Center for Independent Experts (CIE) Independent Peer Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the Gulf of Mexico Large Marine Ecosystem

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Executive Summary

This review covers the use of the Gulf of Mexico Atlantis model for strategic use in understanding broad outcomes around the populations of penaeid shrimps. The Gulf of Mexico Atlantis shrimp review was held in Saint Petersburg, Florida, on 11th to 13th April 2023. The aim of this review was to assess the Atlantis model's suitability for providing strategic management advice for three Gulf of Mexico shrimp stocks. Ten different functional groups in the model had been previously identified as especially relevant to the shrimp, covering predators, prey, and bycatch species, and the review focused on these rather than the entire model.

When dealing with ecosystem models it should be understood that these are large and complex models, which are attempting to represent large and complex systems. There will always be deficiencies in both the process understanding and the data availability to produce such models, and as such they will always present a rather imperfect representation of reality. At the same time, a well-constructed ecosystem model does give the best available tool for summarizing the functionality of an ecosystem, and for investigating (albeit with large and often unquantifiable uncertainties) potential ecosystem responses to different drivers. As such, despite all their problems, this class of model undoubtably provides "best available science" for understanding these ecosystem-wide questions. Tropical shrimp stocks are frequently driven by environmental factors, rather than by fisheries pressures. Therefore, an ecosystem model is a highly suitable tool for attempting to understand shrimp dynamics and their likely response to different environmental drivers.

The question then is "does this particular model perform well enough to provide useful management advice?", and "to what extent are the individual scenarios presented formulated in a reasonable way?".

The GOM Atlantis model reviewed has a number of serious issues that require rectification before it could be considered for use in providing management advice. One is that even during a 50-year projection aimed at reaching stability, several of the key groups identified were still changing their weight at age to a degree that was not biologically plausible. This is likely pointing to serious errors in the energy flow through the system and/or in the parameterization of key stocks. The other key issue identified at the review was that an error had been made in constructing the shrimp groups. Rather than living for 1 to 2 years, the shrimp had been set to live for 10 years. This resulted in the stock dynamics being unrealistically stable. There were a range of secondary but still serious issues affecting the dynamics, for example a misspecification of recruitment timing or a potential over-reliance of untracked senescence mortality as a stock driver. All of these would need addressing before the model could be considered for use.

The model diagnostics were presented almost entirely in terms of internal model dynamics, occasionally compared with other models. Both of these are valid and useful, but "sanity check" comparisons with available data to establish the realism of the simulations were severely lacking. As a result, it was not possible to identify the degree to

which the model was providing an accurate representation of reality, or what were the areas of strengths and weaknesses.

The proposed ecological drivers were presented as “proof of concept”, rather than as scenarios which could be used for management advice. Once the model is improved, any given scenario would require a separate review of some kind to ensure that the parameterization of underlying the results is reasonable.

In summary, the GOM Atlantis model is a potential basis for strategic management advice, but is not currently in a state to provide such advice.

Background

Description of reviewer’s role in review activities

In understanding the review below, it is important to understand the background of this reviewer. He works in single-species stock assessment and in providing quota advice, as well as in multi-species statistically tuned modelling. He has been involved in several projects involving ecosystem models (EwE and Atlantis), but never as a model developer. As part of this, he has been involved in the “F_{eco}” work finding ways of including ecosystem model output information into tactical quota-setting advice. In terms of previous experience, his work has been mostly concentrated in northern Europe (mostly in Norwegian and Icelandic waters). Of specific relevance here is that he has in the past also worked on a two species mixed-fishery model for shrimp in the Sofala Bank in Mozambique.

Thus, this review can focus in detail on the large details of model utility and overall diagnostics, the degree to which the model can be considered realistic, the utility for management, and on specifics of the modelling of individual species within the model. However technical details of the modelling, or any Gulf of Mexico specific issues, can only be covered to a superficial level.

Findings for each TOR, with the weaknesses and strength described

1. **TOR 1. Comment on the technical merits and deficiencies of the methodology and recommendations for remedies.**

The Atlantis model is one of two main categories of ecosystem model (alongside Ecopath with Ecosim) which is typically used to produce detailed models of marine ecosystems. Atlantis includes spatial (both horizontal and by depth) resolution as well as user definable species groups and aggregations. The model is successfully used in many regions around the world. As such this modelling tool absolutely represents a suitable tool for producing ecosystem models, and for providing strategic information for managers. Furthermore, tropical shrimp are typically heavily driven by ecosystem conditions, and there is therefore high potential for such an ecosystem modelling approach to give useful management advice. The question (addressed in ToR2 below) is then "to what extent is this particular Atlantis model useful".

a. *What are the data requirements of the methodology?*

In general, ecosystem models would ideally make use of more data than is available. As such, they should use all of the available data, and constantly check against both data and expert knowledge that the outputs of the model are reasonable. The model requires ocean current forcing, and should ideally have as wide a range as possible of data for tuning stock size and dynamics, life history values (mortality, growth, fecundity,…) and predation interactions. It should be noted that the model cannot be formally statistically tuned to the data.

b. *What are the general situations, management uses, and spatial scales for which the methodology is applicable? (also to be discussed further in TOR 2)*

Given the data deficiencies and lack of formal model fitting, it is difficult to justify the use of ecosystem models alone for tactical management advice (e.g., quota setting). However, they are well suited for giving strategic advice, being the only models available to examine effects across the whole ecosystem. The Atlantis model is therefore a suitable tool for investigating how a specific driver (environmental or anthropogenic) might affect the wider ecosystem. Furthermore, using the new F_{eco} (Howell et al. 2020) approach they can be combined with statistically-tuned assessment models to refine (but not set alone) quota advice. The spatial scale of the model used here is designed to accommodate the whole Gulf of Mexico, and the model is therefore limited in providing results on a fine scale. In general, any specific question to be addressed will need to be evaluated according to the model formulation to determine the utility of the model in providing specific advice. It may be that the spatial structure will need to be refined in an iterative manner during the development of the modelling tool to adequately address specific issues.

c. *What are the assumptions of the methodology?*

The Atlantis model essentially works by tracking nitrogen flow through the ecosystem and is driven by imposed oceanographic forcing fields, but the overall structure of the resulting model is highly flexible. As part of the model formulation, the spatial structure and functional groups to be modelled must be specified. Within each functional group there is a large amount of flexibility in how the dynamics are modelled. The choices involved here, balancing realism against a need to limit complexity, are likely to be the key factors in determining the success of the final model.

d. Is the methodology correct from a technical perspective?

