# Predicting Community Changes in Marine Reserves

RONALD L. HILL
*NOAA/NMFS*
*Southeast Fisheries Science Center-Galveston*
*4700 Avenue U*
*Galveston, Texas 77551 USA*

ABSTRACT

Although marine reserves are proving, throughout the world, to be valuable tools for fishery management, uncertainty in the timing and magnitude of expected changes has left some resource managers and many fishers hesitant to accept establishment of reserves. Trophic models, using *Ecopath* with *Ecosim*, can be used to predict changes in target species, to assess differences in reserve performance based on inclusion/exclusion of different habitat types, and to predict time frames within which changes in species abundance and size distributions can be expected. A trophic model of a Caribbean coral reef ecosystem, representing the Turromote reef platform off La Parguera, is being generated using both extensive historical data sets and recent field data. By using the combination, we can track historical trends in community changes, evaluate fishing pressure over time, and predict future changes in fish assemblages. The first stage of model construction, updating and completing a generalized Caribbean model, is presented along with model simulations run over space and time. Results of the model simulations can estimate the effects of a no-take reserve on different target species and can predict time frames within which benefits should accrue. Future work will continue the customization of the model and will use changes in field conditions to validate the model. Reliable predictions should help fishery managers to understand the use and applicability of no-take marine reserves for improved management and realistic time frames for assessing reserve effectiveness.

KEY WORDS: Marine reserves, Ecopath, coral reef ecosystem

# Prediciones de Cambios de la Comunidad en las Reservas Marinas

Aunque las reservas marinas estan demostrando, a traves del mundo, ser herramientas valiosas para la gerencia de la industria pesquera, la incertidumbre en la sincronizacion y la magnitud de cambios previstos ha dejado algunos encargados de recurso y muchos pescadores vacilantes aceptar el establecimiento de reservas. Los modelos troficos, usando *Ecopath* con *Ecosim*, se pueden utilizar para predecir cambios en especies apuntados, para determinar diferencias en el funcionamiento de la reserva basado en la inclusion/exclusion de diversos tipos del habitat, y para predecir los marcos de tiempo dentro de los cuales los cambios en la abundancia y distribucion de tamano de las especies pueden esperar. Un modelo trofico de un ecosistema del arrecife coralino del Caribe, representando la plataforma del arrecife de Turromote afuera del la Parguera, se esta generando usando ambos conjuntos historicos extensos de datos y datos recientes del campo. Usando la combinacion, podemos seguir tendencias historicas en cambios de la comunidad, evaluar la pression de la pesca en un cierto plazo, y predecir cambios futuros en ensambladuras de los pescados. La primera etapa de la construccion modelo, poniendo al dia y terminando un modelo del Caribe generalizado, se presenta junto con el funcionamiento de simulaciones modelo sobre espacio y tiempo. Los resultados de las simulaciones ejemplares pueden estimar los efectos de un no toma la reserva en la especie apuntada diferente y pueden predecir los marcos de tiemp dentro de los cuales las ventajas deben acrecentarse. El trabajo futuro continuar el arreglo para requisitos particulares del modelo y utilizara cambios en las condiciones del campo para validar el modelo. Las predicciones confiables deben ayudar a encargados de la industria pesquera a entender el uso y la aplicabilidad de no toma las reservas marinas para la gerencia mejorada y los marcos de tiempo realistas para determinar eficacia de la reserva.

PALABRAS CLAVES: Reservas marinas, modelos trophic

## INTRODUCTION

Marine reserves ("no-take") are being used throughout the world as tools to reduce habitat loss and degradation, to conserve biodiversity, and to enhance fishery management. They have found particular utility in tropical settings where fisheries have been difficult to manage using conventional management regimes. In parts of the United States, fishers and fishery managers voice doubts about the ability to accomplish fishery goals through area-based management such as marine reserves. Although scientist have been able to point to examples of marine reserves successfully improving fishery conditions throughout the world, resistence has continued. In instances where marine reserves have been established in the United States, managers have set time limits, often five to ten years, within which time the reserve should demonstrate its efficacy.

Trophic models, using *Ecopath* with *Ecosim*, can be used investigate some of these questions and to offer a predictive method that can be readily tested in systems where reserves have been instituted. *Ecopath* is used to portray the trophic structure of an ecosystem with the option of including fishing as a type of predation mortality within the system. The *Ecosim* module is designed to test the effects of different fishing management options on the modeled community structure and can be used to predict changes in target species. The recent inclusion of *Ecospace* has presented the opportunity to examine the effects of the *Ecosim* simulations over heterogeneous habitat types (Christensen and Pauly). This can allow the testing of various hypotheses regarding the dynamics and performance of marine reserves.

