Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the California Current Large Marine Ecosystem

External Independent Peer Review

by

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Executive Summary

An independent peer review panel (Panel) met with several participants at a workshop to review Atlantis modelling of the California Current at the Northwest Fisheries Science Center (NWFSC) in Seattle, from June 30 to July 2, 2014.

As outlined in this review, discussion focused on the Atlantis modelling framework (Framework) and a model (Model) of the California Current (CC) developed within that framework, its strengths, weaknesses and applicability to assist the Pacific Fishery Management Council (Council) in the future management of regional fisheries. During the review, however, it was made clear that this particular modelling framework and model have now been replaced. This meant that although the outgoing model could be sufficiently assessed, unfortunately, the new one – of most relevance - could not.

The Atlantis modelling framework (old and new) represents the state-of-the-art methodology for end-to-end models which incorporate spatial oceanography, chemistry, the biology of significant invertebrate and vertebrate groups in a framework which allows a range of fishing controls to be simulated. Of necessity with such a wide coverage and extraordinary data requirements, it is not a statistical model, and the way it handles uncertainty does not meet the requirements of present stock assessments designed for dynamic tactical use. It is, however, well suited to strategic uses such as the focus of management discussions and the formulation of strategic decisions through Management Strategy Evaluation (MSE), which looks at complex tradeoffs in the context of a range of sometimes-unspecified uncertainties.

The outgoing CC Model has a number of limitations, some imposed on it by the old Framework, and others due to limitations in data or model development resources. Nevertheless, the Model and Framework have demonstrated a wide range of applications and have been used for a range of reviewed scientific publications. For a number of reasons, however, when considered for a significant contribution to

management (such as with forage fishes) it has thus far been found wanting. It has had a range of validations performed (though more were suggested at the review) and appears to be quite competent to address a range of strategic management questions. By its nature it should not be used to address tactical questions, and therefore any indices that may be output should not be confused with those from more statistical approaches better focused on short-term outcomes. For tactical use it is a blunt instrument with as yet no proven track record.

The new CC Model was at the time of review still 'untuned', and several functional groups represented do not persist in the model simulations even in the absence of fishing. As such, validation is not really possible. With the model in this state it is not possible to fully review it or consider its uses except by extrapolation from the outgoing Model. I have assumed that the greatly improved Framework will address many past concerns. Further, the new model separates many groups previously lumped and extends the spatial coverage in a way that incorporates the total range of many fisheries of interest. It appears to have tremendous potential but this could not be fully assessed. It was apparent that fisheries managers and economists must in the future liaise more closely with the Model developers to ensure its accuracy and relevance. Further, the funding of this important tool appears to have taken place with piecemeal funding and relied on goodwill from overseas scientists (themselves under increasingly severe budgetary constraints). If this tool is to be useful in the relatively risk-adverse management of fisheries in the region it will require more support through funding and directed liaison with end-users. This is required now during the current development cycle or it will continue to be an underused but 'interesting' scientific research tool.

Background

This review is based principally on information (material and presentations) made available before and at a meeting held at the Northwest Fisheries Science Center (NWFSC) in Seattle, from June 30 to July 2, 2014. A bibliography of published and report material provided is listed in Appendix 1 and the formal statement of work is given in Appendix 2 (including terms of reference (ToR) in Annex 2 and tentative meeting agenda in Annex 3) (these were provided when this work was agreed as 'Attachment A: Statement of Work' to this reviewer – and are similar to the ToR (Appendix 3, Annex 2) provided to the entire review panel (Panel) via a website by the chair which will also be covered more broadly in my review). Annex 4 in Appendix 3 provides the list of Panel participants. The meeting was conducted with presentations on the topics given in the Appendix 3, Annex 3 along with considerable and useful discussions among the participants on most topics. A comprehensive yet draft version of the Panel's review report was made available (on this reviewer's) July 12. This was after this independent review had been written but I have subsequently added specific references to the Panel's report where appropriate.

This reviewer has a background in fisheries management and advice based mainly on statistical stock assessment methods, both single and multispecies models. In addition, I have decades of experience doing scientific programming, modelling and more recently ecosystem modelling using the Ecopath with EcoSim (EwE) and Atlantis frameworks. The review necessarily reflects this background to some extent.

The formal project description for this review (from Appendix 2) is as follows:

The purpose of this review is to evaluate the performance characteristics and to identify appropriate management applications of an Atlantis ecosystem model, employed at NWFSC as an operating model in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the California Current Large Marine Ecosystem. This review is being undertaken based on recommendations by the Scientific and Statistical Committee (SSC) of the Pacific Fishery Management Council (PFMC), who will chair the

review panel.

Phil Levin presented on why the council had interest in the use of ecological modelling and in particular Atlantis to assist in guiding management decisions. There was a need to know about potential reactions to perturbations, tradeoffs, effects on ecosystems and cumulative impacts. Initial assessment sponsored by the Moore Foundation indicated that these models (this software) had the potential to provide strategic information but not tactical guidance. It is known to have huge data requirements but as such this does highlight the value of much information being collected via existing monitoring programs. The question seems to be 'what, if any role could these models offer now or in the future to the PFMC?'.

The Panel review conducted at NWFSC methodically went through aspects of the model structure, its data need, its construction, calibration and published applications which are well described in the Panel's draft report. It must be said, however, that in some ways this review was ill timed. From time to time there have been major updates to the Atlantis model framework (Framework) (the underlying software) which defines limits to the structure and operation of models developed within that Framework. It is clear that most of this review, and almost all of the written submissions including published papers related to a Framework that has been replaced within this last year. Further, the review focused on a version of the California Current (CC) Model (Model) developed in that now superseded Framework. As a result, only the last half-day was focused on the new Framework, which is on the, as yet, not calibrated and functional CC Model (referred to by the Panel's report as the 3rd version of the model). Much time and effort went into critiquing aspects or limitations of the old Framework or Model. Some of these concerns have been addressed in the new Framework and in the new Model within that expanded Framework. Unfortunately, it is not yet possible to demonstrate much of the new work fully and it is yet to be well tested. Therefore, I have chosen to provide my comments on the Framework and Model presented for the bulk of the review process but to annotate where improvements or changes have occurred (or been promised) by/in the new Framework and Model.

There are many points in this review where comments/recommendations may fit within more than one ToR. For brevity, however, these will not be repeated in the text but they will be collected together in a section on recommendations. I will be discussing under ToR3 the elements of Model application covered in ToR1 provided to the Panel. I will deal with the Panel's ToR2 elements as appropriate throughout this review (but particularly in my ToR2) but special attention was made not to omit material that was appropriate to the Panel's ToR.

ToR 1 – Review documents detailing Atlantis ecosystem model methodologies according to the PFMC ToR for the Methodology Review Process for Groundfish and Coastal Pelagic Species. Evaluate if the documented and presented information is sufficiently complete. Document the meeting discussions and contribute to a summary panel report.

Documents were provided via FTP and as email attachments that outlined the Atlantis Framework and a range of published and unpublished accounts of the application of the California Current (CC) Model that was developed under that Framework. As state above, the Framework presented was one that had already been superseded, and as such most of the review's resources were spent discussing and critiquing a Framework and Model that will not have relevance to the future Council management. Some material was provided on the new Framework and CC Model, but this was relegated to the third (half-day) of a multiday process.

Nevertheless, the documents provided were sufficient to ascertain both systematic and specific characteristics of both the Atlantis Framework and the CC Atlantis Model as they pertain to its possible use in future Council management. The meeting discussions followed a series of presentations (Appendix 3). This reviewer contributed to these discussions and to the Panel's recommendations. Some of the details will be dealt with in ToR2 below.

It is my opinion that the review process was sufficient to evaluate the outgoing Atlantis Framework and CC Model but <u>not</u> timed properly to evaluate the new Framework or Model. Apparently this new Model has been under development for some months. The inability to review the new, and therefore most relevant Framework and CC Model is unfortunate. The bad timing may have stemmed from lags in arranging the review, and in the uncertain and at times apparently *ad hoc* update schedule for the underlying model framework which very much dictates what type of models can be developed. This in turn likely arises because of the low level and discontinuous level of support funding. Both the Australian scientist, Dr Beth Fulton, who developed the Framework (all versions), and Dr

Isaac Kaplan are dependent funding from a range of sources (with interests likely not central to those of the Council) and discontinuous in nature. This constrains both the delivery of updates to the model framework and the very labor/data intense development of models such as the CC within that Framework.

Recommendation: Schedule an additional (additive) minor methodological review (summer 2015) to evaluate the anticipated changes/improvements to the Framework and the new Atlantis CC Model.

