Guyana/Suriname Seabob Stock Assessment: Results Summary

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31st October 2019

Base Case Results

- Both Suriname and Guyana stocks are fluctuating at or above their MSY level (Figure 1).

- However, both stocks are low compared to the unexploited state and on average is below the 40% SSB_0 (Figure 2), although this is precautionary for finfish rather than shrimp.

- There is some evidence of seasonality in spawning stock biomass (Figure 3). Although seasonality is present in the recruitment, this pattern is weaker. The seasonality is opposite between Suriname and Guyana.

- There is no evidence that recruitment has been reduced significantly by fishing (Figure 4).

- Fishing mortality has tended to be higher than F_{MSY} for Suriname but fluctuating around or lower than F_{MSY} for Guyana in recent years.

- Suriname has dome-shaped, but highly uncertain, selectivity. Guyana selectivity is logistic in shape and appears more typical for trawl.
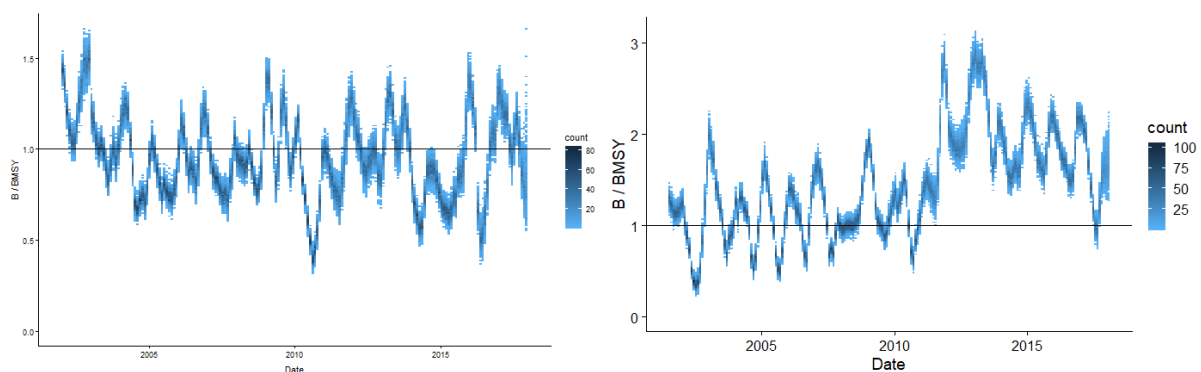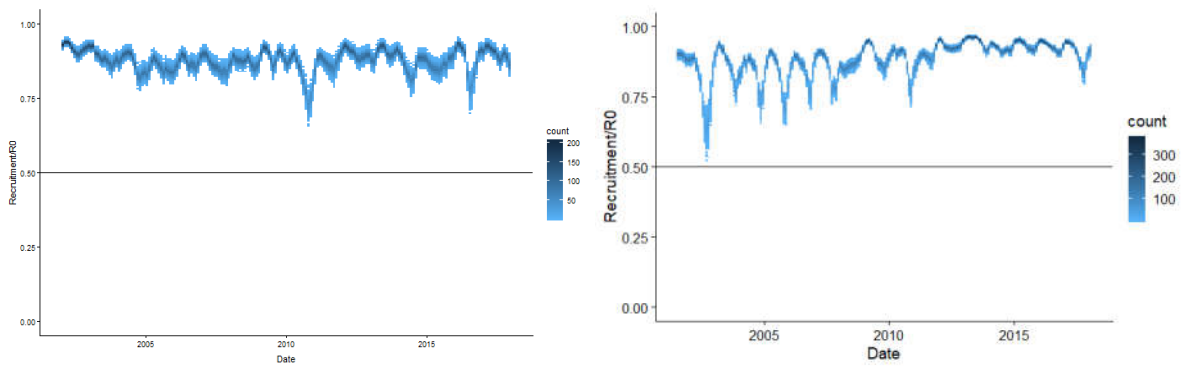