This paper is an initial presentation of a multi-year project designed to build a trophic model of a Caribbean coral reef ecosystem, representing the Turromote reef platform off La Parguera, Puerto Rico. It is being generated with current and historical data in order to mimic historical trends in community changes, evaluate fishing pressure over time, and predict future changes in fish assemblages. The first stage of model construction, updating and completing a generalized Caribbean model, is presented along with sample model simulations. Future work that will allow prediction of reserve dynamics and allow for future validation of simulation work will be discussed.

## MATERIALS AND METHODS

The *Ecopath* modeling system is a modification and refinement of an approach presented by Polovina (1984) for the estimation of the biomass of the various elements (species or groups of species) of an aquatic ecosystem. It was modified with various approaches from theoretical ecology, notably those proposed by R.E. Ulanowicz (1986), for the analysis of flows between the elements of ecosystems. It is readily available (www.ecopath.org), has simple data requirements, is constantly being updated and improved, and offers a wide variety of helpful routines to help with model building.

One improvement in the basic routine of *Ecopath* is a shift from its original assumption of steady state. *Ecopath*, instead, bases the parameterization of the model on an assumption of mass balance over the chosen time period, typically a year. In its present form *Ecopath* parameterizes models based on two master equations, one to describe the production term and one for the energy balance of each group.

The series of equation are developed on the premise that "Mortality for a prey is consumption for a predator." The first *Ecopath* equation describes how the production term for each group (i) can be split in components. A box (group) in an *Ecopath* model may be a group of (ecologically) related species, a single species, or a single size/age group of a given species. This is implemented with the equation,

**Production = Catches + Predation Mortality + Biomass Accumulation + Net Migration + Other Mortality**

Secondly, the energy input and output of all living groups must be balanced. The first *Ecopath* master equation (above) includes only the production of a box. When describing the energy balance of a box, other flows should be considered. So as to ensure mass balance between groups, energy balance is ensured within each group using the equation:

**Consumption = Production + Respiration + Unassimilated Food**

This equation is in line with Winberg (1956) who defined consumption as the sum of somatic and gonadal growth, metabolic costs and waste products. The main differences are that Winberg (along with many other bioenergeticists, see Ney 1990) focused on measuring growth, where Ecopath focuses on estimating losses. The

*Ecopath* formulation does not explicitly include gonadal growth. The *Ecopath* equation treats this as included in the predation term (where nearly all gonadal products end up in any case).

Once a trophic model has been built in *Ecopath* it can be used directly for simulation modeling using Ecosim. This approach is fully integrated with *Ecopath*, and is a complex simulation model for evaluating the impact of different fishing regimes on the biological components of ecosystems. One identified short coming was the lack of a means to investigate habitat mediated differences in trophic relationships. This has been remedied through the development of *Ecospace* (Walters et al. 1998), a dynamic, spatial version of *Ecopath*, incorporating all key elements of *Ecosim*.

Data sources and reliability are a concern for developing a model that correctly reflect the relationships and functioning of a complex system. In the case of the coral reef ecosystem of La Parguera, including coral reefs, mangroves, seagrass beds, algal plains and other interacting habitats, a large body of research and monitoring has gone on for the last four to five decades. This has been a focus of residents and visitors to the Marine Science Department of the University of Puerto Rico-Mayagüez All aspects of the area have been examined in varying detail. Fish assemblages, benthic communities, and planktonic organism have been examined. Sedimentology, tidal regimes, and current patterns have been documented. Where sampling has been done locally, information from the wider Caribbean is generally available that will complete the data needs of the project. Continuing sampling and research will allow updating a modification of the model into the future.

## RESULTS

The initial work with the Optiz models has begun with evaluation of the dynamics of the 20-box model produced as a representation of a generalized Caribbean reef from the Puerto Rican-Virgin Islands area. The Opitz model, modified with representative fishing information, has been run under a variety of scenarios that examine trophic and fishing interactions. Figures 1, 2 and 3 display results of different intensities and durations of fishing mortality. Under a constant, low level of fishing pressure the biomass levels for each species group are stable over the 20 year run cycle (Figure1). If fishing mortality is doubled for a longer period of time, various biomasses are changed but when fishing pressure returns to its previous low level, the biomasses return to their original levels, too (Figure 2). If, however, the fishing mortality is increased for a slightly longer period of time, the biomasses shift and do not regain their original relationships even when the model is run for 50 years instead of 20 years. These are particularly significant in the interacting groups of competitors, predators and prey.