Comments on Provided Reviewed Literature

Kaplan et al. (2013) demonstrated the variability in projected output biomass in some groups between the CC Model and the comparable EwE ecological model. In the case of the euphausiid group, it exhibited highly variable biomass dynamics, which the authors ascribed to its high productivity and rapid turnover rate. This prompted researchers to average the values over the last 20 years of the simulation, whereas they found no such variability (seasonality) in this group and other forage groups in the EwE model. Such differences were not uncommon in published comparisons of models in the two modelling frameworks for the same area. Often it is the Atlantis model, which is less responsive/reactive. This does demonstrate, however, that different approaches to recruitment (forced or as a result of stock-recruitment relationship assumed) tend to dominate the behavioral dynamics of lower trophic vertebrates (and those preying on them). *[It may also indicate that the models differ in the way they restrict interactions between predators and prey, and hence change the nature of top-down versus bottom-up control – with resulting differences to stability]*

Fulton et al. 2011, which is the paper describing the appropriate use of the Atlantis modelling framework by the creator and the developer of the Atlantis CC model, stated "Atlantis is best suited to the investigation of cumulative impacts, as a strategic tool to explore ecosystem dynamics and to test general management approaches". This reinforces the position that this system is not for the provision of tactical advice. They

later stated “it is important to focus on accuracy rather than precision. In turn, this means that while Atlantis is suitable for strategic direction setting, other models, such as fishery stock assessment models (e.g. Methot 2009) or extended stock assessment models (Townsend et al. 2008) and spatial allocation software packages such as MARXAN (Ball and Possingham 2000; Possingham et al. 2000), are much more appropriate for addressing specific, tactical fisheries and conservation management questions. Atlantis is useful for strategic analyses at a whole-of-system where the questions involve the intertwining of many species, biophysical processes, fleets and management levers. Even then end-to-end models like Atlantis should be considered as one tool in a properly stocked toolbox for EBM”. And they later summarized again that “It is a strategic model best used to consider broad management strategies and large-scale system dynamics and should be considered as one among a range of many tools available to those interested in natural resource dynamics, exploitation and management“. The position that Atlantis models can help with strategic advice only in concert with other models and approaches was reinforced continuously throughout the Panel’s review. In fact, the times when the model and its output were most criticized were when there was a risk that the form of the output (exact numbers or indices) would be used or cited for tactical purposes. This is a tremendous temptation to move its use from the strategic to the tactical, and it must be avoided.

In general, there was sufficient peer-reviewed literature provided to establish the broad efficacy of the Atlantis Framework and the Atlantis CC Model to investigate in a broad strategic way, important research issues of interest to the Council. Being scientific papers, however, this was assessed by other scientists, likely ecological modelers, and not by those directly involved in the management of resources in the CC. That is the direct relevance of the published applications to the Council is yet to be determined until there is sufficient liaison. The Panel review will greatly assist but not substitute for this.

ToR 2 – Evaluate the <u>technical merits and deficiencies</u> of the proposed method(s) taking into consideration the data requirements of each method, the conditions under which the method is applicable, the assumptions of each method, and the robustness of model results to departures from model assumptions and atypical data inputs. Recommend alternative methods or modifications to the proposed methods, or both, during the panel meeting. Recommendations and requests for additional or revised analyses during the panel meeting must be clear, explicit, and in writing. Comment on the degree to which the methods describe and quantify the sources of uncertainty in the results.

I will proceed to discuss the merits and deficiencies in a similar order to the way they were discussed during the review process - but perhaps it is relevant here to discuss briefly how Atlantis models compare with the alternatives available.

Of course, classical stock assessments such as are used currently to make management decisions are themselves 'models', and at a minimum they include (at least implied) representations of at least two species – one the target of the fishery and the other humans (arguably the target of the management). Some would consider these models simple and therefore transparent and reliable. While discussion about this is beyond this review brief it should be said that those reviewing models will of course have bias based on their past exposure. Some are quite content to accept uncertainties with conventional assessment but frown on more 'complicated' and 'unproven' approaches. This is particularly so when (even) the 'simple' approaches have often failed to describe accurately and tactically the future states of nature. Some have decided that these failings can be addressed by considering more complications (requiring even more data) while others simply want to invest limited resources in better data to support 'conventional' (proven/accepted) approaches.

These unavoidable biases were evident in the review process. The level of complexity must of course be appropriate to the task (and data) at hand. Part of the problem is that the 'task' is somewhat ill defined. That is, there is an element of, having adopted a Framework and Model within it, there now a process of deciding what it can (and cannot)

be used for. While this is not uncommon - it is of course not the best approach.

Basically in the view of this reviewer there is a spectrum of complexity (as indeed there has developed in 'classical' assessment methods as well) that range for the simplest biomass models of 'one' target species to those of medium complexity (incorporating only one or two coupled species), to those of more species with only functional relationships that predict basic (directional and proportional) relationships (loop models). Beyond that we have a range of ecological models (those relevant to the CC are summarised below) of which one of the most comprehensive is Atlantis. This is of course not where the spectrum stops. True end-to-end models used conventionally by oceanographers are extremely detailed but do not traditionally concern themselves with modelling the range of aspects that Atlantis attempts, nor are they usually candidates for management-support roles.

Some of the Panel clearly feel more confident with using 'traditional' assessment methods and would prefer that any new methods support these. The Panel stated in their report that "Atlantis is a tuned simulation model, not a statistical estimation model like stock assessment models that the Council and its advisory bodies are accustomed to". I fully agree. Traditional methods have driven the data collection processes and will continue to attract the funding. Perhaps most importantly, their use has become mandated. Others believe that the models of intermediate complexity (MICE) should be developed as needed (including only those species required and immediately (and obviously) impacted). While there is support for ecological modelling, there is a reluctance on the part of many to fund their development adequately, to support their huge data and computing needs, and to engage with the development of their management and economic/social sub model development. In fact, there are those that clearly believe that models have only two useful (traditional) levels of complexity. They prefer either those of accepted assessments, or otherwise, those of the extreme end-to-end models developed by oceanographers and climatologists and the like.

This reviewer believes that the problem to be addressed must be identified, and the most suitable approach funded and developed. However, that said, we must continue to

develop future approaches well in advance of unforeseen demands. While it is evident that traditional methods will not be replaced anytime soon, there are strong synergisms possible with a range of ecological modelling approaches.

Ecological modelling approaches used for the California Current

Summarised from Draft Report of the Pacific Sardine Harvest Parameters Workshop (2013)

CALIFORNIA CURRENT ATLANTIS MODEL: spatially explicit, models sardine and anchovy as distinct species, and may be well suited to capturing climate and oceanographic impacts on these stocks as well as movement of purse seine fleets.

NORTHERN CALIFORNIA ECOSIM MODEL: not spatial, models sardine as an individual species. However other forage fish are aggregated into a single group (Northern Anchovy, Pacific herring, sand lance, eulachon, American shad, surf smelt, whitebait smelt, and other clupeids). This model has been included in analyses for the 2011 Integrated Ecosystem Assessment (Levin and Schwing 2011), the 2012 Integrated Ecosystem Assessment, and analyses of potential food-web impacts of forage fish harvest (Kaplan et al., in press; Smith et al., 2011).

ECONOMIC ANALYSES: not spatial, two economic analyses of the indirect effects of sardine harvest in the California Current involved the static (Ecopath) version of Ecosim-NCC

NORTHERN CALIFORNIA CURRENT ECOTRAN MODEL: complements other California Current ecosystem models in two areas: 1) Assessing small pelagic (especially sardine) risks and management scenarios that can be influenced by climate, and 2) providing Monte Carlo simulations to address observational uncertainties and natural variability in scenario simulations. This model has proven useful for examining scenarios of alternative (forage fish, krill, jellyfish) food web pathways (Ruzicka et al., 2012).

NEMURO-SAN: spatially explicit, models sardine and anchovy as distinct species, and may

be well suited to capturing climate and oceanographic impacts on these stocks as well as movement of purse seine fleets.

Data requirements

There was much time used in the Panel review to discuss the data requirements of the Atlantic CC Model and of the Atlantis Framework in general. As expected with an 'end-to-end' model, these requirements are extensive and are well beyond that of conventional assessments. Beyond these needs, there was often discussion about using yet more data sources for attempts to validate parts of the model output or even its transitional states. For example, to check that evolved diets in the model matched those in nature. There were suggestions by panel members that the CC Model had more data requirements that for models used in SE Australia. When the new Model was discussed there was a sense that although there is now more extensive data available (or has been located) the extended Model coverage and other aspects will demand more data. For complex models, being continuously data 'deficient' is a considerable problem. Some argue that the way in which this process values data (from monitoring programs) and binds it together in new ways – validates established data collection/monitoring processes in place and that is a positive feature.

The specific data needs are well outlined in the published data and the technical material available (and reflected well in the draft Panel report). These start at the spatial and oceanographic model including the need to either extend smaller surveys, or more often downscale larger oceanographic models to provide the current flows, nutrient data for the specific geography defined. Habitat mapping is required for the areas. Then there has to be historical data sets to describe the abundance of all living model components, information on their dynamic processes, diets, recruitment etc. Often data do (or should) constrain model detail. Not all aspects of the living world are (or should be) included (the Panel argued that some groups that cannot be well represented should be omitted). Some groups are left out, while ours are combined. Much information for fish is taken from the on-line source FishBase (growth, size of maturity etc.) but for commercial species there is

usually much information from other research and monitoring programs available (though usually not segmented for the same spatial areas distinguished in Atlantis which has depth layers are well as boxes).

Model Fitting and Calibration

As would be expected given the composition of the panel, there was considerable discussion of model fitting and calibration. Such a complex model (with so many interactions) is very hard to fit and calibrate. When models are built the process of selecting the areas, the groups, collecting the relevant data and combining them into the model takes many months. There is simply no flexibility to reassemble model areas or functional groups at will within or similar Frameworks. This means that decisions taken early in the process can constrain greatly how models are developed and used later.