Figure 1 Suriname (left) and Guyana (right) stock status (count represents the MCMC simulations).
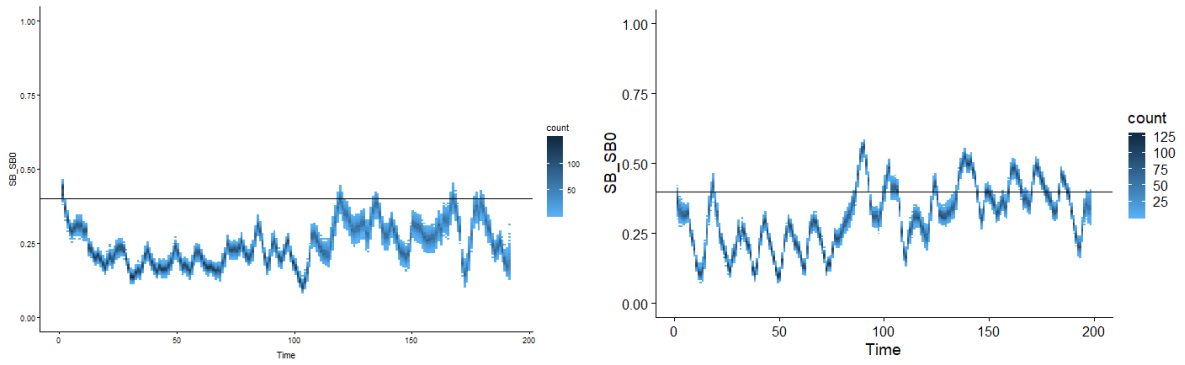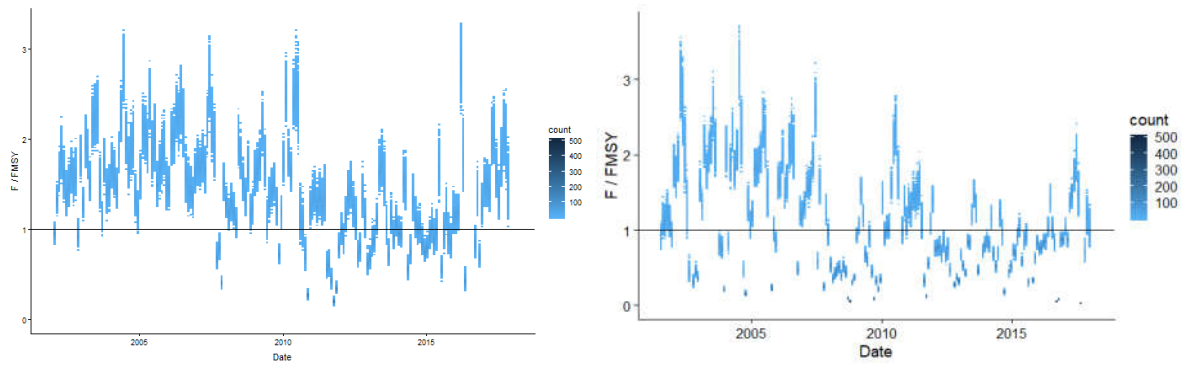
Figure 2 Suriname (left) and Guyana (right) stock status relative to the unexploited state.
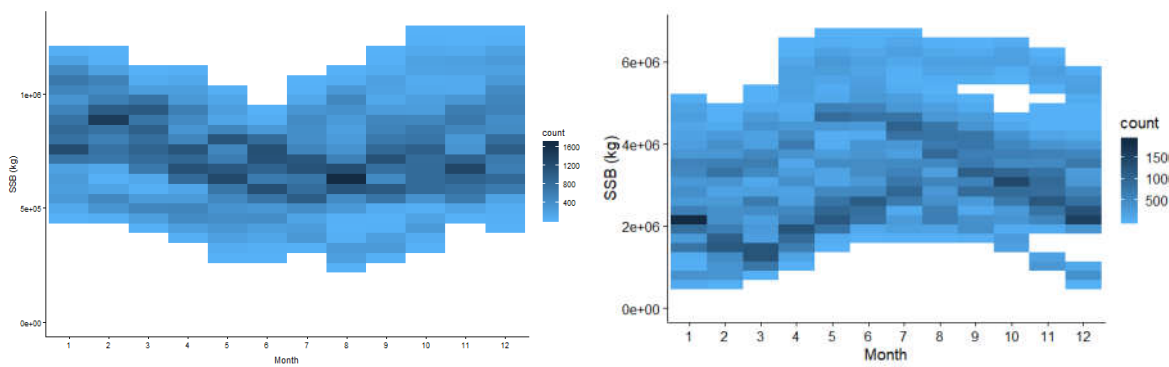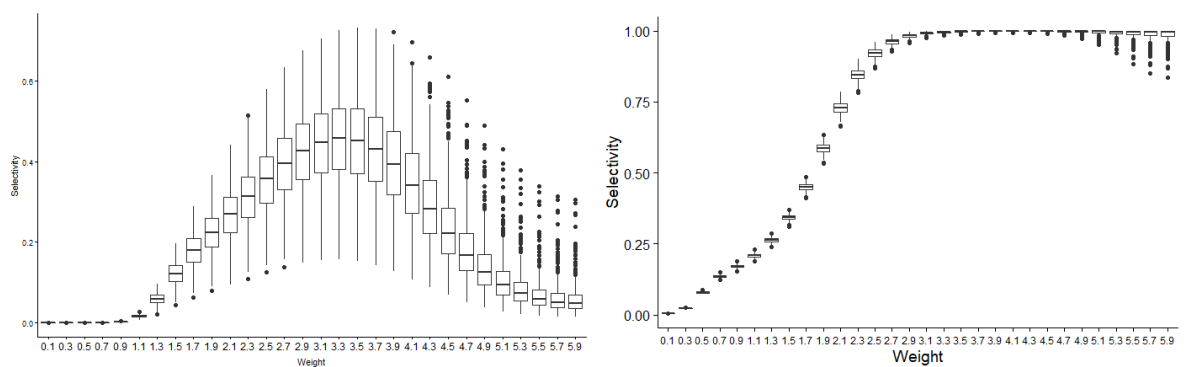

Figure 3 Suriname (left) and Guyana (right) spawning stock biomass by month January (1) – December (12).

Figure 4 Suriname (left) and Guyana (right) recruitment relative to the unexploited state.