This reviewer lacks the expertise to judge the details how well the Atlantis model has been implemented, and the review was too short to make any such judgement in any case. As mentioned above, the complexity of the modelling tool renders this a case of "the devil is in the details", and the key question is rather "how appropriate is the specific structure for the specific ecosystem and purpose?". Specific concerns about details of the model formulation are addressed under ToR2 below.

e. How robust are results to departures from the assumptions of the methodology?

The results could potentially be highly sensitive to any misspecification within the functional groups: either grouping disparate species together or mis-specifying the dynamics within a group. In addition, some results can be sensitive to the choice of area structure (both horizontal and vertical). The degree to which this sensitivity is problematic will depend on the particular use to which the model is put, and it is therefore valuable that this review is focused on a specific set of uses of the Atlantis model. In the event that a given model is approved for one use, this should not be taken as approval for all possible uses. Again, specific concerns are enumerated under ToR 2.

f. Does the methodology provide estimates of uncertainty? How comprehensive are those estimates?

The model run-time is such that the model is poorly suited to typical uncertainty estimation techniques (e.g., bootstrapping). Some uncertainty estimation is possible, both through scenario testing and through the use of high powered computing to mitigate the run-time issues. Some of results from this were presented as part of the review, but not with a great deal of focus. In general, it would be unrealistic to expect the uncertainty estimates to compare with, say, those from a single species assessment model.

g. What is the process of model fitting and calibration?

The model presented was based on a pre-existing Atlantis model, and thus the main fitting and calibration was not subject to this review. In general, Atlantis calibration is conducted manually to produce a system which "looks reasonable", rather than being statistically tuned to the data in the sense of something approximating a minimum likelihood scheme. This is unfortunate, but likely necessary given the complexity of the ecosystem being modelled and the limited data available. Focus in this review was given here to 10 pre-identified key groups which interact in different ways with the shrimp. Beyond this we rely on previous work examining the overall model.

h. Areas of disagreement regarding panel recommendations: among panel members; and between the panel and proponents.

The panel was largely in agreement, and the severity of the identified model misspecification issues (e.g., the mis-specification of shrimp age structure and the weight at age issues) mean that a recommendation of addressing the issues and re-examining the resulting model is largely uncontroversial.

i. *Unresolved problems and major uncertainties, e.g., any issues that could preclude use of the methodology*.

The key issue with the methodology (rather than the specific model example which is discussed below) is that there are enough unquantifiable uncertainties that it would be difficult to rely directly on the ecosystem models for quota setting or assurance of the precautionary nature of any management. This does not prevent the use of the methodology in management advice, but it needs to be borne in mind when deciding the appropriateness of any specific use for the model. In the context of the ToRs for this review, this limitation does not impact on the ability of the model to give strategic management advice.

j. Management, data or fishery issues raised during the panel review.

The key issue raised was the lack of "sanity checking" of the results against the data. As previously mentioned, there were a range of cases where the model results could have been checked against data or expert knowledge and this was not done. As a result, it is difficult to make a judgement as to the realism of the model. This is not a limitation of the modelling approach, but rather of the specific implementation. Where such comparison was possible there were a number of critical errors identified.

k. Prioritized recommendations for future research and data collection.

On the assumption that this ToR is talking about developments for the Atlantis model, then if it turns out that age categories of less than one year are not possible then it would be highly advantageous to allow age categories to be defined as less than one year.

On the data side, the generic recommendation is to use as wide a range of data as possible in tuning and validating the model.

2. **TOR 2. Model readiness concerning priority capabilities**
    a. Evaluate data, parameterizations and skill of GOM Atlantis with emphasis on Penaeid shrimp.

During the review a critical bug was discovered in the parameterization of all three shrimp species in the GOM Atlantis model. The model setup used a full age structure (10 age classes) in order to be able to track the different development stages of the shrimp. This is valuable given the different dynamics of the near shore juveniles from the more offshore adults. Unfortunately, each age class was set to be one year, giving an overall age of the shrimp of 10 years. In reality the actual lifespan of these species is on the order of one to two years, with few surviving more than one year. As a result of this bug, the dynamics of the shrimp were far too stable to be considered realistic. This needs to be rectified before any interpretation can be made of the model results. It is this reviewer's understanding that Atlantis has the capability to set age classes with lengths of less than one year. If this is possible then this should be done, as it will allow the different life stages to be more accurately modelled. If this is not possible, then the shrimps will need to use a different structure (or the Atlantis model should be modified to permit sub-year age classes).

The other key issue was that during a 50-year run to check the stability of dynamics, the weight at age of least one species was variable, signifying that a key stock was not stable. Rather the weight at age varied considerably even in the last 10 years of the 50-year projection, to an extent which was not biologically plausible. This suggests that there is a serious misspecification of the energy flow through the system. No comparison to actual weight at age estimates were presented to identify which (if any) of the different values were realistic.