From Horn et al. (2010) these are the steps taken:

Phase 1: Spin up to unfished conditions

Phase 2: Sensitivity to fixed fishing mortalities (estimates of MSY Fmsy)

Phase 3: Comparison to historical trends

As was explained, the first step in fitting is to achieve a degree of balance in unperturbed, unfished systems where groups reach and maintain some persistent and credible 'quasi' equilibrium. This may seem trivial or a rather low-order requirement for a model that is supposed to help managers deal with fisheries where the 'human/societal' aspects can be the most challenging. This is not so. Reaching a point where modeled groups all persist can take months of work during which time the diets, the spatial overlaps and many aspects have to be reexamined in detail (as commented on elsewhere the modeller or Framework developer needs to find ways to fit parts of the model in relative isolation/simplicity in order to speed things along). Further, as there are two biomass or nutrient pools for most groups – skeletal and somatic (gonadal) being monitored –this makes it even more complicated. After 'persistence' is achieved (largely) then the dynamics can be investigated.

The new Atlantis CC Model has not passed this first challenge yet of model fitting – several groups still 'collapse'. This reinforces that the timing of the current review with regard this new model is poorly timed. The model cannot yet reproduce the basic characteristic of nature – persistence. In fact, there was some discussion that even the older developed models has slow trends in some groups – the 'quasi equilibrium' was not stable, and that longer runs should be studied (which of course would require more computer time). Also, if an important functional group like 'kelp' goes extinct (in the Model) then there are flow-on impacts to other groups that critically rely on this habitat. Any group well networked in the model will have impacts on many others (this is why ecological models are created in the first place) – therefore groups with strange dynamics can impact the entire model and its predictions. Deciding to reject them from the model in order to expedite development can be highly problematic.

When models are 'spun up' and reached a 'quasi equilibrium' without fishing, it is considered reasonable that groups converge on their B_o level. The level that the model estimates is then compared to data sources and expected to be within 50% of the expected value. Importantly, they do not attempt to tune the model to produce a specific B_o but rather this is used to decide if the model is behaving reasonably. If the model is not producing the expected result then tuning adjustments may include adjusting the growth rates, the diet suitability coefficients ('A' variables), and recalibrations of recruitment. Unfortunately, as discussed at the workshop, some long-lived groups like whales may not have been allowed to 'spin up' long enough to decide on their 'quasi equilibrium' levels. This is in part a tradeoff of the complexity of model tuning and the long computation times required by model trials (which were about 18 hours per trial apparently for the older model but will have increased for the newer one).

Best Practices for Ecological Modelling

There was some discussion about 'best practices for ecological modelling' as described in FAO (2008). At least one of the panel members was on the group that created the

publication. This group believed that the major uses of ecological modelling were to assist with: conceptual understanding, strategic and tactical advice/support. They described the range of models in existence at that time and their uses.

Perhaps of most relevance to this review (and mentioned at the review in this context) were their statements about uncertainties in models. They stated "best practice requires clear statements about uncertainties in model parameters". They continued "similar to uncertainty in model structure, evaluating the sensitivity of model outcomes to parameter uncertainty is essential for all of the strategic and tactical questions and issues that may be addressed with ecosystem models". They concluded that "best practice for quantifying parameter uncertainties in more complex ecosystem models is currently not clear (this is an area of active research). Nevertheless, the current practice of adopting default parameter values, and their distributions if such are available should be improved so that careful attention is paid to all parameters. At a minimum, this requires: 1) that there is an explicit accounting of the number of parameters that are being estimated and fixed, 2) qualitative estimates of the uncertainty in every parameter, and 3) sensitivity analyses".

It is clear that this is still an area where clarification and further research is needed. At present attempting to reconstruct historical data, looking at internal representations that develop like diet or size at age and ensuring they match published accounts, and probing the sensitivity of modeled outcomes to parameter with a range of possible values seems to be what is the current practice (even if the best practice is unclear). The development of the Atlantis CC Model and its treatment of uncertainty, though it might worry those used to simpler and less data intensive assessment models, is nevertheless 'state of the art' and 'best practice'.

Model Framework and Model Versioning

As the Framework and its characteristics were described, it became apparent that this have developed over time and is continuing to develop. Further, it was clear that the Framework (past and present) offered a range of options that are fully elective (and

parameter values must be supplied for some that are selected). This leads to potential confusion. When this reviewer asked about how versions were controlled he was told that the version control software allows updates from the developer (CSIRO in Australia) to be downloaded and synchronized. But what is required is for versioning numbers to be prominently used. For example, the Framework we initially reviewed could be version 2.5.2, whereas the vastly altered new Framework (which was not completely reviewed) could be 3.0.1. This would at least allow everyone to know what version we are talking about especially if a document was provided which specified changes to the each version of the Framework (including bugs corrected etc.).

Further, the CC Models developed within that Framework also require a versioning system that controls the numbering and relates this to legacy documents that describe relevant changes. Given the, at times, great uncertainty about which of the multitude of 'features' were selected to produce model runs, I think is it entirely appropriate that for each CC Models within the Framework there should be a document (or database) which provides sufficient and persistent (legacy) details. These were provided for the outgoing CC model in part by a table in the 'tech manual', and which was subsequently extended at the Panel's request, but they should be an indelible and obvious part of the Model's description. It could well be that some of the Model's behaviour could be ascribed to the use of a particular feature which was subsequently found to be problematic for that particular version of the Framework.

As a scientific programmer with decades of experience, this reviewer knows that the need to make rapid progress makes it difficult to implement these types of controls. The more professional the approach, however, the stricter the control processes - but without sufficient funding this will never be a priority. Levels of funding sufficient to allow fully professional approaches are necessary to ensure the level of confidence that the Council will require to use this methodology.

The technical merits and capabilities of the latest Atlantis CC Model within the latest Framework could not be adequately assessed, therefore as stated above, much of my

review discussion must necessarily focus on the now superseded work/Model/Framework.

Problems/concerns/recommendations with Atlantis Modelling Framework

Problems/limitations discussed and identified with the modelling framework necessarily are inherited by any model developed within that Framework. Below are those worth mentioning at the review process but are not necessarily confined to the outgoing Framework. These have been abbreviated to points for brevity.

- Problems identified with capturing lower trophic dynamics particularly as it pertains to the early life history recruitment variations (this is picked up in the draft Panel review). These are discussed in more detail in ToR 3 below. There were suggestions, however, that this is a common problem and therefore other modelling, and even more conventional assessments, often do not rely upon stock and recruitment relationships for all groups but rather resort to specific 'forced recruitment' even though it is recognised that this limits the model application to essentially replaying the past. There seemed to be some problems with fast dynamics, which may impact its ability to handle problems of multiyear recruitment failure and its consequences. Recruitment may not be able to be linked to oceanographic conditions. It will be necessary to convince those associated with conventional stock assessments that recruitment is handled at least as well as the *status quo* or the model developed in this Framework will not be adopted for management input.

Recommendation: thorough testing and validation of a wide range of recruitment events before model outputs are trusted for even strategic purposes.

- Limitations to the number of functional groups (fixed in the new Framework) forced commercial (often assessed) species to be merged with others (sardines in with herring and anchovy, Dungeness crabs in with other crustaceans, commercial shrimp with others, halibut grouped with others, Jack Mackerel lumped with

others etc.). Of course all groups cannot be represented individually in the model. The computational constraints are already severe. The Model cannot be expected to do all things or it will fail.

Recommendation: providing anticipated 'end-user' guidance in the degree of detail representing species is highly recommended from those most likely to anticipate how the Council might want to employ the Model in the future.

- A limitation is that no lags are possible with recruitment with invertebrates in only two pools consisting of immature and mature. This may make it difficult to model long-lived species like valuable Dungeness crabs (which are mixed in a functional group with other crabs currently).

- There appears to be a failure to document easily which functional forms/options were selected in any particular model variant (modelers should be able to systematically and easily list the options etc. selected and identify unique model versions accordingly).

- The Framework (software) is in rapid development with limited time to test/validate it (and the need to identify exactly which release was used in conjunction with model variants to produce output) – complete provenance needs capturing.

- There is a strong need to reinforce the purely strategic nature of modelling – i.e. the MSE purpose rather than the tactical for which traditional stock assessments, augmented by medium complexity MICE models (discussed earlier), would currently be the best approach.

- There appears to be a need to clarify just how Atlantis (or similar) modelling has impacted management decisions anywhere – there was a great deal of uncertainty about whether or not it has had an influence in Australia. One panel member

suggested that the modelling has simply given managers the confidence to do what they were doing anyway. This suggests that the results of Atlantis-style modelling have contributed little to management other than a forum for discussion and a focus for data concentration

- There was an identified need to model fishing size selectivity explicitly.

- Need to handle density dependent recruitment by area rather than doing it as a single pool and redistributing them afterward to areas (currently for example, temperature effects are used in each cell to affect recruitment, but then these are pooled and density effects used before redistributing them to cells)

- The potentially problematic use of quadratic mortality – 'closure' used to reduce numbers of sharks and others with linear recruitment which otherwise would persist in the model – this currently appears to be a 'Band-Aid' approach to what might be symptoms of other problems.

- Limited number of age groups (two for invertebrates and 10 equal parts for vertebrates) which control most parameters like gap size, diet etc. which may not be appropriate for some species, and worse, as the age groups are set as a 1/10 of maximum age span for each functional group of vertebrates (ever reached), it does mean that there are few numbers in some older classes while ironically not necessary enough useful age groups to model management scenarios fully.