Figure 5 Suriname (left) and Guyana (right) fishing mortality relative to the F$_{MSY}$.

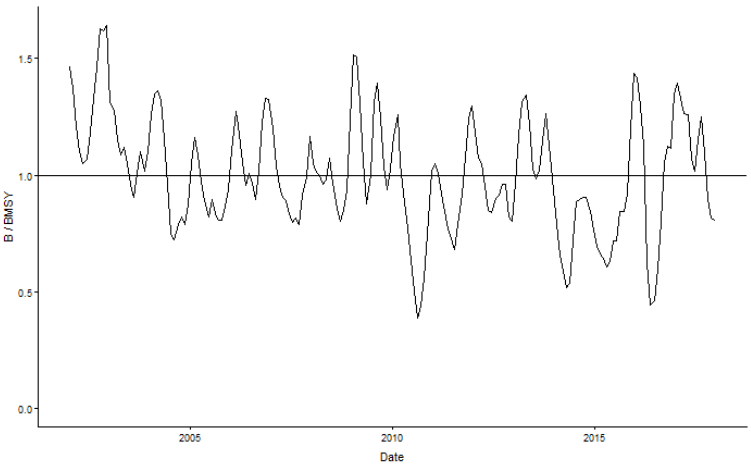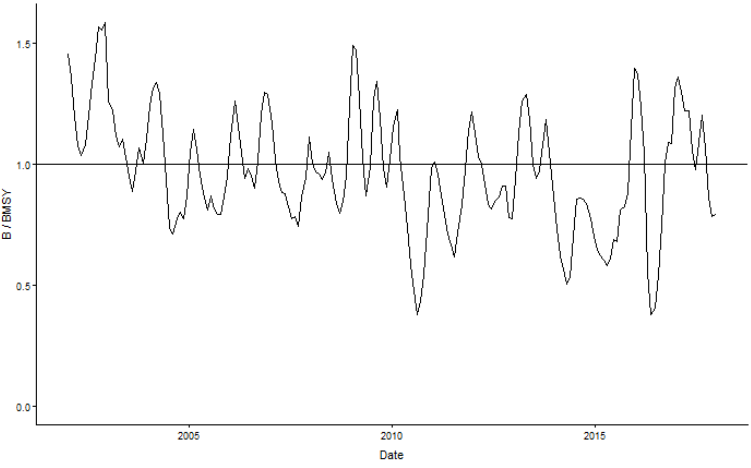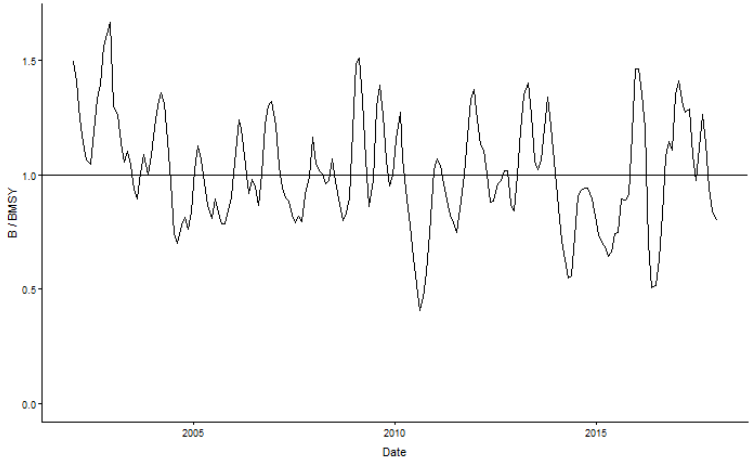**Figure 6 Suriname (left) and Guyana (right) selectivity ogives.**