A second issue around the shrimp dynamics relates to recruitment. The timing of recruitment events is set as a window within each year, with constant recruitment within that window. It became apparent during the meeting that the recruitment timing within the model did not match the known recruitment timing of the shrimp. Furthermore, for some species recruitment occurs at more than one time during the year, and there are peak recruitment times but minor levels of recruitment in other months. This needs to be investigated and the model adapted to provide the best match to the actual recruitment patterns technically possible.

It was of considerable concern that mortality estimates at age (both natural mortality M and fishing mortality F) were not presented during the meeting. It was stated that computing these with Atlantis was problematic. However, given that numbers and biomass are available each year in the outputs alongside the catch taken, then it should become a trivial matter to compute these mortality values post hoc. Without such estimates it was not possible to identify the degree to which each species was following biologically plausible dynamics.

One related issue of concern to this reviewer is the uncritical use of functional groups without a plus group. There is a technical choice to be made in designing an Atlantis group in that the oldest age category can be either an exact age (e.g. 10 years old) or a "plus group" (e.g. 10 years and older). The difference is that without a plus group, any individuals "aging out" of the oldest age class simply die (i.e., approximating senescence). The former formulation is used throughout this model. This is not necessarily a problem; allowing senescence in this way may be reasonable and can help to stabilize the model by preventing a build-up of biomass in the oldest age group. However, this mortality is not well modelled. Therefore, the mortality induced in this way should be relatively minor, and it would be very concerning if it were to be a major driver of stock dynamics. It is therefore important that a check be conducted to identify the fraction of the total mortality arising from this design choice for each species and rectify the structure where required. Neither of these were done.

There is a real deficiency in the whole modelling approach, in that checks against the available data have not been carried out. These are absent in cases where it should really be obvious (for example the weight at age issue mentioned above), and there is an absence of "out of the box" thinking to identify ways in which comparisons can be made. One example would be the MSY estimate. In this case although there is no direct data on the MSY value, one could compare the reported catches to the MSY estimate, which indicated that the stocks were fished at around 4% of MSY. There should be expert knowledge to identify if this extremely low value is realistic.

The area structure (vertical and horizontal) appeared to be inherited from a previous version of the model. This is typical in model development, but nothing was presented to establish that this was suitable for the specific dynamics of the modelled shrimp. It may be that the structure was appropriate, but it may also be that the shrimp dynamics could be better modelled with a revised area structure.

The model assumes knife-edge selectivity for all stocks. For some stocks this may be a reasonable assumption, for others it will not be. There needs to be a stock-by-stock evaluation of this, and revision where required.

b. Evaluate the treatment of environmental processes in the model relevant to shrimp production.

Given that the shrimp dynamics were not in any way realistic (due to the age structure bug and the weight at age issues mentioned above) it is not possible to make any judgement about the realism of any modelled environmental drivers. There was limited information presented at the review on such drivers in any case.

c. Evaluate the readiness of the model to perform climate change simulations, including habitat effects.

At the review, several "proof of concept" examples were presented of impacts of environmental changes (e.g., climate change) on the shrimp. However, these were only at the level of proof of concept, and were not ready for consideration for management advice. There were discussions at the review about the appropriateness of the presented examples, but the simulations were not at a sufficient level of development to reach a conclusion about their appropriateness.

It can be said that the tool is suited to simulate the impacts of changing environments, and that the utility of any given simulation will lie in the appropriateness of the parameterization of the specific scenario. Therefore, the conclusion is that each individual scenario will need individual scrutiny and some kind of review (in addition to a review of the model in general) before being used for management advice.

d. Evaluate the use of a novel seagrass routine (C++) developed for the GOM by USF and CSIRO

This reviewer has no experience of seagrass, and it is therefore difficult to pass any judgement on the method used. It is clear that there is a greater level of realism than was previously possible. It is also advantageous that the new method is able to distinguish between destructive feeding on sea grass (affecting the roots) and non-destructive (grazing on the leaves). One limitation is that although it is possible to model the impacts of increased or decreased coverage of sea grass within the model, this simulation does not account for the changes in other seafloor habitats. For example, if the seagrass cover is increased there is no corresponding decrease in non-seagrass habitats. This may somewhat limit the range of questions that could be asked, and may result in slight overestimating of the impacts of changing seagrass cover. A second limitation is that the sea-grass is largely externally forced, rather than being dynamically driven inside the model. Again, this limits the range of questions which can be asked. However, it is likely that there are many questions which can be addressed using the existing formulation; the point here is that (as ever) care should be taken to ensure that the question being asked is compatible with the structure of model.

Conclusions and Recommendations

The key conclusion is that while a GOM Atlantis model represents a potentially viable platform for estimating potential shrimp response to environmental variation to provide strategic management advice, the specific model is not currently in a state where this is possible. Errors within the model (e.g., incorrect age range for shrimp, lack of stability in weight-at-age for key stocks, misspecification of recruitment time windows) mean that the dynamics of the shrimp are not currently realistic enough to use for management advice. Indeed, they mean that it is not currently possible to evaluate the realism of the model. The sea-grass component is an improvement on the previous formulation, and potentially allows for a more nuanced approach to modelling sea-grass response and as an ecosystem driver – although the range of questions that can be asked is limited. The ecosystem drivers presented were very much at the “proof of concept stage” and while it can be seen that the model does respond, no conclusions can be drawn as to the appropriateness for management of these drivers (both due to the early stage of development of the drivers and the serious bugs in the model). Furthermore, even with a sound underlying model, each specific application (e.g., a particular environmental driver) would need a separate check of the methodology before entering management advice. Finally, and critically, the overall lack of “sanity checks” against data makes it currently impossible to identify in which areas (if any) the model performs realistically.

One of the main weaknesses of the GOM Atlantis model and the whole modelling approach at present is the lack of checks against the data. Such checks can be used both to increase confidence in the model, but also as diagnostics where there are model performance issues. For example, the trend in weight over time in the red snapper would be a lot easier to interpret (and hence fix) if it was known if the weight was moving towards or away from something sensible. Rectifying this deficiency should help with model calibration and improvements, as well as being able to approve the final model for practical use.