- Outside the primary model spatial domain there is only growth and simple mortality modelling so when they are scheduled to reenter the model they may not have been appropriately treated compared to animals 'remaining' in the model.

- Handling of sub stocks is unknown – for example, it cannot model salmon well. Accounting at individual ages (as opposed to age blocks) is currently not available

in a complete way though there was an indication at the review that this is done internally.

- There are concerns about modelling management scenarios (such as required in MSE support) that are driven by total numbers rather than F because of the complexity of bycatch across fisheries represented – it appears that this is forced for only a single fishery currently to match historical catches and a more complex approach is not possible.

Recommendation: Identify clearly the limitations to investigating bycatch (including gear interactions) representations in the model.

- Timing of harvest represented within the annual modelled cycle is critical when modelled fishing seasons are short. There was concern that integration used within the model may lose critical detail such as forced closures due to bycatch within a season.

Recommendation: Exact timing of harvest in model - test to see if this represents a real problem for the harvest control rules being modelled.

- Tracking errors or confidence in outputs is not apparently possible but modelers instead must use a range of parameter values but this is not 'best practice' for any tactical operation.

Recommendation: Recognize the lack of complete treatment of uncertainty or any real statistical approach within the modelling framework limits tactical use of the models and do not imply in outputs that specific values are significant or based on statistics

- When it was discussed how models are parameterized there was much criticism that 'data' used were taken from other models output (such as the EwE model of CC). These were clearly not considered as 'data' by some on Panel.

Recommendation: Clearly classify the provenance of model input parameters and establish an objective simple quality attribute to be maintained within model documentation

- When the recruitment process modelled in Atlantis was described there were some concerns over how parameters were taken from assessments where this process has a different meaning.

Recommendation: Clearly evaluate whether recruitment modelling can mirror the spectrum of historical events and make adjustments if necessary including the use of forced recruitment in some circumstances.

- It is evident that model runs and tuning are extremely computer intensive. Current approaches are not able to use parallel processing. In fact the 'spin-up' simulations (to reach a 'stable' state before perturbation) can require the majority of the computer time. Further, when models are tuned (as is happening now with the newest Atlantis CC Model) there is a huge range of interactions, which make diagnostics extremely difficult.

Recommendation: Urgently invest the necessary resources to make parallel processing work within the computer intensive Atlantis Framework.

Recommendation: Develop ways of saving snap-shots of states such as a fully 'spun-up' future situations so they can be saved onto disk and loaded for future work (to save computer time and ensure the ability to replicate past work) (similar to the Panel's draft recommendation).

Recommendation: Develop ways of taking parts (especially higher trophic interactions) 'off-line' to allow critical parts of the model be worked on in relative isolation so as to reduce tuning time and to facilitate validation with other analyses and data.
22

Problems/concerns/recommendations with Atlantis CC Model (as points)

- Though fitness tracking is provided by monitoring separate skeletal and somatic nitrogen pools, is it is not apparently used to restrict breeding in the current model, likewise when 'condition' of individuals is reduced there appears to be no 'starvation' mortality invoked. It is unclear whether this can be addressed in the new Framework.

- Larval dispersal is possible in the Framework but is not enacted (not sufficient information for oceanography to test it). This may be quite relevant to some model uses.

- Need to check diets in model runs versus the known diets for validation purposes. Like the examination of size and numbers at age, looking at assigned diets is one of the relatively few ways to validate that the internal computations and decision rules are performing as expected.

- Estimates of Myctophidae in the old model were old and not supported by the latest data. The new model has increased the biomass of many groups but unfortunately these groups do not always persist in the model.

Recommendation: It is highly important to ensure that there is sufficient modelled biomass of prey and spatial overlap to support the new biomass estimates of some smaller fish species, especially myctophidids.

- A draft Panel recommendation was that "minimal standards for model performance be established prior to undertaking model calibration, although the Panel does acknowledge that standards for the performance of ecosystem models are not yet well established". This reviewer agrees. One of the problems is that there are no well-established standards in a highly dynamic area of complex research. The FAO Best Practise (FAO, 2008), however, can and should be used to

provide an overall operational framework for quality control. The Panel also suggested that dropping groups that cannot be parameterised for persistence in the model might be appropriate (though this reviewer suggests that important groups like myctophidids have to be retained). The model does not represent all groups and species but it must be clear how these groups interact before they are dropped, or indeed whether they are represented in the model in the first place.

ToR 3 – Evaluate technical merits and deficiencies of the <u>application of the methodologies</u> (incorporating general review panel's ToR 1 a-g)

<u>Historical Application of Atlantis and Atlantis-like Models to Fisheries Management</u>

Of necessity, discussion and decisions about the application of this and similar models to the needs of the council will rest partially on what evidence there is (historical) that such models have played a role in assisting fisheries management elsewhere. This is not a trivial point because with litigation looming when systems are altered, there is of necessity a conservative approach to change. It was therefore of considerable interest when the application (broadly) of Atlantis models to fisheries management was discussed in the review. While Dr Kaplan suggested that the models have played a role it was uncertain from the response of some reviewers that they agreed. One reviewer suggested that the result of similar modeling in Australia (held as a precedence) was merely to reassure managers that what they had already decided to do was correct and supported by the output of models. Whilst it was often suggested that the role of such modelling could only be broadly strategic in nature it nevertheless is important to know whether evidence exists that management decisions have been altered.

I have reviewed the literature and find claims by Fulton et al. 2014 (as it relates directly to the ToR) that Atlantis modelling has had a significant impact. Here I quote:

> *A focus on integrated management is prominent in the Australian Ministerial Direction of 2005 (available at http://www.daff.gov.au/fisheries/domestic/fishingfuture) that reshaped the management of the SESSF following the rethink that was informed by the work presented in this paper. Discussions regarding the final form of the restructuring were supported by information from the earlier stages of the project; ultimately, the restructuring saw the fishery take on a form of management based on a modified version of the integrated management strategy explored here. Interestingly, the integrated management strategy was so far removed from the*

management practices prior to 2005, and the alternatives under serious discussion by stakeholders at the time, that it was originally referred to as the 'blue sky' strategy. However, by the time the project finished the management had shifted to the point that many features of integrated management had become almost business as usual.

The authors claim that the Atlantis modelling directly supported integrated management strategy evaluation (MSE) in a way that reshaped opinions, facilitated critical discussion and resulted in long-term management change. This reviewer has no evidence to refute these claims and therefore is inclined to accept that in Australia and possibly elsewhere, Atlantis and similar modelling is directly impacting at least strategic management decisions in ways that are of interest to the council. That said, there are many claims of ecosystem-based management that are at best superficial and do not utilize ecosystem models.

Discussion of Specific Applications Discussed During Review

a) **Food web impacts of groundfish fisheries, pelagic fisheries, and other anthropogenic impacts. Policy example: Evaluating trophic impacts of forage fish harvest policies on abundance and yield of other species.**

There was much discussion here about whether there was merit in using models from another modelling framework (EcoPath with Ecosim (EwE)) for comparison in an attempt to determine whether the Atlantis model was "replicating reality". Arguably this can only be suggestive at best. In terms of output shown (and appearing in the referenced papers) it is clear that the expected direct effects on predators was replicated but unfortunately the indirect effects (perhaps of most interest) cannot be validated by data, and may have arisen due to differences in diet. This raised a reoccurring problem flagged with regard to the outgoing Atlantis CC Model imposed largely by limitations of the older Atlantis Framework. In the Framework that was used for the Model dominating the review there were only a limited number of functional groups (80) possible. This limitation led to

important commercial species being lumped with others in functional groups (see Problems and Limitations in Tor 1). This specifically impacted on the modelling of important forage species.

Specifically let me quote/paraphrase/summarize previous expert findings with regard to the outgoing Atlantis CC Model (and Framework) with regard to forage species as considered in February 2013.

The Draft Report of the Pacific Sardine Harvest Parameters Workshop (2013) **concluded** that:

> "currently [February 2013] available ecosystem models are not sufficiently well developed to form the basis for an evaluation of the impact of sardine control rules on broader ecosystem impacts"
>
> "Ecosystem models should not be used to provide quantitative predictions of the impacts of alternative HCRs, but rather to evaluate trade-offs qualitatively; ideally multiple ecosystem models should be applied to identify which conclusions are robust to the choice of the specific assumptions underlying the ecosystem model"

With regard to the Atlantis modelling framework the Draft Report of the Pacific Sardine Harvest Parameters Workshop (2013) **stated** that:

> "the model will be unequally informed across ecosystem component groups. Therefore, it can be used to elucidate patterns that would not be observable from the current data time-series, but cannot be used for tactical decision-making. Rather, Atlantis is better suited to provide strategic advice about the possible consequences to ecosystem components when faced, individually and in concert, with environmental or managerial perturbations. As a result, Atlantis could be considered a very high level model used to allow for a common currency between any number of user groups or sectors to evaluate the trade-offs between them under a number of management strategies."

The Draft Report of the Pacific Sardine Harvest Parameters Workshop (2013) **agreed**:

> **"**that the purpose of ecosystem models is not to determine absolute values of abundance or biomass but, rather, to evaluate and rank the likely tradeoffs between objectives in response to modeled management strategies."