Sensitivity Analyses

The base case was determined though the review process. The review used information from the sensitivity analyses to make its decisions (Table 1). The general results are outlined below:
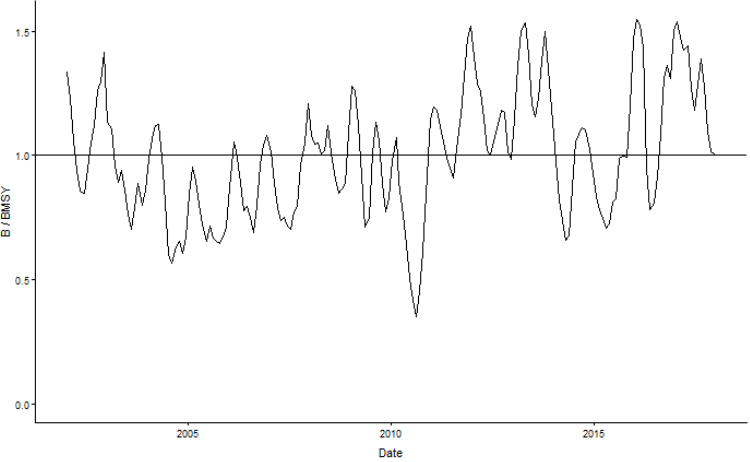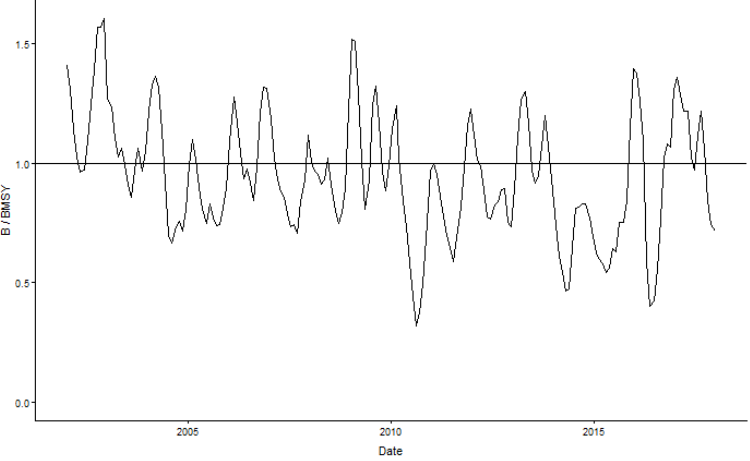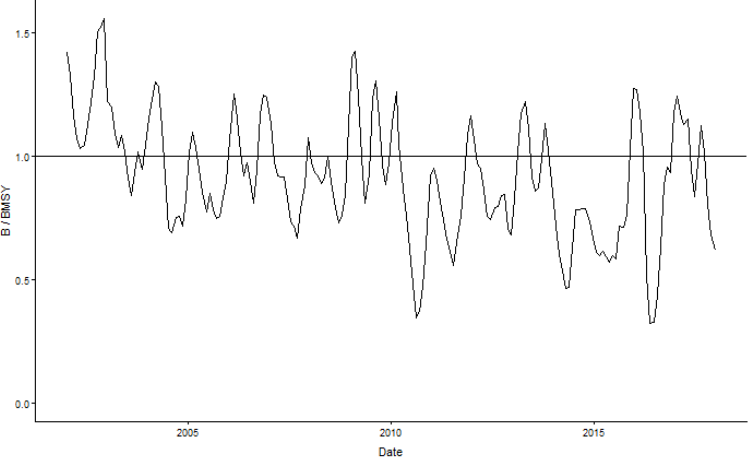
- The results were broadly unaffected by the growth rate (K). The growth rate is partially estimated by one of the parameters (G$_{sig}$) used to define the transition matrix.
- Results were sensitive to the natural mortality, with a significant change in status resulting over a plausible range of natural mortality. The choice of natural mortality is discussed further below.
- There were very slightly better fits to the data with higher growth rate and higher natural mortality rate.
- Forcing the model to fit the average count data improved the stock status slightly for Suriname and made it slightly worse for Guyana. In both cases, the fit to the other data deteriorated.
- Removing the smallest size category, which included "broken" shrimp, and including a factor that accounted for artisanal catch made no significant difference to stock status.

On balance, the final choices suggested that the model and determined stock status were precautionary in the base case.

Table 1 Suriname sensitivity analysis results: Positive change in log probability indicates a better fit. Log probability for the base case model was -944171.96.
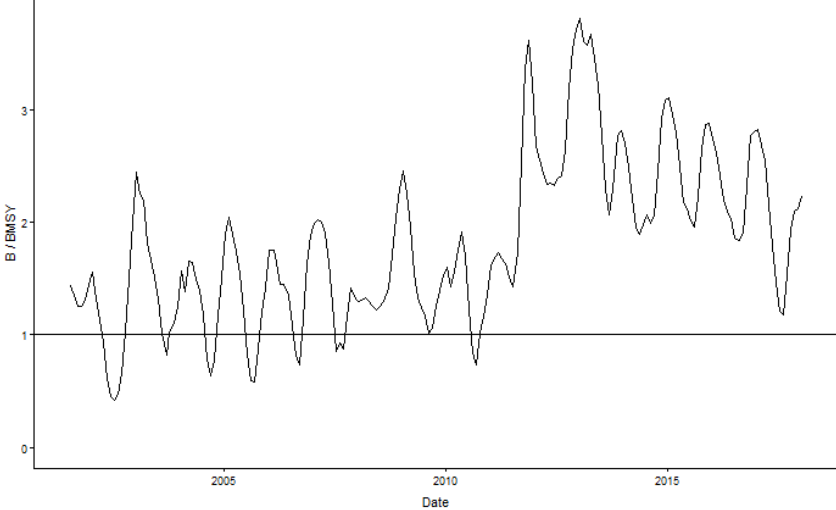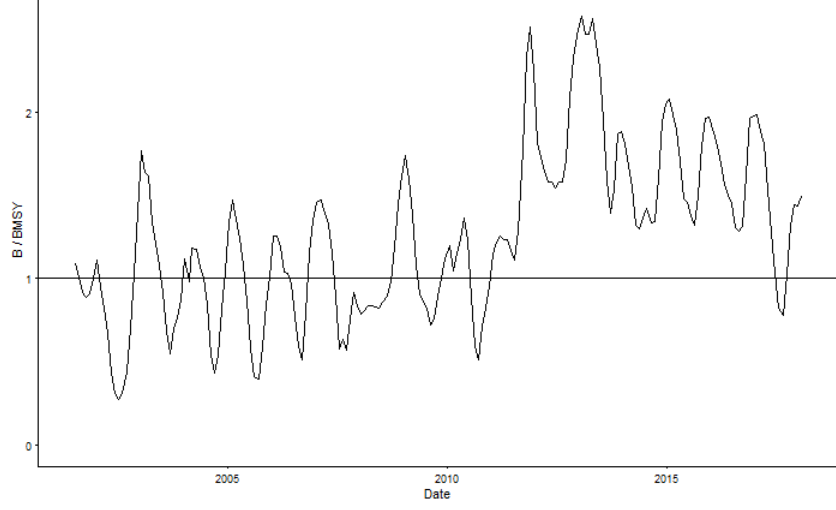
Sensitivity	Change in log probability	Stock Status
Base: M=0.2, K=0.2	0.00	
Fixed parameters: M=0.2, K=0.15	-47.79	
Fixed parameters: M=0.2, K=0.25	36.37	

