Ecopath to Analyses, Tools, and Evaluation

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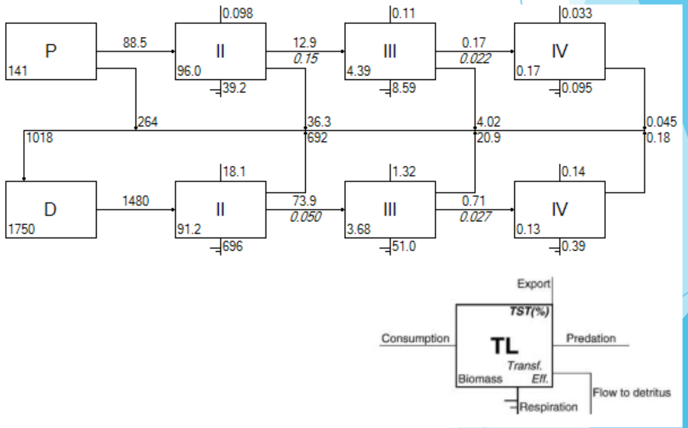
EwE Components and Indicators

- Ecopath, Ecosim, and Ecospace (EwE)
  - Snapshot in time (Ecopath) ->
    - Trophic dynamics over time (Ecosim) ->
      - Trophic dynamics over time and space (Ecospace)

EwE Components and Indicators

Two general approaches to evaluating EwE outputs:

1. Ecosystem indicators built into EwE (Odum, Ulanowicz, Lindeman)
   - Structure and function of the ecosystem
     - Key groups, sensitive groups, system size, trophic flows
     - Snapshots (Ecopath), or indices over time (Ecosim)



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        - Snapshots (Ecopath), or indices over time (Ecosim)

2. Model selection framework (Hilborn and Mangel)
    - Confront models with data; compare model iterations
        - Model sensitivity to parameter variability or assumptions
        - Model sensitivity to management actions (MSY, effort reduction)
        - Scenario building under divergent environmental forcing functions, MPA designs
    - May require third party applications (e.g., R)

1. Ecosystem Indicators

- Ecopath and Ecosim
  - Total System Throughput
    - Ecosystem size
  - Mean Trophic Level of the Catch
    - Fishing effects on the community
  - Keystoneness
    - Group importance or influence

Table 1. Ecological and fisheries related indicators used in this comparison.

Acronym	Indicators	Units	Definition
Ecological indicators			
TST	Total System Throughput	t·km^{-2}·y^{-1}	The sum of all the flows through the ecosystem
PP/TST	Primary production/TST		Primary production over the sum of all the flows through the ecosystem
FD/TST	Flows to Detritus/TST		Flows to detritus over the sum of all the flows through the ecosystem
Q/TST	Total consumption/TST		Total consumption over the sum of all the flows through the ecosystem
R/TST	Total respiration/TST		Total respiration over the sum of all the flows through the ecosystem
Ex/TST	Total exports/TST		Total exports of the system over the sum of all the flows through the ecosystem
PP/P	PP/Total Production		Primary production over total production
MeanPz (MaxPz)	Mean (Max) proportion of total mortality due to predation		The mean (or Maximum) proportion of each group's total mortality that was accounted for by each predator
meanEE	Mean Ecotrophic Efficiency	%	Ecotrophic efficiency of a group is that proportion of the production that is utilized in the system.
TBco	Total Biomass (excluding first trophic level)	t·km^{-2}	Total biomass of the community excluding detritus and primary producers
mTLco	Mean Trophic Level of the Community		Weighted average trophic level for functional groups with a TL>2
TEm	Mean Transfer Efficiency	%	Geometric mean of transfer efficiencies for trophic level II to IV
A/C	Ascendency/Capacity	%	Relative Ascendency, dimensionless index of ascendency - index of organisation of the food web
O/C	Overhead/Capacity	%	Relative overhead, dimensionless index of the ecosystem's strength in reserve
IFO	Internal Flow Overhead or redundancy	%	Indicator of the change in degrees of freedom of the system, or an indicator of the distribution of energy flow pathways in the system
FCI	Finn's Cycling Index	%	Quantifies the relative amount of recycling and is an indication of stress and structural differences either among models [44]
SOI	System Omnivory Index		Variance of trophic levels in the diet
KS	Keystoneness		Index of the ability of a trophic group with low biomass to influence others
KD	Dominance		Index of both high biomass and high influence
Fishing indicators			
TC	Total Catches	t·km^{-2}·y^{-1}	Total landings and discards exported from the system
TLc	Mean Trophic Level of the Catch**		Average trophic level of all caught species using weighted by yield

Heymans, J.J., Coll, M., Libralato, S., Morissette, L. and Christensen, V., 2014. Global patterns in ecological indicators of marine food webs: a modelling approach. *PloS one*, 9(4), p.e95845.

1. Ecosystem Indicators

- Ecopath and Ecosim
  - Keystoneness
    - Total Effect of a unit change in biomass
    - Weighted by the contribution of biomass

by Libralato et al. (2006) was also applied. Keystone species are those that show relatively low biomass but have a structuring role in the ecosystem (Power et al., 1996). Therefore, they can be identified by plotting the relative overall effect (ε_i), calculated from the MTI (m_{ij}), against the keystoneness (KS_i). The overall effect (ε_i) is described as:

$$\varepsilon_i = \sqrt{\sum_{j=1}^{n} m_{ij}^2} \qquad (4)$$

where m_{ij} is calculated from the MTI analysis as the product of all net impacts for all the possible pathways in the food web linking prey, i, and predators, j. The keystoneness (KS_i) of a functional group is calculated as:

$$KS_i = \log[\varepsilon_i(1-p_i)] \qquad (5)$$

where p_i is the contribution of the functional group to the total biomass of the food web. This index is high when functional groups (species or groups of species) have both low biomass proportions within the ecosystem and high overall effects, in line with the keystone species definition.