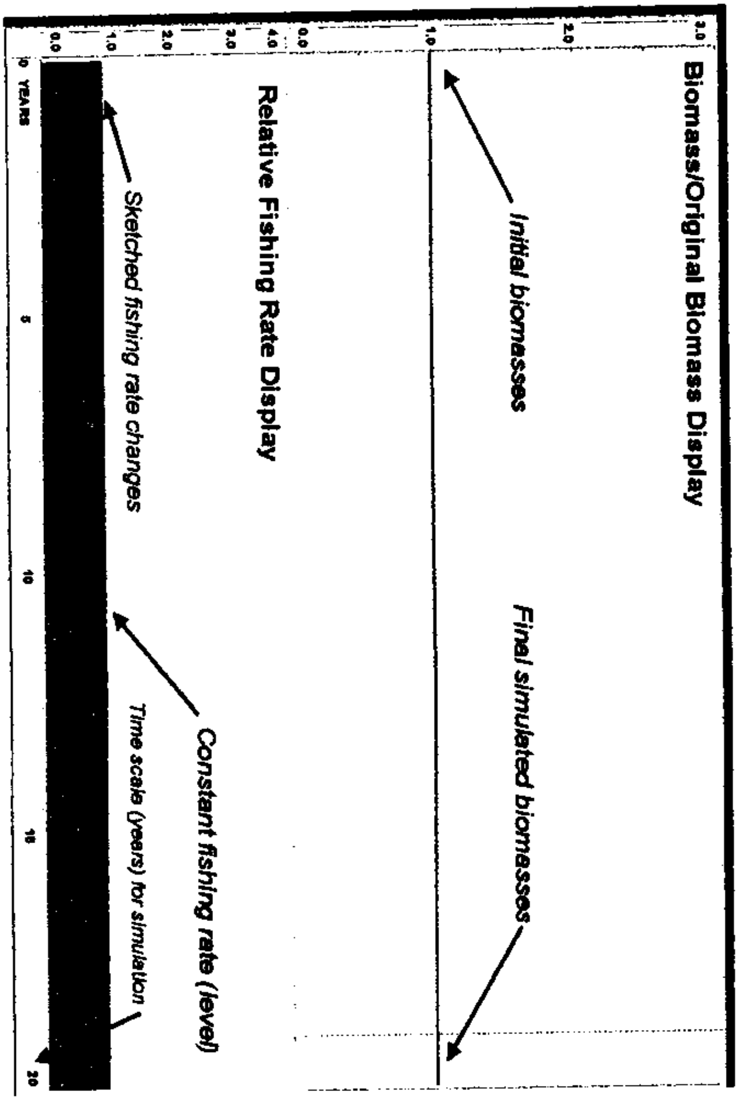


**Figure 1.** Computer "screen capture" of mass balanced model from EwE simulation. Model run with base constant fishing rate. Biomass ratios (compared to starting biomass) are displayed, all with a ratio of 1.0; all biomass levels remain constant throughout the simulation.