Sensitivity	Change in log probability	Stock Status
Fixed parameters: M=0.1, K=0.20	-96.18	
Fixed parameters: M=0.3, K=0.20	26.36	
Artisanal catch	5.11	

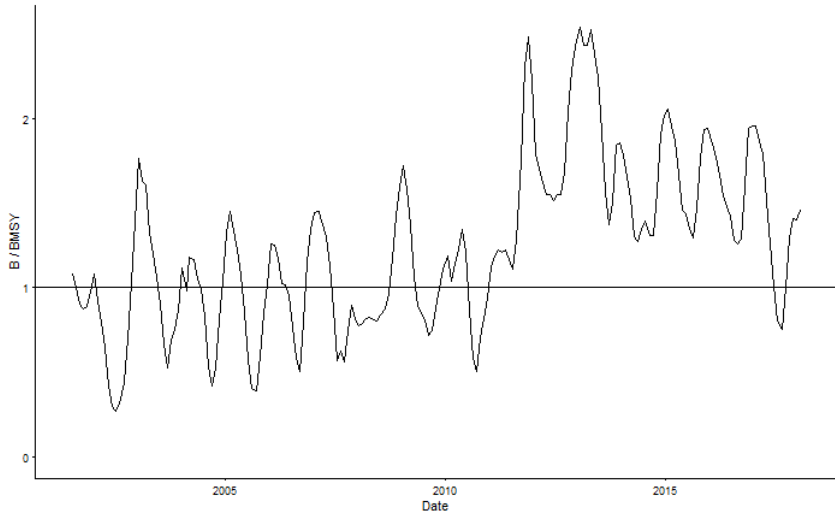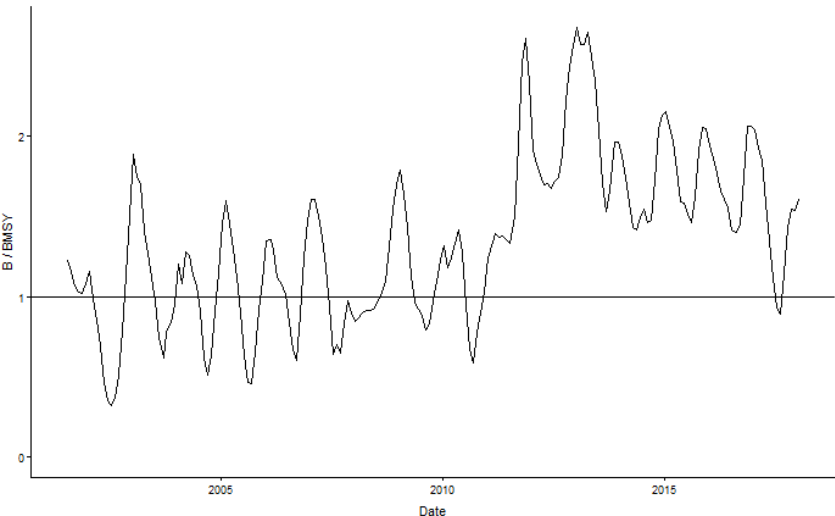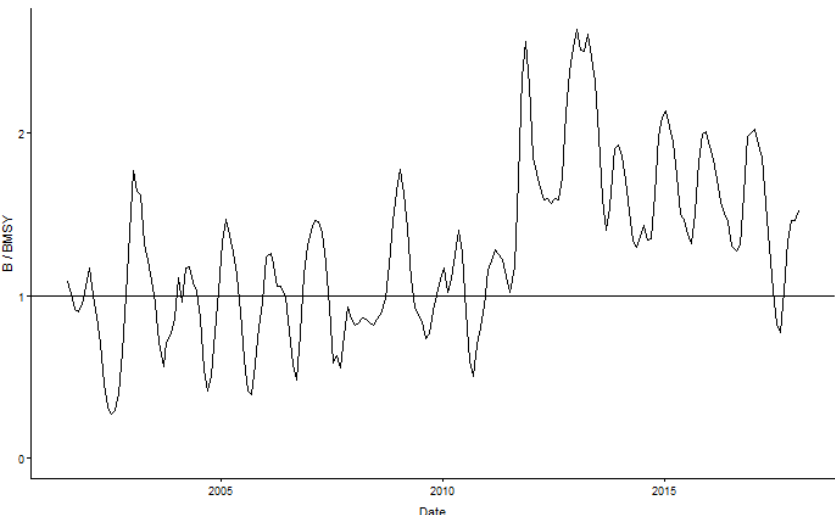| Sensitivity	Change in log probability	Stock Status
Force fit to average count data	-1508.23	
Nominal days-at-sea	-136.86	
Remove smallest size grade	NA	

