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Report of Meeting of CRFM Continental Shelf Fisheries Working Group (CRFM-CSWG) on Atlantic Seabob, *Xiphopenaeus kroyeri*, fisheries of Guyana and Suriname

CRFM Secretariat, Belize
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LIST OF ACRONYMS AND ABBREVIATIONS

BRD	Bycatch Reduction Device
CCTV	Closed-Circuit Television
CPUE	Catch-Per-Unit-Effort
CRFM	Caribbean Regional Fisheries Mechanism
CSWG	Continental Shelf Fisheries Working Group
DAS	Days-At-Sea
ETP	Endangered, Threatened and Protected
FAO	Food and Agriculture Organization of the United Nations
FMP	Fisheries Management Plan
HCR	Harvest Control Rule
JABBA	Just Another Bayesian Biomass Assessment
LRP	Limit Reference Point
MCMC	Markov Chain Monte Carlo
MPD	Maximum Posterior Density
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield
NGO	Non-Governmental Organization
PDF	Probability Density Function
SMART	Specific, Measurable, Attainable, Realistic & Timely
SSB	Spawning Stock Biomass
SWG	Seabob Working Group
TED	Turtle Excluder Device
TOR	Terms of Reference
VMS	Vessel Monitoring System
WWF	World Wildlife Fund

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INTRODUCTION

Suriname's Atlantic seabob trawl fishery acquired MSC certification on 8 November 2011, with annual audits occurring and a re-assessment of the fishery in 2016. At present, the MSC certification has been extended until 9 January 2022 for Suriname's Atlantic seabob trawl fishery. The supporting public certification report noted two binding conditions and two non-binding recommendations for attention by the fishery and its managers. The two conditions identified included the need to show: that there are well defined and effective harvest control rules in place, and; that there is effective and timely review of the fishery-specific management system (Southall *et al*., 2017)[1].

In comparison, Guyana's Atlantic seabob trawl fishery acquired MSC certification on 6 August 2019 for the first time; the certificate is expected to be valid for a 5-year period and expires on 5 August 2024. The supporting public certification report listed six binding conditions and four non-binding recommendations for attention by the fishery and its managers. Among the conditions that would need compulsory attention included: appropriate review of the stock assessment; provision of updated evidence of compliance since the latest changes to the fisheries regulations, and; a holistic review of overall fishery performance (Southall *et al*., 2019)[2].

In seeking to address the conditions of MSC certification pertaining to assessment review, HCR review, fishery management performance review and regulation compliance review, the governments of Suriname and Guyana requested CRFM to convene a meeting of the CRFM CSWG in 2019 with the following aims: to provide a critical review of the 2019 scientific assessments of the Atlantic seabob fisheries of Suriname and Guyana, proposed Harvest Control Rules, and the related fisheries management plans, taking into account compliance and conditions requirements of the assigned Marine Stewardship Council certifications for the two fisheries concerned. To complete its agenda of work, the CRFM CSWG meeting was convened in three sessions as follows: Session 1 – Face-to-Face meeting held in Guyana, 20-22 August 2019; Session 2 – Electronic Meeting, 24 September 2019; and Session 3 – Electronic Meeting, 27 September 2019.

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[1] *Southall, T., Blythe-Skyme, R. and Tremblay, J. 2017. MSC Sustainable Fisheries Certification Suriname Atlantic Seabob Shrimp: Public Certification Report. 169p*

[2] *Southall, T., Addison, J., and Keus, B. 2019. Marine Stewardship Council Assessment Guyana Seabob Fishery: Public Certification Report. 192 p.*

SESSION ONE

Face-to-Face Meeting in Guyana, 20-22 August 2019.

1. OPENING

The meeting was called to order at 9:00 a.m. and the Chairperson, Dr. Susan Singh-Renton, Deputy Executive Director, CRFM Secretariat, made a few opening remarks on the meeting and its importance to the two countries. The general objective of the meeting was to review and validate the most recent scientific assessments of the Atlantic Seabob fisheries of Guyana and Suriname, proposed harvest control rules, and the related fisheries management plans, taking into account compliance with Marine Stewardship Council certification requirements.

The participants included members from the Seabob Working Groups of both Suriname and Guyana, government officials, industry personnel and NGO (WWF) representatives from both countries, as well as fisheries technical staff from Jamaica, St. Vincent and the Grenadines, and the CRFM Secretariat. Dr. Paul Medley, who served as the stock assessment scientist, was also in attendance. The list of participants is given at Appendix 1.

The list of meeting documents and the Terms of Reference for the meeting were reviewed and agreed upon (List of meeting documents and the meeting TORs are given in Appendices 2 and 3 respectively). The Meeting Agenda was reviewed and the following timing and approaches to addressing agenda items were agreed.

i. Item 2 Review completed Scientific Assessments of Atlantic Seabob Fisheries for Guyana and Suriname - would remain open throughout the meeting.
ii. Item 2 (d) Harvest Control Rule - would be presented on the last day before items 4 and 5.
iii. Item 3 Review of national fisheries management plans for Atlantic Seabob fisheries of Guyana and Suriname - would be done on Wednesday.
iv. Item 4 Next steps - as revisions to the assessment were expected to be finalized after the face to face meeting, CRFM would convene an e-meeting of the CSWG to conclude this item.
v. Item 5 Any other business -would include discussion of environmental considerations in relation to seabob and associated fisheries, and of key research gaps.

The adopted agenda is given at Appendix 4.

2. REVIEW COMPLETED SCIENTIFIC ASSESSMENTS OF ATLANTIC SEABOB FISHERIES OF GUYANA AND SURINAME

The stock assessment work progress was presented by Dr. Medley.

Overview of the assessment approach

The stock assessment used an integrated assessment that utilized all available information in a single model to estimate the past stock dynamics and current status for seabob within the separate national boundaries of Suriname and Guyana. For the purposes of the present assessment, the CSWG has recommended to keep the assumption of separate stocks for Suriname and Guyana. The assumption of separate stocks will be kept under review and re-examined when results become available following the completion of doctoral research work on the population genetics of both stocks that was currently being undertaken by a PhD candidate from Ghent University, Belgium. The assessment consisted of a population model that described the dynamics, an observation model that calculated what would be the expected observed values of total catch, catch and effort and size composition derived from the population model and a likelihood model that linked the observation model to the data. The stock assessment was applied to both Guyana and Suriname fisheries with the same priors and model structure, but independent data. This allowed direct comparison between the assessments and should be informative on differences, if any, between the fisheries. The stock assessment was fully implemented in a Bayesian MCMC using Stan (mc-stan.org). Growth was modeled using a size transition matrix, which avoided maintaining the population in age categories and the excessive smoothing that occurred in converting weight to age or *vice versa*. A full summary of the changes made to the 2013 assessment approach is given in the assessment method summary report, the final version of which is given in Annex 1 to this report.

Explanation of fishery data inputs, sources and data application

The data used for the assessment included total catch which was collected monthly by the governments from all processing plants. The whitebelly shrimp, which was part of the catch and which formed part of the 'broken' category in the catches, or the small sized seabob, was estimated and removed from the catch. Catch and effort data were used from spreadsheet forms used by Noble House Seafoods (Guyana) and Heiploeg Suriname (Suriname) to record landings and processing operations. It was found that number of trips was a better indicator of a trip's catch than days-at-sea. Days at sea may not measure trawling effort well, since it included other activities, such as travelling to the fishing ground and search for the shrimp. A standardization method also used in 2013 was used to define effort and this resulted in a better relationship between landings (catch) and effort, but the measurement of fishing effort remained unsatisfactory.

Explanation of use of the commercial size category

The processing facilities routinely collected average count data from the commercial categories. This was used to monitor the average size within each category. This information should be useful in theory within the stock assessment model to fit to changes in mean size within the category if such changes were significant. One processing facility in each country provided average counts recorded by the quality control staff.

It was pointed out that the change of shrimp size in the population and changes in selectivity caused not only changes in the landings recorded as change in the amounts of each commercial category, but could also cause changes of size within categories over time. A simple analysis of variance (Medley 2013)[3], estimating the average count data dependent on the Year term as a factor, suggested that Year had a significant effect on within-category size in the stock assessment (see Table 1 of the stock assessment method summary report – Annex 1 to this report). This would indicate that average count data should be included in some form in the stock assessment model to account for such changes over time.

Explanation of use of data on sex and maturity

A significant improvement in the model fit, compared to the 2013 assessment, was achieved by modelling not only maturity, but sex allocation as applied in the random sampling. The basis for this was that immature males were easily confused with immature females as external parts may not have been present (e.g. lost through damage or not yet formed through a moult). The maturity model was therefore included in the stock assessment model and data were provided in three categories: immature females, mature females and males.

[3] *Medley, P. A. H. 2013. Seabob Stock Assessment. MS Submitted to Seabob Working Group / CRFM.*

There was now a considerable data set linking female size (tail weight in grams) to maturity (presence of a "green vein") in females. This allowed the maturity ogive to be estimated, which could be used to estimate spawning stock biomass within the stock assessment model. For the 2013 assessment, this was done externally to the stock assessment model. It was now done within the model because it was found that the size composition data could be best explained if some (estimated) proportion of immature females were actually males. In this context, maturity also increased the correct sex identification and so there was a need for maturity to be estimated within the model.

Explanation of the use of tail weight: random samples
The random samples needed to be converted from unpeeled tail weight to processed tail weight for use in the assessment. The tail weights were multiplied by 0.78 to adjust for peeling based on morphometric data collected in 2007 (CRFM 2009[4], Table 5 p.115). Unpeeled tails were measured on electronic scales to within 0.01 of a gram. Within the database, these were held as whole numbers (integers) and compiled into 0.2g class frequencies. These data were provided in the three sex and maturity categories described above.

However, for Suriname in 2015 the accurate scales failed and scales measuring to the nearest gram were used instead. This degraded the precision of the measurements considerably. These data were still used, but treated differently in the model.

Explanation of the population model
The model was based on a standard forward-projection design, but applied a transition matrix for growth. Therefore, rather than modelling age explicitly, animals were modelled based on their size. Standard models (e.g. Stock Synthesis III) were not used so that, among other things, the assessment was able to use the growth model with the weight data and grading information correctly. Age data were not available.

Where possible, the observations and model were kept distinct. So the model was adjusted to fit a sufficient data set, but processing the data to produce estimates that might be treated as observations was avoided where possible. In some cases, exact fits were obtained because there were enough parameters to allow the model to closely follow the data. This applied to the total catch. For other data, where observation errors were presumed to be significant, the model may not have fitted the observations closely, and some error was acceptable. Monthly catches, growth, sex and maturity and recruitment were used in the model.

CSWG evaluation

Data Evaluation and method evaluation, including evaluation of base case scenario

Review and discussions
The CSWG noted the use of the integrated assessment model, and accepted that it offered the advantage of simultaneous fitting of information from various sources, and in this way, the impact of each information source could be tracked more easily. The CSWG also noted that this feature also made the model more complex. Notwithstanding, in view of the additional data collected in recent years to improve

[4] *CRFM 2009. CRFM Fishery Report - 2009. Volume 1. Report of Fifth Annual Scientific Meeting – Kingstown, St. Vincent and the Grenadines, 09-18 June 2009. 167p.*

the assessments, the CSWG accepted that the integrated assessment approach afforded a good opportunity to make use of all available, suitable data.

In terms of data inputs and parameter choices for the assessment model, the CSWG was requested to consider and validate suitable choices of parameters and data inputs that would underpin the formulation of a suitable base case assessment and HCR.

The following evaluation was conducted to develop a suitable base case model. It included: (i) an initial set of discussions to inform additional tests and checks of performance of data and parameter choices, and; (ii) subsequent discussions to reconfirm interpretations and expectations, to validate data and parameter choices for the base case assessment, and to agree a suitable formulation and application approach for the HCR.

The set of sensitivity runs requested and completed are presented in Table 1.

Table 1 Sensitivity runs applied to both Suriname and Guyana stock assessments.

	Sensitivity
1	Fixed parameters: M=0.2, K=0.15
2	Fixed parameters: M=0.2, K=0.25
3	Fixed parameters: M=0.1, K=0.20
4	Fixed parameters: M=0.3, K=0.20
5	Include estimates of artisanal catch
6	Force fit to average count data
7	Use nominal days-at-sea (DAS) instead of standardized DAS
8	Remove smallest size grade

Choice of K

The CSWG recalled that a value of K=0.20 was used for the previous assessment, and the choice was based on data from available studies. For the present assessment, this choice of parameter in the transition matrix would tend to model a higher K equivalent for the von Bertallanffy model. For this reason, a value of K=0.15 seemed appropriate, which would yield a K value between 1 and 1.5 for the year. This value would therefore be consistent with the literature, and also accommodate for use of the transition matrix.

Following review of the revised model runs, and noting that a K=0.2 would be slightly more precautionary, the CSWG agreed to use K = 0.2 for the base case scenario for the present assessment. The CSWG also recommended that K would be kept under review, to take into account the latest research information.

Choice of M/ maturity ogive

The CSWG noted that the choice of M affected the outputs considerably, as the assessment model was fairly sensitive to changes in M. It was also agreed to test the performance of using an independent maturity ogive.

Following consideration of the outputs of the additional tests, there was a query about the choice of M, relative to K. It was pointed out that M was usually higher than K (now estimated at ~1.5). The CSWG was informed about Brazilian research studies, which had estimated a much smaller M, but there was uncertainty about the quality of the studies. The CSWG considered the importance of ensuring coherence of stock parameter combination choices as well. Clarification was sought and obtained regarding whether the model was accounting for gender-specific growth, which it was, but only in estimating separate L_∞.

Further discussions centred on the information from the other studies and the maturity ogives developed from these. Based on the quality of sampling, the CSWG agreed to use the information provided in the study by Castilho *et al*, (2015)[5]. The CSWG also recommended that local scientific sampling should be done to inform development of a suitable maturity ogive and to determine if the 'Castilho' ogive remained applicable. Similarly, the value of M would also be kept under review in the immediate future.

Fitting of average counts data

CSWG considered the challenges in using average counts (fitted as mean weights) data, and the consistency of the sizing/ grading procedures used by the processing plants which is modelled, and the random sampling data. The CSWG reviewed the treatment of immature shrimp in the random sampling. While there was unexplained patterning in the random sampling residuals, probably due to misidentified females and males, this problem has very much reduced since 2013. These data also appear to conflict with the average counts data. During the initial evaluation discussion, the meeting could not reach consensus on a concrete decision about force fitting the average counts into the model for a better fit, but it was agreed to conduct some sensitivity runs to see if a better fit could be obtained.

Following the sensitivity analyses, there remained an issue in obtaining a good fit for the smallest category of average counts data. The CSWG recommended that there be further examination of this category, as it likely contained also broken pieces of larger shrimp, and perhaps also significant white belly shrimp. As a result, the CSWG agreed not to force the fitting of the average counts data in the model. In addition, the CSWG also recommended that the smallest size category should be excluded from the assessment.

Analysis of CPUE as an index of abundance, its suitability for HCR, and of factors affecting the effort measure (DAS)

Regarding the choice of CPUE, there were concerns about the patterns observed in the residuals. For this, the CSWG gave attention to factors that affect the effort measure, so there could be common agreement on treatment of effort data for preparing the CPUE series. For instance, there was some discussion about what other activities at sea could be involved, which were not related to fishing for seabob and which could affect trip length. Deeper understanding of trip activities would be expected to improve catch rate standardization.

The CSWG noted that Sargassum had become a widespread and recurring feature, and the meeting agreed that the likely impact of Sargassum on the measure of effort should not be ignored. As no data could be made available for the 2019 assessment, the CSWG identified some potential sources of data on Sargassum occurrence to be considered in the future.

In addition, the importance of documenting management actions, and dates of implementation was noted, as this too, could be very useful in explaining changes in CPUE patterns. Similarly, in respect of gear changes, the CSWG recalled that bycatch reduction devices had been introduced and also changes had been made in the design of these devices. The CSWG noted the importance of recording the information on these changes, as they would need to be taken into account for improving CPUE standardization.

[5] *Castilho, A. L. et al. 2015. Lifespan and Reproductive Dynamics of the Commercially Important Sea Bob Shrimp Xiphopenaeus kroyeri (Penaeoidea): Synthesis of a 5-Year Study. Journal of Crustacean Biology, 35(1), 30-40, 2015*

Concerning VMS data, the CSWG considered their use and agreed that it was worth examining these data to identify if there had been changes over time in the fishing areas used. Dr. Medley undertook to run some tests to see how such data would affect the catch and effort data and its application.

Following these tests, the CSWG observed that the standardized days-at-sea (DAS) effort measure gave a better fit, with more noise removed. However, there was no direct evidence that trips were longer because the boats were fishing longer as well, and this posed a disadvantage to use of the standardized effort measure. There was some discussion about use of camera and VMS data to help answer questions about variability of fishing time by trip, but this could not be taken further for the present assessment.

The CSWG then turned its attention to the influence on the HCR and effort controls, and noted the need for the choice of effort was related to fishing mortality. It was agreed to re-examine the performance of both measures.

Inclusion of artisanal catch data
The CSWG sought clarification on the omission of artisanal catches in the stock assessment. Dr. Medley explained that he intended to do a sensitivity run using the data but did not think it would make a difference as the level of artisanal catch was small. While the artisanal catch was incomplete for Suriname, annual artisanal catch data were available for Guyana. Guyana's representatives in the meeting, on request by Suriname, agreed to share their protocol for the collection of artisanal seabob catch data.

Following the sensitivity runs that confirmed that the artisanal catches did not have a great impact, the CSWG concluded that these data could be excluded for the present assessment because they were incomplete and not recorded at an appropriate scale and precision for the assessment method. However, the CSWG recommended that the countries consider options for improving data collection on artisanal catches, to ensure that these catches were being adequately monitored.

Estimating whitebelly shrimp levels in seabob catch
It was noted that whitebelly shrimp was excluded from the assessment and this was queried. Dr. Medley clarified that the catches of whitebelly were less that 2% of the total catch even though it had increased over the years. The landings had been adjusted to reflect white belly in the smallest broken category. This bycatch may still be treated as wider ecological implications even if accounted for in the catch statistics.

Additional tests with data inputs and parameter choices
Based on the conclusions and recommendations regarding data inputs and parameter choices, it was agreed that Dr. Medley would work on the various scenarios for the base case assessment using additional data provided by the two countries, and would also conduct the agreed sensitivity analyses, along with advancing work on the harvest control rules for the two fisheries. In terms of the additional data supplied by the group, Dr. Willems supplied some maturity data, while Guyana Fisheries Department provided artisanal catch data and VMS data. The CSWG also requested checks on selectivity differences between Guyana and Suriname, paying particular attention to the variation(s) with turtle excluder devices (TEDs). It was agreed that a table would be developed, to provide information on what was introduced and when, to produce a time series.

Stock Status
This was considered during Sessions two and three.

Harvest Control Rule Evaluation
The HCR was presented for both countries and the CSWG noted that work was still to be done to finalize the revised HCR. There were several issues requiring consideration and guidance from the CSWG.
Development of the HCR needed to consider the following:

- Whether it should be based on monthly calculation of CPUE
- Use reference points based on MSY
- Effort measure
- A limit on effort in each month based on *previous* month CPUE index
- *Previous* should include a delay to process data
- LRP at which point the fishery would close
- Closed seasons defined
- Status quo effort defined

There was discussion about the time interval to be used in the HCR, as it was important to take into account its practical application. The CSWG considered the need to test the HCR using both a quarterly and monthly index. A concern raised by both countries was that the limit reference point (LRP) had too long a reactionary time, and it was suggested that a three (3) months reactionary time be set instead of 12 months. This would mean controls would be set over shorter intervals more in line with the population dynamics response time.

Regarding the effort measure to use (DAS versus trips), and the process of effort control and closure (stepwise reduction, versus continuous reduction), the CSWG noted that partial trips could be an issue for implementation. The point was also made that the national seabob working groups each needed to set up a protocol for HCR application. In this regard, there was consideration of the capacity required to do the calculations for the HCR, as well as the capacity for the fishing companies to submit the data at the required frequency and on time. The meeting was advised about introduction of an automated system if possible. Suriname representatives confirmed that other fisheries management measures require weekly submission of data. Hence the monthly interval could work.

Guyana confirmed that it would continue with its closed season for 6-8 weeks. Suriname confirmed that it did not have a closed season. The CSWG asked Dr. Medley to explore more HCR options, taking into account the inputs so far, and to have them ready for presentation to the proposed e-meeting. The final, agreed HCR is given in Annex 1 to this report.

3. REVIEW OF NATIONAL FISHERIES MANAGEMENT PLANS FOR ATLANTIC SEABOB FISHERIES OF GUYANA AND SURINAME

The Chairperson gave a brief review of the first day's session. She then referred to the Terms of Reference and noted those items that had been completed and those for which work was ongoing. Day 2 would address the term of reference 6: Review, amend and finalize national fisheries management plans for the Atlantic Seabob Fisheries for Guyana and Suriname, taking into account MSC certification requirements. The Chairperson then drew the Meeting's attention to the Agenda and reminded the meeting that item 2 remained open and would be completed on Day 3. The Chairperson then indicated that the day's session would focus on Agenda Item 3, which would commence with presentations of the FMPs by Guyana and Suriname. This would be followed by discussions on the presentations, including discussions on how the principles of the MSC certification were being addressed in the fisheries management plans. After this, the meeting would break into 2 groups – one focused on review of Guyana's FMP, and the second group focused on Suriname's FMP. Each group would review the plan, and address the gaps and other issues raised in the discussions. Each Group would therefore identify the steps required to finalize each plan. If time permitted, the groups would make a second presentation on their discussions, conclusions and recommendations.