The key recommendations can be broken into three groups. The first group is simply to fix the errors and deficiencies identified in the model. The second is that there should be a lot more "sanity checking" to identify the degree to which different parts of the model are, or are not, realistic. It may be that some parts of the model perform well, other parts less well – this does not invalidate the model but does restrict the range of questions which can be addressed. Therefore, having this overview would help identify potential uses for the model. Finally, there are some recommendations for revisions and improvements to the model structure.

Recommendations

- **Fix the shrimp age structure**. If possible, retain the age structure but reduce the length of the age categories to an appropriate range (adding functionality for sub-year age categories into Atlantis if needed). Being able to model at the least the separation in dynamics of the juvenile near-shore from the adults in deeper water. If full age structure is not possible, then find an alternate structure.

- **Check the weight at age through time for all of the key groups, and fix the model as required**. All of the key stocks should remain within a realistic weight at age range throughout the hindcast and forecast. If this is not the case, then this needs to be fixed.

- **Compute M-at-age and F-at-age** for the shrimp stocks and the other key stocks. This will facilitate sanity checks, allow for direct comparison with stock assessments, and likely be a key output for different scenarios of environmental change.

- **Fix the shrimp recruitment windows** if possible then use multiple windows, or high and low spawning times rather than a single binary window. If this is not technically possible, then at least ensure that the windows match the available biological knowledge.

- **Fix the predation dynamics.** There were a number of cases where predators were clearly eating unrealistic prey items. This clearly needs to be fixed. Given the presence of completely unrealistic predation patterns, it is plausible that there are other, less obvious errors. The whole diet data matrix therefore needs a thorough check (both in the input matrix and in the realized predation through time).

Wherever possible **all outputs of the model should be "sanity checked"** against available data and knowledge. These need not be exact matches, merely that the model outputs are reasonable. A few examples are listed below; however, these should be taken as illustrative rather than exhaustive – as many checks should be made as possible. These fit into three overall categories:

- Qualitative knowledge
  - Prepare a conceptual model of shrimp dynamics, and then compare this to the model outcomes. Modelled shrimp should be recruiting at the "right" times and places, moving between areas at the "right" times, dying at the "right" rate and so on.
- Direct comparisons:
  - E.g., compare weight at age (at model start in 1980, at the "now" tuning point, at all points in the forecast and especially the end of the stability forecast). Here there should be direct data for many stocks for comparison
  - E.g., compare M-at-age and F-at-age with fisheries assessments and scientific knowledge.
- Order of magnitude/main trend comparisons
  - E.g., stock trends compared to assessment history. These will not match exactly, given the lack of year factors for recruitment, but the overall order of magnitude and main trends (roughly constant, steeply up or down) should match.
  - Compare relative biomasses of different stocks on a qualitative level to identify if these are realistic.
- More imaginative comparisons (where only indirect information is available)
  - E.g., take MSY estimates and compare with known catches. How does the fraction of estimated MSY taken on average each year compare with knowledge of the fishery?

- **Check of fraction of M arising from senescence assumption** implicit in not using plus groups. Where the senescence M is a significant part of overall M, then consider moving to a plus group. Unless there is good supporting evidence, **no stock should have this poorly modelled senescence mortality as an important driver**. Any stock where this is the case should be converted to a stock with a plus group.

- **Check key life history values and stock biomasses at the start of the model run, the "now", and at the end of the stability forecast**. These need not match available knowledge exactly, but if they are completely out then the model may need re-tuning.

- Once there are approved single species shrimp models available, then use these for comparison.

- Maintain the existing diagnostics, but expand to check against "reality" as described above.

- Consider all of the stock groups to see if the assumption of no plus group should be revisited. Part of this is the senescence mortality check mentioned above. However, having a plus group can also allow the maximum age to be reduced, which would allow for more realism at the younger ages. These younger ages are often more dynamic and rapidly changing, and may therefore need the realism more than the older ages.

- Revise the fisheries selectivity assumptions. The model currently assumes knife edge selectivity for all stocks. Where this is not a good approximation then it should be improved.
- Use a wider year-range of data for model tuning. The model tuning was based on very limited number of years of data (both oceanographic and fisheries). This is likely to miss the variability in the system and potentially represents a biased sub-sample.
- Investigate expanding the seagrass dynamics to allow these to be more responsive to ecosystem drivers.
- Check the spatial structure (vertical and horizontal), bearing in mind the focus on shrimp dynamics. The spatial structure seems to be inherited from a previous version of the model; it may need to be revised to be able to examine specific questions around the shrimp dynamics.
- The environmental drivers on the shrimp should be considered via the conceptual model mentioned above. This should inform any future revision of the shrimp dynamics within the model.

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Appendix 2: Performance Work Statement

Performance Work Statement

External Independent Peer Review by the Center for Independent Experts

Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the Gulf of Mexico Large Marine Ecosystem

March 28 - 30th, 2023

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards[1].

[1] https://www.whitehouse.gov/wp-content/uploads/legacy_drupal_files/omb/memoranda/2005/m05-03.pdf

Scope

The purpose of this review is to evaluate the performance characteristics and to identify appropriate management applications of an Atlantis ecosystem model, employed by the University of South Florida to support SEFSC's evaluation of Ecosystem-Based Fishery

Management (EBFM) strategies for the Gulf of Mexico (GOM) Large Marine Ecosystem. This review is being undertaken as part of an EBFM funded project at the SEFSC.

NMFS strongly endorses the concept of Ecosystem-Based Fisheries Management and the related need for the development of Integrated Ecosystem Assessments, in support of EBFM. Although this review is directed at efforts in the SEFSC, and more specifically for the U.S. federal waters of the Gulf of Mexico, the findings will be more broadly applicable throughout the agency.