Coll, M., Santojanni, A., Palomera, I., Tudela, S. and Arneri, E., 2007. An ecological model of the Northern and Central Adriatic Sea: analysis of ecosystem structure and fishing impacts. *Journal of Marine Systems*, *67*(1-2), pp.119-154.

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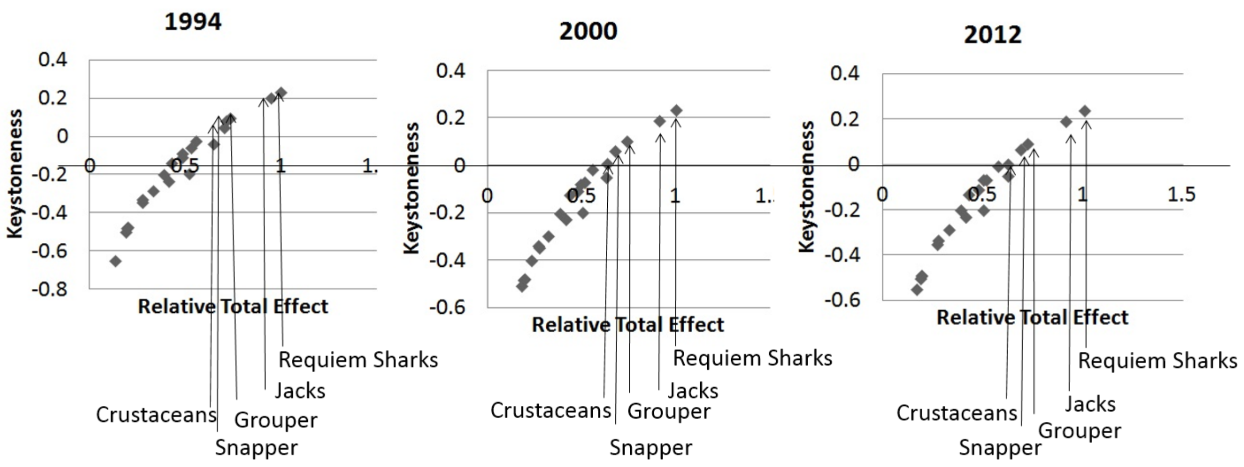
Florida Keys 36-Box Model



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1. Ecosystem Indicators

- Management applications
  - Sanctuary Condition Reports

9. What is the status of biodiversity and how is it changing? Selected biodiversity loss has caused or is likely to cause severe declines in some but not all ecosystem components and reduce ecosystem integrity; therefore, this question is rated as "fair/poor." Recently the relative abundance and diversity across a

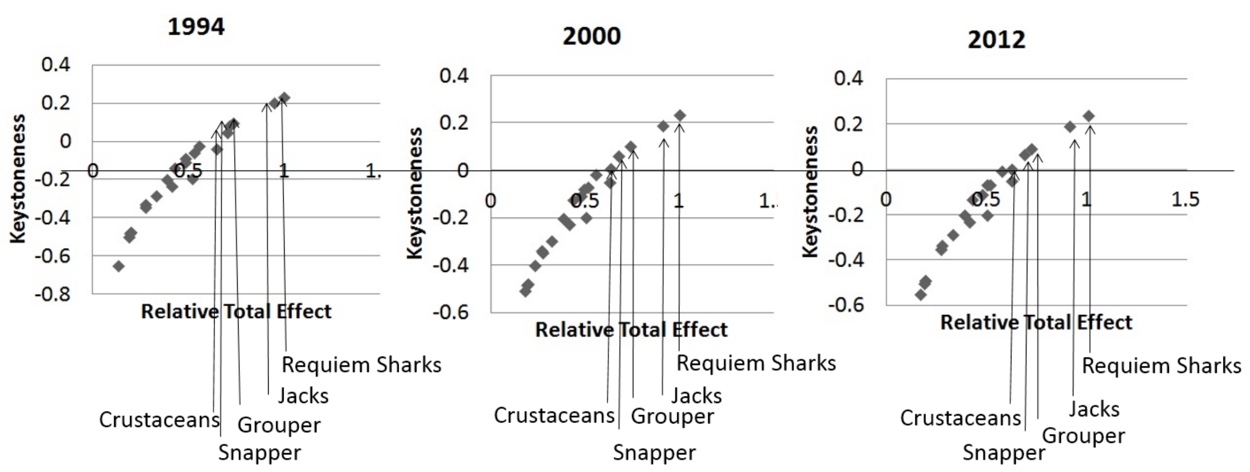
10. What is the status of environmentally sustainable fishing and how is it changing? The status and trend ratings for this question are based on the available scientific knowledge from published studies, unpublished data, and expert opinion for targeted and non-targeted living resources that

12. What is the status of key species and how is it changing? The key species or taxa in the sanctuary selected for use in this report include stony corals, seagrasses, queen conch, Caribbean spiny lobster, long-spined sea urchin, the snapper-grouper complex and sea turtles. These species are important for their

  - Marine Biodiversity Observation Network

The Marine Biodiversity Observation Network (MBON) is composed of regional networks of scientists, resource managers, and end-users working to integrate data from existing long-term programs to improve our understanding of changes and connections between marine biodiversity and ecosystem functions. In the United States, MBON projects have been established in the Chukchi Sea (Alaska), Santa Barbara Channel (California), and the National Marine Sanctuaries in Monterey Bay (California) and the Florida Keys (Florida).

