensitivity can be conducted that examines the effect of this constraint by removing it.

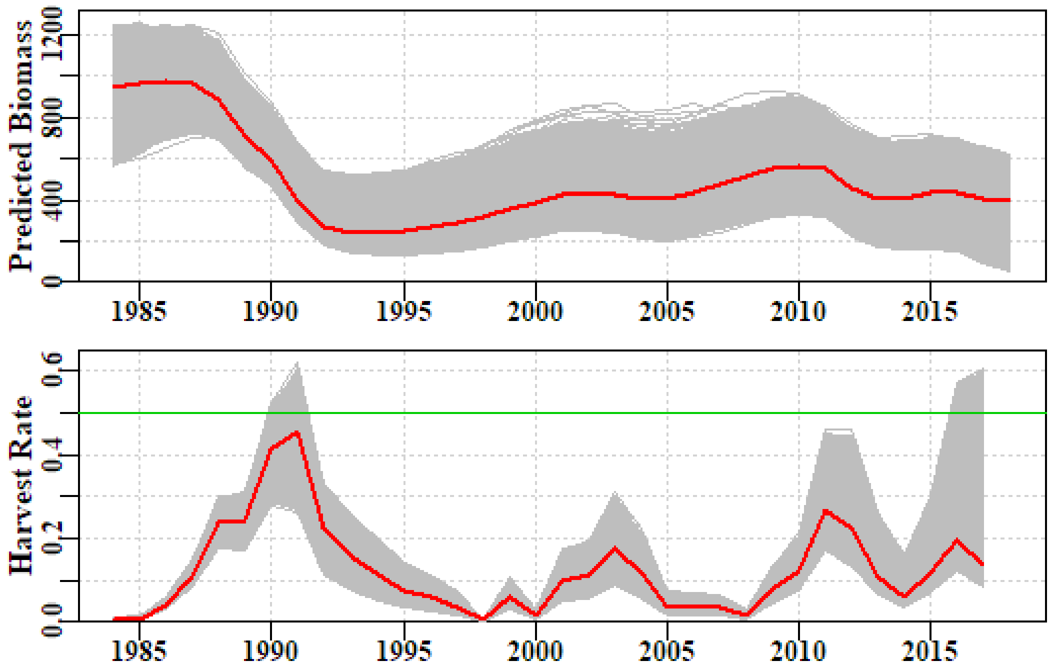

Figure 7: An alternative catch-MSY analysis removing the maximum harvest rate = 0.5 constraint so as to illustrate the impact of that assumption. Note the maximum harvest rate now reaches 0.6 in 1991, 2016, and 2017.

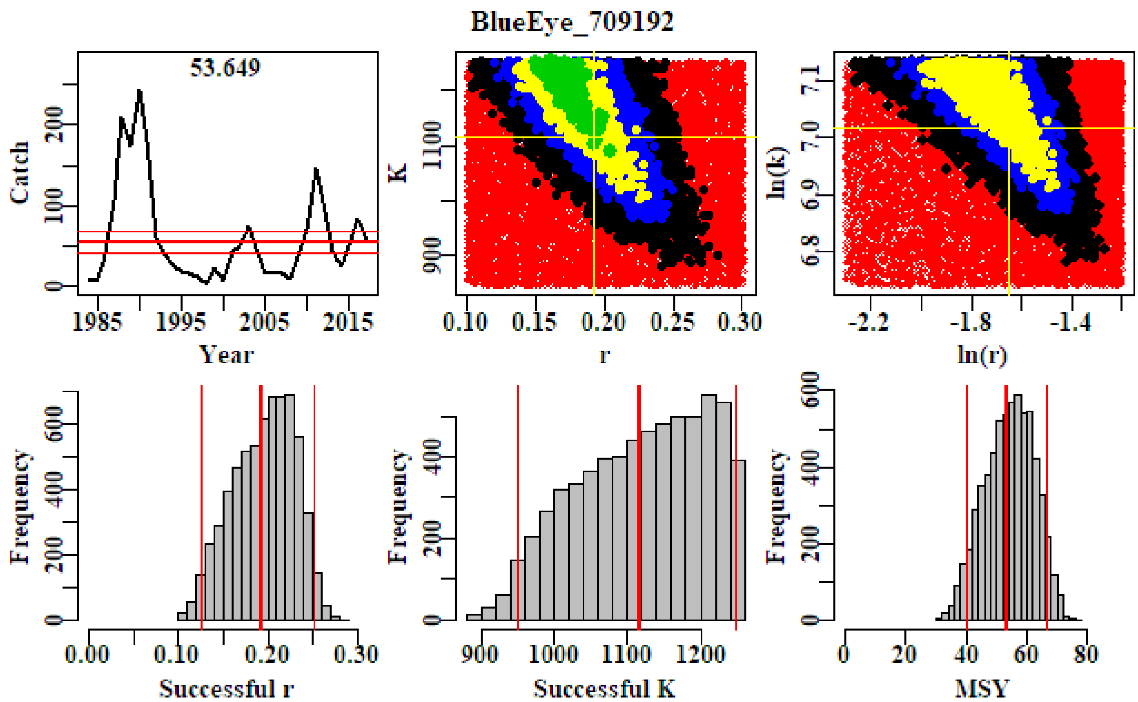

Figure 8: The catch-MSY analysis for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91). The ~53 t is the approximate estimate of the MSY of the stock.

