Review Report
for the
2019 South Atlantic Ecopath with Ecosim Model
September 2020

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1 INTRODUCTION

The South Atlantic Fishery Management Council (SAFMC) Ecopath with Ecosim (EwE) Model Review Workgroup (**WG**) comprised of selected members of the Scientific and Statistical Committee (SSC) was established to provide an initial review of the South Atlantic EwE model. This review focused on the appropriateness of data, model parameterization and decisions, and initial model outcomes that would support a defensible base model for the South Atlantic region. A series of workshops, conference calls and webinar meetings were held between July 2019 and September 2020 to complete the review. An in-person workshop was held on July 24-25, 2019 to discuss the collection of diet information and the spatial settings. A conference call was held on December 6, 2019 to develop the Terms of Reference (TOR), and four webinar meetings were held on February 6, March 10, August 27 and September 10, 2020 to review Ecopath and Ecosim components of the EwE model and to complete the review report.

The SAFMC EwE Modeling Team (**MT**) comprised of the Fish and Wildlife Research Institute (FWRI) staff, Council staff, and other technical experts presented the model development, and addressed the questions and requests from the WG during these meetings. The WG discussed extensively the validity of data sources, the justification of individual input values, the appropriateness of model assumptions, the validity of model setup that can realistically represent the model region, and the potential application of the model in fisheries management.

Overall, the WG is impressed with the tremendous effort that the MT has dedicated to developing, maintaining and updating such a complicated model system with great details. During the review process, the MT was very responsive to the WG's questions and request, and modified the model according to the WG's recommendations, which significantly strengthens the functionality of the future use of the model. The WG concludes that the MT addressed each of the TOR adequately and this EwE model provides a valid base model that can be modified for specific research and management needs. The base model was developed based on the best information available currently, and will be updated and improved as new data become available. Additional comments on each of the TOR are provided throughout the remainder of this report.

2 TERMS OF REFERENCE

2.1 Ecopath

2.1.1 Are the functional groups in the model reasonable and do they characterize the biotic components of the ecosystem to be considered?

There are currently 140 functional groups in the model. These groups represent single species (e.g. red snapper), taxonomically-grouped species (e.g. mullets), taxonomically- and habitat-grouped species (e.g. mid-shelf snappers), and trophically-grouped species (e.g. demersal coastal piscivores). These functional groups have been detailed through 20 years of expert input, SSC requests, and modeling team consultation. As the model was being tuned as part of recent iterations, data-poor species previously placed in their own group have been re-grouped, taxa of particular commercial and ecological interest have been isolated, and species being considered for future management have been added.

- *The WG agreed that the functional groups currently in the model reasonably characterize the biotic components of the ecosystem based on current information. The functional*

groups can be adjusted to address a specific research or management question. The functional groups can be also modified in model improvement and evolution process when new information on ecosystem structure becomes available.

- *The WG noted that the total number of functional groups in the model is currently constrained by computing capability.*

2.1.2 Do the Ecopath model inputs (biomass, production per unit biomass, consumption per unit biomass, diets, and ecotrophic efficiencies (if used)) come from reliable sources?

A pedigree document has been created to document the sources of the model inputs. Primary sources for the diets include SEAMAP/MARMAP/NOAA gut content analyses and published dietary analysis studies. In order to characterize all possible diet items, videos of predation events were also considered. Where possible, biomass estimates were obtained from published literature, stock assessments, and GIS calculations performed by FWRI staff. Where necessary, biomasses estimated during previous iterations of the model were used. However, GIS data was used to constrain the habitat of seagrass, oysters, and encrusting fauna (corals) when biomass calculations were made. All motile species were given access to the full habitat of the model area to allow the EwE to calculate the area as a "bathtub" of interactions. The biomass of seagrass and oyster was adjusted for habitat. Production rates were obtained from the literature and calculated from empirical formulae, and it also proved helpful to use rates that were used in other balanced and published models. Production rates were also considered flexible within reasonable range during the balancing process. Consumption rates were adopted from published literature, calculated from empirical formulae, and obtained from models of similar ecosystems. Ecotrophic efficiencies ranged from 0 to 0.99, and are considered highly predictable. Ecotrophic efficiencies can be estimated by the model if one of the other inputs (biomass, production, or consumption) is specified, and vice versa. Ecotrophic efficiencies are usually specified for groups for which a highly reliable input (e.g. biomass of demersal coastal invertivores) could not be found.