Florida Keys 36-Box Model



2. Comparing Iterations

- Examine alternative EwE model runs
  - Sensitivity to management actions
  - Scenario building
  - Sensitivity to parameter estimates and data gaps

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- Examine alternative EwE model runs
  - Sensitivity to management actions
  - Scenario building
  - Sensitivity to parameter estimates and data gaps
- How exactly?
  - Sum of squares routines to test different Ecosim models or competing datasets within EwE
  - Export deterministic results from EwE and compare a range of options
  - Run Monte Carlo simulations on parameter estimates to examine a range of results

2. Comparing Iterations

- Examine alternative EwE model runs
  - Sensitivity to management actions
    - Policy actions (Heymans 2009, Chagaris et al. 2015)
    - Marine aquaculture (Forrestal et al. 2012)
  - Scenario building
    - Climate change (Ainsworth et al. 2011)
    - Invasive species (Pinnegar et al. 2014)
    - Hypoxia (De Mutsert et al. 2016)
  - Sensitivity to parameter estimates and data gaps
    - Florida Keys 36-Model
- Nearly all examples have clear research questions

2. Comparing Iterations

- Examine alternative EwE model runs
  - Sensitivity to management actions
    - Most fishing policy explorations are done by changing fleet parameters

Chagaris, D.D., Mahmoudi, B., Walters, C.J. and Allen, M.S., 2015. Simulating the trophic impacts of fishery policy options on the West Florida Shelf using Ecopath with Ecosim. *Marine and Coastal Fisheries*, *7*(1), pp.44-58.

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  - Examined the change in biomass under Ecosim scenarios:

    1. Status quo
    2. Two management actions (RF Fishery Management plan 30B and 31.)
       - Reducing fishing mortality on Gag by ~30%
       - Reduced longline fishing effort by 60%
    3. Expansion of baitfish fishery
    4. Two scenarios with different levels of phytoplankton productivity

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    3. Expansion of baitfish fishery
    4. Two scenarios with different levels of phytoplankton productivity
  - Monte Carlo simulations on biomass projections
  - Complemented single species stock assessment

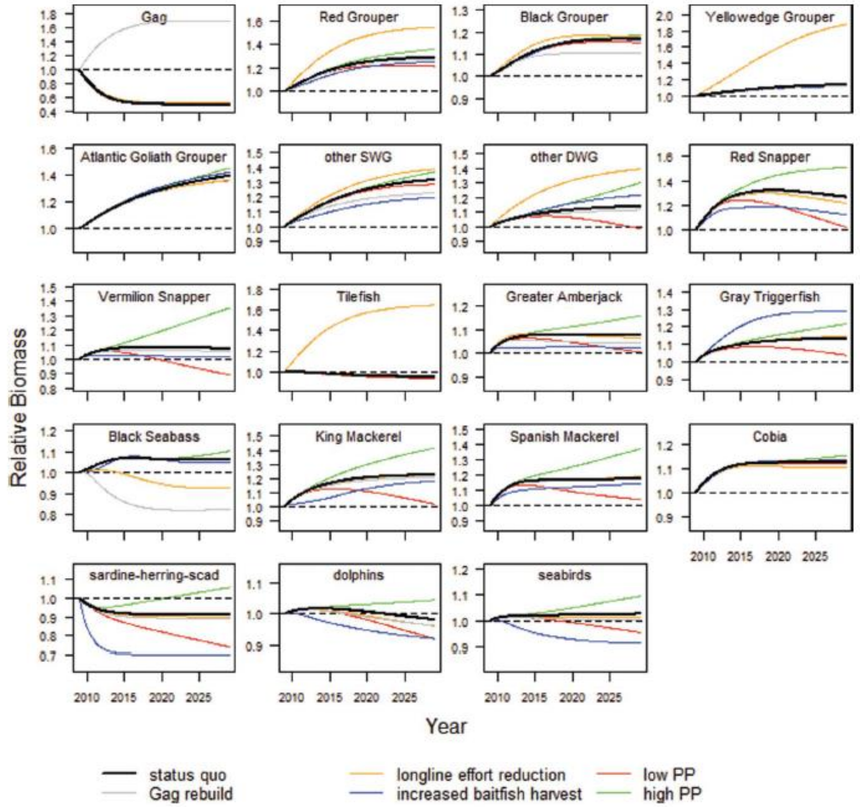


FIGURE 3. Future biomass trajectories simulated by the Ecosim model. Scenarios that caused an increase or decrease in biomass from the status quo are indicated by lines above or below the solid black lines. In some cases there was little change, and those scenarios may be obscured by the status quo line. The dotted line represents the Ecopath base 2009 biomass level.

2a. Ecospace Scenarios

Two general approaches to evaluating EwE outputs:

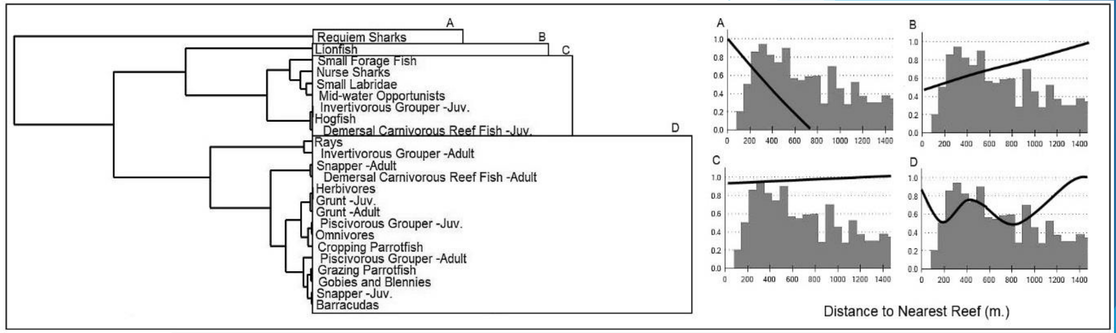
1. Ecosystem indicators built into EwE
2. Model selection framework