Initial Depletion between 0.9 - 1.0

Rather than assume the default initial depletion level of between 0.7 - 0.95 it is simple to restrict the analysis to closer to the unfished state.

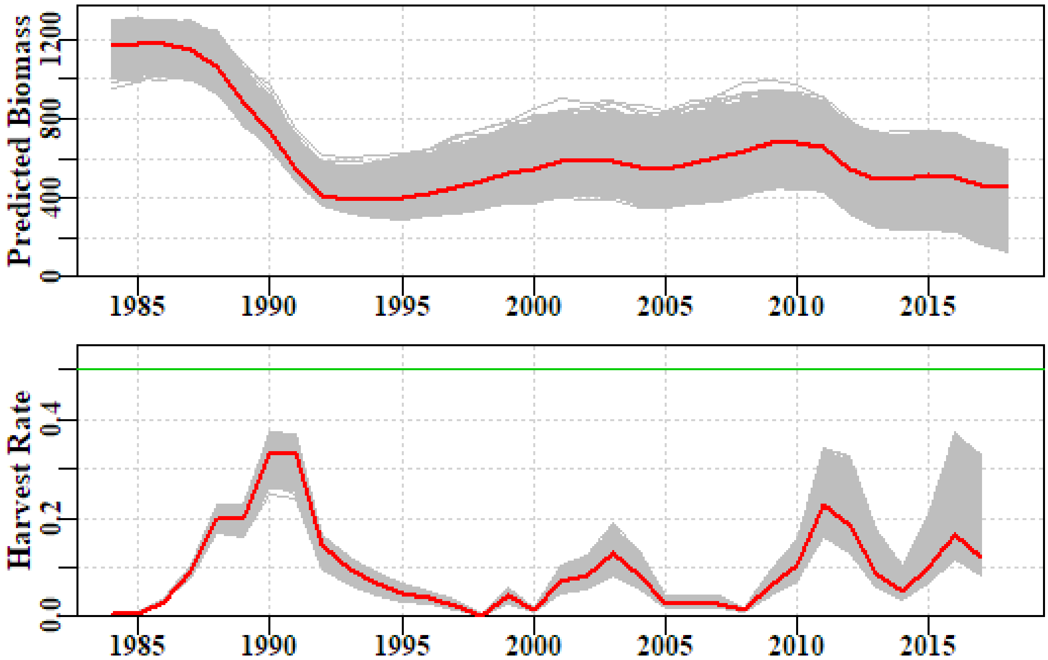

Figure 9: The estimated stock biomass and the implied harvest rates for the successful stock reduction analyses from the catch-MSY analysis for Blue-Eye on the eastern Seamounts with intiial depletion levels ranging fdrom 0.9 - 1.0 (although the assumed process error of 0.025 will alter these exact values).

