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

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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.

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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**.

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