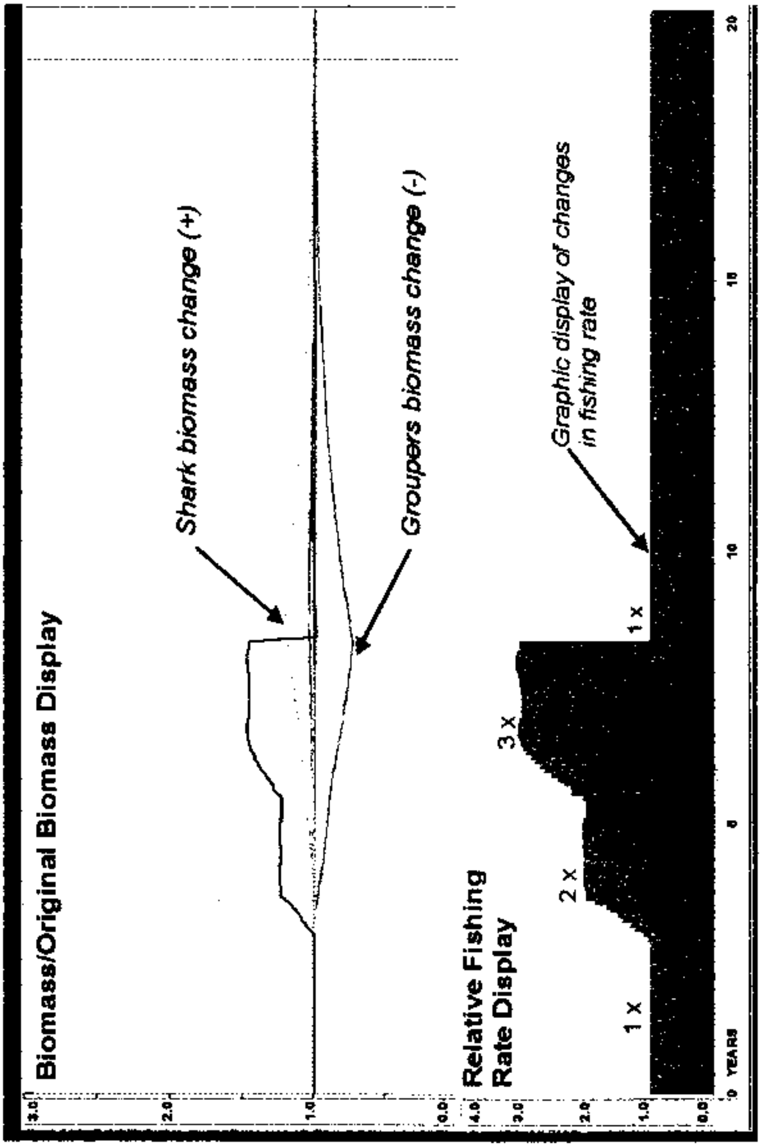


**Figure 2.** Model run with increased fishing mortality over a relatively short duration. Notice different biomass responses of different species.

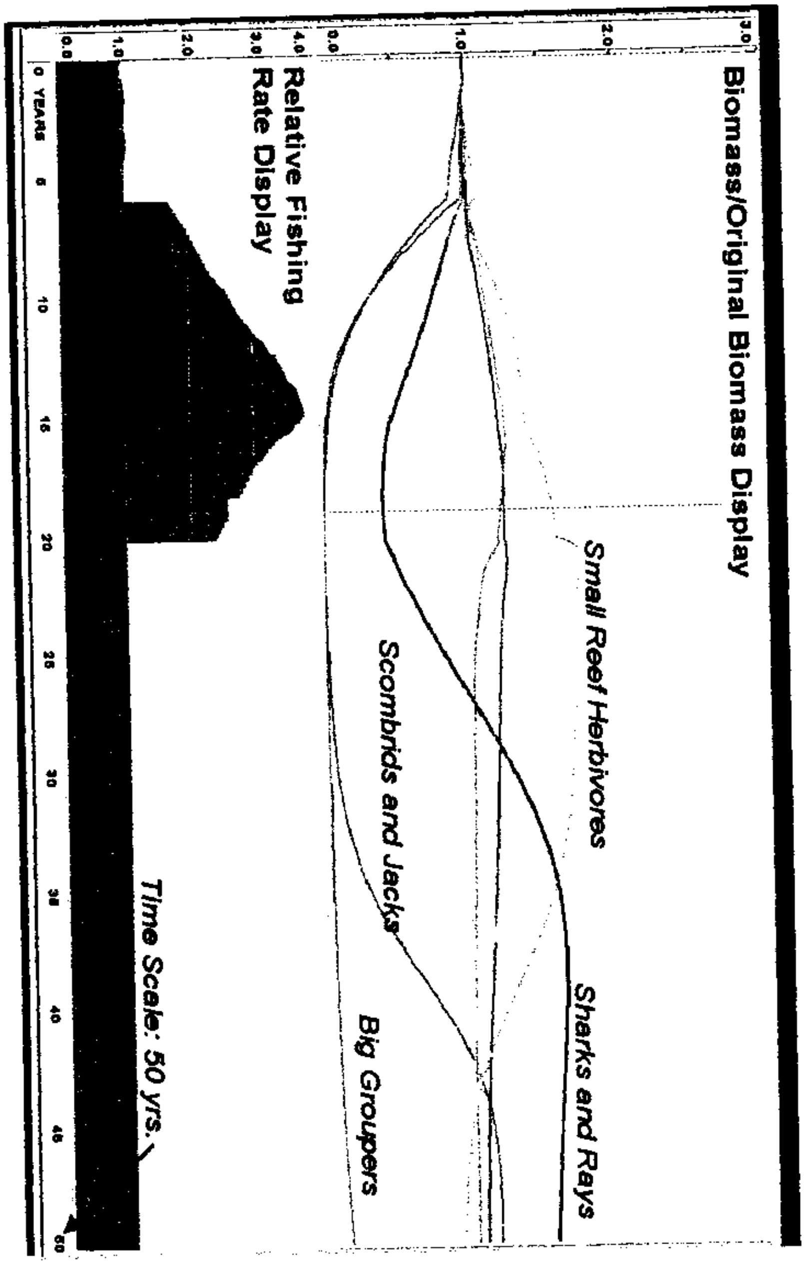


**Figure 3.** Computer "screen capture" of EwE simulation run with increased fishing mortality over a longer duration. Notice different biological responses of different trophic groups.

## DISCUSSION

*"Real ecosystems are more complicated than the mass-balance fluxes of biomass in Ecopath, however large the number of functional groups we include in our models. Real ecosystems also have dynamics far more complex than represented in Ecosim. The issue to consider, when evaluating the realism of a simulation software is, however, not how complex the software and the processes are that are represented therein. Rather, the question is which structure allows a representation of the basic features of an ecosystem, given a limited amount of inputs."*

## LITERATURE CITED

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