- *The WG discussed the justification of individual input values with a focus on the values used for discard mortality, e*cotrophic efficiencies *and biomass.*
    - ***Recommend establishing a well-maintained and regularly updated documentation of model inputs with justification for the use of individual values.***
- *The WG raised concerns over the difficulty of justifying input values for species with great uncertainty due to lack of information (e.g., golden crabs).*
- *The WG discussed the tradeoff between inputting biomass versus letting the model estimate biomass given input parameters for ecotrophic efficiency, productivity and consumption.*
    - *The WG noted this decision may depend on the specific research and management questions.*
    - *The WG supports the MT's suggestion to input biomass for species with biomass information available, and to allow the model to estimate biomass for species lacking biomass information (e.g., tarpon).*
    - ***Recommend validating the model estimated biomass based on similar species in this model or in other models for this region.***
- *The WG discussed specifying biomass accumulation for invasive species (e.g., lionfish), the species that are overfished and/or undergoing overfishing, and the species that*

experienced substantial biomass change (e.g., red snapper, black seabass, red porgy and king mackerel) during the reference time period (1995-1998).

- ***Recommend tuning the biomass accumulation based on available information to match the biomass trend of the species during the reference time period, including the trends from fishery independent indices, biomass estimates from stock assessments and biomass estimates from surveys (e.g., surveys for shellfish).***

2.1.3 Are there limitations in the fisheries data used to initialize the Ecopath fishery groups?

Commercial fisheries data were obtained from the Atlantic Coastal Cooperative Statistics Program (ACCSP) and will be updated annually as new landings are added to their database. Queries to ACCSP were meticulously modified by FWRI staff and ACCSP data analysts to ensure that the landings reflect only the species, locations, and gears specified by the model while maintaining ACCSP's confidentiality agreements. Recreational catches were obtained from the NOAA Marine Recreational Information Program (MRIP) online query tool in 2019, and were the values after the MRIP transition to mail Fishing Effort Survey and subsequent adjustments. Headboat fisheries data were also provided directly by the Southeast Regional Headboat Survey (SRHS). Fisheries data were divided amongst the 19 fleets specified by ACCSP, MRIP and SRHS.

- *The WG raised concerns over the potential over-parameterization of the model with a total of 19 fleets.*
  - *The WG agreed to keep 19 fleets in the model because having fleets separated would allow for mapping landings with high spatial resolution in Ecospace, and would allow for specifying discard mortality by gear type.*
  - *The WG agreed that each of the 19 fleets represents sufficient catches for inclusion.*

2.1.4 Have discards and the fate of discards for the fisheries been well characterized?

Recreational discards were derived from the SRHS and MRIP released-alive counts multiplied by the average weight of the adults of each species. Commercial discards were calculated as 20% of the landings, except where SEDAR stock assessments had estimates for the model region. Fates of discards were obtained from multiple sources, including NOAA technical reports, stock assessments, and published literature. Where two discard mortality rates were available, the higher rate was used. If no discard mortality rate was available from a reliable source, a default value of 100% was used. This overestimate of mortality is intended to serve as a buffer against overly optimistic population estimates.

- *The WG discussed the specification of discards and discard mortality in the model and emphasized the importance of correctly incorporating discards.*
  - ***Recommend validating individual discard mortality rates.***
  - ***Recommend potentially adding a "discard fleet" to the fisheries data in the future. This would allow for a time series representing changes in discard mortality over time, such as before and after changes to gear regulations.***
- *The WG raised concerns with the current default value of 20% for calculating commercial discards for species with no discard estimates available from stock assessments.*

- *Both the WG and MT realized this default value may not be realistic for certain species. However, the WG agreed this assumption is acceptable at this stage without any additional information. Additionally, the WG noted that improving commercial discards input may not substantially improve the model performance and functionality.*
- ***Recommend exploring other alternatives for this default value.***
- ***Recommend requesting discard estimates from states, especially for inshore species.***

2.1.5 What assumptions about the data or model beyond the established EwE assumptions have been made?

Production and consumption rates were obtained from taxonomically similar trophic groups when rates were unknown. The ecotrophic efficiency was specified based on the ranges calculated from other EwE models and recommendations from modeling experts for approximately 50% of the groups where biomass was unknown. This method is particularly useful for large groups consisting of 50+ fish species or hundreds of species of invertebrates.

- *The WG noted the uncertainties in model outcomes due to these assumptions on the production and consumption rates, and the ecotrophic efficiency. The model will be updated with improvement as new information becomes available.*
- *The WG noted improvements in biomass input and diet input will substantially improve the model performance, compared to any improvements in production and consumption rates. The species listed below are ranked in the order of the impact on the model performance.*
  - ***Recommend research into South Atlantic Regional biomass estimates for species important to the ecology and/or fisheries of the model region.***
    - ***Ecologically high-impact species: Forage fish (such as herrings, anchovies, shad and sardines), Auxis mackerels (bullet and frigate mackerel) and red drum.***
    - ***Fisheries-important species: Nassau grouper and Goliath grouper***
  - ***Recommend research into the diets of species for which the current literature lacks recent, local diet information necessary to accurately characterize feeding ecology.***
    - ***Species: Auxis mackerels (bullet and frigate mackerel), blue runner, tarpon, mutton snapper and Nassau grouper.***
    - ***Recommend further monitoring of lionfish diet in order to fully evaluate their impact on the ecosystem.***

2.1.6 Are the estimates from the Ecopath model (food web characteristics) suitable to inform stock assessment and fisheries management?