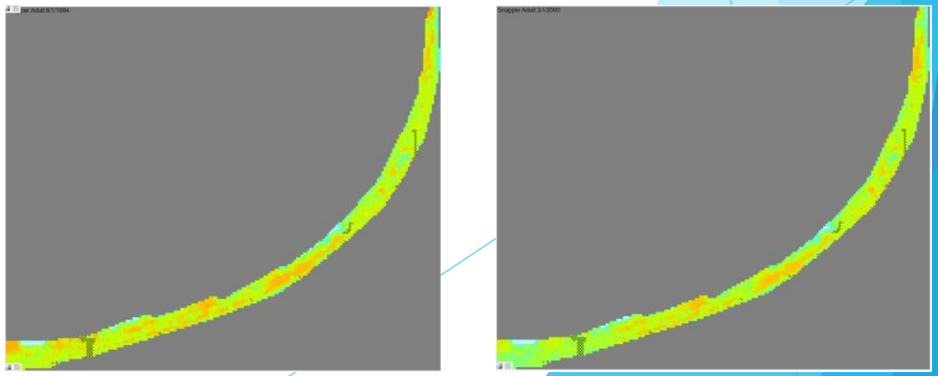
2a. Ecospace habitat capacity functions

2a. Ecospace Scenarios

- Habitat capacity functions in Ecospace
  - Species distributions will reflect functional responses with few exceptions
- “Traditional” functional response
  - Static maps
  - Generalized Additive Models (GAMs)

Florida Keys 36-Box Model





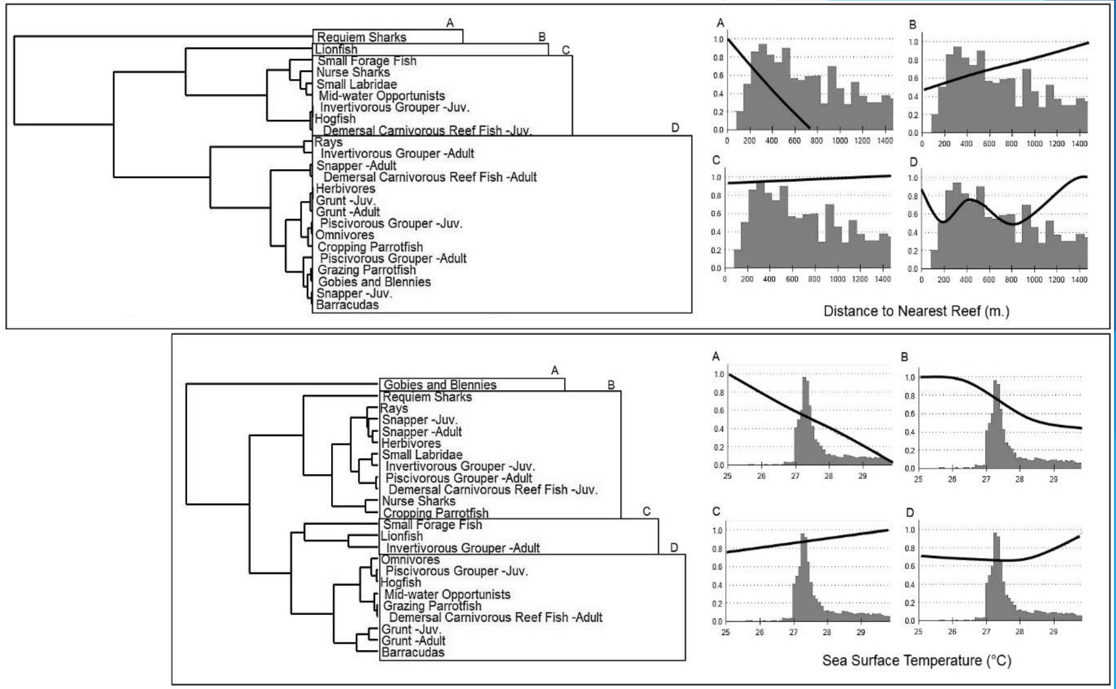
Snapper 6/1/1994 → 3/1/2000

2a. Ecospace Scenarios

- Habitat capacity functions in Ecospace
- “Traditional” functional response
  - Static maps
  - Generalized Additive Models (GAMs)

- New habitat capacity function that leverages remote sensing time series
  - GAMs on monthly time steps
    - Sea Surface Temperature
    - Chlorophyll a
    - Any remote sensing product of ecological relevance