Presentation of National Fisheries Management Plan for Seabob Fishery of Suriname

The FMP for Suriname was presented by Ms. Yolanda Babb-Echteld.

The presentation included information on policy and legislation (Sea Fishery Act 2001, Fishery Regulations & Ministerial Ordinances; and MSC Regulations (2011-2022); description of the fishery (number of companies, number and types, and sizes of vessels, fishing zones, management measures, target species, landed by-catch and discards); fishery management planning and decision-making process; fishery monitoring arrangements; research support; control and surveillance; stock assessments; and review and evaluation.

Presentation of National Fisheries Management Plan for Seabob Fishery of Guyana

The Draft management plan for the Guyana seabob fishery was presented by Mr. Randy Bumbury.

The topics covered in the FMP were similar to those included in the Suriname FMP, specifically, description of the fishery, policy and legislation (Fishery Act 2002, Maritime Boundaries Act 2010, Fisheries (Marine) Regulations 2018, Guyana FMP 2013-2020, Guyana Seabob FMP 2015-2020, Captain's Code of Conduct); fishery management and decision-making process (management plan evaluation and update, FAC, Review, Ministerial approval, implementation and monitoring); management objectives (there were 11 fishery specific objectives for the seabob fishery); fishery monitoring; Seabob stock assessment; research support; control and surveillance; and review and evaluation.

CSWG Evaluation

Following presentations of the FMPs, several fisheries management issues were raised and discussed. There was some discussion about the need to include mention of the 'move on' rule for encountering ETP species, and how such activities should be recorded in practice. In terms of research, the meeting acknowledged that biological studies were needed, and use of students could be a cost-effective way of having the necessary research done. Moreover, training in identification of ETP species was needed for accurate by-catch monitoring and reporting, and this should be reflected in the FMPs. Ms. Babb pointed out that the ETP issues were already reflected in Suriname's FMP.

Concerning the management strategy, it was important for the strategy to include key uncertainties and governance arrangements to counter these uncertainties. The CSWG considered that the FMPs should also include clear long-term goals and objectives, and there should also be operational objectives that should include specific targets.

In this regard, there should be a clear path outlined for achieving the MSC standard. This should inform development of time-bound implementation schedules, which were also supported by budgets. Additionally, the CSWG highlighted the need for inclusion of a section to deal with reporting on implementation of each FMP. In respect of the section on research support, the assistance provided by specific projects should be mentioned. This would also help to keep donor-supported activities focused on agreed management objectives. There were also some discussions about reporting responsibilities of the seabob working group in each country and the CSWG agreed that these should be reflected when the FMPs were revised.

Concerning other issues and how they should be reflected in the FMPs, a query arose about use of cameras, and whether these were compulsory and their real purpose. Technical representatives from Guyana confirmed that the CCTV cameras were compulsory for the Guyana fishery. It was also pointed out that where cameras had been installed, these were used to monitor tampering with the BRDs, especially as random at sea inspections found vessels not using their TEDs. It was also proposed that the cameras could be used to monitor other malicious activities and monitoring catches. In contrast, private sector industry representatives in Guyana noted that there had been issues with piracy, and that this was the real reason for the installation of the cameras. The initiative proved successful, and the industry proposed that the national fisheries authority in Guyana encourage the widespread use of cameras. These points inspired further debate about the usefulness and relevance of camera and VMS data for monitoring illegal fishing practices, e.g. incursions into the artisanal fishing zones, and removal of TEDs.

Following these general exchanges for informing relevance of issues for inclusion in the FMPs, the Chairperson then gave participants the following specific steps to guide the working group sessions in their review of the FMPs.

1) Each FMP should be re-organized/re-worded to include not only general long term goals and objectives, but also more specific objectives that were measurable for easier accountability through time.
2) As the 2 fisheries were MSC-certified, it was important to review MSC Standard that included 3 principles, and associated performance indicators.
3) Each group should identify which section of the FMP addressed each principle and associated performance indicators.
4) Each group should identify the gaps in addressing the MSC Standard, including where these may relate to lack of specification of procedures, roles and responsibilities, and were not reflected in the implementation schedule.
5) Each group should ensure that the implementation schedule included information on: task/ section; agency responsible; partner projects; time period of implementation.

The participants then divided up into 2 working groups (Suriname group & Guyana group) to examine and discuss the FMPs and revision needs in accordance with the guidelines provided.

FMP working group reports

Main recommendations identified by Guyana group on Guyana's FMP

1) The group agreed that the specific objectives noted were vague, and needed to be more strongly aligned with the MSC standard.
2) The FMP also needed to reflect better management efforts directed at non-target species. In this regard, there was recognition of a data-limited situation that would have to be addressed, while a precautionary approach had to be reflected in the FMP in the meantime.
3) A section would be included to explain the MSC standard in a summarized manner, and would include the conditions and needs that were identified during the MSC assessment process to be part of the 5-year plan. In addition, consideration would be given to including a linkage table in the FMP, which would provide a guide that linked key MSC aspects to FMP areas of focus.
4) In terms of major outstanding gaps, the implementation schedule did not have all the essential elements required, e.g. procedures, roles, etc. Other gaps identified for further attention included: climate change and development of an adequate research plan.
5) The group acknowledged the need for annual reports to be done, as this was a suitable medium for providing regular measurements of FMP performance.

Main recommendations identified by Suriname group on Suriname's FMP

1) The group noted the need to convert its FMP objectives to 'SMART' objectives. Additionally, the objectives needed to be re-organized with the objectives placed into different categories or specific objectives (ecological, biological, social and economic): biological – e.g. to maintain Seabob stock at maximum sustainable yield (MSY) level; economical – e.g. to increase maximum economic yield consistent with the biological target (MSY); ecological – e.g. maintain the environment with international standard, and; social – e.g. reduce environmental impact of the Seabob fisheries (sustainable fisheries).

2) The FMP would be further reviewed in depth, taking into account the MSC Standard, and to address outstanding gaps.
3) The research and development section would be expanded to ensure that the key gaps, in relation to the MSC Standard, were included.
4) A separate implementation schedule would need to be prepared, which would include setting targets and timelines for satisfying stipulated MSC recommendations and conditions for fishery certification.
5) A budget would be indicated and included to support FMP implementation.
6) The group identified labour, climate change, and linkages with oil and gas industry management as key omissions that would have to be addressed in preparing the revised FMP.

<u>The following general points were added following the group presentations</u>

1) Stock assessment needed governance/policy support for application of precautionary measures and such arrangements should be included in the plans.
2) Included in the management plans should be references to the various pieces of supporting legislation that the plans were based upon along with the regional and international agreements.
3) Consider a section in the plans for environmental health.
4) Budgets should be developed for both FMPs.

<u>Deadlines for completion of FMP revisions</u>

The Suriname working group indicated that it would work to prepare a revised FMP draft by September 2019. The Guyana working group indicated that it would work to prepare a revised FMP draft by December 2019.

4. NEXT STEPS

Based on the decisions taken under items 2 and 3, the CSWG agreed that the reviews would be finalized after the assessments were revised. This would therefore require the CSWG to convene an e-meeting to do so.

The e-meeting was tentatively scheduled to be held on 25 September 2019.

5. ANY OTHER BUSINESS

The point was raised that seabob did not exist in isolation, and so it was important to consider other forms of fishery evaluation, such as ecological modelling and multispecies, multigear analyses. This had the advantage of bringing management attention to other species and fisheries. In response, the meeting noted that data could be gathered to facilitate same, e.g. a multispecies yield per recruit could be done. Data for the same time period covered by the integrated assessment was desirable to minimize variation due to other factors.

Mapping of the seabed was also highlighted for attention in the future, as well as Sargassum and climate change. The WWF representative from Suriname provided information on a marine spatial habitat mapping activity that was providing inputs to inform development of a marine spatial plan. The activity involved development of a base map, which was then shared with local communities, who populated the map with their local knowledge of the area and the fisheries. Training was also to be provided as part of the planned tasks.

In concluding this agenda item, the meeting agreed that all the points raised were valid. It was timely to introduce these additional elements to the current assessment and management work on the seabob fisheries.

6. ADJOURNMENT

In closing, the meeting acknowledged the strong role of CRFM in providing technical and chairing support for leading the review discussions. Participants concluded that the meeting had been successful, and agreed that the CSWG should strive to convene meetings annually.

The Chairperson thanked all participants for their contributions, and for the opportunity for the CRFM CSWG to support the stock assessment peer review process required for the Guyana and Suriname seabob fisheries.

SESSION TWO

Electronic Meeting, 24 September 2019

2. REVIEW COMPLETED SCIENTIFIC ASSESSMENTS OF ATLANTIC SEABOB FISHERIES OF GUYANA AND SURINAME (cont'd)

Evaluation of revised assessments and HCR

The Chairperson, Dr. Singh-Renton, welcomed all to the second session and noted that this session was being convened at Dr. Medley's request so that he could share information in relation to the documents he had submitted for the CSWG's review.

Dr. Medley advised the meeting that he had shared 6 html documents (from RMarkdown notebooks) and 2 word documents with the CSWG, and was working on the preparation of a third word document, which would be the summary of the results. The html documents contained the detailed analyses used in the stock assessments and the HCR evaluations. The Word documents were written summaries of the information contained in the html files. Dr. Medley then briefly indicated what was contained in the two word documents. The first was the *Guyana/Suriname Seabob Assessment: Method Summary* which gave an overview of the methodology used in the assessments. Dr. Medley indicated that the document had been updated to include a flow diagram and to take into account other comments received from CSWG members. The assessment method was similar for both Guyana's and Suriname's fisheries; the configuration of the model was the same, but the fitted parameters differed as they were fitted to different data.

Explanation of revised HCR

Dr. Medley referred to the *Guyana/Suriname Seabob Assessment: HCR Summary* and gave a verbal presentation on it. In his presentation, Dr. Medley drew the Meeting's attention to the HCR that he had tested and pointed to the HCR definition and urged that it be read carefully so as to understand what was defined in the projections in the model (what had been tested). Dr. Medley added that the HCR was defined almost as an algorithm in terms of what was done month by month - a quarterly average amount of effort which was applied under normal circumstances, set around the MSY definition available from the stock assessment; additionally a rule was triggered which reduced this effort if the stock fell below an agreed trigger point based on the index. The moving average index being applied on a monthly basis was the same that was applied yearly. Dr. Medley noted that there were two points for consideration: (i) was the HCR as defined acceptable to the fishery, the government and stakeholders; and (ii) was it possible to implement the HCR as written based upon how the data collection system worked and how the control would work? If not, what changes needed to be made?

The reference point definitions were drawn from the stock assessments. In the case of Guyana the status quo seemed to be that the stock was being exploited slightly below the MSY point; while for Suriname the stock appeared to be exploited on average slightly above the MSY point. In terms of projections, a 16% reduction in effort was suggested for Suriname and a 20% increase in effort for Guyana. Dr. Medley noted that these were not recommendations in terms of the change, but pointed out that if the stock status for Suriname was accepted then it suggested that some reduction in effort would be necessary. Dr. Medley said that if other measures, such as a one-month closed season was desirable, that could also be projected to determine if it would meet the desired objective. In the HCR definition, parameters that controlled what happened under different circumstances must be applied. For example, as well as deciding where the trigger point was and when action should be taken, the index required a moving average parameter that controlled how quickly it updated based upon new data. If there was a closed period when there was no fishing, then a parameter that decided how the index would change as a result of that would be needed. Dr. Medley suggested that in reviewing the document CSWG members look at all the parameters, including the ones that had been chosen, and decide if there were other parameters that could be used and under what circumstances. Dr. Medley noted that there was a little change to the previous parameters used in annual HCR but there was justification for these changes and some tests had been run on how to choose what those parameters were. Dr. Medley said that he had run this against only one HCR (base case HCR) and there were two tables for measuring the performance of the HCR. The first table (#5) was related to measures of biomass, catch, and fishing mortality and the index for Suriname and Guyana; and the relationship where those indicators lie in relation to MSY. The breaks used in the table were 0.0-0.05; 0.05-0.8; 0.8-1.0 (1.0 represents at MSY); 1.0-1.2; and >1.2. Dr. Medley then explained how to interpret the results presented in Table 5. Using the SSB_{MSY} index, Dr. Medley explained the results as follows: For values between:

- 0.8-1.2 - fluctuating around MSY;
- 0.5-0.8 - trigger point; action needed to reduce effort;
- 0.0-0.5 - spawning stock biomass below the limit reference point; assumptive action to rebuild stock required.

Dr. Medley pointed out that the table included values for SSB_{MSY} (spawning stock biomass); B_{MSY} (total biomass); exB_{MSY} (exploitable biomass, which was biomass times selectivity – most related to catch rates); C_{MSY} (catch at MSY – performance in terms of the catch being taken); F_{MSY} (fishing mortality at MSY); and the index. The ideal in all cases would be 1.00 (i.e. between 0.8 – 1.2).

The other measure of performance was how often the HCR got it right versus how often it got it wrong. Two types of errors that the HCR could make were noted. These were (i) no response (e.g. stock overfished, but no response triggered) shown in red in Table 6; and (ii) some response (e.g. the index indicated the stock was at a low level when it was not) shown in Table 6 in blue. Error (ii) occurs on this HCR hardly ever. The issue of note was the *no response* error, particularly when B< the limit and the Index was at the target or above. In all cases, occurrence of (i) *no response* was low. The default HCR appeared to be achieving its objective in that respect. These two performance measures would be used for any other HCR that the CSWG proposed.

CSWG Evaluation

Suriname requested further explanations regarding the figures in red in Table 6. In his response, Dr. Medley noted that tables 5 and 6 were different. Table 5 showed the status of the stock (what was really happening in the fishery); while Table 6 showed the difference between what was thought to be happening in the fishery and what was actually happening. The response was related to the index, as shown in the table rows as follows: row 1– index<limit; row 2 – index<trigger; row 3 – index= target. The columns (state of nature) represented what was really occurring. The red figure in the left-most column represented when the biomass was really below the limit reference point (less than the point of recruitment impairment) but the index did not show this. Hence the HCR was in error because it was not signaling the need for a response when in reality a response was needed. However, this error occurred in the projections very rarely; less than 1 percent. When biomass was less than the trigger, the error was greater (22%) for example, the biomass fell, but the index, due to errors and use of a moving average, was delayed in reflecting this. Dr. Medley referred to risk assessment tables used at FAO meetings, which were introduced by Juan Carlos Seijo, and noted that these tables were very similar to those. These risk tables of what might happen, how to respond, and whether the response was successful were actually a good measure of whether the HCR was working.

The Chairperson observed that based on Dr. Medley’s explanation there was a lag because of the use of the moving average, which appeared to correct itself as there was a much lower probability of the biomass falling below the limit point, and queried if this was a correct interpretation. Dr. Medley concurred with the Chairperson's assessment and said that ideally all the red and blue cells would have 0.00 results indicating that the HCR was working perfectly. However the index was not perfect; some error was observed when the biomass was below the trigger, but it was expected that the index would improve over time and the stock would not fall below the limit before there was some response. In fact, the stock very rarely went below the limit point. Dr. Medley noted that this was probably so, not only because of the index, which for these 10-year projections was based around the MCMC draws for the parameters, but because the effort levels, which were related to fishing mortality, were about right.

Guyana requested a clarification in Table 3, regarding the projected 16% decrease in effort for Suriname and 20% increase in effort for Guyana. In his response, Dr. Medley explained that he had simulated only one HCR. In order to do the projections, an effort level was required; the options were MSY effort level estimated from the stock assessment or status quo (no change in the effort level used previously). The MSY effort level was used for the HCR simulation and the projections were as shown in the table. Dr. Medley pointed out that the countries would need to consider what effort level should be used in the simulations, based on what would be applied in the fisheries. He noted further that what had been presented was only a computer simulation, but it was still evidence that these controls in theory could work and could be used as justification for choices which would be applied to the fisheries.

Further to Guyana's request, the Chairperson noted the projected 16% reduction in effort for Suriname and queried if this was indicative that current effort was 16% above MSY levels. Dr. Medley said that the results from the stock assessment suggested that effort level in Suriname was slightly above MSY.

Dr. Medley said the that the intent behind this e-meeting was really to give a broad idea of what was in the documents so that they could be reviewed for further discussion on Friday. He suggested that the documents be studied and other questions/comments could be communicated to him via email or raised on Friday. Also, in preparation for the discussions on Friday, consideration should be given to the HCR that could possibly be applied to the fisheries and the principles by which to run the simulations to show that it was or wasn't sustainable.

Guyana made reference to and sought clarification on the following sentence "Catches are measured here as a relative loss of opportunity, so for Suriname around 14% of monthly catches are less than 50% of the MSY level compared to 8% for Guyana." In his response Dr. Medley said the sentence was referring to Table 5, which was concerned with the status of stock or the spawning stock biomass. Also of importance was the catch (C_{MSY}), which should be maintained as close as possible to MSY. Under this HCR (base case HCR) the catches were less that 50% of the MSY level around 14% of the time. This implied that sometimes catches on average were much lower than expected for the MSY level. While it was not possible to have all catches at MSY level since MSY was a fixed number and the catches fluctuated, it was important to get as many of the catches as close to MSY as possible so as to derive maximum economic and social benefit from the resource. Smaller catches would keep more resources in the sea and bolster the sustainability of the stock, but would represent a loss of opportunity in terms of catches.

The Chairperson also referred to Table 5 and specifically to the C_{MSY} and SSB_{MSY} figures in the *'desirable'* bracket (0.8-1.2) where all the indicators would be in the vicinity of MSY. The Chairperson queried if, compared to other similar assessments, this level of performance was typical. In his response, Dr. Medley said that the nearest equivalent was probably the stock assessments done for tunas that produced the Kobe plots, which examined percentage charts of the stock going forward being at or around MSY, but catch was set as part of the projection. In HCRs that he had run, effort was projected and catch was a free variable. Following some further explanation, Dr. Medley said that the HCR summary allowed for comparison between two fisheries but not between two HCRs and indicated that he would attempt to run some other HCRs before Session 3, so that the CSWG can see the comparison between the two tables.

Explanation of assessment of stock status

Dr. Medley referred to the six html files he had shared with the group, which contained the details of the assessments, and advised that there were three files per country. Dr. Medley then proceeded to give some of the highlights of the base case stock assessment that was done. He noted that according to the base case assessment the SSB/MSY results showed that for Guyana the stock was fluctuating above MSY; while for Suriname the stock was fluctuating at or slightly below MSY, which suggested that the exploitation level in Suriname was a little high; hence there may be some argument for being precautionary and reducing effort slightly. Dr. Medley added that in comparing the results for Guyana and Suriname a key difference was selectivity and suggested that this be discussed further during Session 3.

Dr. Medley then drew the meeting's attention to the HCR parameters shown in Table 4 and noted that these were the parameters used to run the base case HCR. Some modeling was undertaken to look at developing the reference points based around the MSY and calculating what a good moving average parameter would be, based upon the simulated biomass. A moving average parameter between 0.5 - 1.0 was a reasonable choice. The same code and almost the same text was run for Guyana data and the Suriname data, as there was no evidence for a different HCR in the two fisheries. Apart from MSY, which was different, the standard HCR, the moving average, the recovery rate parameter, and the Fmax and Fmin used to test the HCR were similar between the two fisheries.

CSWG Evaluation

Suriname made reference to the difference in selectivity when comparing the results from Guyana and Suriname and queried this. Dr. Medley explained that there were a few differences: one was that there was evidence of more seasonality in recruitment and spawning stock biomass. He then drew attention to the selectivity graphs and noted that Guyana's selectivity was classic logistic selectivity as evidenced by an S-shaped curve that increased up to a plateau. Suriname's selectivity was dome shaped; it was much more uncertain with much wider variation in the selectivity. Dr. Medley noted that the difference in selectivity was significant between the fisheries, but was uncertain as to the reason for this, and suggested that further research to determine the cause may be warranted. Dr. Medley remarked that there were differences between the fisheries, likely environmental differences that were becoming more apparent as the assessments were run. Dr. Medley emphasized that because of this uncertainty, stock assessment results should not be treated as ultimate truths, as assessments were based on models.

The Chairperson noted that in testing the HCR performance, the MSY level of effort was used and queried if the level of effort was something that must be decided on during Session 3. Dr. Medley explained that measures or controls to be put in place would be decided on by the managers; and suggested that what could be done in Session 3 was for the countries to indicate the set of scenarios on the HCR to run the simulations on. Based on Dr. Medley's response, the Chairperson urged the countries to think about the possible scenarios, so as to provide Dr. Medley with further guidance on the simulations to be run, with the view to covering as many scenarios as possible. The Chairperson also urged the CSWG to study all the documents so as to be prepared for Session 3. Dr. Medley indicated that he would complete the Results Summary for the base case HCR agreed on at the face-to-face meeting and share with the group before Session 3. He would also present the Results Summary in Session 3 so that the CSWG could sign off on it and then it could be included as an appendix to the Review Report. In terms of preparations for Session 3, Dr. Medley said that he would probably run another HCR so that the CSWG could see how the comparisons worked. He reiterated that countries should sketch out all the scenarios for the HCR they wish to have run which would help them in making the final decision. With regard the scenarios, the Chairperson queried if this was related to the levels of effort. Dr. Medley said it could be the level of effort or any other of the HCR parameters, and noted that the level of effort to be set was critical and countries may want to do some calculations based on the licenses, activity of vessels, number of fishing days, etc. Dr. Medley also pointed out that there should be some discussion about the practicality of the HCR implementation, how it would be controlled, who would control it, how it would be enforced, how would the measurements be reported, can they be run on 2-month delays, or would 3-month delays be preferred, etc. The Chairperson reminded about the proposed quarterly turnover and noted that when it was proposed there had been no objections, but if there were objections, these should be indicated.