Estimates from the Ecopath model, including ecotrophic efficiency or biomass, production rate and thermal dynamic rules, are considered biologically feasible based on diagnostic tests and published literature. Ecopath establishes baseline ecosystem dynamics that are used to understand the structure of the ecosystem and key trophic relationships. The baseline dynamics in Ecopath inform time-dynamic models in Ecosim and space-time dynamic simulations in Ecospace.

- *The WG emphasized that the EwE model will serve as a living tool to complement stock assessment and fisheries management. The model will be updated and improved as new data become available.*

2.2 Ecosim

2.2.1 Are there limitations in the fishery dependent and independent data used in the Ecosim model?

a. Are the time series of catches for fishery groups reliable?

The catch time series from 1995-2019 were used in the model. The catch time series were calculated from ACCSP, SRHS, and newly-calibrated MRIP, and were used as a forcing time series. The WPUE time series were calculated from the Southeast Reef Fish Survey (SERFS), and were used as a reference time series. The biomass time series were calculated from stock assessments, and were used as a reference time series.

- *The WG evaluated these time series and agreed that they are from reliable sources as listed above.*

b. If other forcing time series have been used (e.g., mortalities, hatchery production), are they reliable?

- *The WG discussed the potential of adding an index of chlorophyll a as a forcing time series to represent primary productivity.*
    - *Currently the MT is exploring how these adjustments would affect model fits.*

c. What methods have been used to generate fishery dependent and fishery independent indices?

Abundance indices are not an input in the model, and thus this TOR is irrelevant.

d. Are there limitations inherent in any of the indices used?

Abundance indices are not an input in the model, and thus this TOR is irrelevant.

2.2.2 Do the time series data used for model fitting represent the functional groups that they are intended to?

The model is currently being fit to address a hypothetical question about interactions between red snapper, red porgy, and black sea bass. The time series for single-species functional groups were obtained from data for only those species (i.e. no proxy groups were used). Stock assessment biomass and WPUE time series were not used for large, multi-species functional groups. For large, trophically-grouped functional groups, the catch time series that represent all available landings for the species in that group were used.

- *The WG agreed that the time series data used for the current model reasonably represent the functional groups in this hypothetical scenario.*
- *The WG noted that the choice of time series data and functional groups in the model can be adjusted for specific research and management questions.*

2.2.3 Are there any limitations to the procedure used to create time series (e.g., catch, abundance indices) for functional groups?

Time series data was obtained directly from data sources, and thus no procedure was used to create time series data.

2.2.4 Are there limitations to the base input parameters for the Ecosim model?

Feeding time adjustment rate was changed to 0, rather than the default value of 0.5 (which is generally used only for early juvenile groups). A non-zero value for this parameter is used to test the effects of risk-sensitive feeding behavior by simulating a direct response of feeding time and food consumption rate to the changes in predator abundance. Otherwise Ecosim base parameters were default values and can be modified as specific management questions are explored.

- *The WG discussed the feeding time adjustment rate and the density of seagrass, and supports the decisions made by the MT.*

2.2.5 Model fitting

a. What process was used to tune the model to time series data?

Predator-prey interactions in Ecosim assume prey modulate their exposure to predation by entering available (i.e. 'vulnerable') and unavailable states. A vulnerability parameter estimate, for every predator-prey interaction defined in the diet matrix, determines the degree to which large increases in predator biomass cause predation mortality on available prey. For example, a high vulnerability estimate (e.g., 100) may indicate a doubling of predation mortality on prey *j* when predator *i* biomass doubles and highly oscillatory changes in predator *i* and prey *j* biomass over time as a result. Ecosim estimates the vulnerability parameters that provide the best fit between estimated and observed biomass and catch time series using a sum of squares routine. Vulnerability parameters default to two and the number of vulnerability estimates that differ from the default (i.e. those that are estimated) should not exceed the number of available observed time series.

Vulnerability parameters were estimated using a sequential process. First, a stepwise fitting plug-in was used to 1) guide how many vulnerabilities should be estimated by determining approximately how many predators and predator-prey interactions, out of all reasonable combinations, were the most sensitive to the changes in vulnerability parameters in terms of sum of squares; and 2) determine if observed catch time series, observed biomass time series, or both, should be used to estimate vulnerability parameters based on Akaike's information criterion (AIC).