Objectives of the CIE review are as follows. Objective 1 is to evaluate the data, parameterization, and skill of the GOM Atlantis model, with emphasis on predicting stock dynamics and catch of Penaeid shrimp (Brown, White and Pink Shrimp groups) and major interacting species. Objective 2 is to identify the extent to which the GOM Atlantis model is suitable for incorporating environmental effects relevant to shrimp production. Objective 3 is to determine the readiness of the model to conduct simulations that assess ecosystem-level impacts of climate change. This could include representation of habitat changes, changes in environmental conditions, and tolerances of species. Objective 4 is to review recent updates to the Atlantis code base specific to the GOM Atlantis model which improves representation of seagrass dynamics. A novel routine was developed in 2021-2022 with CSIRO Australia. The routine partitions seagrass using pseudo age structure to improve representation of herbivory. The review will not otherwise focus on the Atlantis code base nor will it focus on data quality except as it pertains to model performance.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for the Reviewers

Three reviewers shall conduct an impartial and independent peer review of the GOM Atlantis ecosystem model provided, and this review should be in accordance with this Performance Work Statement (PWS) and the methodology review ToRs herein. The chair, who is in addition to the three reviewers, will be provided by the Southeast Regional Office; although the chair will be participating in this review, the chair's participation (i.e. labor and travel) is not covered by this contract.

The reviewers shall have working knowledge and recent experience in the application of multi-species or ecosystem models of marine ecosystems. This application of Atlantis includes a full dynamic, spatial representation of the marine food web including ocean circulation, biogeochemistry and fisheries. Reviewers should have expertise with models that span these levels of complexity, at a minimum coupling several species to fisheries. Reviewers should have published or supervised development of at least two different types of such models (different model platforms or frameworks), though experiences with the Atlantis model itself is not a requirement. Reviewers shall have direct experience in model development with EBFM application, including direct senior level policy applications or recommendations in addition to scientific publications.

Tasks for the Reviewers

Task 1. Review background material.

The CIE reviewers are asked to familiarize themselves with all the articles listed in Background Documents list below. The reviewers should especially be familiar with these publications: Ainsworth *et al.* (2015, 2018); Masi et al. (2017, 2018), Tarnecki et al. (2016), Morzaria-Luna et al. (2018, 2022), Court et al. (2020), Dornberger et al. (2020, 2022). Full references for these articles and other supporting documents are found below in the table Background Documents.

Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewer any recent information required for this peer review. This will include a draft technical document in preparation by Perryman et al. and other technical output.

> *Perryman, H., et al. Draft technical document describing updates to Atlantis. (MS in preparation). Contact: ainsworth@usf.edu.*

Background Documents

GOM Atlantis technical documentation

Ainsworth, C. H., Schirripa, M. J., and Morzaria-Luna, H. (eds.) 2015. An Atlantis Ecosystem Model for the Gulf of Mexico Supporting Integrated Ecosystem Assessment. NOAA Technical Memorandum NMFS-SEFSC-676, 149 p.

GOM Atlantis applications

Morzaria-Luna, H.N., Ainsworth, C.H. and Scott, R.L., 2022. Impacts of deep-water spills on mesopelagic communities and implications for the wider pelagic food web. Marine Ecology Progress Series, 681, pp.37-51.

Ainsworth, C.H., Paris, C., Perlin, N., Dornberger, L.N., Patterson, W., Chancellor, E., Murawski, S., Hollander, D., Daly, K., Romero, I., Coleman, F., Perryman, H. 2018. Impacts of the Deepwater Horizon oil spill evaluated using an end-to-end ecosystem model. PLoS One. 2018 Jan 25;13(1):e0190840. doi: 10.1371/journal.pone.0190840

Court, C., Hodges, A.W., Coffey, K., Ainsworth, C.H., Yoskowitz, D. 2020. Effects of the Deepwater Horizon Oil Spill on Human Communities: Catch and Economic Impacts. In: Deep Oil Spills, (pp. 569-580). Springer, Cham. https://doi.org/10.1007/978-3-030-11605-7_33

Dornberger, L., Montagna, P., Ainsworth, C.H., 2022. Simulating oil driven abundance changes in benthic marine invertebrates using an ecosystem model. Environmental Pollution (in press).

Dornberger, L.N., Ainsworth, C.H., Coleman, F. and Wetzel, D.L., 2020. A synthesis of top-down and bottom-up impacts of the Deepwater Horizon oil spill using ecosystem modeling. In Deep Oil Spills (pp. 536-550). Springer, Cham.

Masi, M.D., Ainsworth, C.H. and Jones, D.L., 2017. Using a Gulf of Mexico Atlantis model to evaluate ecological indicators for sensitivity to fishing mortality and robustness to observation error. Ecological indicators, 74, pp.516-525.

Masi, M.D., Ainsworth, C.H., Kaplan, I.C. and Schirripa, M.J., 2018. Interspecific interactions may influence reef fish management strategies in the Gulf of Mexico. Marine and Coastal Fisheries, 10(1), pp.24-39. DOI: 10.1002/mcf2.10001

Diet

Tarnecki, J.H., Wallace, A.A., Simons, J.D. and Ainsworth, C.H., 2016. Progression of a Gulf of Mexico food web supporting Atlantis ecosystem model development. Fisheries Research, 179, pp.237-250.

Morzaria-Luna, H.N., Ainsworth, C.H., Tarnecki, J.H. and Grüss, A., 2018. Diet composition uncertainty determines impacts on fisheries following an oil spill. Ecosystem services, 33, pp.187-198.