Table 2 Guyana sensitivity analysis results: Positive change in log probability indicates a better fit. Log probability for the base case model was -4004954.14.
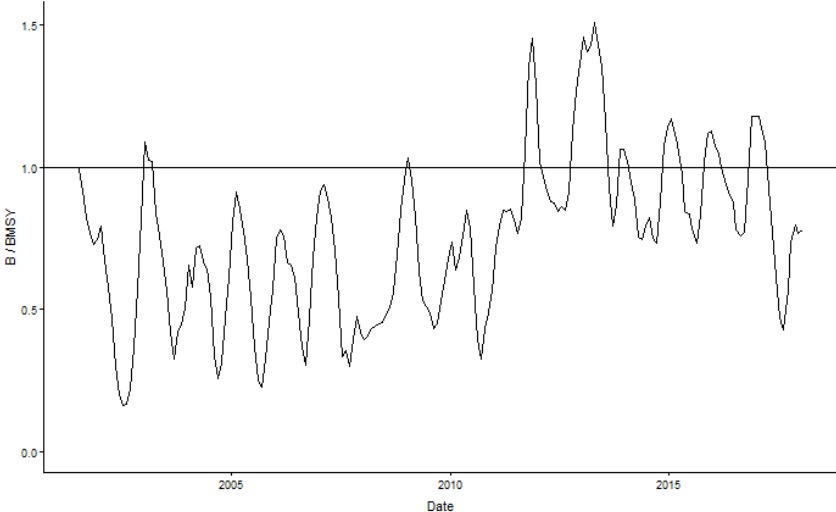
Sensitivity	Change in log probability	Stock Status
Base: M=0.2, K=0.2	0.00	
Fixed parameters: M=0.2, K=0.15	43.78	
Fixed parameters: M=0.2, K=0.25	27.14	

Sensitivity	Change in log probability	Stock Status
Fixed parameters: M=0.1, K=0.20	-37.34	
Fixed parameters: M=0.3, K=0.20	-66.88	
Artisanal catch	9.18	

Sensitivity	Change in log probability	Stock Status
Force fit to average count data	-253.97	
Nominal days-at-sea	-22.06	
Remove smallest size grade	NA	

Natural Mortality

Consistent with methods used elsewhere (Ribeiro De Campos et al. 2011), natural mortality was estimated based on growth and maturity parameters derived from the stock assessment (Table 3). Variation in the parameter estimates was very low, so only the mean MCMC runs are reported here. Natural mortality estimates ranged from 0.093 to 0.29 per month dependent on the methodology. Other simpler approaches suggested that natural mortality would be around 0.2 /month (based on M=1.5*K), which would be in the mid-range of methods in Table 3. Therefore, 0.2 /month was used in the base case.

Table 3 Mean growth and natural mortality parameter estimates from 500 MCMC runs.

PARAMETER	SURINAME	GUYANA
Female L_∞ (CL mm)	32.29	32.32
Female K (/month)	0.14	0.13
Age 50% Maturity (months)	15.41	15.33
Male L_∞ (CL mm)	29.54	27.81
Male K (/month)	0.12	0.093
M: female (Pauly 1980)	0.29	0.27
M: female (Rikhter & Efanov 1976)	0.093	0.093
M: male (Pauly 1980)	0.26	0.22

Harvest Control Rule

The following harvest control rule was tested using projections based on the MCMC parameters draws for the stock assessment model. 500 MCMC draws were used and each projection applied the designated HCR over 10 years. The HCR was defined as follows (Figure 7):

1. The HCR index is calculated as a moving average of the catch rate each month so:

$$I_t = ma\frac{C_t}{f_t} + (1 \quad ma)I_{t-1}$$

    where I_t = HCR index in month t, C_t = monthly catch associated with effort f_t, m = moving average parameter.

2. The maximum fishing effort of X trips/days-at-sea are set for each quarter (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Nov). Vessels may use that fishing effort as they see fit during the quarter, but the maximum effort must not be exceeded in any quarter. $X = 3*f_{max}$ which is the monthly effort set at a value consistent with MSY. Effort is calculated as the nominal days at sea plus one day (to avoid 0 day trips).

3. If I_t falls below the trigger reference point I_{trig} but above I_{lim}, the monthly effort in the second month after the index has fallen will be limited according to the following:

$$f_{t+2} = f_{max} \frac{I_t - I_{lim}}{I_{trig} - I_{lim}}$$

4. If I_t falls below the limit reference point I_{lim}, the effort in the second month after the index has fallen will be limited according to the following:

$$f_{t+2} = f_{min}$$

5. The rule will apply strictly on a monthly basis when $I_t < I_{lim}$ and vessels will not be able to carry over unused effort to the following month.