The Draft Report of the Pacific Sardine Harvest Parameters Workshop (2013) **agreed:**

> **"**that none of ecosystem models presented were sufficiently well developed to form the basis for an MSE, and that substantial modifications would need to be made before they could be used for this purpose. The Workshop identified any ecosystem model would need (minimally) to include the following features:
>
> 1. It must cover the entire range of the northern subpopulation of Pacific sardine (Baja California to northern Vancouver Island) – the implications of the southern boundary of the northern subpopulation changing with temperature, and perhaps even entering U.S. waters presents a unique challenge to correctly representing space in an ecosystem model.
> 2. The fisheries in Mexico, California, the Pacific Northwest and Canada must be explicitly represented (owing in particular to differences in selectivity).
> 3. The model hindcasts must be validated. For example, they should replicate the behavior of major ecosystem components (especially sardine) during 1930-present.
> 4. The dynamics of sardine should be modeled to a level consistent with the level of complexity developed during the workshop for objective 1.
> 5. Management of other groups in the ecosystem (e.g. groundfish / salmon) should be based on the control rules actually in place (rather than assuming constant catch or constant fishing mortality)."

The Draft Report of the Pacific Sardine Harvest Parameters Workshop (2013) **suggested** that the time to include these necessary features would "likely to be years rather than months."

The Draft Report of the Pacific Sardine Harvest Parameters Workshop (2013) and the Draft Summary of Existing California Current Ecosystem Models for Pacific Council Workshop

(2013) examine, in addition to the CC Atlantis Model, other ecosystem models of this region. These were the Northern California Current Ecosim Model (Field et al., 2006), Economic Analyses Using Field et al. (2006) Ecosim model, Northern California Current ECOTRAN model, and NEMURO-SAN.

In Summary, the group best charged to then evaluate the use of the Atlantis CC (and similar ecological models) found that they:

- could only be trusted to provide strategic advise (specifically MSE)
- needed to cover the range of the relevant impacting fisheries
- needed to separate out important forage species and not group them into a single functional group
- hindcasts must be validated
- control rules available within the model must match those used/available.

In addition at the current review meeting it was considered that the treatment of recruitment within the Atlantis Framework might be too general (another recurring theme). Age groups rather than real ages are used. These fixed age groups are limited to one-tenth of the maximum age. It was suggested that 'recruitment' into this model happens at an advanced age compared to stock assessments. There was criticism that there was no 'plus' age category to capture all older animals. There was concern, therefore, that recruitment pulses (of significance to many species) would be lost or smoothed, and moreover, most of the useful age transitions would be missed by the start of the age tracking and compressed into relatively few of the (possibly) wide age blocks (because the mandated older age groups would contain very few individuals). The latter was considered a waste of computing resources in an already computer intense exercise. Because of the concerns above, Members of the Panel suggested that as the Framework/Model currently was, it could not predict stock collapse due to recruitment failure.

These concerns were at least in part addressed by Dr Kaplan's investigation into the methodology and by changes manifest in the new model and modelling framework *viz*:

- internally individual ages are tracked
- the shape of recruitment pulses is not transformed or lost
- the new Framework final provides adequate model resources to separate out important commercial species such as sardines, mackerel, herring etc. – and importantly the newest Model has done so
- the new Model has greatly extended the spatial range represented in the model both north into Canada, south to Mexico and offshore beyond the range of concern
- control rules will be modified after consultation with Council

There seem to be only a few outstanding issues:

- data are needed for some species from Canada to expand the model
- representatives from the Council or their subgroups need to provide input into what management control rules should be included/or modified (otherwise this is being done in a comparative vacuum)
- there needs be further validation of data (hindcasts included).

It needs to be restated here that the new Model is not tuned and is not ready for serious validation yet. So whereas the new Model and Framework have addressed past (and current concerns) it could not be fully evaluated. The older version was not acceptable and the new version has yet to be completed and fully tested.

Recommendation: Hindcasts of data must be validated as completely as possible.

Recommendation: Model developers should meet with a select group of Council representatives to establish which control rules should be developed in the new model

Recommendation: Model developers should liaise actively with groups in Canada and Mexico to ensure the spatial extension of the new Atlantis Model has the best data and to allow synergistic/collaborative development where possible.

b) **Ranking of potential fishery management strategies, including spatial management, harvest rates, quota systems. This expands beyond trophic impacts to include habitat, bycatch, and economic indicators. Discussion may differentiate between pelagic vs groundfish fisheries. Potential policy context: Tier 1 Environmental Impact Statements (10 year strategic planning).**

It appears that the Framework is well suited to examine management tradeoffs (MSE) and had been shown historically (Fulton et al. 2014) to succeed in supporting management development through providing a focus for discussion and scenario evaluation. The biggest question is what confidence the Council and others should have in modelled outcomes (see other sections of this review) and to what degree managers used to more traditional approaches will trust the results. As support for policy development, adjunct to other accepted methods, it would not be the likely focus of litigation - but where it suggested departures in management strategies from the *status quo* it will likely need several years to develop the trust and support required. Nevertheless, the development has to be pursued now before the complexities of climate change impact, etc. require rapid and radical retooling of research and MSE methodologies.

Discussions in the Panel review criticized the current coupling with economic modelling. The long-term projections used in the Atlantis CC Model were not seen as compatible to the short-term modelling supported by the economic packages used. It appears that there have only been limited consultations to date.

Recommendation: Work with economists to ensure that the economic software used is appropriate for the time projections and take their guidance in what the model outputs can reasonably describe in terms of social and economic benefits (these are likely to be strategic 'relative' rankings rather than firm numbers)

c) **Evaluation of risks of climate change and ocean acidification. Example: cumulative impacts analysis under National Environmental Policy Act (NEPA), which may consider the impact of actions (e.g. fishing) in the context of global change.**

There was considerable concern about the differential impact on model functional groups of future impacts, which stem in part for the relative diversity of their diets. Those with a narrow range of prey species are more impacted but whether their diets could be so constrained in reality is unknown. This introduces concerns about how catholic/flexible diets are naturally – i.e. do species become locally extinct, adapt or shift when the normal prey is removed or reduced? How will prey species change their distributions? Models of these impacts (in isolation) test ecological modelers but in truth the devil may be in these very details.

There was some concern over the use of decision support tables resulting from this type of modelling as they suggested a numerical (=statistical) certainty that was not supportable. Here again the strategic (ratio/relative) approach is favored over the tactical results. In this regard it was suggested that if the Council favored, it would be better to show results as radar plots which emphasize relative rather than absolute change. The plots used could show the most likely impacted groups but not use the actual numbers, as these would be taken out of context to represent firm absolute estimates. If 'reference' points are output then they have to be selected cautiously.

Recommendation: Review the diets to ensure that they are not unrealistically limited when used in future projections – consider diet evolution.

Recommendation: Focus on using simple relative reporting methods such as relative radar plots to maintain the focus on strategic support without the temptation to stray to absolute tactical numbers (choose wisely with end-user input).

d) Informing parameters within single species assessments, e.g. M.

It would appear that only ecosystem modelers really consider estimates of natural mortality from ecosystem models to be 'data', and therefore worthy of inclusion in other models and as useful as inputs to more conventional assessments. Nevertheless this is done apparently in Alaska and in ICES multispecies assessments. It was agreed that these estimates have some value to inform but cannot be seriously taken to represent the actual

rates, otherwise things became circular and presented false validation.

This reviewer holds a similar view, however, it must be said that estimates of natural mortality are usually poorly developed and largely untestable in most assessments (conventional or otherwise). The 'plausibility' of model estimates will take some time to establish and of course natural systems (especially when impacted) are in a huge state of flux. In some ways M is a very transient commodity at best.

Recommendation: Do not rank model estimates of M as hard data but rather use them to inform a wider decision process – their reliability is unknown especially when they are the result of modelled impacts that have never been experienced in nature and subject to all the limitations of complex models.

e) **Formal Management Strategy Evaluation to 'simulation test' new methods of stock assessment, data collection, and decision making. Examples: 1) identifying ecological indicators to be tracked by Fishery Council "State of California Current"; 2) evaluating performance of harvest policies that account for spatial impacts of ocean acidification, in context of strategic environmental impact analyses.**

Throughout the review there was a range of discussion that relates to the utility of using models like the Atlantis CC to support MSE. There were suggestions that it can assist with stock assessment practices through provision of parameter estimates (like natural mortality – discussed above) or the provision of new 'ecological' indicators. The consensus is that the modelling will likely reach the ability to support management through MSE but that the strategic rather than tactical focus will (and should) be maintained.

Of most particular concern is where the Model has been used to extrapolate well beyond current system states in ways that cannot be validated with data. We were reminded that what works in nature does not necessarily work in models (no matter how complex) and vice versa – the problem being that only a selection of the input states can be validated.

Hindcasting, while reassuring and highly suggestive that basic modelled process mirror nature, does not necessarily say much about how to assign confidence in future scenario modelling - especially where states of nature are highly altered from historically observed states.

Recommendation: Develop (for MSE support) some sort of relative metric to simply show the degree of departure of modelled states from those observed historically. Though there is no statistical approach likely possible some relative 'truth-stress' metric might be achievable and allow interpretation by end-uses to be tempered.