Spatial biomass calculations for GOM Atlantis

Grüss, A., Drexler, M.D., Chancellor, E., Ainsworth, C.H., Gleason, J.S., Tirpak, J.M., Love, M.S. and Babcock, E.A., 2019. Representing species distributions in spatially-explicit ecosystem models from presence-only data. Fisheries Research, 210, pp.89-105.

Grüss, A., Drexler, M.D., Ainsworth, C.H., Babcock, E.A., Tarnecki, J.H. and Love, M.S., 2018a. Producing distribution maps for a spatially-explicit ecosystem model using large monitoring and environmental databases and a combination of interpolation and extrapolation. Frontiers in Marine Science, 5, p.16.

Grüss, A., Perryman, H.A., Babcock, E.A., Sagarese, S.R., Thorson, J.T., Ainsworth, C.H., Anderson, E.J., Brennan, K., Campbell, M.D., Christman, M.C. and Cross, S., 2018b. Monitoring programs of the US Gulf of Mexico: inventory, development and use of a large monitoring database to map fish and invertebrate spatial distributions. Reviews in Fish Biology and Fisheries, 28(4), pp.667-691.

Grüss, A., Drexler, M.D., Ainsworth, C.H., Roberts, J.J., Carmichael, R.H., Putman, N.F., Richards, P.M., Chancellor, E., Babcock, E.A. and Love, M.S., 2018c. Improving the spatial allocation of marine mammal and sea turtle biomasses in spatially explicit ecosystem models. Marine Ecology Progress Series, 602, pp.255-274.

California Current Atlantis model review

Horne, P.J., Kaplan, I.C., Marshall, K.N., Levin, P.S., Harvey, C.J., Hermann, A.J. and Fulton, E.A. (2010) Design and Parameterization of a Spatially Explicit

Ecosystem Model of the Central California Current. *NOAA Technical Memorandum* **NMFS-NWFSC-104**, 1–140.

Kaplan, I.C., Marshall, K N. 2016. A guinea pig's tale: learning to review end-to-end marine ecosystem models for management applications. ICES J Mar Sci, 73: 1715-1724.

Kaplan, I.C., Brown, C.J., Fulton, E.A., Gray, I.A., Field, J.C. and Smith, A.D.M. (2013) Impacts of depleting forage species in the California Current. *Environmental Conservation* **40**, 380–393.

Kaplan, I.C., Gray, I.A. and Levin, P.S. (2012a) Cumulative impacts of fisheries in the California Current. *Fish and Fisheries* **10.1111/j.1467-2979.2012.00484.x**.

Kaplan, I.C., Horne, P.J. and Levin, P.S. (2012b) Screening California Current Fishery Management Scenarios using the Atlantis End-to-End Ecosystem Model. *Progress In Oceanography* **102**, 5–18.

Olsen, E., Kaplan, I.C., Ainsworth, C., Fay, G., Gaichas, S., Gamble, R., Girardin, R., Eide, C.H., Ihde, T.F., Morzaria-Luna, H.N. and Johnson, K.F., 2018. Ocean futures under ocean acidification, marine protection, and changing fishing pressures explored using a worldwide suite of ecosystem models. Frontiers in Marine Science, 5, p.64.

Task 2. Attend review panel meeting

Reviewers will attend and participate at a panel review meeting. The draft meeting agenda is provided in Annex 3. The meeting will consist of presentations by NOAA. Other scientists will be available to answer questions from the reviewers and to provide additional information required by the reviewers. The review panel will be chaired by a member of the Gulf of Mexico's Fishery Management Council's Scientific and Statistical Committee (SSC), and the panel will include other SSC members as well as Center for Independent Experts (CIE) reviewers. The review will follow the Methodology Review Process established by the Pacific Fishery Management Council, and the Terms of Reference below adapt portions of those Terms of Reference for our application in the Gulf of Mexico.

Task 3. Produce summary report from meeting

Reviewers will assist the Chair of the review meeting with contributions to the summary report from the meeting.

Task 4. Prepare peer-review report

Reviewers will prepare an independent peer review with report following the review meeting in accordance with the requirements specified in this PWS, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines in Annex 1 and peer-review TORs in Annex 2. Reviewers are not required to reach a consensus.

Reviewers will deliver their reports to the Government according to the specified milestones dates listed below.

Foreign National Security Clearance:
When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Foreign National Guest website.

Place of Performance:
Each reviewer shall conduct an independent peer review during the panel review meeting scheduled in St. Petersburg, FL during the following dates: March 28 - 30, 2023.

Period of Performance
The period of performance shall be from the time of award through May 2023. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Delivery
Each reviewer shall complete an independent peer review report in accordance with the PWS. Each reviewer shall complete the independent peer review according to required format and content as described in **Annex 1**. Each reviewer shall complete the independent peer review addressing each stock assessment ToR listed in **Annex 2**.

Tentative Schedule of Milestones and Deliverables
The contractor shall complete the tasks and deliverables described in this PWS in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
Two weeks prior to the panel review	NMFS Project Contact provides reviewers the pre-review documents
March 28 - 30, 2023	Each reviewer participates and conducts an independent peer review during the panel review meeting
Within three weeks of the panel review meeting	Reviewers submit draft independent peer review reports to the contractor's technical team for independent review
Within two weeks of receiving draft reports	Contractor submits final reports to the Government

*The Chair's Summary Report will not be submitted to, reviewed, or approved by the Contractor.