6. If no effort is applied, then a "natural" recovery rate will be applied to the HCR index of R%:

$$I_{t+1} = I_t \left(1 + {^R}/{_{100}}\right)$$

and the resulting index used in the HCR rule above.
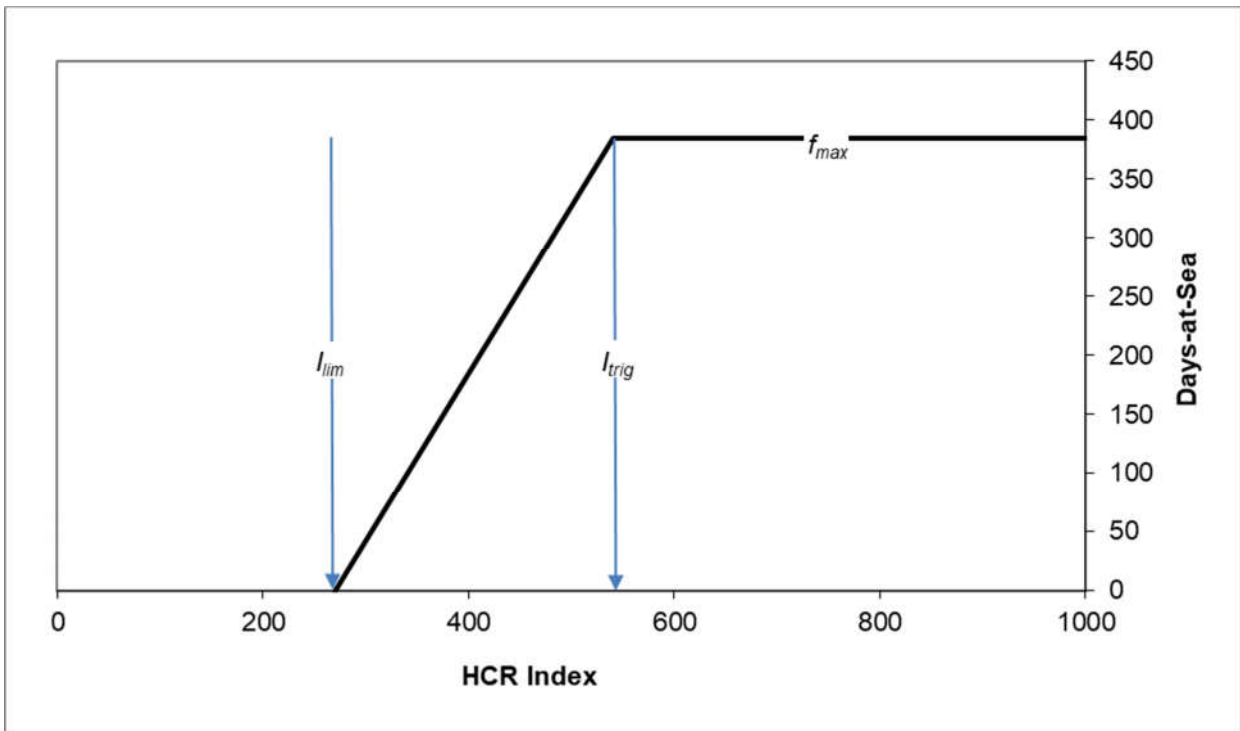
Figure 7 Diagram illustrating HCR with parameters: I_{trig} = HCR Index trigger point below which there is a reduction in the exploitation rate, I_{lim} = HCR Index limit below which effort is minimised and f_{max} = the maximum average effort spent each month, equivalent to the MSY exploitation level.

The reference points used in the default projection were based on MSY rather than the estimated status quo effort levels. For Suriname, this represented a 16% reduction in fishing effort and for Guyana a 20% increase in effort (Table 4). Other parameters were based on evaluations of the behaviour of the harvest control rule made using the available data (

Table 5). The HCR appears to be robust to choices, so reasonable values were chosen consistent with the findings.

Table 4 Possible reference points for the harvest control rule.

RP	Type	Suriname		Guyana	
		MSY	Status Quo	MSY	Status Quo
Limit	Control	0.000	0.000	0.000	0.000
Limit	Index (I_t)	428.857	428.857	142.211	142.211
Trigger	Control	287.229	343.238	2245.940	1872.034
Trigger	Index (I_t)	686.171	686.171	227.538	227.538
Target	Control	287.229	343.238	2245.940	1872.034
Target	Index (I_t)	857.714	857.714	284.423	284.423

Table 5 Default HCR general parameters

HCR Parameter	Value
f_{max}	f_{MSY}
f_{min}	0
ma	0.75
R	15%
I_{trig}	$0.8\ I_{MSY}$
I_{lim}	$0.5\ I_{MSY}$

Based on the stock assessment and HCR parameters for the HCR described above, the results for both fisheries indicate that the its performance is reasonable with low probability (<5%) of the stock being below 50% SSB_{MSY}. Catches are measured here as a relative loss of opportunity, so for Suriname around 14% of months catches are less than 50% of the MSY level compared to 8% for Guyana.