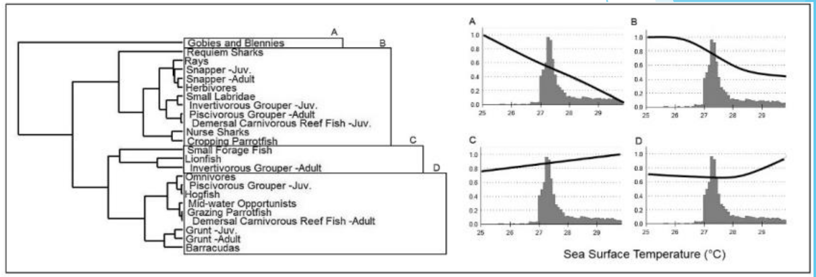
Florida Keys 36-Box Model

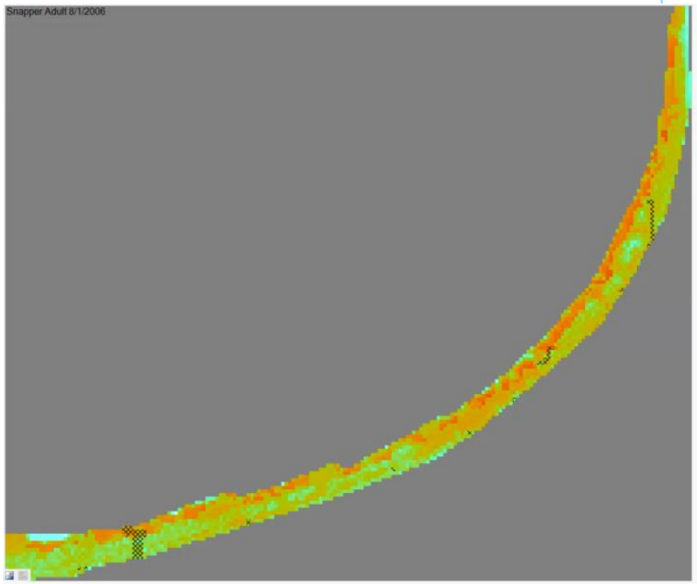


2a. Ecospace Scenarios

- New habitat capacity function leverages remote sensing time series
  - GAMs on monthly time steps
    - Sea Surface Temperature (fish, coral groups)
    - Chl a drives primary production
    - Distance to reefs, Depth remain static
  - Mississippi plume events are of interest

Florida Keys 36-Box Model

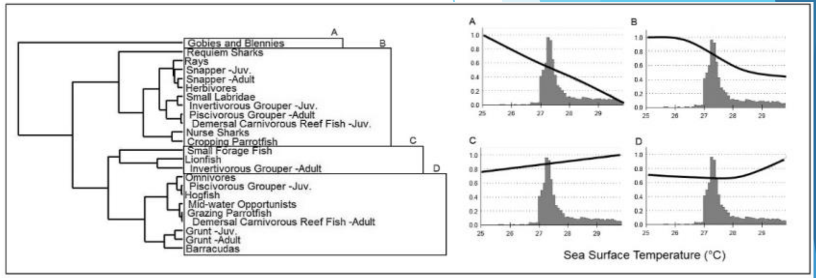




2a. Ecospace Scenarios

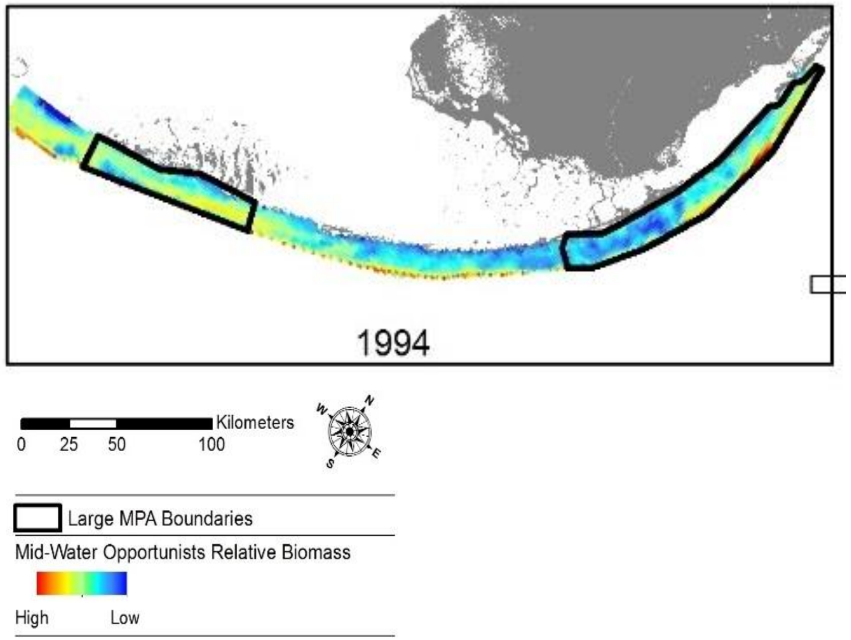
- New habitat capacity function that leverages remote sensing time series
- Management applications
  - Climate change
  - Oceanographic events
  - MPAs
    - Florida Keys National Marine Sanctuary Rezoning
    - Parameter uncertainty

Florida Keys 36-Box Model



2a. Ecospace Scenarios

- Florida Keys 36-Box Model Simulations
  - Examined the effects of movement, fishing effort, and MPA size
  - Underlying functional responses to Chl a, SST, Distance to Reefs, and Depth