Guyana made reference to a suggestion at the face-to-face meeting to have other assessors involved in the online review, and queried if these assessors had been informed and if any would be involved in Session 3. The Chairperson said her understanding was that national and regional levels of review were being used at present and once the assessment was completed and signed off on, then an independent person could be provided with all the reports, including those prepared and submitted by Dr. Medley, so that the independent reviewer could do the critique. Dr. Medley concurred with the Chairperson and added that the independent reviewer he had identified was not available; but that he would support a peer review if another person could be identified. The Chairperson said that the CRFM would facilitate an independent peer review if the CSWG considered it necessary.

Suriname reminded the Meeting that the idea was to carry the review to the next level in CRFM, i.e. review at a scientific meeting. An independent review was not required for MSC certification; what was needed was to have the HCR in place by January 2020.

There being no further interventions, the Chairperson thanked Dr. Medley for the explanations provided and thanked those persons who took the time out to participate in the session and urged participants to study the documents and come prepared for Session 3. The Chairperson also briefly summarized what should be done in preparation for the next session as follows:

- Dr. Medley would complete the summaries for the base case, so that CSWG could sign off on the assessment report in Session 3.
- The CSWG would also need to agree on the HCR; Dr. Medley will look at another possible HCR scenario.
- CSWG would consider the practicality of implementing the HCR; if any challenges and in particular the proposed quarterly time scale.
- What levels of effort could be considered for the fishery; level that was practically acceptable.
- Consider some recommendations/next steps.

SESSION THREE

Electronic Meeting, 27 September 2019

2. REVIEW COMPLETED SCIENTIFIC ASSESSMENTS OF ATLANTIC SEABOB FISHERIES OF GUYANA AND SURINAME (cont'd)

Evaluation of Revised Assessments and HCR (continued)

Explanation of assessment results, stock status, and sensitivity analyses (continued)

Dr. Medley drew the meeting's attention to the Results Summary and gave a verbal presentation of it. The Results Summary is given in Annex 1 to this report. In his presentation Dr. Medley went through the various graphs and tables and provided explanations for the results. Most of the explanations, particularly regarding the HCR general parameters, the status of the stock, selectivity, and the testing of the HCR performance (risk assessment) have already been captured in detail in the report of Session 2.

Regarding the spawning stock biomass by month there was some evidence of seasonality in both recruitment and spawning stock biomass, which was expected based on changes in rainfall and river outflows, which influenced productivity and hence population size. Recruitment relative to unexploited recruitment showed a slight decrease in both fisheries. Actual recruitment in the unexploited fishery was uncertain as it was dependent on a stock-recruitment relationship that was estimated. Fishing mortality appeared to be generally low in Guyana and for Suriname it decreased between 2012 and 2016 and then increased a little for 2016-2017. Overall the stocks in both countries seemed to be in a good state – around the MSY level, with Suriname biomass a little under and Guyana slightly over the MSY level. Generally, the exploitation patterns were quite good and the fisheries overall appeared to be achieving their objectives.

For the sensitivity analysis, Dr. Medley said that all the sensitivities were re-done, so that they were worked from the base case decided (Session 2), but there was little difference to the outcomes. Both fisheries were insensitive to the choice of the growth parameter, which was fixed. For natural mortality there was a big change, but 0.2 used for the base case was considered to be reasonable. Consideration of artisanal catch, use of nominal days at sea, and removal of the smallest size grade made little difference to the stock status determination. The same sensitivities were applied for both Suriname and Guyana, with similar results. Dr. Medley noted that he had also included a short section on the justification for the choice of 0.2 for natural mortality and gave a brief explanation of this section. Dr. Medley remarked that the primary results in terms of the fisheries going forward would be the HCR, as the stock assessments results were 2-years old (based on 2017 data), and stock status changed month by month; the assessment was primarily to look at the performance and whether the harvest strategy was working. In concluding Dr. Medley said that overall the harvest strategy was working for these fisheries.

CSWG evaluation of assessment, sensitivity tests and stock status, and decision

Suriname expressed some concern that the Suriname stock could be below MSY, while the Guyana stock was above and noted that this result was counter-intuitive to what industry personnel perceived. Catch rates in Suriname were substantially higher than in Guyana although the gears were the same. There was uncertainty regarding how to deal with this result concerning the HCR and moving forward. Dr. Medley in his response noted that the result was unexpected but it was what was given when the model was fitted to the data. The model was fitted independently except that the priors and model structure were the same; the data were different. If there was a problem it was likely to be the data and its interpretation. Dr. Medley said that one of the differences was the dome-shaped selectivity for Suriname, which implied that the spawning stock got more protection from the fishery and that would push the stocks in the opposite direction to the way they were estimated in the model. The Suriname recruitment was a lot lower hence the model would indicate that productivity in the Suriname stock was less. The catch rate was much higher in Suriname than in Guyana, giving the perception that the stock was in a better state, but this could be explained by the fact that there was a higher density of seabob in a smaller area. The size composition data did not support the idea that Suriname was less exploited than Guyana seabob. Dr. Medley suggested that some research may be warranted to get a better understanding of the pattern being seen; it could be just an error with how the data were collected, although the data sources were the same and size compositions were the same, so it was difficult to envision such errors. Dr. Medley added that further work in this regard may prove that subjective perception was incorrect and objective data collection was correct. Also, the data provided no evidence that there was unexploited resource in Suriname as opposed to Guyana.

Guyana queried if using a higher CPUE would have made a difference to the results. Dr. Medley said he was not sure as, due to time constraints, he had not been able to explore all avenues in this stock assessment. Some additional data were available and it was possible to generate a new CPUE series, but there had already been some discussion about the interpretation of catch and effort and the uncertainty regarding whether CPUE was operating as a good abundance index. A better understanding of the catch rate data, as well as any other data to be used to generate CPUE was needed.

Guyana noted that the assessment was up to 2017, and queried whether assessments should be done more regularly. Dr. Medley indicated that now that this assessment had been set up, it should be fairly easy to update it. He noted that the HCR was designed to reduce the need for complex stock assessments, as it would run around the CPUE and this would keep the stock safe. Dr. Medley reiterated the need to look more closely at catch and effort and to determine a better way to deal with that data. Dr. Medley also suggested that future assessment not be done so remotely; they should be conducted more locally so that stakeholders could be more involved and have a better understanding of the how and why, and produce more outputs that could be of use to them. Doing assessments annually was too often. Generally they were done every 5 years, but could also be done every two or three years.

The CSWG agreed and approved the stock assessment and stock status results as presented.

Explanation of Harvest Control Rule performance tests

Dr. Medley drew the Meeting’s attention to the Harvest Control Rule Evaluation (Annex 1) and gave a verbal presentation of it. Dr. Medley explained that testing the HCR included simulating/ testing its application as though it was being applied in the fishery during the projections. The projections came out of the stock assessment and the MCMC draw for the parameters and included the uncertainty in recruitment and the uncertainty in the CPUE. It should be borne in mind that in the projections it was assumed the model structure was correct, e.g. the CPUE was genuinely tracking abundance. Dr. Medley said that the key information outputs for the HCR were the performance table (stock status) and the risk table, which he went through again, explaining the various rows and columns. Most of the explanations, particularly regarding the stock status and the testing of the HCR performance (risk assessment) have already been captured in detail in Session 2. Dr. Medley noted that the base case HCR was fairly robust and the choice of reference of points was not too critical as the stock would not likely fall below the limit point. In theory, and assuming the model was accurate, a small reduction in effort would not cause the catches to decline.

CSWG Evaluation and decision

Clarification was sought as to whether effort should be decreased in Suriname or not as earlier explanations suggested it was not worth decreasing effort and then later on it was indicated that a small reduction in effort would not affect catches. By way of response, Dr. Medley said that the definition of MSY means that if fishing mortality on average was set to F_{MSY} then yield would be maximized; and conversely if fishing mortality was above MSY then yield from the fishery would be lower. The result from the stock assessment showed that the Suriname yield was a little lower, and if it was assumed that the model was correct then a slight reduction (16%) in effort would address this. Dr. Medley however noted the uncertainty with this and made reference to the Guyana fishery where the recruitment pattern was not consistent through the time series. The pattern indicated changes in the recruitment and the most recent recruitment was quite high and there was no reason to assume that this had not occurred in Suriname as well. As the modeling was only an approximation of what was occurring, Dr. Medley said that he was concerned about asking for changes in the fishery for which there was weak evidence, as these could be onerous. He suggested that the focus should be on making sure the system was robust and as long as it was possible to reduce effort even when catch rates fell below the optimum that should be enough to keep the stock round about the MSY level. Dr. Medley remarked that when the HCR was implemented it might be that it would trigger rebuilding more often in Suriname than in Guyana. It was noted that in this context, "rebuilding" was formulated as a much more rapid response compared to a slow growing species. Within the HCR, this was a precautionary management response to maintain catch rates at higher average levels, rather than rebuilding in the MSC sense.

Based on Dr. Medley's response it was further queried if it would not be more practical to work with a slightly lower effort and so avoid frequent triggers for which responses/actions would be required, possibly as frequently as every quarter in keeping with the suggested quarterly monitoring process. Dr. Medley pointed out that if the status quo level of effort was maintained, rebuilding would be triggered about 20% of the time; if effort was reduced by 16%, then the frequency of the triggers would drop by about 5%. The other option could be to maintain status quo effort; implement the HCR; monitor the outcome and make adjustments as necessary.

Following some further discussions, there was general agreement with the proposal to implement the HCR using the status quo effort level. There was also agreement to monitor how the HCR performed and revisit the performance, perhaps in a year.

Reference was made to the HCR parameters and a query was raised as to whether an explanation of the HCR parameters would be included in the text. In his response Dr. Medley indicated that Table 3 of the Seabob Stock Assessment: HCR Summary contained the reference points and the control points used in the HCR both for the MSY and status quo points for Suriname and Guyana. Table 4 showed the specific parameters related to both how the HCR worked and the projection summary. The critical ones were the **ma** (moving average calculation) and **R** (the default rule applied when there was no fishing in the month). Both the F_{MSY} and the I_{MSY} were calculated from Table 3 depending on which option was selected – MSY or status quo. Assuming the two options – MSY and status quo – MSY was more precautionary for Suriname and less precautionary for Guyana; while status quo was less precautionary for Suriname and more precautionary for Guyana. In view of the lower stock status level observed for Suriname, the HCR was designed to use MSY as the target reference point.

Clarification was sought on what was the 'moving average'. In his response Dr. Medley drew the meeting's attention to HCR definition and particularly paragraph 1 which dealt with this. Dr. Medley then provided further explanations for the various steps of the HCR. He said that the index was based around the moving average parameter of 0.75. The index was calculated as the moving average (0.75) times the catch over the effort in the month (re-calculated every month), plus 0.25 (1-.75) plus the previous index calculation, thus developing a time series of the index, which varied month by month. Paragraph 2 defines how fishing effort was limited; there was limit on fishing within each quarter in the HCR to allow more flexibility. Within the quarter a maximum number of trips or maximum number of days at sea was applied. However, actual effort must be measured in each month and this measure included in the calculation of the index on a monthly basis. If the index fell below its trigger point in the quarter, then the control was applied monthly. The reduction in effort would be proportionate to the fall in the index. If the index fell below the limit reference point, fishing stopped for a month.

Reference was made to X which represented trips/days at sea for each quarter, and a query was raised as to whether different scenarios in terms of numbers, based on what occurred in the past, would be proposed. By way of response Dr. Medley referred to Table 3, [Column 2: Type; Row 4: Control] and said that the Control was the standardized days at sea, which could be converted to trips or nominal days at sea by multiplying by a constant. Dr. Medley suggested that whatever was easier to use, whether number of trips or nominal days at sea, since effort data was not fully understood and it was counter-productive to use what was difficult to calculate and understand.

A request was made for Dr. Medley to develop a spreadsheet that could be used as a tool by the Ministry to calculate catch and effort and the HCR rule to see how much the effort needed to be reduced over the next month. Dr. Medley indicated that if a formal request was made that he could develop the spreadsheet. He noted that such a spreadsheet had been developed for annual HCR and this could possibly be adapted for the month. Following some further discussion it was agreed that Suriname would draft the spreadsheet and Dr. Medley would review it.

Dr. Medley queried which of the measures of effort - number of trips or nominal days at sea or standardized days at sea - was considered easiest in terms of monitoring and data collection so that this could be included in the HCR. Dr. Medley indicated that he did not have a recommendation on which measure to use, but would suggest that whichever was easiest to obtain and most accurate be used, so that if the HCR was determined not to be working well, it would not be because of issues with the measure of effort used. Following some more discussion it was agreed that the measure of effort to be used in the HCR was nominal days at sea.

Table 3 was referred and a clarification sought regarding the information in the columns labeled RP and Type. Dr. Medley explained that the under the RP column the rows labeled limit, trigger and target were the reference points. The control was the effort applied at the particular reference point and the index was the index number at that reference point.

The Chairperson sought confirmation that there was agreement on the Harvest Control Rule (HCR), the choice of the parameters, and the choice of effort.

In terms of the measure of effort - nominal days at sea, some discussion ensued with regard the inclusion of the +1 and how it would be applied in the calculations. It was queried if at the national level, in keeping the data set in real time and accurate, if the calculation of the nominal days at sea would have to include the +1. Dr. Medley responded yes, the countries would need to calculate the nominal days at sea in the same format as he used in the stock assessment and the HCR. The "+1" was included to avoid trips of zero length since they were calculated as the return date minus the departure date (times were not available), so including +1 rounds up the trip length to the next day. It was then queried if an explanation about the inclusion of the +1 would be included in the report. The Chairperson said that her understanding was that there was agreement to use nominal days at sea as the measure of effort, but that how it would be applied needed further discussion and queried if this was the correct impression. This was confirmed to be so.

In summary, there was agreement on the HCR, the choice of parameters, and the choice of effort, with the understanding that there would be further discussions regarding the application of the +1 in the calculation of nominal days at sea, which was the preferred measure of effort.

4. NEXT STEPS

For future stock assessments, in order to get a more accurate measure of CPUE, logbook data should be digitalized. A standardized spreadsheet to capture the logbook data that could be used by both countries (Guyana and Suriname) could be developed and this would make it easier to use in the stock assessment. Following on this recommendation, the Chairperson referred to the stock assessment results and discussions about the catch and effort data and the catch rates, and asked Dr. Medley if he had any suggestions/recommendations on how best to improve the catch and effort data. Dr. Medley said that an opportunity to build a dataset around logbook data; VMS data, which could be used to estimate fishing effort on a daily basis; and available information on vessels that would allow for estimation of individual catchability parameter for each vessel, would facilitate a better understanding of the fisheries and provide a basis to divide up the observed variation from different potential causes. The issue that pointed to the need for standardization was the asymptotic catch regardless of trip length. There was need for detailed information on a range of trips - size composition, VMS data, total catch, days at sea (day of departure and day of return) – and if this could be built up for a few hundred trips, this should provide a detailed picture of the fisheries. Dr. Medley noted further that much of the data may already be available so it would be a case of connecting the available data; and once assembled there was no end of possibilities in terms of modeling. It would take perhaps a year to assemble this data.

The Chairperson noted that the assessment was up to 2017, and queried what years' logbook data should be digitized and who would undertake this work, as it may not be possible to rely on external sources, at least not initially. Hence, what years should be digitized, who would do this, and when. Dr. Medley pointed out that the data that went into the stock assessment was already in a database and if this was connected with VMS data, as well as the logbook data, and if available CCTV data, for a few hundred trips then this would create a good dataset. It was suggested that in terms of digitizing the data, it should be from 2017 and going forward. A query was raised with regard to the suggested number of 100 trips for which data would be entered; was 100 for each country enough? Dr. Medley explained that too large a sample would create problems in terms of updating routinely, so it would be better to use a smaller sub-set, at least initially, and include as much detailed data as possible. A joint dataset could be done for Guyana and Suriname, although the preference was for separate ones as the fisheries were different. Dr. Medley concluded by suggesting that separate datasets be developed for Guyana and Suriname with data for 100 trips for each country. Following some further discussions, it was agreed that logbook data should be digitized for 2018 and onwards.

The Chairperson referred to earlier discussions about the differences in the selectivity patterns and asked if there were any recommendations going forward concerning this; explanations of these differences appeared to be required. Dr. Medley said that it would be interesting to look at the comparison of spatial fishing patterns between Guyana and Suriname, as, assuming the size of the resource was correct, fishing in Suriname should be focused in a smaller area than in the Guyana fishery; this could be obtained from VMS data. He added that a fair amount of comparative work could be done from the VMS data, fishing time, etc., to come up with summary statistics that would facilitate these comparisons. Dr. Medley said that he did not have any strong recommendations at this time, but hopefully after examining the data he may be able to suggest some other research recommendations that would facilitate a better understanding of the fisheries.

The Chairperson queried if there were any other suggestions/recommendations in terms of data and research. The Chairperson also made reference to discussions at the face-to-face meeting in August about Sargassum and climate change and their impacts on the fisheries and what data in this regard may be available. The Chairperson said that these data were not looked at for conventional stock assessments.

However, she recommended that these impacts should be considered and evaluated, and opportunity sought to incorporate them into management decisions and planning for the fishery. There was general agreement with this.

The Chairperson then made reference to a data limited analysis completed by Mario Yspol, Suriname, and invited Mr. Yspol to give a presentation on his work. Mr. Yspol said that a data limited analysis using JABBA was done at a training workshop in Barbados in July and the results were quite different to the stock assessment results shared by Dr. Medley. In some instances the results obtained from the two assessments were opposite, e.g. the assessment done in Barbados indicated that the Suriname stock was far above MSY level and Guyana's stock was closer to the MSY, while the assessment conducted by Dr. Medley showed that Guyana's stock was above MSY and Suriname's below MSY. Mr. Yspol said he did not have a powerpoint presentation but he had uploaded the assessment, all the R-scripts, scenarios, etc., so that Dr. Medley could see what was done in Barbados. Mr. Yspol added that the results from the analysis in Barbados were more in keeping with what was experienced in the fishery.

The Chairperson thanked Mr. Yspol for his presentation and said that it was good to explore alternatives for examining stock status; it was good to have different assessments that could be compared as this would help to show where the data needed to be improved and to identify other weaknesses, and also provided assessment options to inform management decision-making. The Chairperson said this work should continue and suggested that a recommendation could be included that recognized that this alternative method was attempted and some preliminary results were available, which the CSWG could look at in greater detail in the inter-sessional period. She suggested moving forward with the two types of the analyses, which would perhaps require more coordination, but which may lead to better convergence in the next assessment.

Dr. Medley acknowledged Mr. Yspol's efforts and indicated that he hadn't been able to look at the assessment in detail, but noted that he had wanted to do what Mr. Yspol had done, but was unable to due to other work commitments. Notwithstanding, Dr. Medley was able to share the following points concerning the data limited assessment:

- The Biomass Dynamics Model used was similar to that used in the previous assessments, before the size composition data were available; it was good practice to do the same analysis again even if moving to a new assessment model.
- There was need to recognize the degree of uncertainty in the new assessment (size composition model). There had been concern about the catch and effort data in the new assessment, perhaps the data limited assessment could help to shed some light on this. However, JABBA assessment relied entirely upon on the CPUE abundance, the reliability of which was questioned in the integrated assessment.
- A Kobe plot in Suriname scenario 1 in the data limited assessment was referred, which showed a scattering of stock status with the MSY point to the left of the plotted values. If the logistic model were used then the MSY point would appear in the middle of the plotted biomass. However, the Pella & Tomlinson model used in this data limited assessment shifted the MSY point to the left to half way between zero and the unexploited state; for shrimp there was an argument that it could be shifted to the left, but this would imply MSY occurred at lower biomass levels than in the default logistic model case. For the model used in the new assessment, based upon the growth and biology of the stock, it may be possible to estimate what that shift should be, but it would probably not be as far left as shown in the Kobe plot. If these two assessments were studied in more detail, it may well be possible to get a better convergence between the two models. The integrated size structure model may be underestimating MSY point a little bit, while the data limited model may be overestimating MSY point slightly; studying the models in detail could possibly give some convergence.

- For the JABBA state space model, a critical issue was the input priors, which required very careful consideration. The priors could be calculated from the integrated model, as there was available information on growth, length to weight transition, mortality, etc., all of which could be included in this model. A main difference between the structure of the JABBA model and the integrated model was that density dependent mortality was included in adult stage, whereas in the integrated model it was only in the stock-recruitment relationship. One of the advantages of using the biomass model was that it included density dependence in the adult stage - density dependent growth, if it was occurring, was probably ignored in the integrated model, but was included in the biomass model, which would shift the MSY point to the left of where the stock was. If there was evidence of density dependent growth and mortality, this would make a big difference to the outcome of the results. However, the L_∞ estimated in the integrated model was not significantly different between Suriname and Guyana. If density dependent growth was occurring, it might have been expected that these would be different.
- In the CPUE time series used in the state space model there was no depletion, so the state space model could explain the fluctuations in CPUE quite easily as it allowed the stock to randomly change its state from month to month. However, because there was no clear depletion it made the model heavily dependent on the input priors. If initial depletion data could be included, it would potentially improve this model and possibly change some of these results.
- Undertaking the data limited analysis (biomass dynamic model) was a valuable exercise, with the potential for this model to inform the integrated model and vice versa. The biomass dynamic model did not use all the data, which was a downside but it did include some effects that could be important but were not captured in the integrated model. These could however be included in the integrated model if developed further, so that it captured some of these changes that were in the structure of the biomass dynamics model.
- Given a situation where two conflicting models were giving differing results, if the precautionary approach was applied, then the decision should be based on the more precautionary model, unless there was evidence to support a switch, for example to include density dependence. Density dependence was the critical question. The integrated models took the precautionary view that density dependence occurred before recruitment to the fishery; if it was included after recruitment then it often could lead to recommendations of high fishing mortality which were risky. It was good to do these assessments that allowed for comparisons as they could give different insights that would assist in defining the way forward.