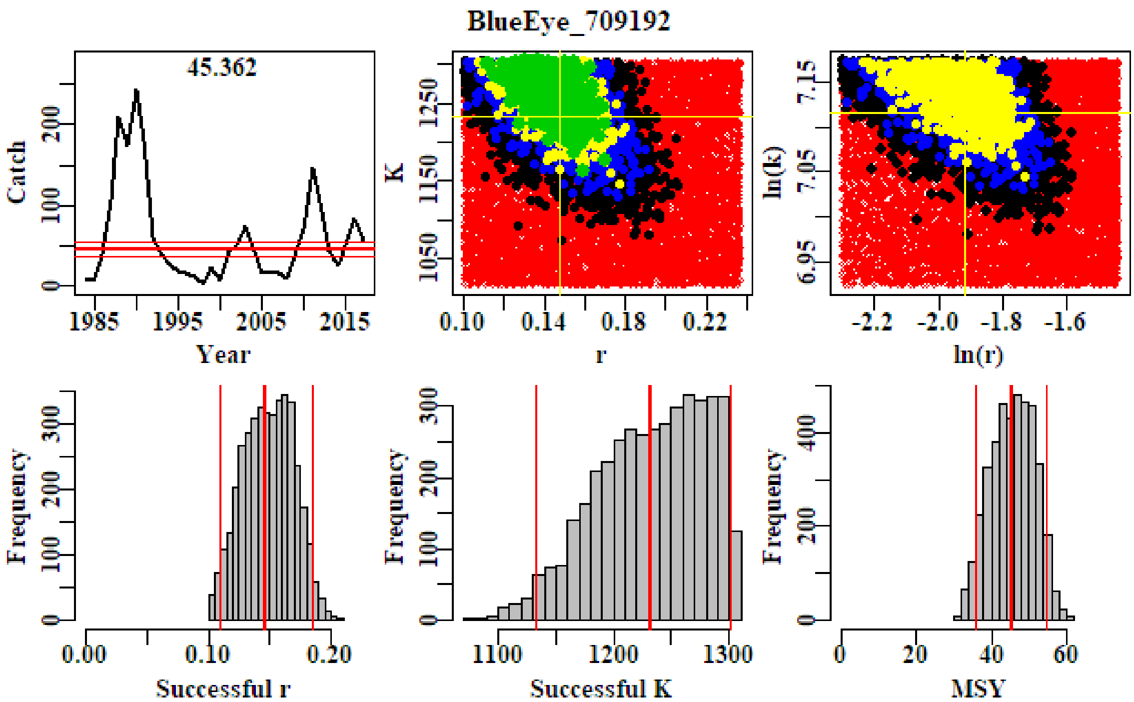

Figure 10: The catch-MSY analysis for Blue-Eye on the eastern seamounts (Zones 70, 90, and 91).

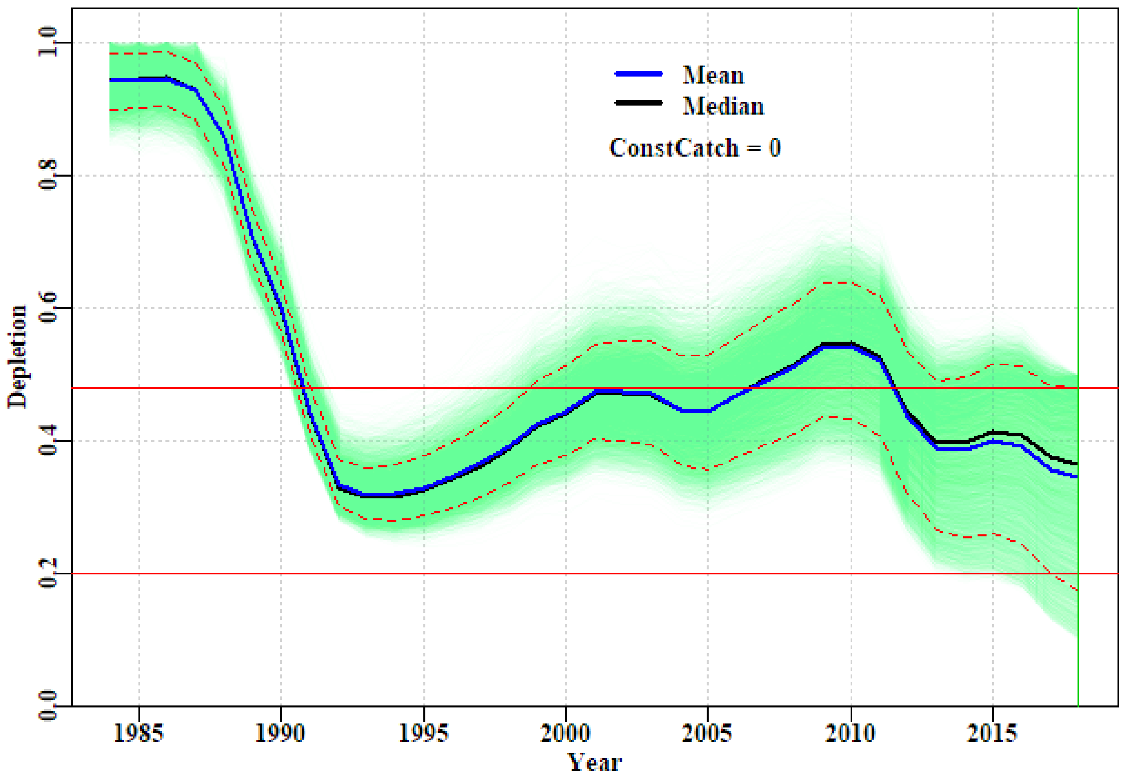

Figure 11: The catch-MSY analysis of stock depletion for Blue-Eye on the eastern Seamounts (Zones 70, 90, and 91) when starting from 0.9 - 1.0 depletion levels.The green line denotes the end of the final year in which data are available.