Second, the initial vulnerability estimates from the first step were used to visually assess any gross divergence or dynamic instability between predictions and observations (i.e. predicted extinctions or excessive increases in biomass). In these circumstances, the pedigree of data was re-evaluated to determine if any adjustments were appropriate (e.g., outliers within the catch data or production estimates that were borrowed from taxonomically similar trophic groups).

Last, model fits were evaluated to determine if additional adjustments to vulnerability estimates improved model fits, in terms of lower sum of squares, in cases where the sensitivity analysis in the first step did not identify the potential improvement. For example, commercially important trophic groups may not necessarily be the most sensitive to changes in vulnerability estimates out of all trophic groups, but fits might improve with minor adjustments nonetheless.

b. Are there limitations to the process used for model fitting?

The goal of fitting process is to find the vulnerabilities that give the best fit to the data with a priority on fitting certain time series for species of interest in a particular scenario. The model is

currently being fit to address a hypothetical question about interactions between red snapper, red porgy, and black sea bass, and this process is ongoing.

- *The WG noted the model is complicated but also flexible to suit a specific question by adjusting the inputs, and this model fitting process will need to be modified or redone for each question being explored. Thus, the WG had no specific recommendations on the model fitting process at this stage.*
- *Making the stock assessment outcomes more directly accessible to the MT will better facilitate the process of model development and fitting in the future.*
- *The WG noted the inputs of biomass and diet are critical to the model performance of Ecopath, and can further influence the fitting of Ecosim. Improvements in these two inputs will substantially improve the performance of both Ecopah and Ecosim.*

c. Is the process used to contain extreme estimates reasonable?

The extreme estimates refer to extinction events or extremely high biomass estimates. In the current model, extinction events were evaluated by checking the production rates, the outliers in catch time series and the initial biomass input to ensure these inputs are from reliable sources and are realistic. Any extreme input values that can be confirmed unreasonable were removed. For those outliers in catch time series that cannot be confirmed at the current stage, the corresponding time series was set as reference instead of as forcing time series in the model. The issues with extremely high biomass estimates were explored by adding predators or setting biomass as a forcing variable. The model will be updated and improved as new information becomes available.

- *The WG was satisfied with the process used to contain extreme values. These values were investigated and modified by the MT during this review process to improve the model performance.*
- ***Recommend identifying and evaluating extreme estimates.***

2.2.6 How have productivity changes been incorporated into the model?

Ecosim fits to time series, and subsequent vulnerability estimates can improve when primary production is forced by a time series of chlorophyll a or other environmental indicator of primary production. Currently, the MT is evaluating how satellite-derived chlorophyll a time series might affect Ecosim model fits. Satellite-derived chlorophyll a can be highly variable because 1) the study area is large and contains coastal and oligotrophic waters, and 2) satellites that estimate chlorophyll a (i.e., MODIS and SeaWiFS) capture different time periods. The latter issue requires NASA to produce a calibrated time series product that combines chlorophyll a data over different time periods. Currently, the combined product serves as the basis for the chlorophyll a time series that is being evaluated in Ecosim.

- *The WG realized the current uncertainty of incorporating primary productivity, and agreed with the MT's current approach and direction.*

2.2.7 Are the estimates from the EcoSim model (e.g., time series output of fishing mortality rates, changes in the strength of foodweb interactions) suitable to inform stock assessment and fisheries management?

The EwE will serve as a living tool to complement stock assessment and fisheries management. The EwE can be used to inform management decisions (e.g., management strategies evaluation),

multi-species management, and ecosystem-based management (e.g., identifying biotic and abiotic drivers of the population dynamics). It can also be used to test hypotheses related to trophic interactions, and to evaluate uncertainties of parameters at ecosystem scale. For example, a similar Ecosim model was used in the Gulf of Mexico to explore the consequences of changing fishing effort in specific fleets and changes in primary productivity under alternative Reef Fish Fishery Management Plans (Chagaris et al. 2015, Marine and Coastal Fisheries). Furthermore, Ecospace has been effectively used worldwide to explore the consequences of alternative Marine Protected Area designs. The EwE will be updated and improved as new data become available.

- *The WG agrees that the EwE is suitable to inform stock assessments and fisheries management. The WG mostly focused on evaluating Ecopath as it is the foundation for the EwE model. The WG was unable to fully evaluate the Ecosim model. Once specific questions are developed by the SSC or the Council, further evaluation of the Ecosim model is possible.*
- ***Recommend establishing a standing workgroup to help with future update and development of EwE, including Ecospace, in order to increase the functionality of EwE for fisheries management.***