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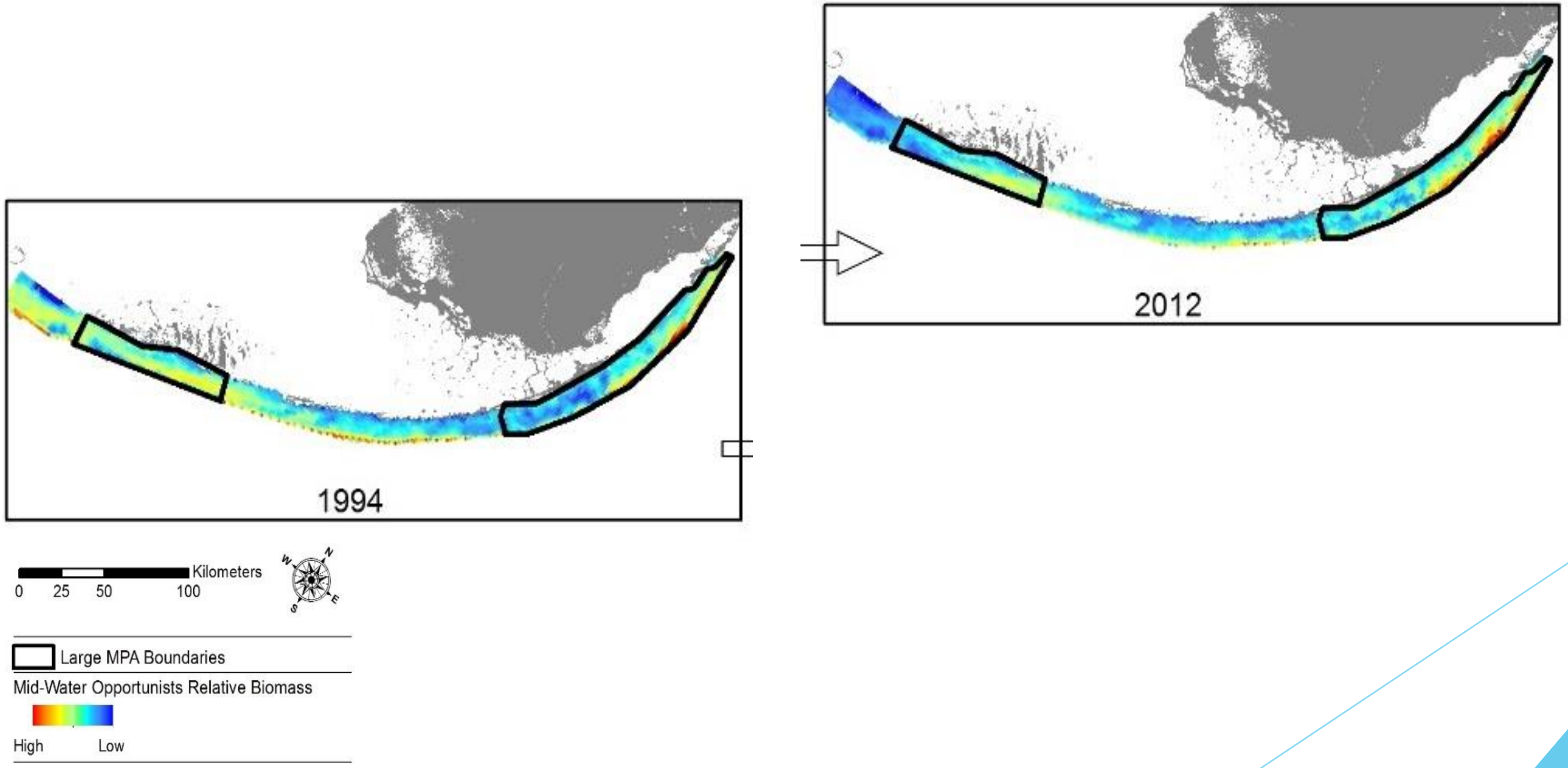
- Florida Keys 36-Box Model Simulations

Baseline Effort, Movement



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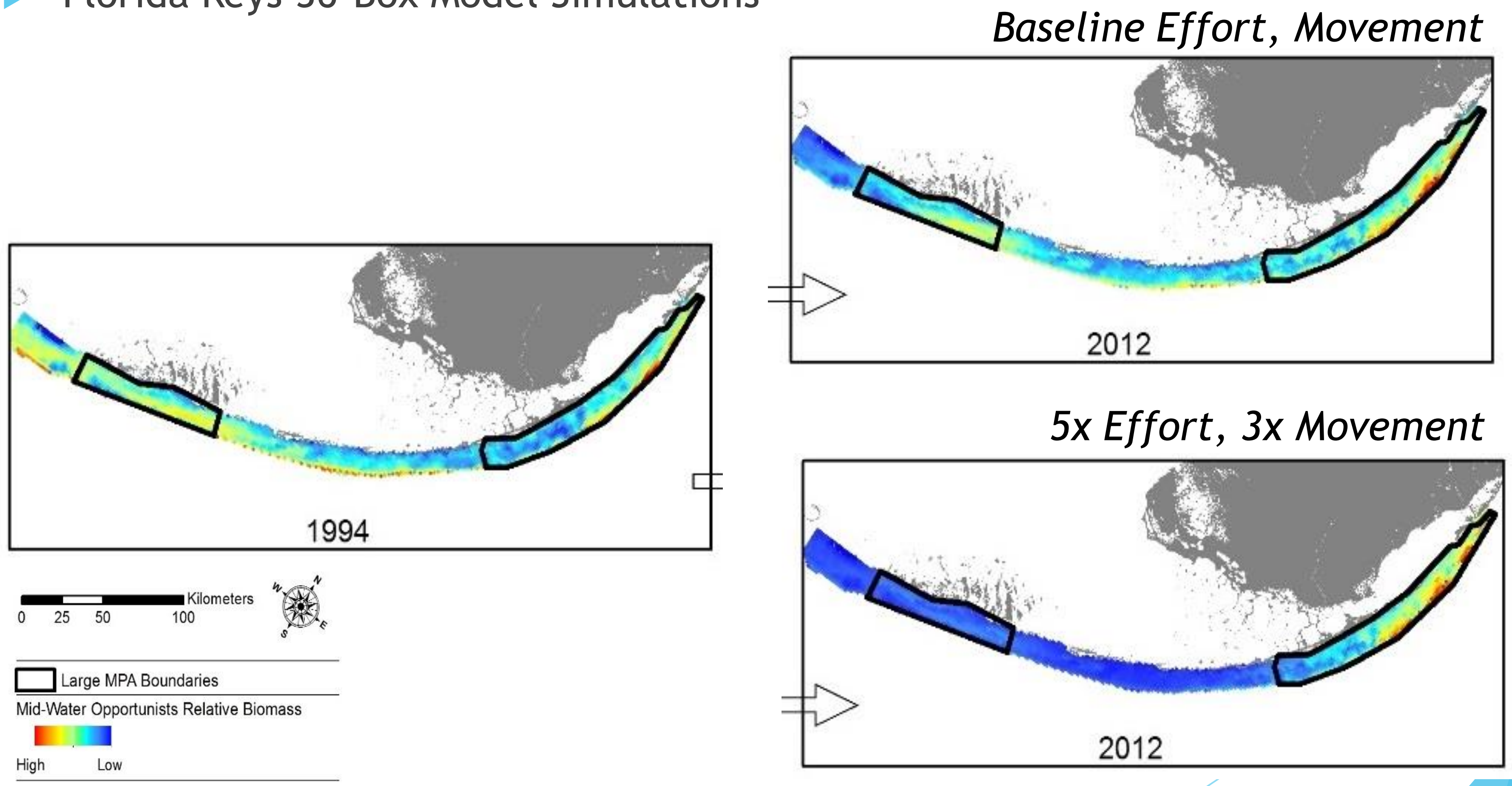