Reference was made to work done by Seion Richardson on the Guyana Seabob Fishery and it was suggested that this could also be reviewed. It was agreed that in the inter-sessional period, efforts could be made to gather information on some of these other techniques, and to write these models up to better explain what the scenarios were, what the conclusions were, and explain some of the observed patterns. These elements could be written up in a brief report and this task should form part of the work programme for the CSWG going forward.

Recommendations

1. Logbook data for 2018 to be digitized. The digitized logbook data along with the VMS and CCTV data should assist in improving understanding of the catch rates, selectivity patterns and CPUE, as well as the spatial fishing patterns in the two countries. A Sub Working Group (P. Medley, D. Maison, R, Bumbury, T. Willems & Y. Babb-Echteld) was established to undertake the following tasks: (i) look at samples of the logbooks and develop a standardized spreadsheet for logbook data to be digitized; (ii) examine available data and develop list of trips to be included in the 2018 data set; (iii) make arrangements for digitization of the data in agreed format. The Sub Working Group will commence its work the week of 30 September 2019. VMS and CCTV data for 2018 should be transmitted to Dr. Medley.

2. The agreed HCR be implemented and performance monitored for a year then reviewed and adjustments made for practicality purposes, as necessary. Dr. Medley will prepare a first draft of a standardized spreadsheet for tracking HCR performance by 01 October 2019, and share with CSWG for review.
3. The data limited method presented should be further developed so that an alternate method of analysis would be available for comparison, which would serve to broaden understanding and appreciation of the results and possibly support better convergence of ideas and hence results.
4. Consideration to be given to the impacts of Sargassum and climate change on fisheries and how these impacts could be incorporated into management decision-making in the future.
5. Local scientific sampling should be done to inform development of a suitable maturity ogive and to determine if the ‘Castilho’ ogive (Castilho *et al*., 2015) as currently used in the stock assessment remains applicable. In this regard, the value of M should also be kept under review in the immediate future.
6. A chronological table should be developed (both for Suriname and Guyana) providing information on changes in fishing gear and/or fishing practices (e.g. introduction or changes to BRDs and TEDs) that might influence catchability and selectivity, in order to better understand the observed differences in selectivity between Suriname and Guyana.
7. Similarly, management actions should be documented (and preferably also reconstructed from the past), including dates of implementation. This could be very useful in explaining changes in CPUE patterns.
8. The exact composition of the ‘broken shrimp’ category as reported by the peeling plants should be assessed as it is currently unclear what shrimp sizes are contained within this group.
9. Dr. Medley and the CSWG acknowledged that future stock assessment efforts should preferably be done less remotely and would benefit from increased interaction and input from local stakeholders during the assessment process.

6. ADJOURNMENT

The Chairperson thanked all those who took the time to attend this session, as well as the other sessions. The Chairperson thanked Dr. Medley for the hard work he had done leading up each of the meeting sessions and noted that lot of careful thought had been put into the assessment and the development of the HCR. The Chairperson also commended the countries for their efforts, particularly in terms of the interactions and development of dialogue with the industry. The Chairperson also expressed thanks to the WWF and FAO (Tomas) for their inputs which helped to enrich the outputs, and encouraged all to continue with their efforts. The Chairperson said that there had been discussion about the CSWG meeting again in another year and, until then, the Group should keep in touch inter-sessionally. The Chairperson added that a Dgroup had been set up for the CSWG, and information could also be shared by group email, but suggested that it would be good if at intervals, there could be a sharing of material among group members.

There being no further interventions, the Chairperson once again thanked all for their attention and adjourned the meeting.

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APPENDIX 2: LIST OF MEETING DOCUMENTS

1) Meeting Information Note and TORs
2) Meeting Agenda
3) Guyana/Suriname Seabob Assessment: Method Summary
4) Guyana/Suriname Seabob Assessment: HCR Summary
5) Guyana Seabob Management Plan 2015-2020
6) Fishery Management Plan for Suriname Seabob 2010-2015

APPENDIX 3: MEETING TERMS OF REFERENCE

1) To review completed scientific assessments of the Atlantic Seabob fisheries of Guyana and Suriname;
2) To discuss and provide guidance on use and interpretation of the data used for the scientific assessments;
3) To agree and finalize a base case scenario for informing refinements of the scientific assessments and their interpretations;
4) To determine the status of Atlantic seabob fishery stocks of Suriname and Guyana;
5) To consider and agree on suitable Harvest Control Rules for the Atlantic Seabob fisheries of Guyana and Suriname, taking into account the stock assessment advice;
6) To review, amend and finalize national fisheries management plans for the Atlantic Seabob fisheries of Suriname and Guyana, taking into account requirements for sustainable and responsible fisheries management practices, including the MSC certification requirements;
7) To document the Meeting's activities and decisions, producing a report for each stock with the following headings:
    a. Executive Summary
    b. Background
    c. Data Evaluation
    d. Method Evaluation
    e. Stock Status
    f. HCR Evaluation
    g. Participants

APPENDIX 4: AGENDA

CSWG 2019-02
20-22 August 2019
DRAFT AGENDA
(9:00 a.m. – 5:00 p.m. each day)

1. Opening
2. Review completed scientific assessments of Atlantic Seabob fisheries of Guyana and Suriname
    a. Data Evaluation
    b. Method Evaluation, including evaluation of base case scenario
    c. Stock Status
    d. Harvest Control Rule (HCR) Evaluation
3. Review of national fisheries management plans for Atlantic Seabob fisheries of Guyana and Suriname
4. Next steps.
5. Any other business
    a. Environmental considerations
    b. Research needs.
6. Adjournment.

ANNEX 1: GUYANA/SURINAME ATLANTIC SEABOB STOCK ASSESSMENT REPORT

STOCK ASSESSMENT REPORT: ATLANTIC SEABOB, *XIPHOPENAEUS KROYERI,* FISHERIES OF GUYANA AND SURINAME

CONTENTS

METHOD SUMMARY

1. INTRODUCTION

The following report provides a technical summary of the seabob stock assessments for Suriname and Guyana. It does not include results, but only describes the modelling approach and methodology.

The stock assessment is an integrated assessment that uses all available information in a single model to estimate the past stock dynamics and current status for seabob within the national boundaries of Suriname and Guyana. The assessment consists of a population model that describes the dynamics, an observation model that calculates what would be the expected observed values of total catch, catch and effort and size composition derived from the population model and a likelihood model that link the observation model to the data.

All assessment work, apart from the initial data preparation to produce raw data (total catch, catch-effort and average count-per-pound by commercial size category, and the sample counts by sex/size weight bin) have been carried out in RMarkdown scripts (notebooks). All analyses are therefore fully documented and reproducible. The specific work carried out in each case is described in these documents. All results are also presented in these, not in this document.

The original data for catch effort and random size/sex sampling is held in MS Access databases. Data have been extracted from the databases using SQL queries. Total catch data was obtained from the respective governments in spreadsheets.

The model is implemented in Stan (mc-stan.org). All important model calculations were defined as functions, which could be exposed in R and tested separately. This ensured model code was testable and correct.

1.1 Summary of Changes from 2013 Stock Assessment

The stock assessment model has broadly remained the same as previously developed in ADMB (Medley 2013), with the following key changes:

- The stock assessment has been applied to both Guyana and Suriname fisheries with the same priors and model structure, but independent data. This allows direct comparison between the assessments and should be informative on differences between the fisheries.
- The stock assessment is fully implemented in a Bayesian MCMC using Stan (mc-stan.org).
- Growth is modelled using a size transition matrix, which avoids maintaining the population in age categories and the excessive smoothing that occurs in converting weight to age or *vice versa*.
- Selectivity is now modelled as a flexible spline function.
- Recruitment is modelled properly as a log-normal latent variable (“random effect”).
- Commercial size grading is modelled directly as a process using multiple normal distributions.
- Catches have been corrected for the presence of white belly shrimp.
- The random size composition now incorporates a model of allocation between mature females, males and immature males/females.
- The likelihood for the random size composition now accounts for over-dispersion by using a Dirichlet multinomial.
- The entire analysis from (almost) raw data to the final fit has been implemented in RMarkdown. This includes detailed documentation of the entire analysis. For example, the stepwise decision making in processing the data to a form suitable for the model is provided, with supporting graphs and equations in a single document. This also means that any changes made to the input

data, decisions or analysis can be rapidly incorporated and the full analysis re-run relatively easily.

2. DATA PREPARATION

2.1 Total Catch

Total landings are reported to governments by each processor. Information reported has not always been consistent, but has improved over the years. There are initiatives to improve data reporting in Guyana so that it is more timely and accurate.

Monthly landings were available from all processors back to January 2002. Before this, monthly data were not consistently available, but annual landings were reported. Landings are reported as total tail weight in pounds or kilograms by commercial size categories. Annual landings are available as gross weight to the start of the fishery. Discards are assumed to be negligible. Landings of “sour” shrimp are reported in the landings, although they would not be used.

In contrast to 2013, all catches have been corrected for the presence of white belly shrimp (*Nematopalaemon schmitti*). The average quantity of white belly was estimated from the catch sampling and removed from the smallest size category, which includes the “broken” category. Although the percentage of white belly compared to total catch is small, the white belly formed a slightly more significant proportion of the smallest shrimp with which it would be combined.

2.2 Catch and Effort

Catch and effort data were obtained from spreadsheet forms used by Noble House Seafoods and Heiploeg Suriname to record landings and processing operations. The spreadsheets are used for internal monitoring of their business. Data were extracted from these forms and held in a database for further manipulation. Using the database, it was possible to match trip information (trip dates of departure and return) with processed landings weight, fuel used, and commercial size grades produced.

The landed catch is recorded as pounds or kilos of processed shrimp, representing about 43% of the live weight. Effort might be measured in several ways, but here days-at-sea are used as this is consistently measured.

Plots of trip effort against catch reveal an asymptotic relationship with landings (Figure 1). This has been found previously (Medley 2013) and examined using generalized linear models. Alternate measures were also examined in this case, and it was found number of trips was a better indicator of catch than days-at-sea. Therefore, a logistic model was fitted to the data to adjust the raw effort and linearize the relationship within trips between catch and effort (Figure 2). This resulted in a relationship between landings (catch) and effort which was acceptable (Figure 3).

The reasons why trip length has an asymptotic relationship with landings is not clear, but it is apparent that trip length does not measure trawling effort. Clearly within a trip, time is being spent on other activities, such as travelling to the fishing ground. For more recent data, the trip activity should be cross referenced with the VMS and other information.

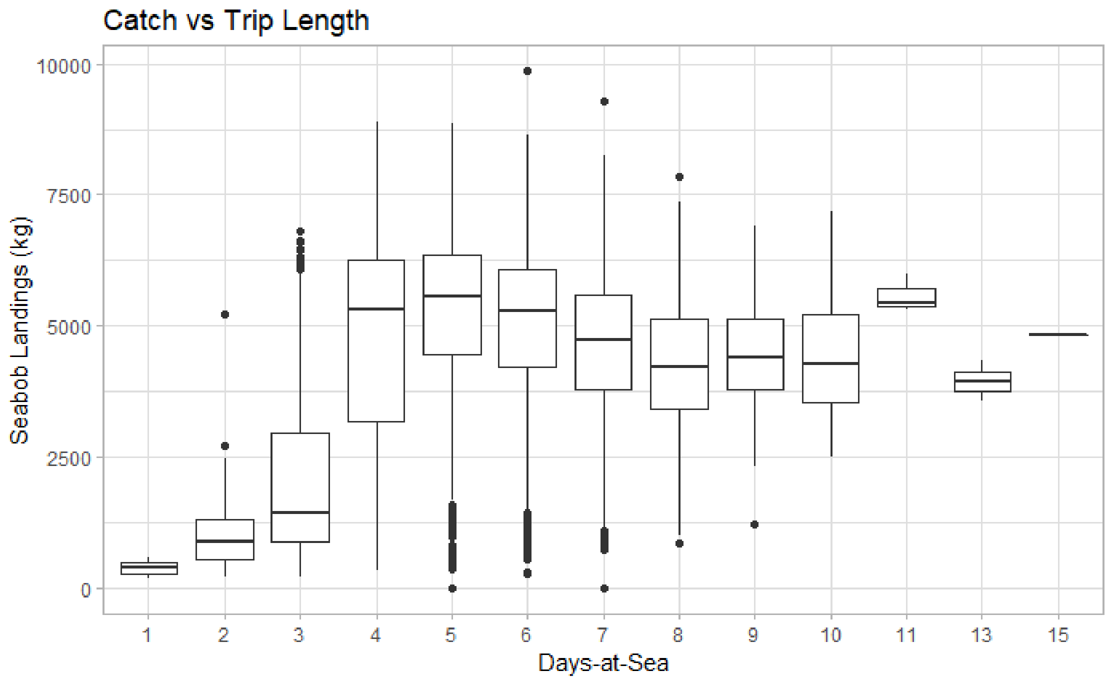


Figure 1 Box plot of landings (kg) plotted against the raw measure of effort: days-at-sea for Suriname, showing asymptotic relationship.

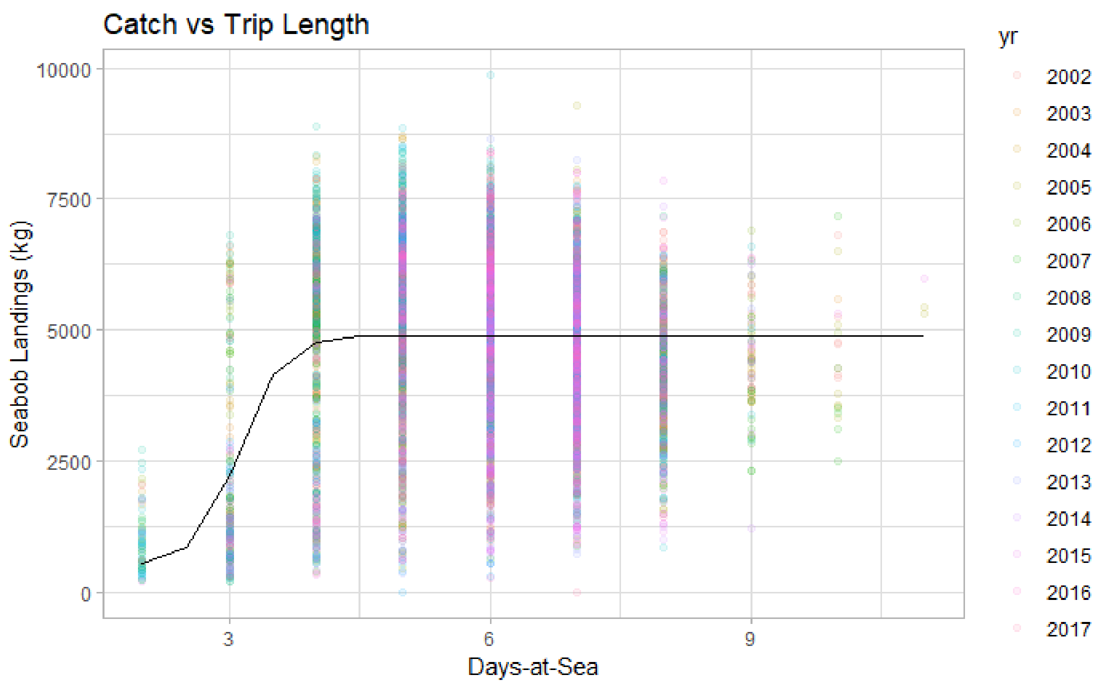


Figure 2 Landings (kg) plotted against the days-at-sea with the logistic standardisation model.

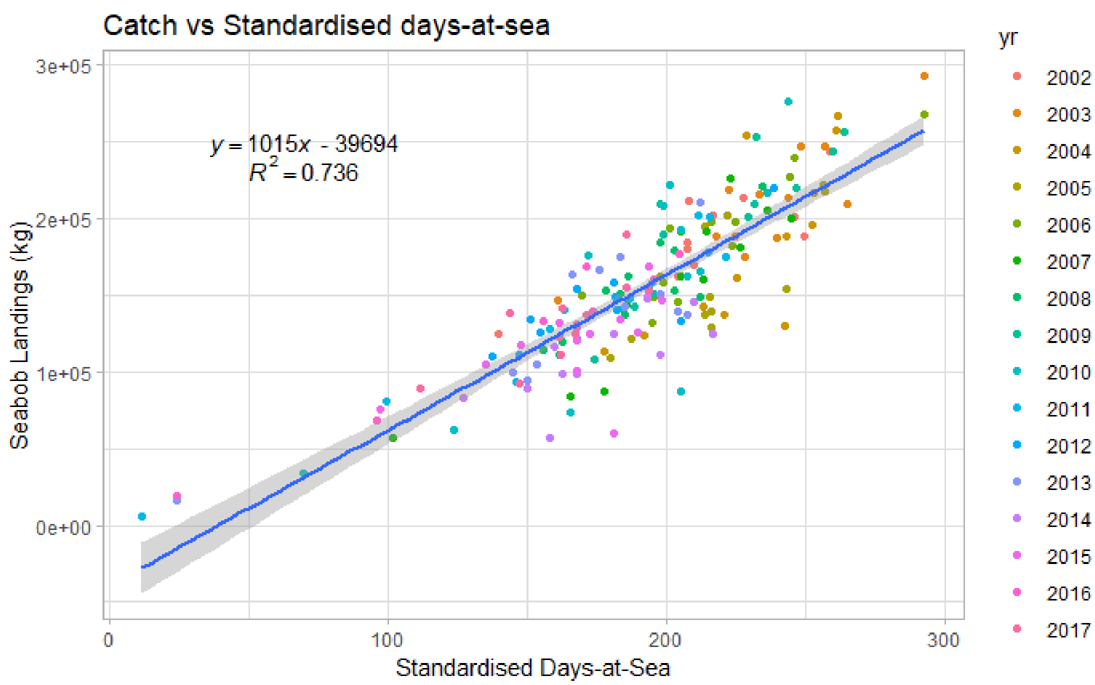


Figure 3 Landings (kg) plotted against the standardised measure of effort showing a linear relationship.

2.3 Commercial Size Category

The processing facilities routinely collect average count data from the commercial categories. This should monitor the average size within each category. This information should be useful within the stock assessment model to fit to changes in mean size within the category if such changes are significant. One processing facility provided average counts recorded by the quality control staff.

The change of shrimp size in the population and changes in selectivity will cause not only changes in the landings recorded as change in the amounts of each commercial categories, but may also change size within categories over time. A simple analysis of variance (Medley 2013) estimating the average count data dependent on the Year term as a factor suggested that Year has a significant effect on within-category size (Table 1). This would indicate that average count data should be included in some form in the stock assessment model.

Table 1 Analysis of variance for average counts in commercial category for a standard log-linear model (Medley 2013).

	Residual degrees of freedom	Residual Deviance	Degrees of freedom	Deviance	Pr(>Chi)
AvgCount ~ Category	105404	99057335			
AvgCount ~ Category + Year	105394	97897240	10	1160095	< 2.2e-16
AvgCount ~ Category * Year	105312	90699966	82	7197274	< 2.2e-16

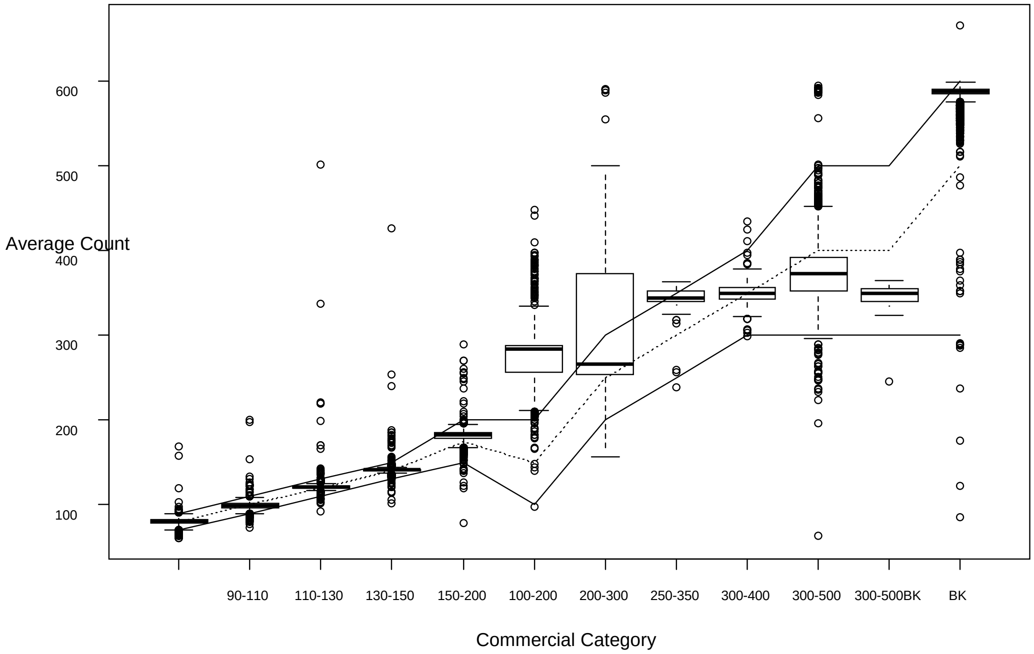


Figure 4 Box and whisker plot for average count data in commercial size categories, showing the median, 25th and 75th percentiles and 1.5 times the interquartile range for the average counts in each category. The solid lines represent the minimum and maximum count for each category (based on the name) and the dotted line is the mid-point.