As part of the HCR performance is how often it makes mistakes. Type I errors occur when the HCR should reduce effort but doesn't (stock is overfished but his is not detected) and Type II errors are where the HCR reduces effort when it shouldn't (stock is not overfished but index says it is). Type I errors are generally considered worse. The HCR performance in both fisheries is good in this respect (Table 7) with <2% probability that there will be no reduction in fishing effort despite a reduction in effort being advised because the stock has fallen below the limit reference point. Note that this would include errors of delay, for example the stock falls just below 50% MSY, but the index only moves below the trigger point a month later.

It should be emphasized that these are model based estimates consistent with the data, but there will still be significantly more uncertainty in the real fishery.

Although the stock assessment used only Heiploeg / Noble House processor data for the catch and effort time series, the HCR will be based on all processor data combined as gathered by Government. The catch-effort patterns are the same between the 2 time series. The stock assessment only used those processors because of their additional trip information.

Table 6 Default HCR performance using MSY reference points in MCMC stock projections compared to MSY reference points. The performance is measured as the proportion of projected months with values relative to MSY target levels. For example, 0.008 (0.8%) of projected months for Suriname were below 50% of SSB_{MSY}. (SSB = spawning stock biomass, B = total biomass, exB = exploitable biomass (selectivity*biomass), C = catch, F = fishing mortality, Index = HCR index calculated as above).
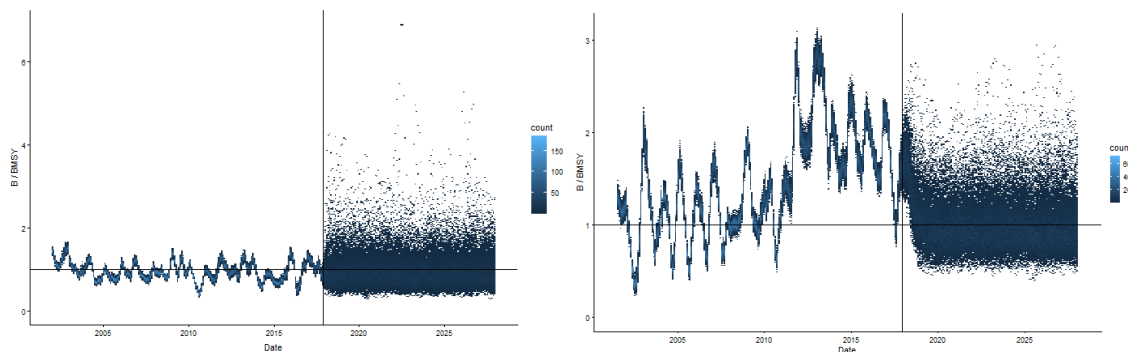
Suriname

Breaks	SSB_{MSY}	B_{MSY}	exB_{MSY}	C_{MSY}	F_{MSY}	$Index_{MSY}$
0.0- 0.5	0.008	0.011	0.232	0.155	0.148	0.004
0.5- 0.8	0.256	0.243	0.442	0.267	0.267	0.248
0.8- 1.0	0.282	0.273	0.165	0.171	0.175	0.292
1.0- 1.2	0.204	0.207	0.081	0.133	0.135	0.205
>1.2	0.250	0.267	0.080	0.275	0.276	0.251

Guyana

Breaks	SSB_{MSY}	B_{MSY}	exB_{MSY}	C_{MSY}	F_{MSY}	$Index_{MSY}$
0.0- 0.5	0.001	0.002	0.000	0.084	0.043	0.000
0.5- 0.8	0.195	0.177	0.182	0.272	0.266	0.166
0.8- 1.0	0.310	0.305	0.323	0.186	0.262	0.334
1.0- 1.2	0.234	0.248	0.240	0.158	0.210	0.244
>1.2	0.259	0.269	0.255	0.301	0.219	0.256

Table 7 Risk decision table based on default HCR projections, with decision based on index (I_t) and state of nature (SSB relative to limit, trigger or target). Type I errors are red, Type II errors are blue.

Response	Suriname B<Limit	B<Trigger	B=Target	Guyana B<Limit	B<Trigger	B=Target
I_t<Limit	0.001	0.010	**0.006**	0.000	0.000	**0.000**
I_t<Trigger	0.013	0.052	**0.077**	0.000	0.056	**0.005**
I_t=Target	**0.007**	**0.092**	0.663	**0.015**	**0.073**	0.851

Figure 8 Stock status for Suriname (left) and Guyana (right) based on MCMC results and default HCR projections after the vertical line.

Recommendations

- The stock assessment model and HCR are heavily dependent on measures of fishing effort. New data are available from VMS to evaluate this. This evaluation should be carried out with a matter of urgency.

- Combine data for 2018 to generate complete trip information.

- An important part of the assessment is estimation of selectivity and catchability. More information on selectivity and catchability would be useful to better determine how to represent changes in the time series. Although flexible, the cubic spline currently used is inherently unstable. Preliminary attempts to change selectivity failed to obtain a fit, suggesting that parameters will be difficult to estimate if selectivity is modelled in this form. Although there may be some justification for changing selectivity with a changing inner line and introduction of BRD, it is not strongly supported by residual patterns. This would need more time and resources to explore properly.

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