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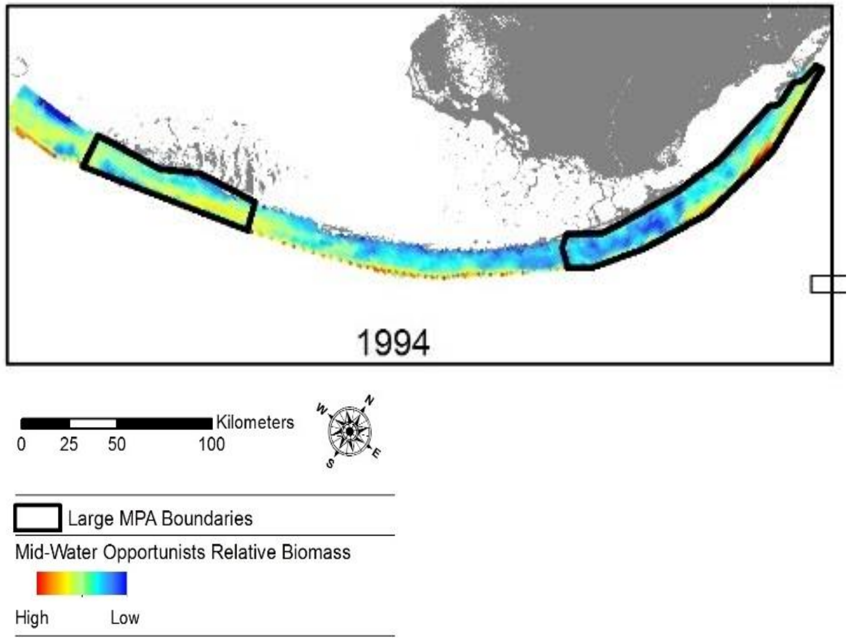

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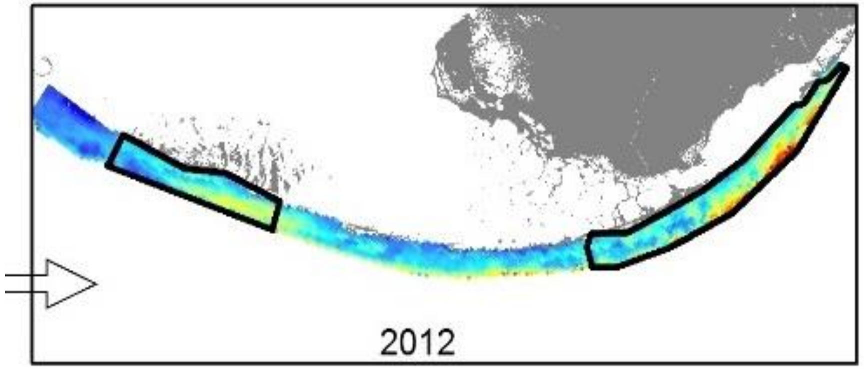
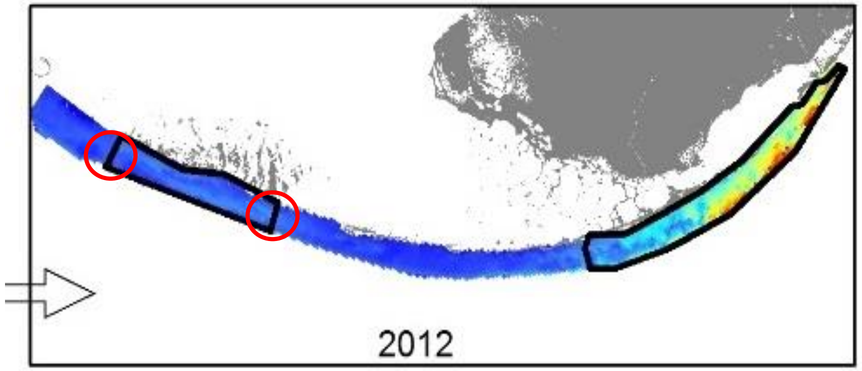