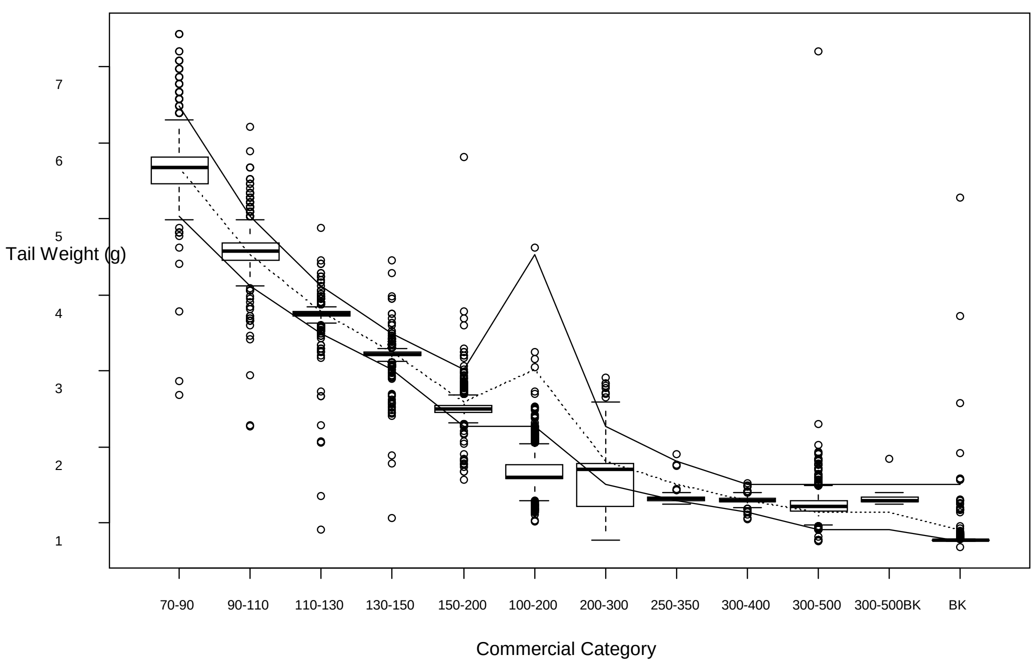


Figure 5 The same data as Figure 4 plotted as peeled tail weight. These data would be used in the stock assessment model.

In contrast to the 2013 stock assessment, a grading model was used to allocate catch size composition among grades. This avoided the need to allocate specific tail weights to commercial grades. The average count was still useful to help define parameters in the grading model.

The expected catch within each commercial size category is calculated through a sequential selection process that models as far as possible the actual grading applied in the processing facilities (Figure 6). The grading parameters are based on the target size category and adjusted to some extent to align with the average counts. The parameters (mean and standard deviation for the weight selectivity normal curve) cannot be fitted freely as they are aliased with other parameters.

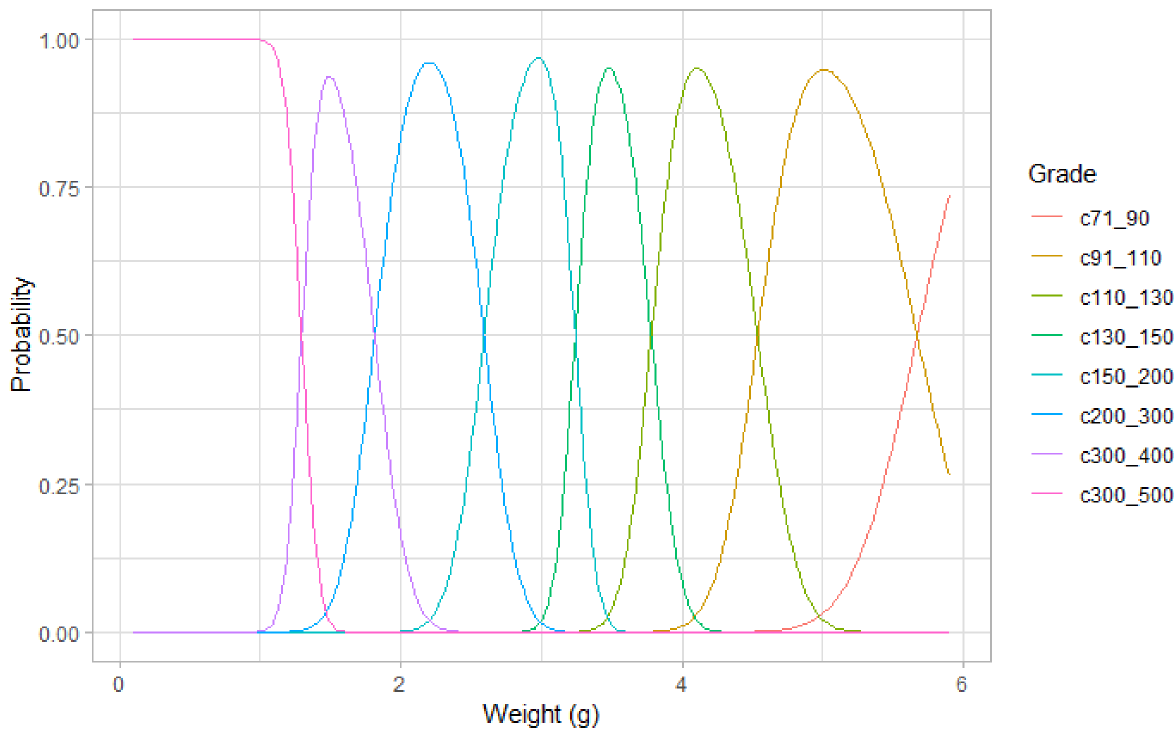


Figure 6 Estimated grading selectivity applied in processing facilities. The numbers in each grade name refer to the count range.

2.4 Sex and Maturity

A significant improvement in model fit compared to 2013 assessment was achieved by modelling not only maturity, but sex allocation as applied in the random sampling. The basis for this was that immature males are easily confused with immature females as external parts may not be present (e.g. lost through damage or not yet formed through a moult). The maturity model is therefore included in the stock assessment model and data are provided in three categories: immature males/females, mature females and males.

There is now a considerable data set linking female size (tail weight in grams) to maturity (presence of a "green vein") in females. This allows the maturity ogive to be estimated, which can be used to estimate spawning stock biomass within the stock assessment model. For the 2013 assessment, this was done externally to the stock assessment model. It is now done within it because it was found that the size composition data could be best explained if some (estimated) proportion of immature females were actually males. In this context, maturity also increased the correct sex identification so need to be estimated within the model.

When calculating the SSB, the maturity ogive, based on the “green vein” observations, were found to result in a very small proportion of females reaching maturity. This was considered probably unrealistic and reflected the method used to identify maturity. Alternative studies based on detailed observations on reproductive organs (Table 2) indicated much smaller sizes at 50% maturity compared the “green vein” data (***Figure*** Figure 7). Castilho *et al*. (2015) was chosen as a better estimate of 50% maturity based on a 3 year study and being in the middle range of the various studies. This was used to calculate spawning stock biomass for stock-recruitment, reference points and to determine relative depletion. It was not used for other purposes. The decision to use these published estimates was taken by the review meeting in 2019.

Table 2 Maturity ogive logistic parameter based on other studies on seabob.

CL 50% mm	Reference
13.2	Almeida et al., 2012
24.0	Campos et al., 2009
15.5	Castilho et al, 2015

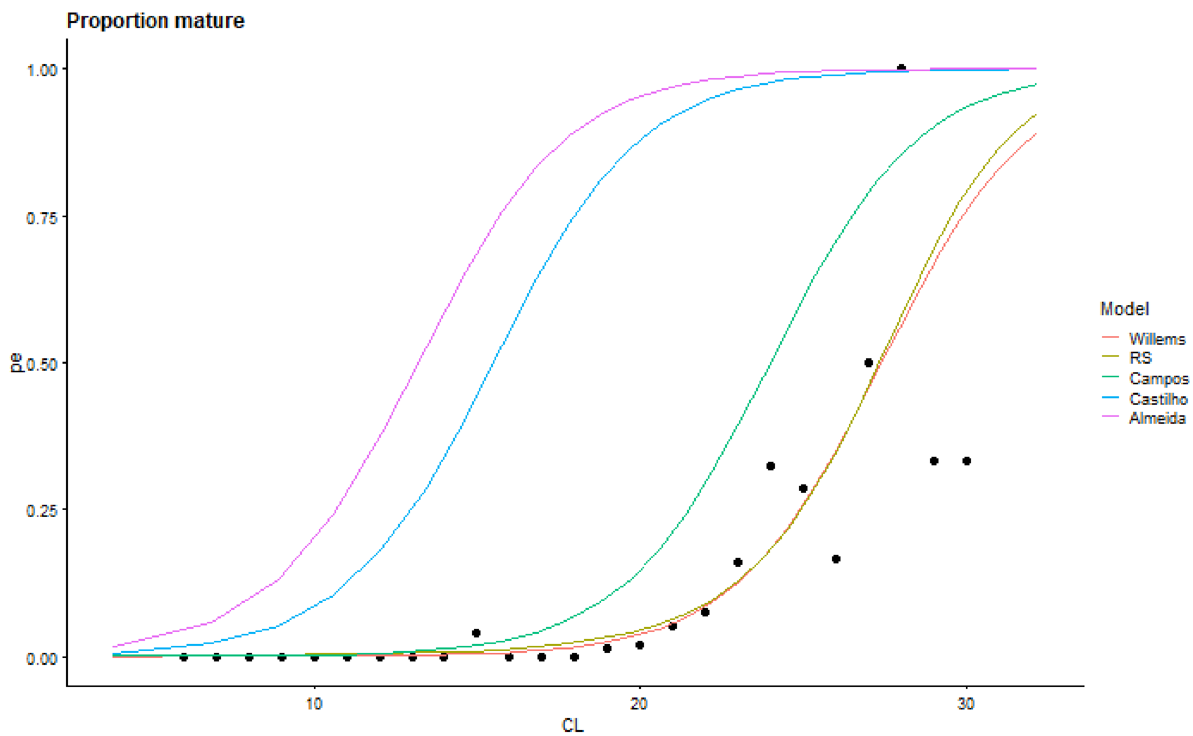


Figure 7 Alternative maturity models based on carapace length (mm). Willems and RS were based on “green vein” observations in Suriname and Guyana. Campos, Castillo and Almeida were published maturity studies from elsewhere on seabob (Table 2).

<u>2.5 Tail Weight: Random Samples</u>

The random samples needed to be converted from unpeeled tail weight to processed tail weight to be used in the assessment. The tail weights were multiplied by 0.78 to adjust for peeling based on morphometric data collected in 2007 (CRFM 2009, Table 5 p.115). Unpeeled tails are measured on electronic scales to within 0.01 of a gram. Within the database, these are held as whole numbers (integers) and compiled into 0.2g class frequencies. These data are provided in the three sex and maturity categories described above.

However, for Suriname in 2015 the accurate scales failed and scales measuring to the nearest gram were used instead. This degraded the precision of the measurements considerably. These data are still used, but treated differently in the model.

3. POPULATION MODEL

3.1 Overview

The model used in this assessment was a statistical integrated model, implemented with the Stan software (mc-stan.org) in R. In essence, a statistical catch-at-age model simulates population dynamics in time including biological and fishing processes and fits these to all available observations.

The model is based on a standard forward-projection design, but applies a transition matrix for growth. Therefore, rather than modelling age explicitly, animals are modelled based on their size. Standard models (e.g. Stock Synthesis III) was not used so that the assessment was able to use the growth model with the weight data and grading information correctly. Age data were not available.

Where possible the observations and model are kept distinct. The model is adjusted to fit a sufficient data set. In some cases, exact fits can be obtained because there are enough parameters to allow the model to closely follow the data. This applies to the total catch. For other data, where observation errors are presumed to be significant, the model may not fit the observations closely, and some error is acceptable.

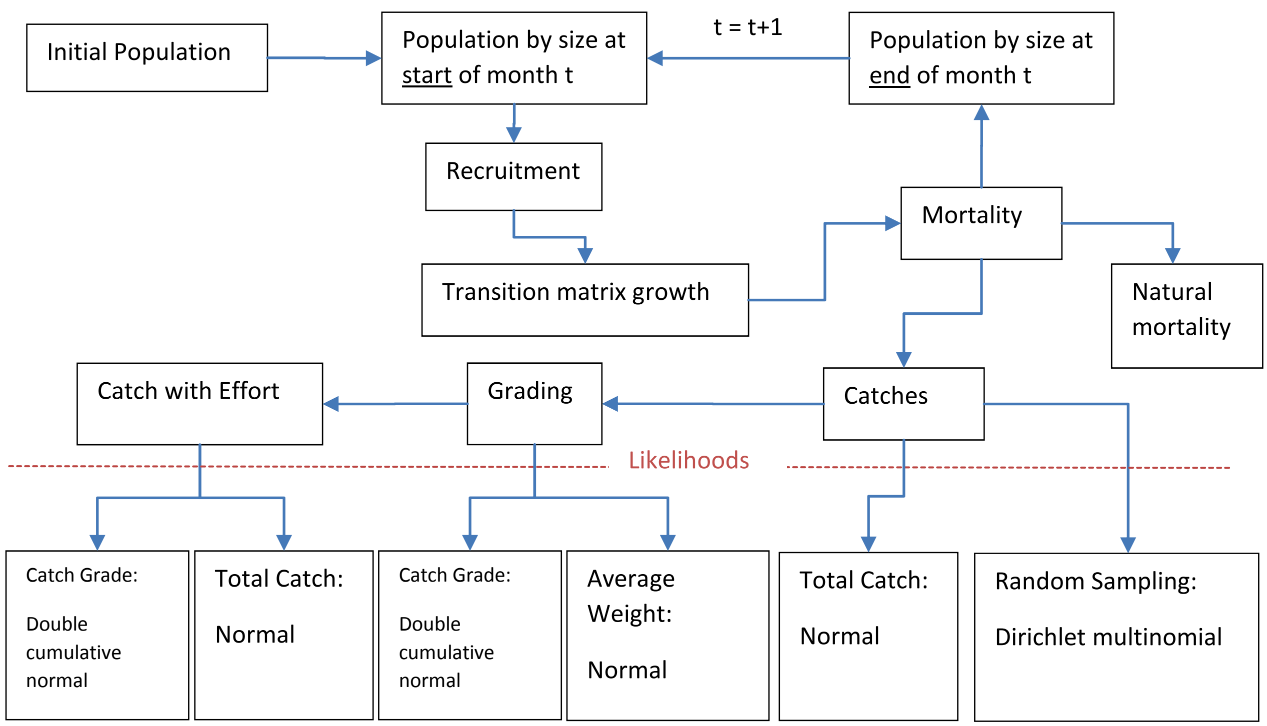


Figure 8 Summary of Seabob Model Structure

3.2 Monthly Catches

The basic population model time step is one month, which was considered appropriate for this species. Separate models are run for males and females. When monthly catch and size composition data are available, a simple approach can be used to model the population, clearly separating the model and data.

For each sex and weight, the numbers at the beginning of each month are calculated based on mortality parameters and standard negative exponential model:

$$N_{w\,t+1} = N_{wt}e^{-\mathrm{M}-F_t S_w}$$

where F_t = fishing mortality in month *t* and S_w = selectivity for weight *w*. Catches in each weight bin were calculated using the standard catch equation. Multiplying the numbers by the mid-point weight bin provides the catch weight.

Growth between weights was estimated in a transition matrix based on the von Bertalanffy growth function (see Equation 1 below) for the mean increment, and another parameter for the variation around the mean.

Selectivity was modelled primarily as a cubic spline function based on tail weight, which allowed selectivity to be very flexible. Because of this flexibility and for simplicity, selectivity was linked directly to weight rather than length. Selectivity can also be modelled as a exponential logistic curve, however the spline curve did not necessarily indicate that this would be a good choice. The cubic spline function was transformed through a logistic function to ensure it was mapped to values between 0.0 and 1.0.

From 1997-2002, only catches are available. The model is run during this period to obtain a level of depletion for the start of the main data series using catches allocated on a proportional basis among the weight bins.

3.3 Growth

Most age-related data are available as tail weight. This includes both commercial size category data and scientific sampling (see section 2). The mean growth of seabob is assumed to follow the von Bertalanffy (vB) growth curve. The general from of the growth model is:

$$L_t = L_\infty(1 - e^{-Kt}) \qquad 1)$$

Parameter L_∞ is estimated within the stock assessment for each sex. The growth transition matrix is based on the normal distribution, with mean growth defined by the vB equation:

$$\mu_\mathrm{i} = \mathrm{m_i} + (L_\infty - \mathrm{m_i})(1 - e^{-K}) \qquad 2)$$

and transition probabilities from weight bin *i* to *j*:

$$\begin{aligned} G_{ij} &= N(\mathrm{h}_j \mid \mu_i, \sigma) - N(\mathrm{l}_j \mid \mu_i, \sigma) & \mathrm{i} < j \\ G_{\mathrm{ii}} &= N(h_i \mid \mu_\mathrm{i}, \sigma) & \qquad 3) \\ G_{\mathrm{ij}} &= 0 & \mathrm{i} > \mathrm{j} \end{aligned}$$

Where *N*()=cumulative normal distribution, m_i = mid-point length for weight bin i, and $\mathrm{h_i}$ is the upper length bound and $\mathrm{l_i}$ is the lower bound for the bin. Notice that σ contributes to the growth rate and negative mean growth increments are allowed, but negative does not occur, the shrimp are more likely to remain in the current bin. Lengths for each weight bin were calculated using the length-weight conversion.

The length-weight conversion was not directly used in this stock assessment due to the use of transition matrices which allowed greater flexibility in the growth. The length-weight relationship was estimated using a log-linear model from the morphometric data collected in 2007/8 (CRFM 2009).

3.4 Sex and Maturity

Unfortunately, relatively little is known about the biology of seabob, so interpretation of the observations is difficult.

The primary problem with the previous 2013 assessment model was the under estimation of females in the smallest size category (Figure 9). This indicated a poor fit with the standard selectivity which was not resolved.

For the 2019 model, residual patterns were resolved to some extent using sex-specific cubic spline selectivity curves. However, there was no justification for the resulting selectivity curves shapes as they would imply separation of sexes by location or other factor. Furthermore, selectivity explained observations using nuisance parameters with no meaning, making the data uninformative on parameters of interest. For example, selectivity was confounded with sex differences in growth, which is the most likely explanation for observed size differences.

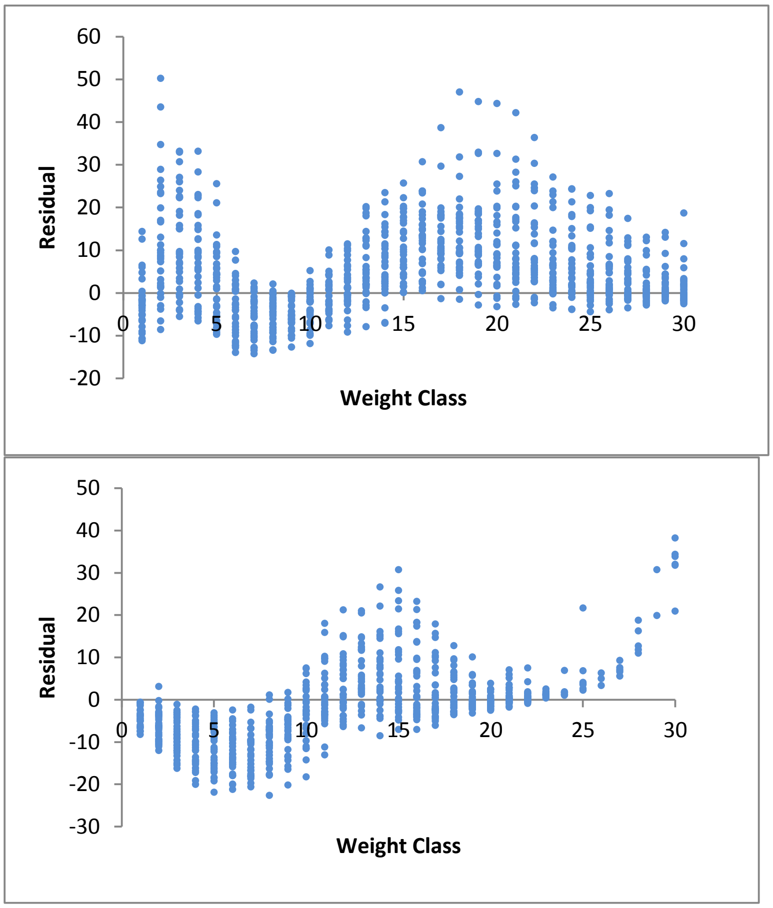


Figure 9 Previous random sampling model female (top) and male (bottom) plot of residuals by weight class.