ToR 4 – Decide through Panel discussions if the ToRs and goals of the peer review have been achieved and determine whether the science reviewed is considered to be the best scientific information available. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all of the ToRs must be described in the Summary Panel Report and CIE Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

It is the belief of this reviewer the panel discussions were sufficiently wide-ranging and comprehensive to establish the level of confidence that a range of experts have in the use of this modeling approach (including the Atlantis Framework) and at least the outgoing Atlantis CC Model to support a range of decision support roles relevant to the management council.

That said, there was only a relatively cursory review the new Atlantis Framework and only a few hours (when key members like Dr Punt were not in attendance) to glimpse the new Atlantis CC Model. I must therefore conclude that with respect to the now superseded Framework and Model that the review was very comprehensive but unfortunately very poorly timed to review the new Framework or Model. The new Model is still being 'tuned' and the first-order tuning – attempts to complete future projections without functional groups disappearing were underway but clearly not completed. More refined tuning (in my view) cannot even proceed until major issues like collapse of functional groups in projections are attended to.

As recommended elsewhere, an additional methodological review would be required to evaluate the incoming Framework and CC Model. Before this can happen there has to be intensive work on the Model tuning, additional data secured and some consultation with representatives from the Council over what management control simulation capacity should be developed to maximise relevance and future uptake.

ToR 5 - Provide specific suggestions for future improvement in any relevant aspects of data collection and treatment, modeling approaches and technical issues.

At times there were criticisms that the harvest control rules or other aspects of the Model as it would pertain to MSE were not adequate or in keeping with real or possible management decision likely at Council. Unfortunately it would appear that thus far Dr Kaplan has had to operate in a relative vacuum.

Recommendation: Dr Kaplan should report a summary of his work to council representatives and that they decide what group might work with him to ensure that relevant management scenarios are developed.

Therefore, in summary, concerning the sufficiency and completeness of the review I would say that the new Framework and Model could not be sufficiently studied, but moreover, the problems relating to funding commitments to the development process are likely to continue, which allows for similar timing problems to recur in the future.

As recommended earlier in this review, it is necessary to have a methodological review conducted once the new Model has been developed, tuned and validated against data (as per other recommendations here).

Unfortunately, it is the view of this reviewer, that without sufficient investment of Council time in the development of useful scenarios for MSE, and without sufficient funding to ensure uninterrupted professional development of both the Model and supporting Framework it seems likely that risk adverse managers will cite both the irrelevance and unreliability of future Model outputs. The more likely scenario is the *status quo* whereby those most invested in current assessment procedures will continue to argue that any funding be used to improve these methods and the data required to support them.

Conclusions

This review concludes that:

- The Atlantis model framework as it was designed previously had limitations (such as restrictions on functional groups and a range of other features described above), however, it is suitable for achieving two of the 'best practice' purposes – that is it can assist with conceptual understanding (stimulating discussion) and assist strategic decision making - such as management strategy evaluation.
- Models developed in the Atlantis Framework then and now should not be used for tactical decision-making - it can only hope to simulate the average, longer-term outcomes and without uncertainty estimates.
- The new but relatively untested Atlantis Framework allows better models to be constructed and should improve the potential uses (within the strategic range)
- The outgoing Atlantis CC Model has proven to offer useful insights and has passed peer-review scrutiny for ecological modelling but was limited by the model framework, available data, as well as management/end-user input.
- The Atlantic CC model under development currently has addressed several limitations such as confounded functional groups and an incomplete spatial range but unfortunately has not been fully tuned so it cannot be adequately evaluated.
- Model development has been, and will apparently continue to be limited somewhat by data, but more so by piecemeal funding (which impacts on model development and testing), but also by limited opportunities to liaise with end-users which would ensure greater relevance – especially with regard to the range of management controls and social outcomes modelled.
- Following the implementation of review recommendations (including those presented here) a further review will be required.

Recommendations

The following is a summary of recommendations presented in this review:

1. Schedule an additional (additive) minor methodological review (summer 2015) to evaluate the anticipated changes/improvements to the model framework and the new Atlantis CC Model

2. Thorough testing and validation of a wide range of recruitment events before Model outputs are trusted for even strategic purposes.

3. Provision of anticipated 'end-user' guidance in the degree of detail representing species is highly recommended from those most likely to anticipate how the council might want to employ the model in the future.

4. Identify clearly the limitations to investigating bycatch (including gear interactions) representations in the model.

5. Exact timing of harvest in Model - test to see if this represents a real problem for the harvest control rules being modelled.

6. Recognize the lack of complete treatment of uncertainty or any real statistical approach within the modelling framework limits tactical use of the models and do not imply in outputs that specific values are significant or based on statistics.

7. Clearly classify/indelibly register the provenance of Model input parameters and establish an objective simple quality attribute to be maintained within model documentation

8. Clearly evaluate whether recruitment modelling can mirror the spectrum of

historical events and make adjustments if necessary including the use of forced recruitment in some circumstances.

9. Urgently invest the necessary resources to make parallel processing work within the computer intensive Atlantis Framework.

10. Develop ways of saving snap-shots of states such as a fully 'spun-up' future situations so they can be saved onto disk and loaded for future work (to save computer time and ensure the ability to replicate past work)

11. Develop ways of taking parts (especially higher trophic interactions) 'off-line' to allow critical parts of the model be worked on in relative isolation so as to reduce tuning time and to facilitate validation with other analyses and data.

12. Highly important to ensure that there is sufficient modelled biomass of prey and spatial overlap to support the new biomass estimates of some smaller fish species especially myctophidids

13. Hindcasts of data must be validated as completely as possible.

14. Model developers should meet with a select group of Council representatives to establish which control rules should be developed in the new Model

15. Model developers should liaise actively with groups in Canada and Mexico to ensure the spatial extension of the new Atlantis Model has the best data and to allow synergistic/collaborative development where possible

16. Work with economists to ensure that the economic software used is appropriate for the time projections and take their guidance in what model outputs can reasonably describe in terms of social and economic benefits (these are likely to be strategic 'relative' rankings rather than firm numbers)

17. Review the diets to ensure that they are not unrealistically limited when used in future projections – consider diet evolution.

18. Focus on using simple relative reporting methods such as relative radar plots to maintain the focus on strategic support without the temptation to stray to absolute tactical numbers (choose wisely with end-user input).

19. Do not rank model estimates of M as hard data but rather use them to inform a wider decision process – their reliability is unknown especially when they are the result of modelled impacts that have never been experienced in nature and subject to all the limitations of complex models.

20. Develop (for MSE support) some sort of relative metric to simply show the degree of departure of modelled states from those observed historically. Though there is no statistical approach likely possible some relative 'truth-stress' metric might be achievable and allow interpretation by end-uses to be tempered.

21. Dr Kaplan should report a summary of his work to council representatives, and they decide what group might work with him to ensure that relevant management scenarios are developed.

Appendix 1: Bibliography of materials provided for review

Atlantis California Current Review

Brand, E.J., I.C. Kaplan. C.J. Harvey, P.S. Levin, E.A., Fulton, A.J. Hermann, and J.C. Field. (2007) A spatially explicit ecosystem model of the California Current's food web and oceanography. U.S. Dept. Commer., *NOAA Tech. Memo*. NMFS-NWFSC-84, 145 p.

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Draft Summary of Existing California Current Ecosystem Models for Pacific Council Workshop on Pacific Sardine Management Strategy and Harvest Control Parameters, February 5-8, 2013, Scripps Institution of Oceanography, La Jolla, California

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Kaplan, I.C., Marshall, K.N., Hodgson, E., and L. Koehn. (2014) Update for 2014 methodology review: ongoing revisions to the spatially explicit Atlantis ecosystem model of the California Current. Report.

Background on ecosystem modeling (as taken from the draft Panel report)

FAO. 2008. Best practices in ecosystem modelling for informing an ecosystem approach to fisheries. FAO Fisheries Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2, Add. 1. Rome, FAO. 78p.

Levin P.S., Fogarty M.J., Murawski S.A., Fluharty D. 2009. Integrated ecosystem assessments: Developing the scientific basis for ecosystem-based management of the ocean. PLoS Biol 7(1): e1000014. doi:10.1371/journal.pbio.1000014.

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Appendix 2: Statement of Work for Dr. Reginald Watson (IMAS)

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 California Current Large Marine Ecosystem

BACKGROUND

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Representative (COR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

SCOPE

Project Description: The purpose of this review is to evaluate the performance characteristics and to identify appropriate management applications of an Atlantis ecosystem model, employed at NWFSC as an operating model in support of the development of Ecosystem-Based Fishery Management (EBFM) strategies for the California Current Large Marine Ecosystem. This review is being undertaken based on recommendations by the Scientific and Statistical Committee (SSC) of the Pacific Fishery Management Council (PFMC), who will chair the review panel.

NMFS strongly endorsed the concept of Ecosystem-Based Management and the related need for the development of Integrated Ecosystem Assessment in support of EBFM. Although this review is directed at efforts in the NWFSC, and more specifically the PFMC, the findings will be more broadly applicable on the West Coast and throughout the agency.