Modifications to the Performance Work Statement: Each reviewer will write an individual review report in accordance with the PWS, OMB Guidelines, and the TORs below. Modifications to the PWS and TORs cannot be made during the peer review, and any PWS or TORs modifications prior to the peer review shall be approved by the Contracting Officer's Representative (COR) and the CIE contractor. The PWS and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables:
The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content; (2) The reports shall address each TOR as specified; and (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel
All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (https://www.gsa.gov/policy-regulations/regulations/federal-travel-regulation). International travel is authorized for this contract. Travel is not to exceed $15,000.00.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

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Annex 1: Format and Contents of Independent Peer Review Report

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

Appendix 1: Bibliography of materials provided for review
Appendix 2: A copy of this Performance Work Statement
Appendix 3: Panel membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference

Peer review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the Gulf of Mexico Large Marine Ecosystem

TERMS OF REFERENCE

These terms of reference are meant to provide guidance for technical requirements for the final peer review report. It is assumed this report will be developed after the panel meeting and will contain inputs from CIE reviewers, SSC members, and others. The final report should address the readiness of the model to address priority model capabilities in TOR 1. Model capabilities can be evaluated on the basis of technical merits and deficiencies indicated in TOR 2.

1. **TOR 1. Reviewers will comment on the technical merits and deficiencies of the methodology and recommendations for remedies.**

    a. What are the data requirements of the methodology?
    b. What are the general situations, management uses, and spatial scales for which the methodology is applicable? (also to be discussed further in TOR 2)
    c. What are the assumptions of the methodology?
    d. Is the methodology correct from a technical perspective?
    e. How robust are results to departures from the assumptions of the methodology?
    f. Does the methodology provide estimates of uncertainty? How comprehensive are those estimates?
    g. What is the process of model fitting and calibration?
    h. Areas of disagreement regarding panel recommendations: among panel members; and between the panel and proponents.
    i. Unresolved problems and major uncertainties, e.g., any issues that could preclude use of the methodology.
    j. Management, data or fishery issues raised during the panel review.
    k. Prioritized recommendations for future research and data collection.

2. **TOR 2. Reviewers will address model readiness concerning priority capabilities**
    a. Evaluate data, parameterizations and skill of GOM Atlantis with emphasis on Penaeid shrimp.
    b. Evaluate the treatment of environmental processes in the model relevant to shrimp production.
    c. Evaluate the readiness of the model to perform climate change simulations, including habitat effects.
    d. Evaluate the use of a novel seagrass routine (C++) developed for the GOM by USF and CSIRO

Annex 3: Tentative Agenda – (*Final agenda to be provided two weeks prior to the meeting***)**

Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the Gulf of Mexico Large Marine Ecosystem

March 28 – March 30, 2022

Florida Fish and Wildlife Research Institute

100 8th Avenue SE

St. Petersburg FL 33701

Tuesday March 28th, 2023

9:00-9:30	Introduction to the role of Atlantis ecosystem model at the Southeast Fisheries Science Center (Michelle Masi)
9:30-10:00	History, goals, and evolution of Atlantis model development at NWFSC and CSIRO (Isaac Kaplan)
10-10:20	Current and potential role of Atlantis ecosystem models for the Gulf of Mexico Integrated Ecosystem Assessment and/or Council's Fishery Ecosystem Plan (Chris Kelble/Mandy Karnauskas)
Break	
10:30-12	Atlantis modeling framework overview (Cameron Ainsworth/Holly Perryman)
Lunch	
1:00-2:00	History of GOM Atlantis and published work (Cameron Ainsworth/Holly Perryman)
Break	
2:15-3:30	Major updates to 2023 tech memo: larval dispersal, seagrass routine/dynamics (TOR #)
	Management strategy evaluation (Cameron Ainsworth/Holly Perryman) (TOR #)
3:30-4:30	Panel deliberation— 1 hr

Wednesday March 29th, 2023

Published Atlantis model (Cameron Ainsworth/Holly Perryman)

9:00 - 9:30 Aims of the modeling effort
9:30 - 9:45 Geography and functional groups
9:45 - 10:30 Data (Cameron Ainsworth)

- Lower trophic levels
- Fish
- Protected species
- Fisheries and management representation

Break

10:45-12:00 Example applications and recent publications (Cameron Ainsworth)

- Testing management scenarios
- Cumulative impacts of groundfish fisheries
- Forage fish harvest and effects on food web
- Linking of Atlantis to economic impacts models

Lunch

1:00 - 2:30 Model calibration (Cameron Ainsworth/Holly Perryman)

- Estimates of unfished biomass
- Sensitivity to fixed fishing mortalities, estimates of MSY and FMSY

2:30-3:30 Handling of uncertainty (Cameron Ainsworth/Holly Perryman)

- Bounded scenarios – uncertainty in biomass estimates
- Bounded scenarios – uncertainty in rate parameters
- Temperature driven movement of shrimp

3:30-4:00 Discussion regarding the appropriate role of this model for management needs defined in TOR 1.

4:00-5:00 Panel deliberation

Thurs, March 30th, 2023

Public Comment & CIE Panel Discussion and Q&As

9:30-11:30 Public Comment (Open to the Public)
Lunch

12:30-2:30 Extra time to discuss any provided model diagnostic material

Appendix 3: Panel membership or other pertinent information from the panel review meeting.

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Review Panel

CIE Reviewers: Drs. Vidette McGregor, Daniel Howell, and Ken Drinkwater
Regional Reviewers: Drs. Luiz Barbieri, Joshua Kilborn, Dave Chagaris

Meeting Facilitator

Matt Freeman (Gulf Council)

Project Team

PIs & Co-PIs: Drs Michelle Masi (SEFSC/SERO), Cameron Ainsworth (USF), Isaac Kaplan (NWFSC), Howard Townsend (OST), S. Sagarese (SEFSC), C. Kelble (AOML) and , Mandy Karnauskas (SEFSC)

Modeling Team: Dr. Cameron Ainsworth (USF), Dr. Holly Perryman (USF/IMR), Rebecca Scott (USF)

Other Attendees

SEFSC and SERO personnel, interested public

Appendix 4: Final agenda

Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the Gulf of Mexico Large Marine Ecosystem