While it has not been confirmed, the most likely explanation is misidentification of immature males in the smallest sizes. Males are only identified by positive identification of the petasma, which may not be present or identifiable in immature shrimp. This would mean that the numbers of immature females would be over-observed in the data and would help explain the patterns in residuals. The interpretation of the data would therefore be positively identified mature females and males are correct observations, whereas immature females could be either female or male, with unknown proportion allocated to each. This is supported from the observations. Of the total number of 1094946 shrimp observed, 59% were identified as female, 35% male and 6% unknown. The unknown proportion is small and probably underestimates misidentification, but does indicate uncertainty in sex designation particularly for smaller shrimp. The 6% unknown sex has been added to the immature group and another “maturity” curve included that allocates males in the population model to the immature females. Hence the model fits the population males and females to each of three groups: mature females, positively identified (probably mature) males and immature shrimp. Immature shrimp are all shrimp not positively identified as males or mature females. Mature females are estimated with a standard logistic curve:

$$p_{fi} = \frac{f_1}{1+e^{-f_s(w_i - f_{50})}} \qquad 4)$$

Positively identified males include a logistic representing maturity as well as a fixed proportion (m_1) applying across all sizes:

$$p_{mi} = m_1 + \frac{(1-m_1)}{1+e^{-m_s(w_i - m_{50})}} \qquad 5)$$

The third category, immature "females" are all other animals not allocated to these groups (i.e. the complements to these functions: see Figure 10).

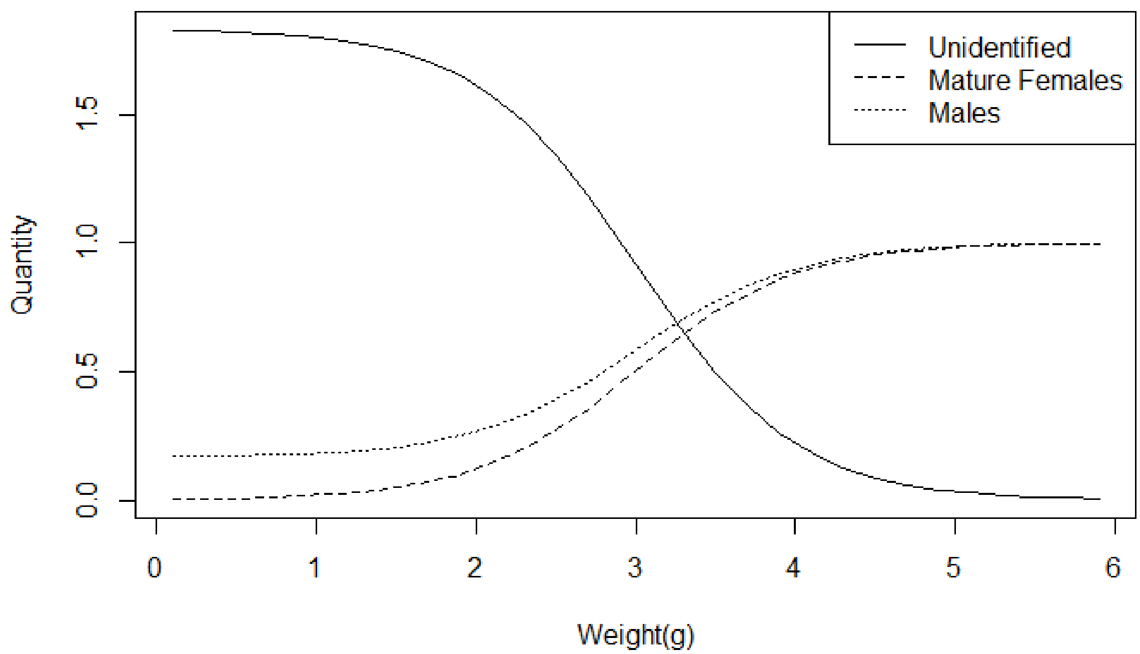


Figure 10 llustration of the logistic models allocating shrimp male and female shrimp to the three categories.

<u>3.5 Recruitment</u>

The stock recruitment model used was the Beverton-Holt model:

$$R = \frac{R_0 S}{R_b + S} \qquad 6)$$

where R =Expected recruitment, S =spawning stock biomass from the previous month or earlier depending on the length of the larval stage, R_0 = the maximum recruitment when the spawning stock is very large (i.e. unexploited) and R_b the spawning stock biomass when recruitment is 50% of the maximum value.

For comparative purposes the "steepness" parameter was calculated separately:

$$R = \frac{4hR_0S}{R_0S_R(1-h)+S(5h-1)} \qquad 7)$$

Where S_0 =spawning biomass per recruit when the stock is unexploited and h =steepness parameter ($0.2 < h < 1.0$).

The recruitment was modelled as a log-normal, with equation 6 the log-normal mean, and individual deviations fitted as random effect parameters from 2002-2017. Before 1997-2002, when only catches are available (model burn-in), no deviations from equation 6 are fitted.

3.6 Likelihood

Overview

The log-likelihood was calculated for each data component based on the Dirichlet-multinomial or normal log-likelihoods.

- The negative log-likelihood for the size composition by size and sex in the random samples is calculated from the Dirichlet multinomial. This is the equivalent to beta binomial, but for multiple category data. For this likelihood, there is an additional dispersion parameter as well as standard multinomial parameters.
- The likelihood for the total catch and catch- effort data were based on the normal. Assuming a Poisson probability function for the catch, the scale parameter was assumed to be the square root of the predicted catch multiplied by an estimated constant σ, so the negative log-likelihood would be:

  $$LL = \sum_k \frac{(o_k - e_k)^2}{\sigma e_k} + \ln(\sigma e_k) \qquad 8)$$

  Where o_k = observed catch, e_k = predicted catch for a particular month k. The predicted total catch weight is predicted from the model fishing mortality and selectivity, with catches summed over all sizes and sex. The predicted catch weight for a given level of effort is derived from the estimated total catch and fishing mortality:

  $$e_k = qfC/F \qquad 9)$$

  Where q = catchability parameter, f = observed effort, C = estimated total catch (in numbers) and F = estimated fishing mortality in each month.
- The catches and catch and effort within commercial size categories is based on integrating over possible catch allocations among categories. This was necessary because commercial categories overlap and are incomplete. The details are given in section 0 below.
- The average count per pound data was assumed to follow a Poisson and therefore the log-likelihood Equation 8 was used. In this case, the predicted count was calculated from the predicted size composition using the size grade selectivity. Most categories had a standard deviation for the observed counts taken in each month which was used as the count standard deviation.
- A recruitment deviations were modelled directly as a log-normal random effect, which included estimating the recruitment scale parameter (σ_R).

In Stan, the normal log-likelihood is provided as a function, which was used to avoid coding errors and having to deal with numerical exceptions. The Dirichlet-multinomial likelihood was not provided, so a function was written to calculate the log-likelihood in this case. In addition, another bespoke function was used to calculate the commercial size category likelihoods.

Random Sampling

The log-likelihood for the random sampling data was a Dirichlet-multinomial, which includes an additional parameter to account for over-dispersion in the multinomial distribution. The distribution includes a conjugate Dirichlet prior, which is the origin for the over-dispersion parameter, and makes the mathematics more tractable.

The random sampling data are defined in 3 categories (mature females, identified males and "immature females") of 30 weight bins each. The population and observation models calculate the proportion expected in each bin category, so this can be compared with the observed proportions. The relative weight of the multinomials compared to other sources of information is controlled by the dispersion parameter.

It should be noted that there are limitations to this approach. Further analyses of these data could yield an improved likelihood accounting for within trip correlations for example. Therefore, although it is more flexible than assuming a strict multinomial, further improvements in the interpretation of the random size composition data is still likely to be possible.

Log-Likelihood for Commericial Size Composition

The log-likelihood used for categories is the same as that used for the previous 2013 stock assessment. An explanation is presented here. However, with the new approach to modelling the grades, the number of overlapping categories was greatly reduced. As noted below, where a single non-overlapping category within a month was identified, the catch relative to the total catch within that category used a normal distribution as an approximation to the Poisson distribution.

For each size composition, it is possible to estimate the number of seabob within it. This is the sum of seabob over the size category from smallest to largest. For example, the 90-110 count per pound size category would contain sizes varying from 5.04 (1000/(2.20462*90)) down to 4.12 (1000/(2.20462*110)) grams weight. The expected number of seabob in each size category can be obtained from the population model based on the fishing mortality for each size category, population abundance in each category and the fishing selectivity.

All commercial categories can be defined as a subset of a larger category which contains it. In the simplest case, the category contains all the catch, so no larger category is required. Therefore in this case, the "larger" category and the category are the same and the log-likelihood is simply based on the expected landings directly from the model. In this simple case, the likelihood for numbers in a particular size category would be Poisson:

$$L = \frac{\mu_a^{x_a}}{x_a!} e^{-\mu_a} \qquad 10)$$

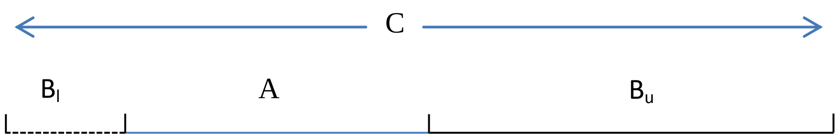
where x_a=numbers observed in the category A and μ_a=expected numbers in category A. The expected numbers can be calculated by simply summing over all sizes from the model within the category. Suitable alternatives to the Poisson can be used to account for over-dispersion and/or to simplify the calculations. Taking advantage of the situation where x_a and μ_a are very large, as in this case, the normal likelihood or log-normal could be used.

Unfortunately, this likelihood cannot be applied in this simple form unless the data are manipulated to allocate all catches to non-overlapping well-defined categories. This should be avoided if possible, since the model would not be fitted to raw data and such manipulations can introduce unknown bias in the result. Instead, it was considered preferable to develop a likelihood which captures what size information there is in the data rather than impose such information by manipulating the data.

In all cases, a significant proportion of the catch will be undifferentiated by size. Any catch allocated to a particular size range can therefore always be defined within the context of a larger size category which is complete. The known catch in the smaller category represents a minimum catch within this range, where other catches within the larger category might also be in the smaller one. The likelihood becomes the sum of likelihoods across possible allocations of catch between the two categories.

To illustrate the basic calculation, we consider categories A and B covering separate size categories (***Figure*** Figure 11) for each of which the statistical model can estimate the expected catch in a particular month. The category B may envelop A (B_l and B_u) or extend it only (B_l or B_u), but it should always be possible to calculate the expected catch for both A and B.

Figure 11



The data however is only available partially for A and B, and otherwise the total catch is made up in C, where C landings have been ungraded among A and B. We need to sum the likelihood over possible allocations of landings in C between A and B, so the likelihood for the joint Poisson likelihood becomes:

$$L = \sum_{x_a=X_a}^{X_c+X_a} \frac{\mu_a^{x_a}\ \mu_b^{(X_c+X_a+X_b-x_a)}}{x_a!\,(X_c+X_a+X_b-x_a)!}\, e^{-\mu_a-\mu_b} \qquad 11)$$

where X_a, X_b and X_c are the observed landings in A, B and C (unallocated A+B), and μ_a and μ_b are the expected catches in A and B which are estimated from the model.

This can be simplified to some extent by reformulating to create a Poisson term for the total catch in A+B and a sum of binomial terms for the proportion in category A:

$$L = e^{-\mu_a-\mu_b}\frac{(\mu_a+\mu_b)^{(X_c+X_a+X_b)}}{(X_c+X_a+X_b)!}\sum_{x_a=X_a}^{X_c+X_a}\frac{(X_c+X_a+X_b)!}{x_a!\,(X_c+X_a+X_b-x_a)!}\left(\frac{\mu_a}{(\mu_a+\mu_b)}\right)^{x_a}\left(\frac{\mu_b}{(\mu_a+\mu_b)}\right)^{X_c+X_a+X_b-x_a} \qquad 12)$$

Similarly, the likelihood for several categories within a larger category can be described using a multinomial.

For large catches it is not possible to sum over possible catches and Eq. 12 can only be simplified by closely approximating the binomial with a normal probability. The binomial term then becomes:

$$B\left(p = \frac{\mu_a}{(\mu_a+\mu_b)}, n = (X_c+X_a+X_b)\right) \approx N\left(\frac{(X_c+X_a+X_b)\mu_a}{(\mu_a+\mu_b)}, \sqrt{\frac{(X_c+X_a+X_b)\mu_a\mu_b}{(\mu_a+\mu_b)^2}}\right) \qquad 13)$$

Similarly, the total catch likelihood can be approximated with a normal density:

$$L \approx N\left((X_c+X_a+X_b); (\mu_a+\mu_b), \sqrt{(\mu_a+\mu_b)}\right) \int_{x_a=X_a}^{(X_c+X_a)} N\left(\frac{(X_c+X_a+X_b)\mu_a}{(\mu_a+\mu_b)}, \sqrt{\frac{(X_c+X_a+X_b)\mu_a\mu_b}{(\mu_a+\mu_b)^2}}\right) dx_a$$

14)

The cumulative normal can be well approximated numerically (West, 2004), so the likelihood can be calculated reasonably easily for each datum.

The binomial part of the likelihood is only informative on landings below those expected in category A. As the expected landings fall below the observed landings in category A, the log-likelihood declines. Clearly, as higher landings have been observed than those estimated, the estimated landings become less likely. Conversely, since any ungraded landings in C could be allocated to A, there is no information on higher estimated landings in A as all are equally possible. Therefore, the log-likelihood asymptotically approaches 1.0 as the expected catch increases. As the expected landings exceed the total landings observed (A+C), then the likelihood begins to decline again (Figure 12). In this case, the estimated landings in A exceed the possible observed landings in A (A+C), and the estimate becomes less likely. The result is a flat-topped likelihood, where the flat top covers the likely range of the landings within the category. Because the likelihood will include a term for the total catch as well, the likelihood should have a mode for the full model, but additional information is likely to be required to be able to estimate parameters defining stock size composition.

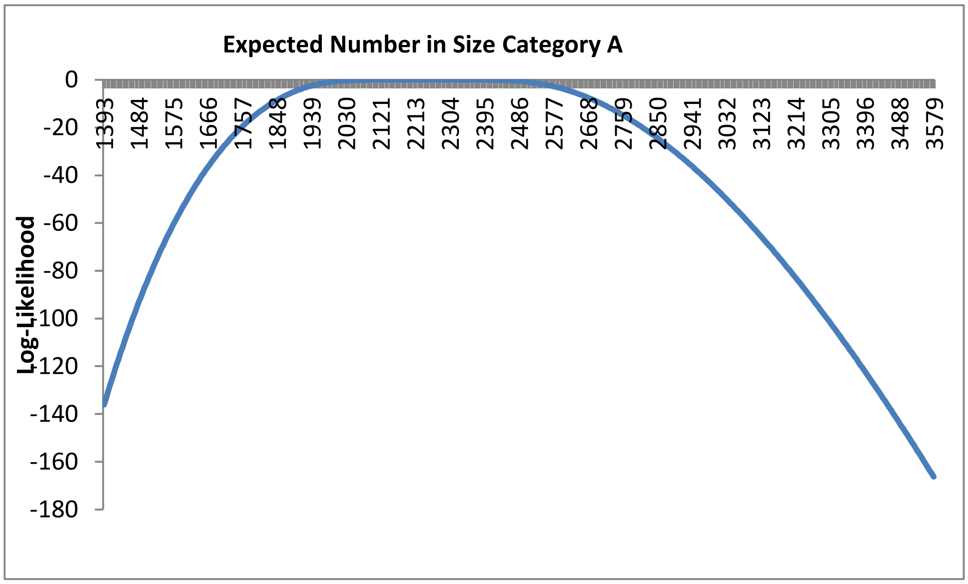


Figure 12 Example conditional log-likelihood of expected number in a category (parameter μa) where the observed catch in categories A and C are 2000 and 500, so 500 may or may not belong to category A.

The process of analysing size category data was somewhat simplified by using the size grade selectivity model, which explicitly accounts for error in shrimp grade allocation, as well as external analysis of the grading data. The main overlaps between categories apply to the smaller size grades, which may also relate to some extent as labelling for quality control rather than related to shrimp size. Therefore, as much simplification was carried out of the categories as possible and as a result only three clearly overlapping categories were identified in all cases.

3.7 Priors

The choice of priors for the various parameters generally followed the Stan advice (see https://github.com/stan-dev/stan/wiki/Prior-Choice-Recommendations). The following table outlines the choices made for the priors. It is important to note that informative priors are important in achieving a tractable MCMC fit, but their influence has been kept to a minimum.

	Parameter	Prior	
stc	Total catch scale	Fixed = 1.0	For the total catches, the scale was fixed at 1.0, which was the default for the Poisson, effectively fitting the total catch exactly.
sca	Size grade catch scale	Cauchy(0, 10)	For the normal scaling parameters a half-Cauchy distribution was used. This is a weak prior that slightly discourages higher scaling values.
sce	Catch effort scale	Cauchy(0, 10)	
dmbeta	Dirichlet-multinomial dispersion parameter	G(0.2*WN, 0.1)	A weak gamma distribution was used, with parameters scaled to the number of weight bins (WN).
FLinf	Female asymptotic growth	N(31.41, 5)	Weak normal for carapace length (mm) based on largest commercial size grade category
dMLinf	Male-Female asymptotic growth Difference	N(-1.99, 2)	Weak normal "empirical Bayes" for carapace length based on the mean difference overall between males and females.
K	Growth rate	Fixed = 0.2	Confounded with Gsig below, but evaluations suggested 0.2 /month appropriate (Ribeiro De Campos et al. 2011, Soomai et al. 2012, review report).
Gsig	Growth sigma	N(2.0, 1)	Weak normal allowing a reasonable carapace length growth increments in a month.
M50	50% maturity	N(4.32, 0.5)	Applies to males and females, normal prior based on "empirical Bayes" ML estimate of female maturity estimated externally from all random sampling data combined.
Msp	Steepness maturity	N(1.58, 1.0)	
pMM	Proportion male	beta(9.5, 0.5)	Weak prior for 95% male identification rate.
Sy	Cubic spline selectivity	N(0, 5)	Weak normal prior on cubic spline parameters to prevent arbitrary small or large values.
lq_t	Log-catchability	N(12.5, 1.0)	Normal prior for log-q relative to R_0, primarily to help convergence in MCMC at reasonable values.
lR0	BH log unexploited recruitment	N(19, 3)	Weak normal prior based on sufficient recruitment to support fishery catch, but prevents arbitrarily high biomass.
lRb0	BH log 50% recruitment	Fixed: h=0.8	Early attempts to estimate were successful, but fixed based on steepness=0.8 to aid MCMC convergence.
lRs	Recruitment log-normal sigma	N(0.5, 0.5)	Weak normal prior covering likely range of reasonable recruitment variance.
lRac	Recruitment autocorrelation	N(0, 0.5)	Weak normal prior on recruitment autocorrelation.
M	Natural Mortality	Fixed = 0.2	Hernández et al. 2003 (cited in Soomai et al. 2012) suggested 0.183 /month based on growth.
lF0	Log mortality for initial depletion level	N(-1.61, 1.0)	Weak normal prior on initial fishing mortality to account for catches before time series start.
leFd	Log monthly fishing mortality difference	N(0, 0.5)	Prior on fishing mortality change from month to month – acts as a penalty on very large changes. This was necessary to ensure MCMC convergence. It presupposes that large changes in fishing effort from month to month are unlikely due to limits in fishing capacity. Closures with zero catch are excluded from fitting.
CatMW	Grade mid-weights	Fixed	Based on mid-point weights for the count range, but adjusted slightly downward to account for bias.
CatSD	Grade standard deviations	Fixed	Set at 16% of the grade widths. Because the grading model is sequential, the grading SD should be small.

4. MODEL CONFIGURATION

The basic structure of the model was designed to minimise problems with aliasing and other issues preventing the MCMC algorithm exploring the full posterior. Three simple linear transforms of the parameters were found to help. These consisted of scaling the log-q (catchability) parameter relative to the recruitment (R_0), defining male maximum average size relative to females and defining fishing mortality as the difference between succeeding values scaled on observed total catch (the first value being a free point estimate). These changes do not affect the underlying model and are only there to support the MCMC algorithm convergence.

It is worth noting an important change in estimating fishing mortality. It was difficult for the MCMC to converge on fishing mortality estimates and, because they changed so much year to year with large changes in catches, a single simple prior was unable to help encourage convergence. To resolve this, the log fishing mortality parameter estimates were adjusted based on the change in catches year to year. The fitted parameters are the difference between sequential log-fishing mortalities (ldF_t). The first log fishing mortality (lF_1) in the series needs to be fitted as a free parameter and thereafter the parameter is fitted condition on the log catches:

$$lF_t \approx lC_t - lB_t$$

$$lF_t - lF_{t-1} \approx lC_t - lB_t - lC_{t-1} + lB_{t-1}$$

$$ldF_t = lF_t - lF_{t-1} - lC_t + lC_{t-1} \sim N(0, \sigma)$$

If the log biomass does not have large changes month to month, a normal PDF around zero provides a good prior for these parameters. This is an example of a non-centred parameterization type solution.

The initial base case was determined from exploring various configurations for the models using the maximum posterior density estimates (MPD). MCMC simulations were only carried out for selected cases to estimate uncertainty. It should be noted, however, that with random effects the MPD is not necessarily reliable so all management advice and HCR evaluation should be based on MCMC results. The MCMC however takes a long time to run, so decisions on model configuration need to be based on the MPD results.

For consistency, the models and priors were kept the same between Suriname and Guyana. No evidence was found to suggest a different model configuration or structure. Keeping the models and configurations the same mean that the results are comparable.

There is no known reason why the sex ratio of recruits will be other than 50:50. The sex ratio in the random sampling favours females, but it is not clear that sexes have been correctly identified in immature shrimp. Accounting for males within the “immature females” category based on expected maturity levels produced much improved residuals, suggesting that this is the most likely cause of problems fitting to the random sampling data.