5x Effort, 3x Movement

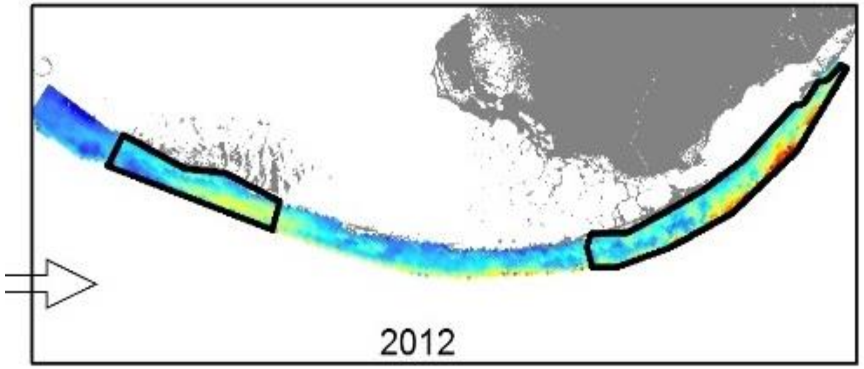


Cumulative Movement Imbalance (Walters 2000)

2a. Ecospace Scenarios

- Florida Keys 36-Box Model Simulations
- Management Applications
  - Research priorities
  - Tests of MPA size in context
  - Boundary conditions

Baseline Effort, Movement



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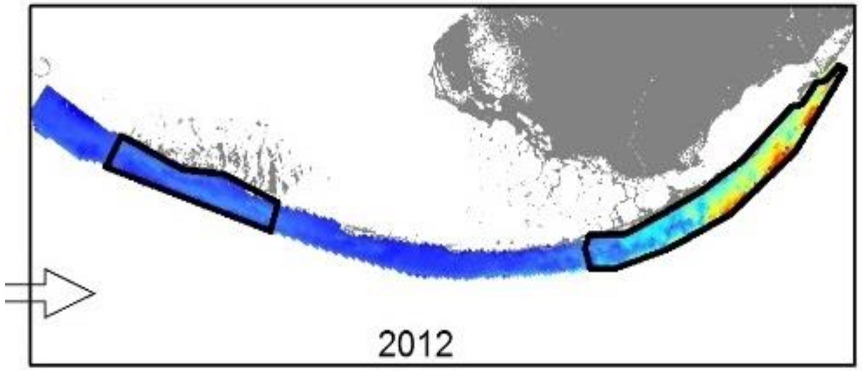

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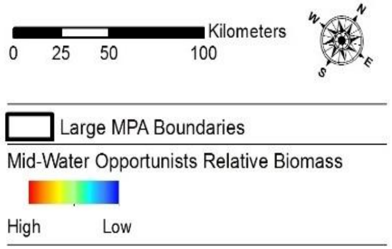
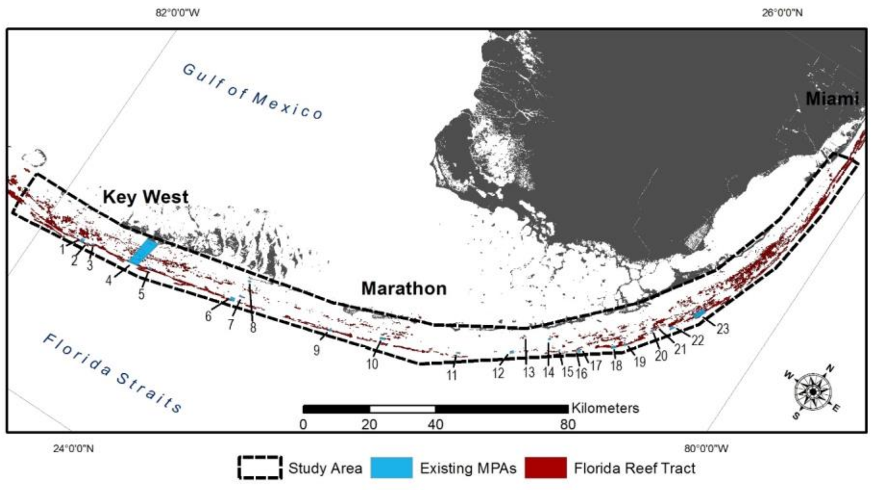


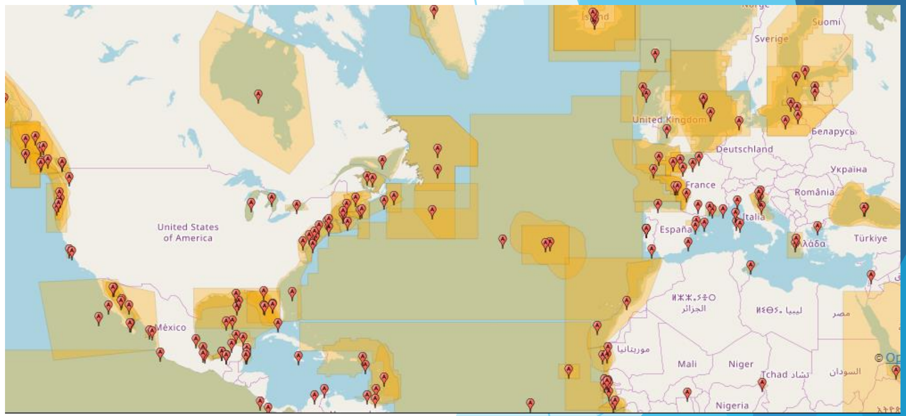
Practical Considerations

- Avoid defining a functional response for some groups and not others, particularly predator/prey connections
- Defining a functional response using a GAM requires occurrence data
  - Other approaches are possible
- Raster time series must represent the whole time period
  - You may need to average images to establish a base condition
  - Creates a challenge for projecting forward
- Spatial validation
- Data volume
  - Specific questions will help



Lasting Capabilities

- The model can be refined after the heavy lifting is over
- New MPA designs, movement rates, etc. can be considered
- Ecosystem structure and function can be examined with ongoing monitoring programs



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  - Jim Bohnsack, Jeremiah Blondeau

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Appendix

- Consequences of remote sensing time series