March 28 – March 30, 2022

Florida Fish and Wildlife Research Institute

100 8th Avenue SE

St. Petersburg FL 33701

Tuesday March 28th, 2023

Day 1 Goals: Overview of the Gulf of Mexico Model Configuration and applications (2015 NOAA Tech Memo and peer-reviewed literature)

9:00-9:20 am Introductions, TORs, roles and rules review (Matt Freeman)

9:20-9:30 am Aims of the modeling effort: project overview & the intended simulation/strategic application of the model post-CIE review (Michelle Masi)

9:30-9:50 am CIE review recap of the NWFSC Atlantis Model, and overview of why we elected to hone in on subset of species (Isaac Kaplan)

9:50-10:05 am How the southeast region is building ecosystem modeling capacity to better address strategic management priorities (Mandy Karnauskas)

Break 25 mins

10:30-12 pm Atlantis End-to-End Model (TOR 1.a,b,c,d)

- The Atlantis Approach (General references)
- CSIRO & world community

GOM Atlantis model

- GOM Atlantis Model Tech Memo (2015) (TOR 1.a,b) Fitting (TOR 1.g)
- GOM Atlantis Tech Memo (Draft)
    - With updates to Feb 2023 (TOR 1.a,b)
    - TOR 1.a, 2.a: Data refinements and parameterization
- Hydrodynamic forcing data
- Biomass of species
- GOM Atlantis fisheries, high-level overview
    - Fleet structure
- Migration
- Statistical habitat effects - Spatial distribution of species
    - 40 fish & invertebrate groups (Drexler and Ainsworth 2013)

    - Pink shrimp PSH (Gruss et al. 2014)
    - 61 fish & invertebrate groups (Gruss et al. 2018b)
    - 32 fish & invertebrate groups (Gruss et al. 2018a.)
    - 2 bird groups DBR SBR (Gruss et al. 2019)
    - 2 marine mammals and 2 sea turtles (Gruss et al. 2018c.)
    - 2 sea turtle (ICHTHYOP) (Scott et al. *in prep*)
- Predator-prey dynamics
    - Food web diagram
    - Dirichlet model (Masi et al. 2014)
    - Improved Western GOM diet data (Tarnecki et al. 2016)
    - Diet uncertainty in simulations (Morzaria-Luna et al. 2022)
    - Improving pelagic interactions (Scott et al. *in prep*)

Lunch 1 hour

1:00-1:45 Additional applications of the methodology (TOR 1.b)

- Effects of the Deepwater Horizon Oil Spill on Human Communities: Catch and Economic Impacts (Court et al. 2020)

GOM model applications (TOR # 1.b, 1.e, 1.f, 1.g)

- Oil fate model coupling (Ainsworth et al. 2017)
    - Uncertainty (TOR 1.f)
- Impacts of deep-water spills on mesopelagic communities and implications for the wider pelagic food web (Morzaria Luna et al. 2022)
- Ecological indicators (Masi et al. 2017)
- Management Strategy Evaluation (Masi et al. 2018)

Break 30 min

2:15 - 3:30 GOM Atlantis model updates to improve representation of environmental processes that drive the distribution and abundance of shrimp, and may be impacted under a changing climate (TOR # 2.b, c. and d.)

- Larval dispersal (Kelly Vasbinder UC Santa Cruz); Hydrodynamics ; Vertical migration behavior
- Nutrient & Detritus cycles (e.g., Dornberger et al. 2022)
- Seagrass routine affect carrying capacity
- Habitat affinity statistical model (in prep)

3:30 - 4:30 Public comment / discussion

Wednesday March 29th, 2023

Day 2 Goals: Overview of GOM Atlantis model updates (New NOAA Tech Memo) and improvements, focused on Penaeid shrimp and their top 10 major interacting species

9:00 - 9:30 Shrimp biology/ecology overview (Michelle Masi, for Jen Leo)

9:30-10:15 GOM Atlantis model tuning and diagnostics regarding Penaeids and their major interacting species groups (TOR #2.a)

- Population dynamics
- Life history and ecology

Break 30 mins

10:45 - 12:00 GOM Atlantis model tuning and diagnostics regarding Penaeids and their major interacting species groups (continued) (TOR #2.a)
[Penaeid shrimp fisheries representation, particularly as compared to Southeast Data, Assessment and Review (SEDAR) reports]

- Updates and improvements to GOM Atlantis Model fisheries
- Landings and discards
    - Bycatch adjustments, following internal panel recommendations
        - Dead discard setup: US otter trawl fishery
        - Dead discard setup: US recreational fishing
    - Summary of simulated US catches and fishing mortalities (Atlantis vs SEDAR)

Lunch 1 hour

1:00 - 2:00 Model sensitivity for penaeids and focal groups (TOR 2.a, TOR 1.e, 1.g)

- Productivity for Penaeids - estimates of shrimp MSY and FMSY from a selection of GOM EwE models
- Equilibrium state under no fishing pressure?
- Penaeid sensitivity to food availability

Break 30 mins

2:30-3:30 Handling of uncertainty (Cameron Ainsworth/Holly Perryman) (TOR 2.a-.c, TOR 2.f)

- Diet composition uncertainty determines impacts on fisheries following an oil spill (Morzaria-Luna et al. 2018)
- Bounded scenarios
    - uncertainty in initial penaeid shrimp biomass estimates
    - uncertainty in seagrass coverage
        - Is shrimp abundance/distribution altered under these scenarios?
    - uncertainty in rate parameters
        - Temperature impacts on recruitment and movement

3:30-4:30 Public comment / discussion

Thurs, March 30th, 2023

Day 3 Goals: Initiate peer review report writing and ensure that the reviewers have all necessary materials to complete the review.

9:00-10:30	CIE Panel Discussion and Q&As discussion: extra time to discuss any diagnostic material
10:30-12:00	Panel deliberation and Report writing
Lunch	1 hour
1:00-2:30	Additional deliberation & closeout