The size grade category average count standard deviation was not fitted, although the average count itself was. In practice it is not clear that standard deviation is useful in this way. In theory, the standard deviation would measure the size variation within the size category, which contains small amount of information on landings size composition. However, given that grading may be adjusted in response to these counts, any useful information may be lost. Including the standard deviations in the model did not appear to make any difference to the model fit, suggesting there was no information on parameters of interest, so the standard deviations were not fitted. They were used instead as determining the precision of the average count data.

Cubic spline selectivity was fitted, with the same selectivity for both sexes. Sex differences in random samples would be used to inform on difference in growth. The selectivity function is logit-transformed to map values from -/+infinity 0-1. The cubic spline function was used to avoid bias effects from the choice of a parametric selectivity function. The cubic spline "knots" were chosen based on initial exploration to allow smooth curves in a variety of forms that explained the data in both fisheries. The same knots were used, but the parameters to estimate the selectivity at each knot were fitted independently.

A break in catchability was introduced for both Suriname and Guyana to improve fit to the catch-effort data. This removed a pattern in the residuals suggesting that catchability had fallen in January 2012 in Guyana. This has not been fully justified and may need to be examined. The inclusion of the break in catchability does not affect the final results of the stock assessments.

The parameter profiling using the optimizer did not work well. Profiles over the MCMC also did not work. The posterior mode is most likely not well defined and therefore the optimizer is unable to adjust after parameters are fixed. The profiles do demonstrate the importance of the higher precision data as this appears to be influential on important parameters. The most effective method would be to use MCMC to do the profiling, but this would clearly take too long as each MCMC simulation takes a few days to run. Improved ways to profile parameters needs to found.

5. CHECKS AND DIAGNOSTICS

The model code was checked by comparing exposed Stan function results against equivalent R functions. The model was run with simulated data to check its theoretical performance. As well as a check that the model fits appropriately, the outputs illustrate the "best possible" residual plots for comparison.

Plots of observed-expected values, standardised residuals-expected values, standardised residuals-time, standardised residuals-month (seasonality) and, where appropriate, standardised residuals-size category, were produced for each data source.

Key parameters were profiled based on the data source. This was done by fixing the parameter being profiled around the MPD and fitting remaining parameters at different levels. This is indicative, but not strictly speaking a marginal PDF.

A retrospective analysis was conducted by sequentially removing the last month's data to detect any bias in final stock status estimates.

All checks and diagnostics are contained within RMarkdown and can be re-run easily. The MCMC themselves are slow to converge and would take some time to complete.

6. FURTHER WORK

The following tasks were identified as requiring attention during the review workshop:

- The stock status compared to unexploited status appears very low. It would be worth considering whether this is realistic. This was resolved by noting that the maturity based on recording eggs in females was shifted well to the right compared to studies based on observations on reproductive organs themselves, which should be much more accurate. Published estimates for 50% maturity were used in this assessment, but further work on the local maturity is recommended.

- Check whether males make up a significant proportion of the "immature females" category, and, if possible, estimate this proportion. It may also be possible to review and improve the sampling protocol.
- Check whether the break in catchability in January 2012 was justified. This has not been yet been justified based on any external information and may need to be examined. Candidates for an effect include Sargassum episodes and changes in the inner line that may affect catches. It would be preferable to include explicit effects of this sort than arbitrary changes. The inclusion of the current break in catchability does not affect the final results of the stock assessments.
- Analyses of the size composition data with respect to their error structure could improve the estimation of the underlying size composition of the catches, accounting for, among other things, the sizes of the trip catches and correlation within trips.
- The reported trip activity (days-at-sea) for more recent data should be cross referenced with the VMS data to improve effort measure. This would be particularly useful in helping to understand why trip length is so asymptotic with respect to catches.
- There is a significant difference in catch rates between Suriname and Guyana. This is not well understood, and current treatment is precautionary rather than scientifically justified. Although catch rates are much higher in Suriname, the model does not estimate that the stock is more abundant or more productive. There are at least two testable hypotheses which would bear further investigation:
    - The Suriname stock is smaller than Guyana but also more densely distributed. Higher shrimp density would raise the catch rates. This is the current model hypothesis. This could be tested by looking at the area trawled footprint. If this hypothesis is true, the Suriname trawl area should be significantly lower even taking into account the smaller fleet size.
    - There are significant density dependent effects on the shrimp adult population. This is not addressed in the model. If density dependent growth was present, then growth parameters in Suriname should be lower. Although this has not been carefully examined, growth rates (K) may be a little lower in Suriname, but maximum lengths appear to be similar, and overall support for this is not strong. There is no assessment natural mortality, but if there was higher natural mortality through density dependent effects in the Suriname stock, this might explain the model fit and the overall mortality rate estimated for this stock. This could be explored further with alternative model runs, but estimating the density dependent effect without raising fishing mortality above the current F_{MSY} would be difficult.

RESULTS SUMMARY

1. 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 (Figure 5).
- Suriname has dome-shaped, but highly uncertain, selectivity. Guyana selectivity is logistic in shape and appears more typical for trawl (Figure 6).

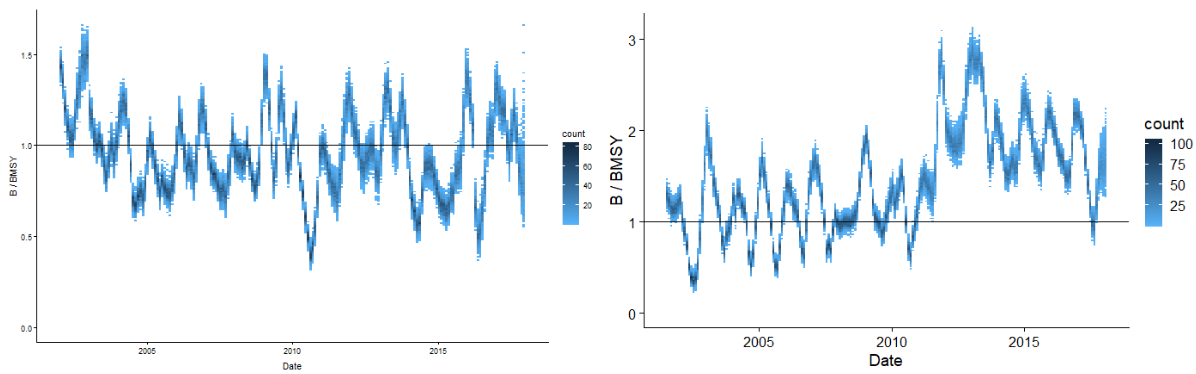


Figure 1 Suriname (left) and Guyana (right) stock status (count represents the MCMC simulations).

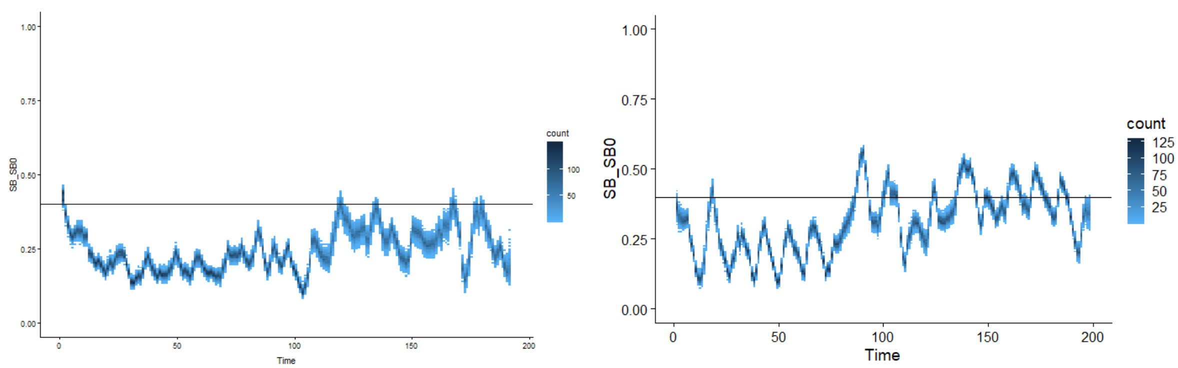


Figure 2 Suriname (left) and Guyana (right) stock status relative to the unexploited state.

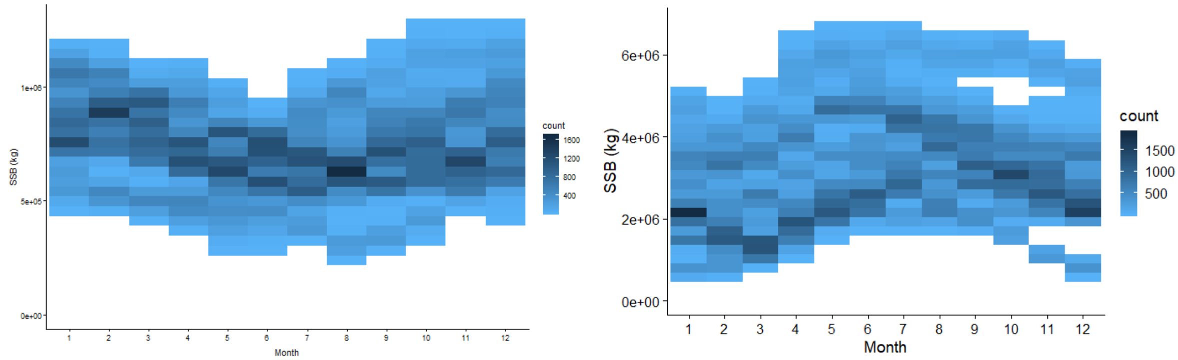


Figure 3 Suriname (left) and Guyana (right) spawning stock biomass by month January (1) – December (12).

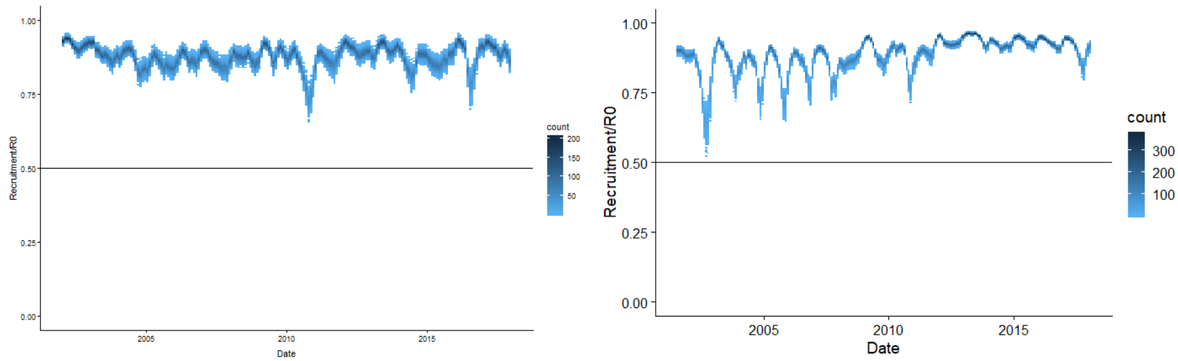


Figure 4 Suriname (left) and Guyana (right) recruitment relative to the unexploited state.

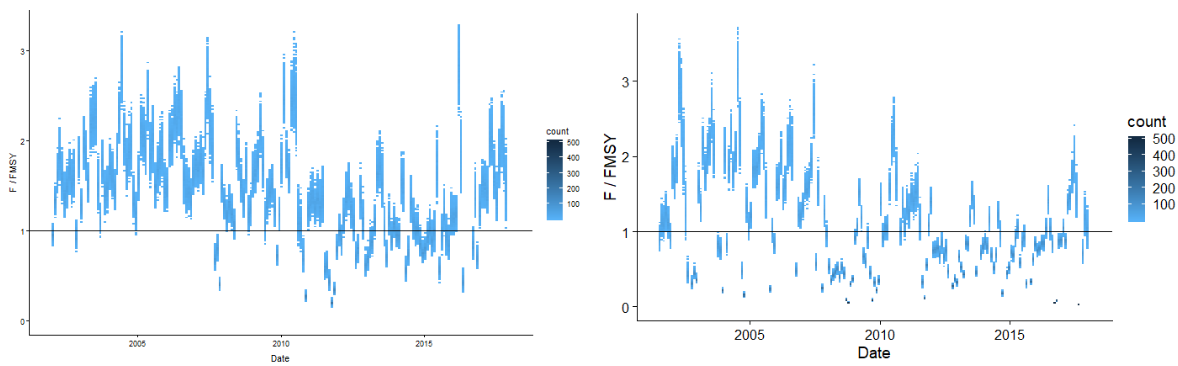


Figure 5 Suriname (left) and Guyana (right) fishing mortality relative to the F_{MSY}.

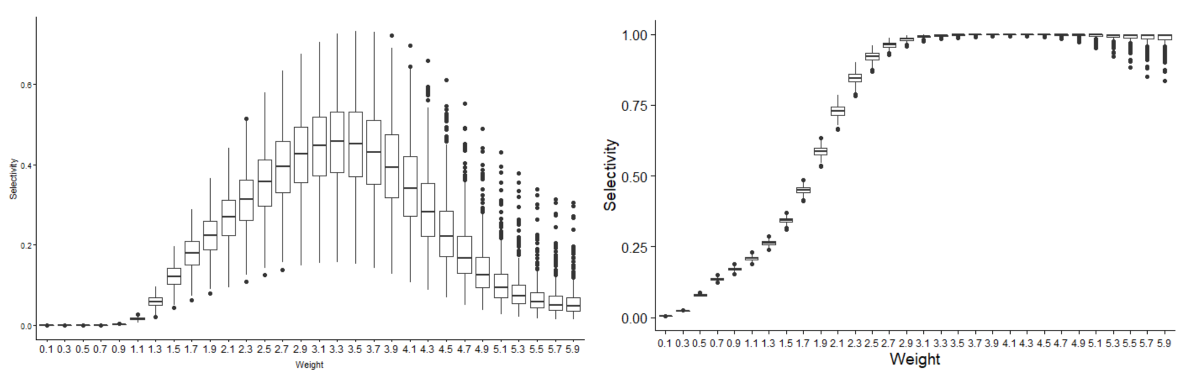


Figure 6 Suriname (left) and Guyana (right) selectivity ogives.

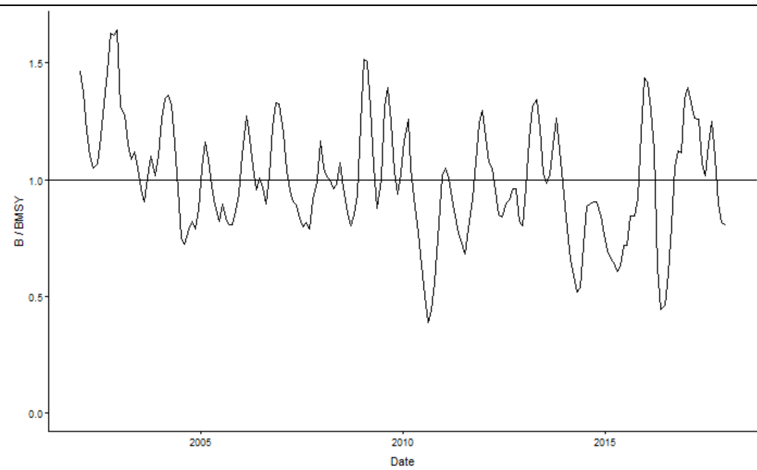
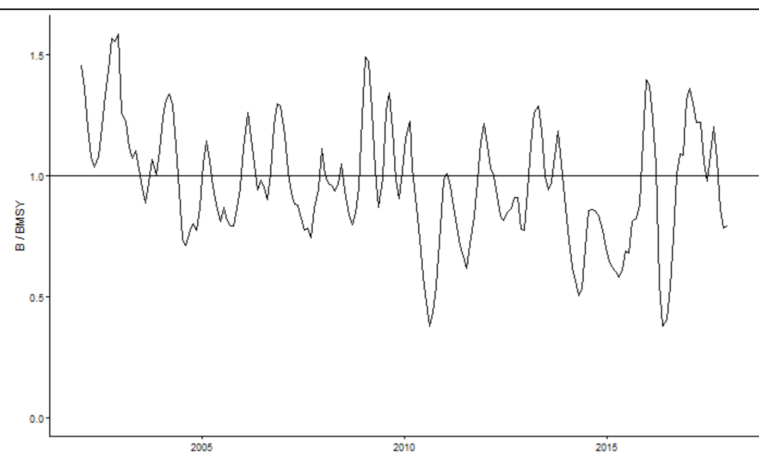
2. SENSITIVITY ANALYSES

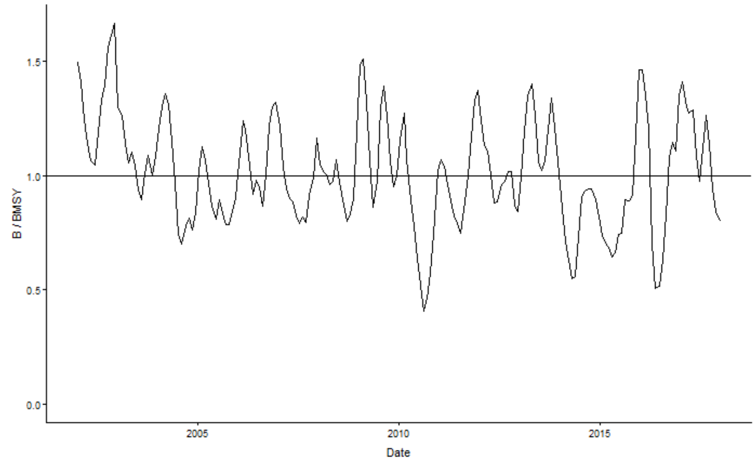
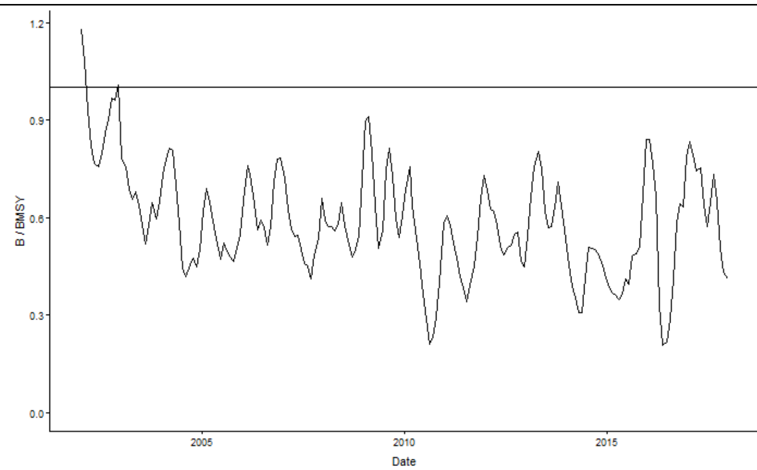
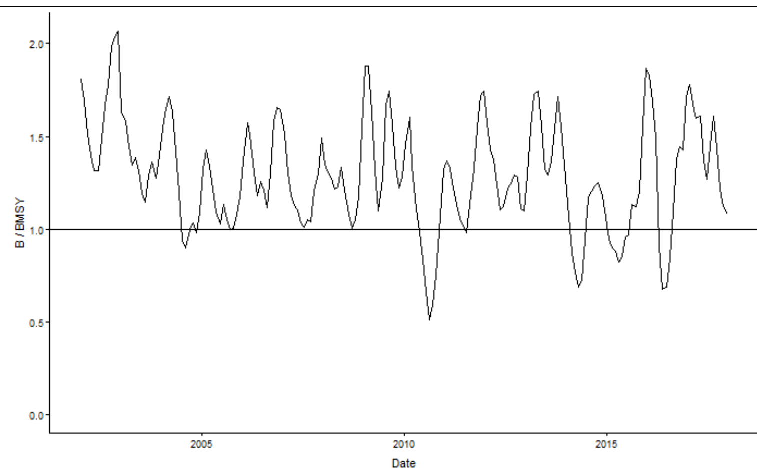
The base case was determined though the review process. The review used information from the sensitivity analyses to make its decisions (Table 1). The general results are outlined below:

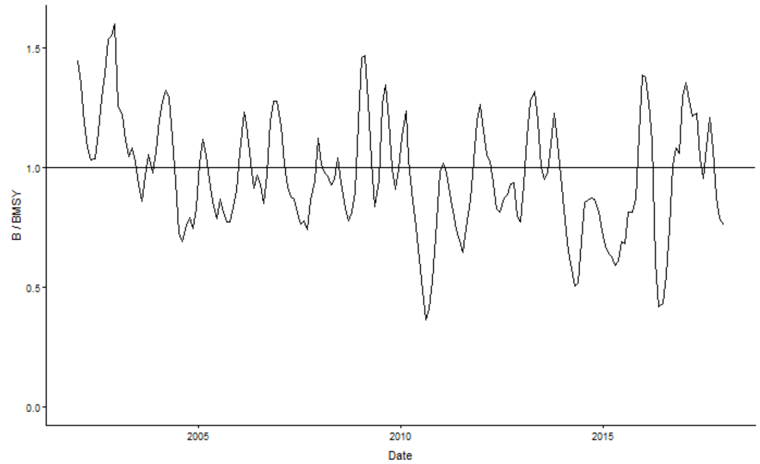
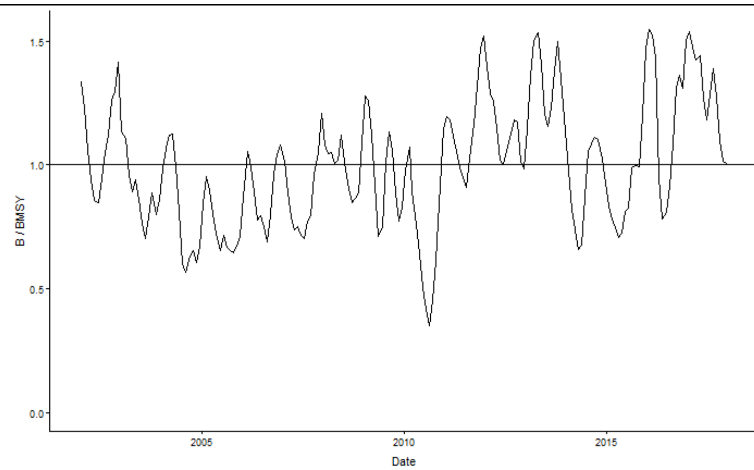
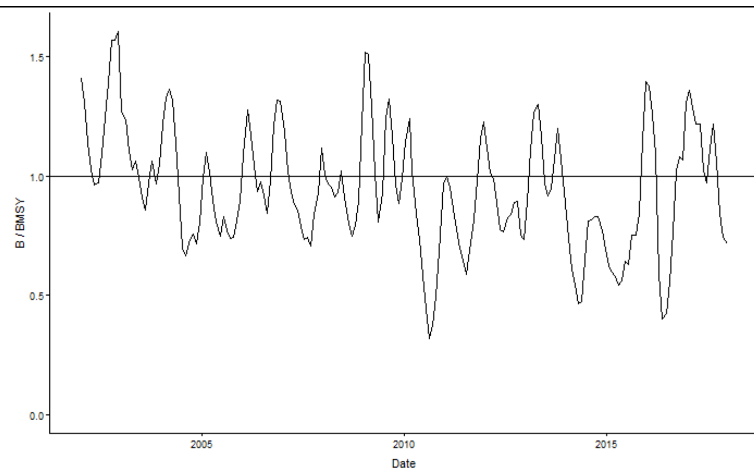
- The results were broadly unaffected by the growth rate (K). The growth rate is partially estimated by one of the parameters (G_{sig}) used to define the transition matrix.
- Results were sensitive to the natural mortality, with a significant change in status resulting over a plausible range of natural 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	

Sensitivity	Change in log probability	Stock Status
Fixed parameters: M=0.2, K=0.25	36.37	
Fixed parameters: M=0.1, K=0.20	-96.18	
Fixed parameters: M=0.3, K=0.20	26.36	

Sensitivity	Change in log probability	Stock Status
Artisanal catch	5.11	
Force fit to average count data	-1508.23	
Nominal days-at-sea	-136.86	

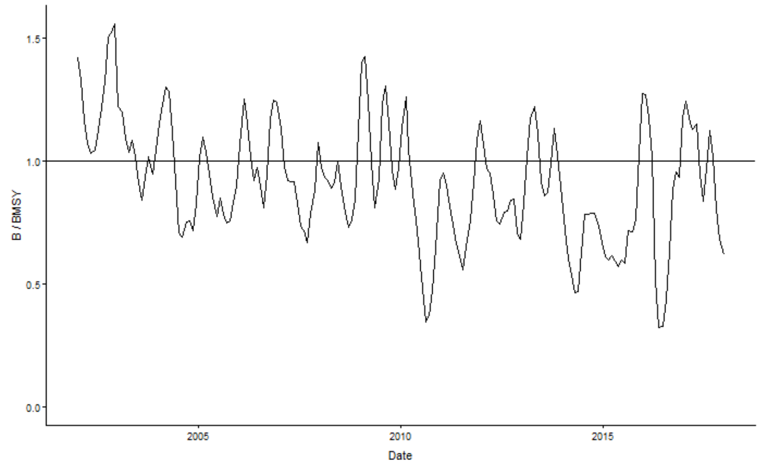
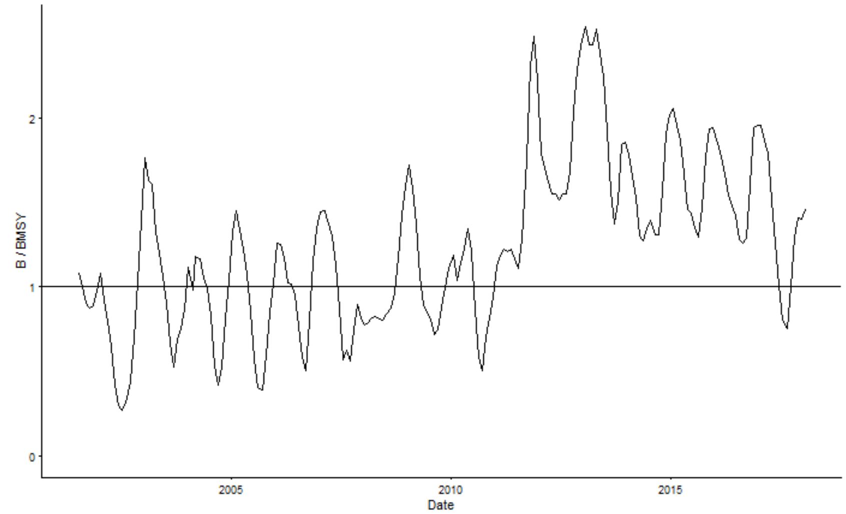
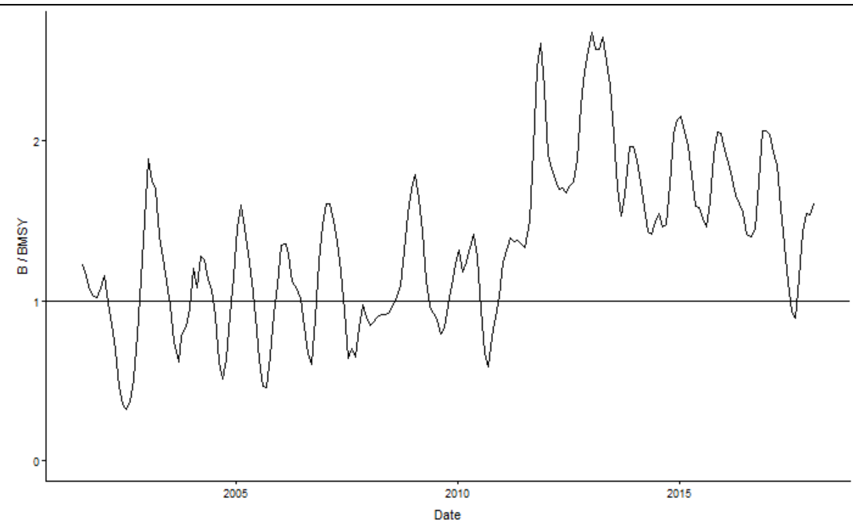
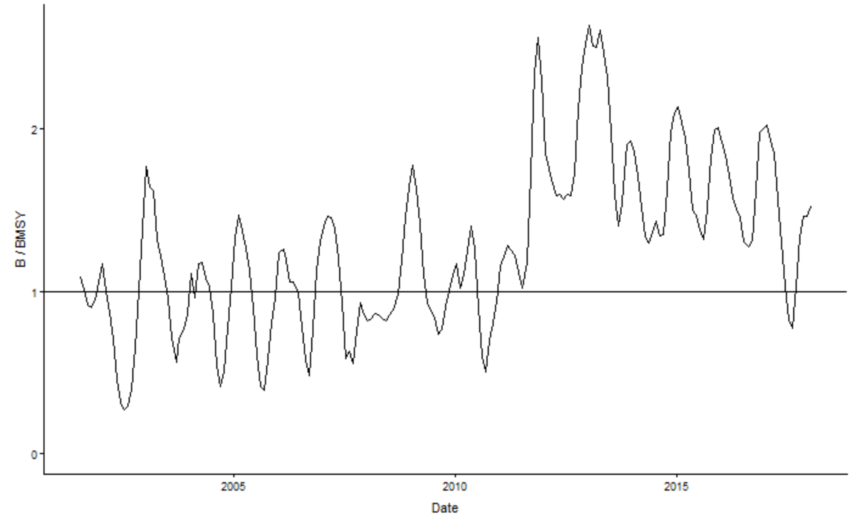
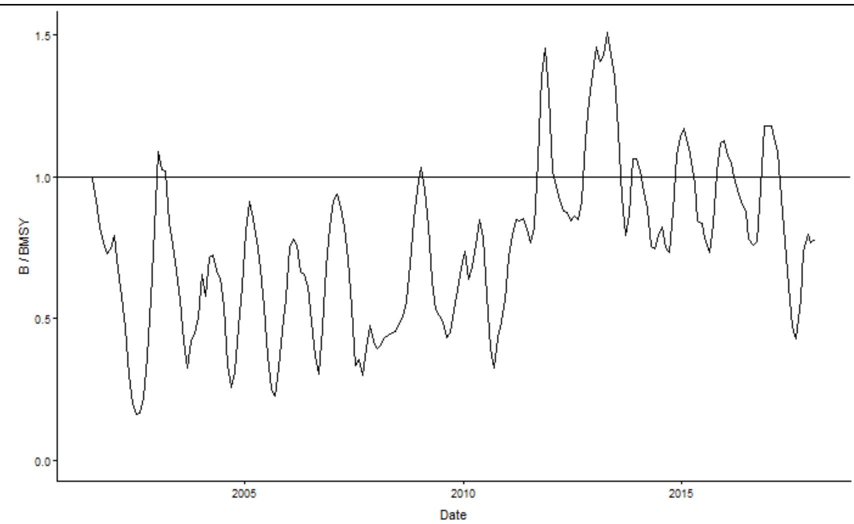
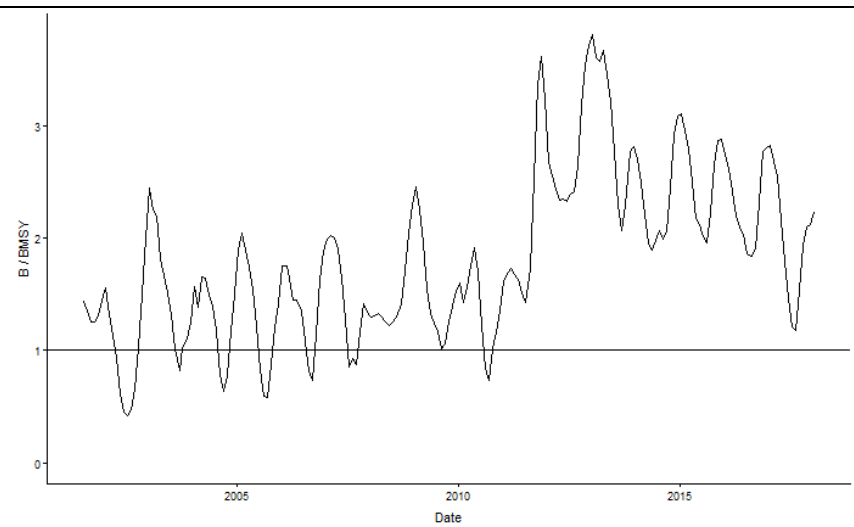
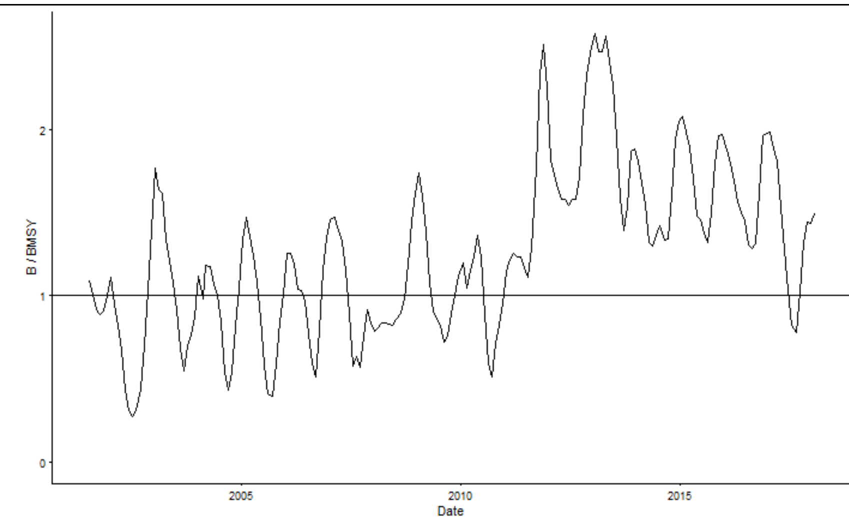
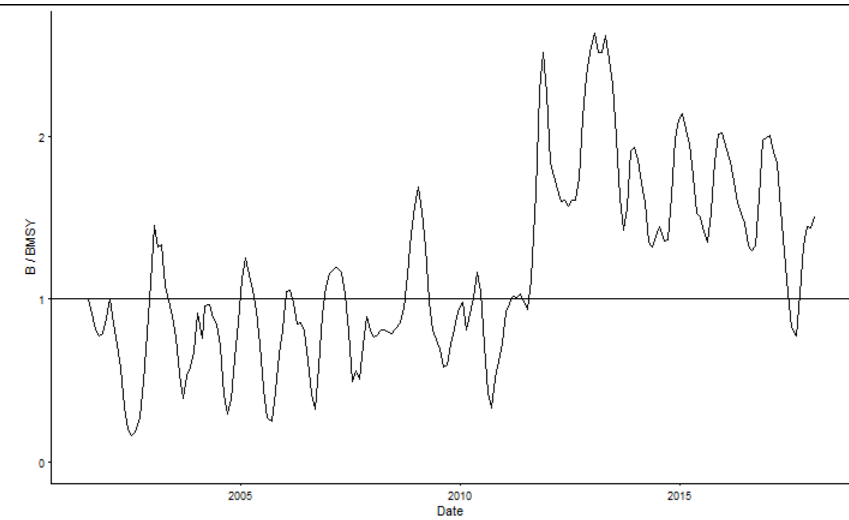
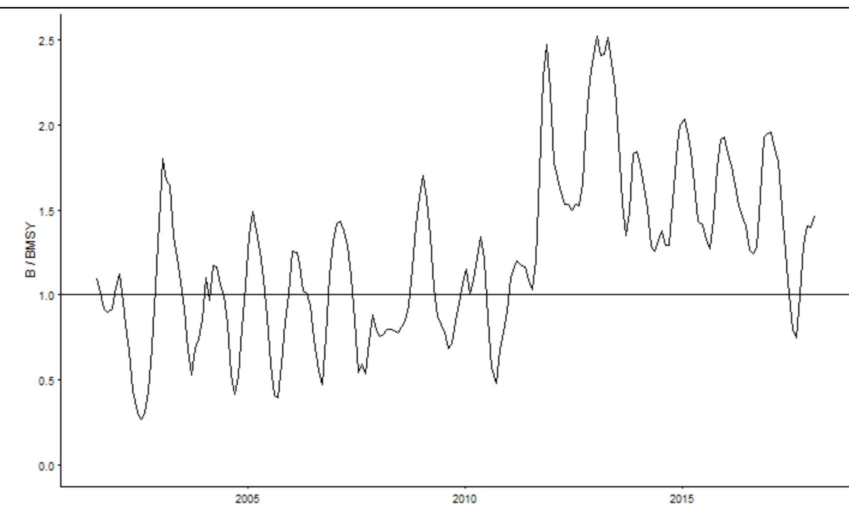
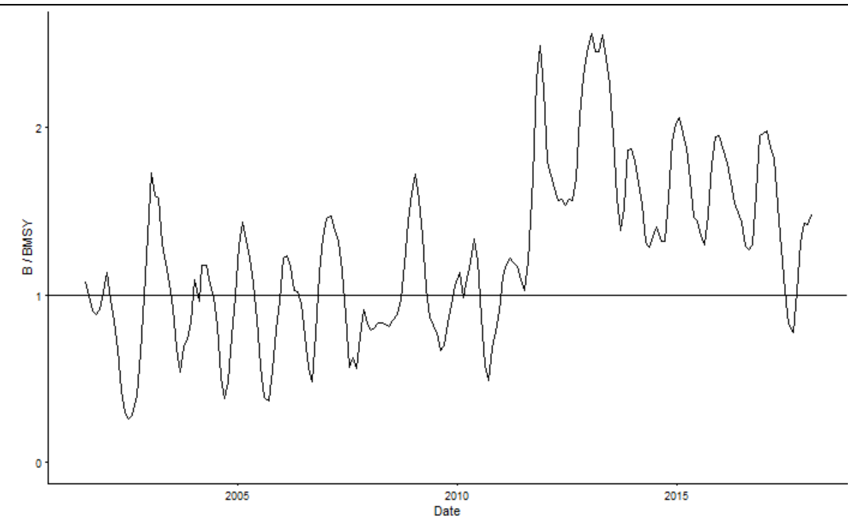
Sensitivity	Change in log probability	Stock Status
Remove smallest size grade	NA	

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	

Sensitivity	Change in log probability	Stock Status
Fixed parameters: M=0.2, K=0.25	27.14	
Fixed parameters: M=0.1, K=0.20	-37.34	
Fixed parameters: M=0.3, K=0.20	-66.88	

Sensitivity	Change in log probability	Stock Status
Artisanal catch	9.18	
Force fit to average count data	-253.97	
Nominal days-at-sea	-22.06	

Sensitivity	Change in log probability	Stock Status
Remove smallest size grade	NA	

3. 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

4. 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:

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

   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*$\boldsymbol{f_{max}}$ 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.

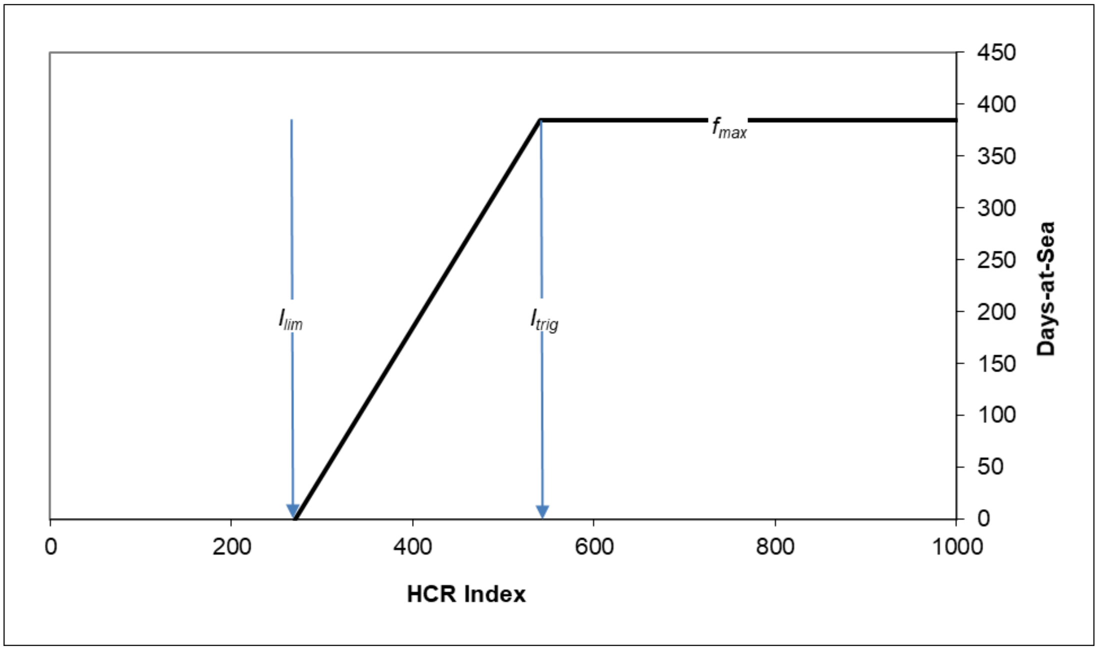


Figure 7 Diagram illustrating HCR with parameters: I_{trig} = HCR Index trigger point below which there is a reduction in the exploitation rate, I_{lim} = HCR Index limit below which effort is minimised and f_{max} = the maximum average effort spent each month, equivalent to the MSY exploitation level.

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.

		Suriname		*Guyana*	
RP	***Type***	***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 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.

	Suriname			Guyana		
Response	**B<Limit**	**B<Trigger**	**B=Target**	**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

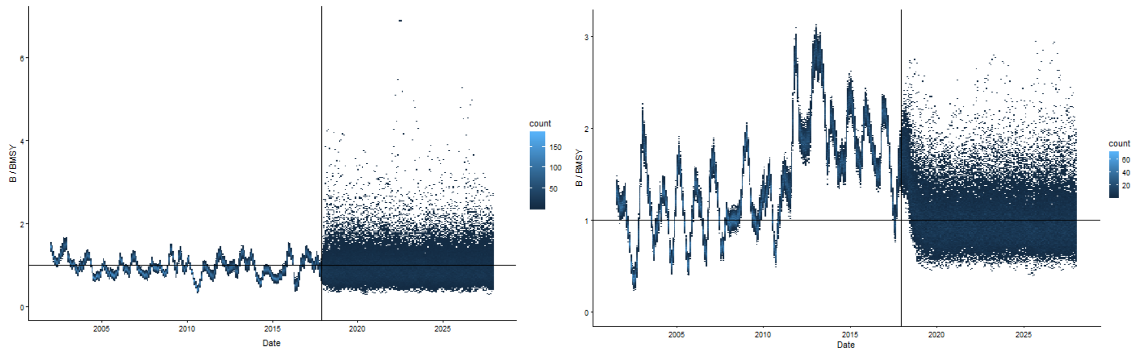


Figure 8 Stock status for Suriname (left) and Guyana (right) based on MCMC results and default HCR projections after the vertical line.

5. 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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