The objectives of the methodology review meeting are to evaluate the performance characteristics of this application of the Atlantis model, and to identify the extent to which this Atlantis ecosystem model is suitable as an operating model to provide strategic guidance related to NOAA management needs on the West Coast. Specific objectives of the SSC are to identify the strengths, weaknesses, and applicability of the model to particular questions and needs in order to facilitate use of Atlantis-generated products in the future. These needs include evaluation of cumulative impacts of groundfish and pelagic fisheries,

evaluation of risks of climate change and ocean acidification, ranking of potential fishery management strategies, and formal Management Strategy Evaluation to 'simulation test' new methods of stock assessment, data collection, and decision making. The review will not focus on the Atlantis C++ 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**.

OBJECTIVES

Requirements for the reviewers: Three reviewers shall conduct an impartial and independent peer review of the Atlantis ecosystem model provided, and this review should be in accordance with this SoW and the methodology review ToRs herein.

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, meaning direct senior level policy applications or recommendations in addition to scientific publications.

PERIOD OF PERFORMANCE

The reviewers shall conduct the tasks according to the schedule of milestones and deliverables as specified in this statement of work (SoW). Each reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein. The tentative schedule of milestones and deliverables is provided herein.

PLACE OF PERFORMANCE AND TRAVEL

Each reviewer shall conduct an independent peer review during the panel review meeting tentatively scheduled during June 30 – July 2, 2014 in Seattle, Washington.

STATEMENT OF TASKS

Each reviewer shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Tasks prior to the meeting: The contractor shall independently select qualified reviewers that do not have conflicts of interest to conduct an independent scientific peer review in accordance with the tasks and ToRs within the SoW. Upon completion of the independent reviewer selection by the contractor's technical team, the contractor shall provide the reviewer information (full name, title, affiliation, country, address, email, and FAX number) to the contractor officer's representative (COR), who will forward this information

to the NMFS Project Contact no later than the date specified in the Schedule of Milestones and Deliverables. The contractor shall be responsible for providing the SoW and stock assessment ToRs to each reviewer. The NMFS Project Contact will be responsible for providing the reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact will also be responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COR prior to the commencement of the peer review.

Foreign National Security Clearance: The reviewers shall participate during a panel review meeting at a government facility, and the NMFS Project Contact will be responsible for obtaining the Foreign National Security Clearance approval for the reviewers who are non-US citizens. For this reason, the reviewers shall provide by FAX (not by email) the 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 before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/.

Pre-review Background Documents: Approximately two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the COR the necessary background information and reports (i.e., working papers) for the reviewers to conduct the peer review, and the COR will forward these to the contractor. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the COR on where to send documents. The reviewers are responsible only for the pre-review documents that are delivered to the contractor in accordance to the SoW scheduled deadlines specified herein. The reviewers shall read all documents deemed as necessary in preparation for the peer review.

Tasks during the panel review meeting: Each reviewer shall conduct the independent peer review in accordance with the SoW and stock assessment ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs shall not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COR and contractor.** Each reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the methodology review ToRs as specified herein. The NMFS Project Contact will be responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact will also be responsible for ensuring that the Chair understands the contractual role of the reviewers as specified herein. The contractor can contact the COR and NMFS Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting tentatively scheduled in Seattle, Washington during June 30 through July 2, 2014.
3) During the panel review, conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than 16 July 2014, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, via email to Dr. David Die ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

DELIVERY

Each reviewer shall complete an independent peer review report in accordance with the SoW. 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 SoW in accordance with the following schedule.

26 May 2014	Contractor sends reviewer contact information to the COR, who then sends this to the NMFS Project Contact
16 June 2014	NMFS Project Contact provides reviewers the pre-review documents
30 June – 2 July 2014	Each reviewer participates and conducts an independent peer review during the panel review meeting in Seattle, WA
16 July 2014	Reviewers submit draft independent peer review reports to the contractor's technical team for independent review
30 July 2014	Contractor submits independent peer review reports to the COR who reviews for compliance with the contract requirements
6 August 2014	The COR distributes the final reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COR within 10 working days after receipt of all required information of the decision on substitutions. The COR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer

review has begun.

Acceptance of Deliverables: The deliverables shall be the final peer review report from each reviewer that satisfies the requirements and terms of reference of this SoW. The contract shall be successfully completed upon the acceptance of the contract deliverables by the COR based on three performance standards:

(1) each report shall be completed with the format and content in accordance with **Annex 1**,
(2) each report shall address each stock assessment ToR listed in **Annex 2**,
(3) each report shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Upon the acceptance of each independent peer review report by the COR, the reports will be distributed to the NMFS Project Contact and pertinent NMFS science director, at which time the reports will be made publicly available through the government's website.

The contractor shall send the final reports in PDF format to the COR, designated to be William Michaels, via email William.Michaels@noaa.gov

Support Personnel:

William Michaels, Program Manager, COR
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-427-8155

Manoj Shivlani, CIE Lead Coordinator
Northern Taiga Ventures, Inc.
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Key Personnel:
Mindi Sheer, IEA Coordinator,
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Seattle, WA 98112
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Stacey Miller, Groundfish Stock Assessment Coordinator
Northwest Fisheries Science Center
55 Great Republic Drive,
Gloucester MA,
Stacey.Miller@noaa.gov Phone: 978-281-9203

Annex 1: Format and Contents of Independent Peer Review Report

1. The independent peer review report shall be prefaced with an Executive Summary providing a concise summary of whether they accept or reject the work that they reviewed, with an explanation of their decision (strengths, weaknesses of the analyses, etc.).

2. The main body of the report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Findings of whether they accept or reject the work that they reviewed, and an explanation of their decisions (strengths, weaknesses of the analyses, etc.) for each ToR, and Conclusions and Recommendations in accordance with the ToRs. For each assessment reviewed, the report should address whether each ToR of the SAW was completed successfully. For each ToR, the Independent Review Report should state why that ToR was or was not completed successfully. To make this determination, the SARC chair and reviewers should consider whether the work provides a scientifically credible basis for developing fishery management advice.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including a concise summary of whether they accept or reject the work that they reviewed, and explain their decisions (strengths, weaknesses of the analyses, etc.), conclusions, and recommendations.

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

   c. Reviewers should elaborate on any points raised in the SARC Summary Report that they feel 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 independent report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not others read the SARC Summary Report. The independent report shall be an independent peer review of each ToR, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

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

Annex 2: Tentative Terms of Reference

Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the California Current Large Marine Ecosystem

The reviewers will participate in the Panel review meeting to conduct independent peer reviews of the Atlantis ecosystem model for the California Current marine ecosystem. The review solely concerns technical aspects of the methods, and addresses the following ToR:

ToR 1 – Review documents detailing Atlantis ecosystem model methodologies according to the PFMC ToR for the Methodology Review Process for Groundfish and Coastal Pelagic Species. Evaluate if the documented and presented information is sufficiently complete. Document the meeting discussions and contribute to a summary panel report.

ToR 2 – Evaluate the technical merits and deficiencies of the proposed method(s) taking into consideration the data requirements of each method, the conditions under which the method is applicable, the assumptions of each method, and the robustness of model results to departures from model assumptions and atypical data inputs. Recommend alternative methods or modifications to the proposed methods, or both, during the panel meeting. Recommendations and requests for additional or revised analyses during the panel meeting must be clear, explicit, and in writing. Comment on the degree to which the methods describe and quantify the sources of uncertainty in the results.

ToR 3 – Evaluate technical merits and deficiencies of the application of the methodologies.

ToR 4 – Decide through Panel discussions if the ToRs and goals of the peer review have been achieved and determine whether the science reviewed is considered to be the best scientific information available. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all of the ToRs must be described in the Summary Panel Report and CIE Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

ToR 5 - Provide specific suggestions for future improvement in any relevant aspects of data collection and treatment, modeling approaches and technical issues.

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 California Current Large Marine Ecosystem

Tentatively scheduled in Seattle, Washington

Tuesday, July 1, 2014

8:30 a.m. Welcome and Introductions

8:45 a.m. Review the Draft Agenda and Discussion of Meeting Format (Panel Chair)

- Review Terms of Reference for Assessment and Review Panel
- Assignment of reporting duties
- Discuss and agree to format for the final assessment document

9:00 a.m. Presentation of Model

- Overview of data and modeling approach
- Q & A session with STAT
- Panel discussion

Wednesday, July 2, 2014

Thursday, July 3, 2014

Appendix 3 Other Materials

Atlantis Model Review TOR Agenda provided to all panel members by FTP prior to meeting

Annex 1: Format and Contents of Independent Peer Review Report

1. The independent peer review report shall be prefaced with an Executive Summary providing a concise summary of whether they accept or reject the work that they reviewed, with an explanation of their decision (strengths, weaknesses of the analyses, etc.).

2. The main body of the report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Findings of whether they accept or reject the work that they reviewed, and an explanation of their decisions (strengths, weaknesses of the analyses, etc.) for each ToR, and Conclusions and Recommendations in accordance with the ToRs. For each assessment reviewed, the report should address whether each ToR of the SAW was completed successfully. For each ToR, the Independent Review Report should state why that ToR was or was not completed successfully. To make this determination, the SARC chair and reviewers should consider whether the work provides a scientifically credible basis for developing fishery management advice.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including a concise summary of whether they accept or reject the work that they reviewed, and explain their decisions (strengths, weaknesses of the analyses, etc.), conclusions, and recommendations.

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

   c. Reviewers should elaborate on any points raised in the SARC Summary Report that they feel 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 independent report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not others read the SARC Summary Report. The independent report shall be an independent peer review of each ToR, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

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

Annex 2: Terms of Reference

Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the California Current Large Marine Ecosystem

BACKGROUND

Atlantis (http://atlantis.cmar.csiro.au/) was developed at CSIRO (Australia) as an 'end-to-end' simulation modeling approach for marine ecosystems that includes oceanographic, chemical (nutrient cycling), ecological (competition and predation), and anthropogenic processes in a three-dimensional, spatially explicit domain (Fulton 2004a,b; Fulton *et al.* 2007, 2011). The simulation approach allows projections through time, and forecasting of system response to specific management actions, physical drivers, or climate change. Atlantis is intended as a strategic management tool to evaluate hypotheses about ecosystem response, to understand cumulative impacts of human activities, and to rank broad categories of management options. It is not intended for tactical decision making, such as precisely setting quotas or siting of marine reserves. Fulton et al. (2011) summarize thirteen recent applications of the Atlantis framework, and discuss the appropriate role and strengths and weaknesses of the approach.

OBJECTIVES

The objective of the methodology review meeting is to:

Evaluate the performance characteristics and appropriate uses of two Atlantis ecosystem models for the California Current.

Previous Atlantis models of the California Current have been published in the peer reviewed literature and technical documents (Horne *et al.* 2010; Kaplan *et al.* 2012a,b, 2013). A new version of the Atlantis model is in development, but includes finer resolution of some forage fish and calcifier (shell forming) species, and an expanded geography that matches the full extent of the California Current. Documentation for this new model will be provided to the reviewers.

The review panel will be chaired by a member of the Pacific Fishery Management Council's Scientific and Statistical Committee (SSC), and the panel will include SSC members as well as Center for Independent Experts (CIE) reviewers. The review will follow the Methodology Review Process established by the Fishery Management Council, and the Terms of Reference below, in part, reflect the Terms of Reference of the Methodology Review Process.
The methodology review Terms of Reference will identify the models' strengths, weaknesses, applicability, and potential areas of improvement with respect to specific management needs on the US West Coast.

The review will not focus on the Atlantis C++ code base, nor will it focus on data quality except as it pertains to model performance.

TERMS OF REFERENCE

All panel reviewers, including CIE reviewers, SSC members, and others, will document the meeting discussions and contribute to a summary panel report that addresses the following terms of reference:

1. **TOR 1. Reviewers will be asked to consider the strengths, weaknesses, appropriate uses, and potential areas of improvement for the Atlantis models with respect to these management needs, in the context of ecosystem-based management.**

    a. Food web impacts of groundfish fisheries, pelagic fisheries, and other anthropogenic impacts. Policy example: evaluating trophic impacts of forage fish harvest policies on abundance and yield of other species.
    b. Ranking of potential fishery management strategies, including spatial management, harvest rates, quota systems. This expands beyond trophic impacts to include habitat, bycatch, and economic indicators. Discussion may differentiate between pelagic vs groundfish fisheries. Potential policy context: Tier 1 Environmental Impact Statements (10 year strategic planning) .
    c. Evaluation of risks of climate change and ocean acidification. Example: cumulative impacts analysis under National Environmental Policy Act (NEPA), which may consider the impact of actions (e.g. fishing) in the context of global change.
    d. Informing parameters within single species assessments, e.g. M.
    e. Formal Management Strategy Evaluation to 'simulation test' new methods of stock assessment, data collection, and decision making. Examples: 1) identifying ecological indicators to be tracked by Fishery Council "State of California Current"; 2) evaluating performance of harvest policies that account for spatial impacts of ocean acidification, in context of strategic environmental impact analyses.

2. **TOR 2. Reviewers will be asked to comment on the technical merits and/or deficiencies of the methodology and recommendations for remedies.**
    a. What are the data requirements of the methodology?
    b. What are the situations, management uses, and spatial scales for which the methodology is applicable, if not discussed in TOR 1?
    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. Will the new methodology or data set result in improved stock or ecosystem assessments or management advice, beyond what is discussed in TOR1?

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

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

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

l. Prioritized recommendations for future research and data collection.

CITATIONS

Fulton, E. (2004a) Biogeochemical marine ecosystem models II: the effect of physiological detail on model performance. *Ecological Modelling* **173**, 371–406.

Fulton, E. (2004b) Effects of spatial resolution on the performance and interpretation of marine ecosystem models. *Ecological Modelling* **176**, 27–42.

Fulton, E.A., Link, J.S., Kaplan, I.C., et al. (2011) Lessons in modelling and management of marine ecosystems: the Atlantis experience. *Fish and Fisheries* **12**, 171–188.

Fulton, E.A., Smith, A.D.M. and Smith, D.C. (2007) Alternative management strategies for southeast Australian Commonwealth Fisheries: stage 2: quantitative management strategy evaluation. *Australian Fisheries Management Authority Report*.

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., 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.

Annex 3: Agenda

Review of the Atlantis Ecosystem Model in Support of Ecosystem-Based Fishery Management in the California Current Large Marine Ecosystem

June 30th – July 2nd, 2014
NOAA Northwest Fisheries Science Center
Auditorium
2725 Montlake Blvd. E.
Seattle WA 98112
Phone: (206) 860-3428

Relevant Terms of Reference (TOR) are noted below.

Monday, June 30th

9:00 - 9:10 Call to Order (*Martin Dorn*)

- Introductions
- Approval of Agenda

9:10 - 9:30 Introduction to the role of Atlantis ecosystem model at the Northwest Fisheries Science Center (*Phil Levin*)

9:30 - 9:50 History, goals, and evolution of Atlantis model development at NWFSC and CSIRO (*Isaac Kaplan*)

9:50 - 10:10 Current and potential role of Atlantis ecosystem models for the California Current Integrated Ecosystem Assessment (*Chris Harvey*)

Break

10:30 - 12:00 Overview of mechanics, assumptions, and functional relationships of Atlantis (*Isaac Kaplan*) [TOR2.a-d]

Lunch

1:00 - 2:00 Continued: Overview of mechanics, assumptions, and functional relationships of Atlantis (*Isaac Kaplan*) [TOR2.a-d]

Break

CURRENT ATLANTIS MODEL
Isaac Kaplan

2:15 - 3:00 Geography and functional groups (Isaac Kaplan) [TOR2.a-d]

3:00 - 4:30 Panel discussion (Martin Dorn)

Tuesday, July 1st

9:00 - 11:00 Data (*Isaac Kaplan and Kristin Marshall*) [TOR2.a-d]

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

Break

11:00 - 12:00 Model calibration and fits to history (*Isaac Kaplan*) [TOR2.e-g]

- Estimates of unfished biomass
- Sensitivity to fixed fishing mortalities, estimates of MSY and FMSY
- Fits to historical data
- Sensitivity to initial conditions

Lunch

1:00 - 2:30 Example applications and recent publications (*Isaac Kaplan*)

a. Food web impacts of forage fish fisheries (e.g. *Kaplan et al. 2013 Environmental Conservation, Marshall et al. submitted*) [TOR1.a]
b. Ranking of potential fishery management strategies, including spatial management, harvest rates, quota systems. (e.g. Kaplan et al. 2012 *Progress in Oceanography*, Kaplan and Leonard 2012 *Marine Policy*, Kaplan et al. 2013 *ICES Journal of Marine Science**). [TOR1.b]
c. Evaluation of risks of climate change, acidification, and cumulative impacts (e.g. Kaplan et al. 2010 *Canadian J. Fish. Aquatic Sciences**, Kaplan et al. *2013 Fish and Fisheries*) [TOR1.c]
d. Informing parameters within single species assessments, e.g. M. (brief discussion of relevant examples from Northeast US) [TOR1.d]
e. Simulation testing new methods and metrics for ecological indicators (Testing of spatial indicators within the Integrated Ecosystem Assessment) [TOR1.e]

*Note the two articles marked with * use an earlier version of the Atlantis California Current model.*

2:30 - 3:30 Treatment of uncertainty [TOR2.f]

- Bounded scenarios – uncertainty in biomass estimates
- Bounded scenarios – uncertainty in rate parameters

Break

3:30 - 5:00 Panel discussion on potential uses of Atlantis to support Council decision-making identified in TOR 1 (*Martin Dorn*)

Wednesday, July 2nd

NEW VERSION OF ATLANTIS MODEL UNDER DEVELOPMENT
Isaac Kaplan and Kristin Marshall

9:00 - 9:30 Goals and applications [TOR 1.a-c,1.e,2.b]

9:30 - 10:00 Geography and functional groups [TOR2.a]

10:30 - 11:00 Data

Break

11:00 - 11:30 Oceanography and global change projections (Al Hermann) [TOR2.a]

11:30 - 12:00 Model calibration and sensitivity tests [TOR2.e-g]

Lunch

1:00- as needed Panel discussion and writing assignments (Martin Dorn)

Annex 4: List of Panel Members

Kerim Aydin, AFSC
Kenneth Frank CIE, DFO
Martin Dorn Panel Chair, SSC, AFSC
Daniel Howell CIE, IMR
Galen Johnson SSC, NIFC
Pete Lawson SSC, NWFSC
Andre Punt SSC, UW
Will Sattewaite SSC, SWFSC
Tien-Shui Tsou SSC, WDFW
Cindy Thomson SSC, SWFSC
Reg Watson CIE, Univ of Tasmania

Provided by

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