Ecosystem Model Overview and Applications

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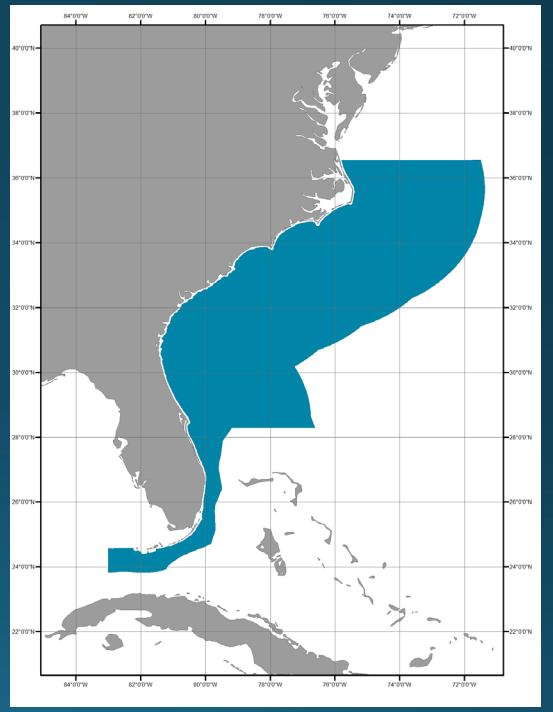
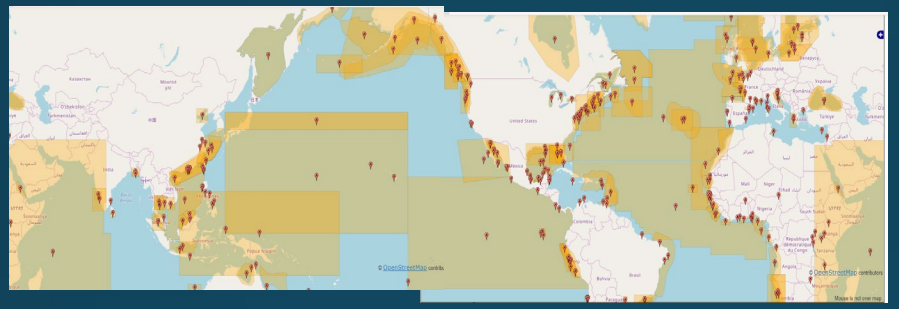
Outline

- Ecosystem Model Components
- Where are we?
- Where can we go from here?



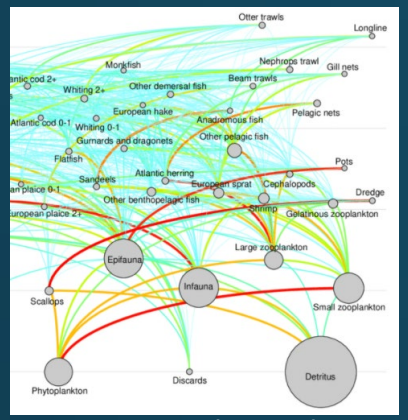
Ecopath with Ecosim and Ecospace (EwE)



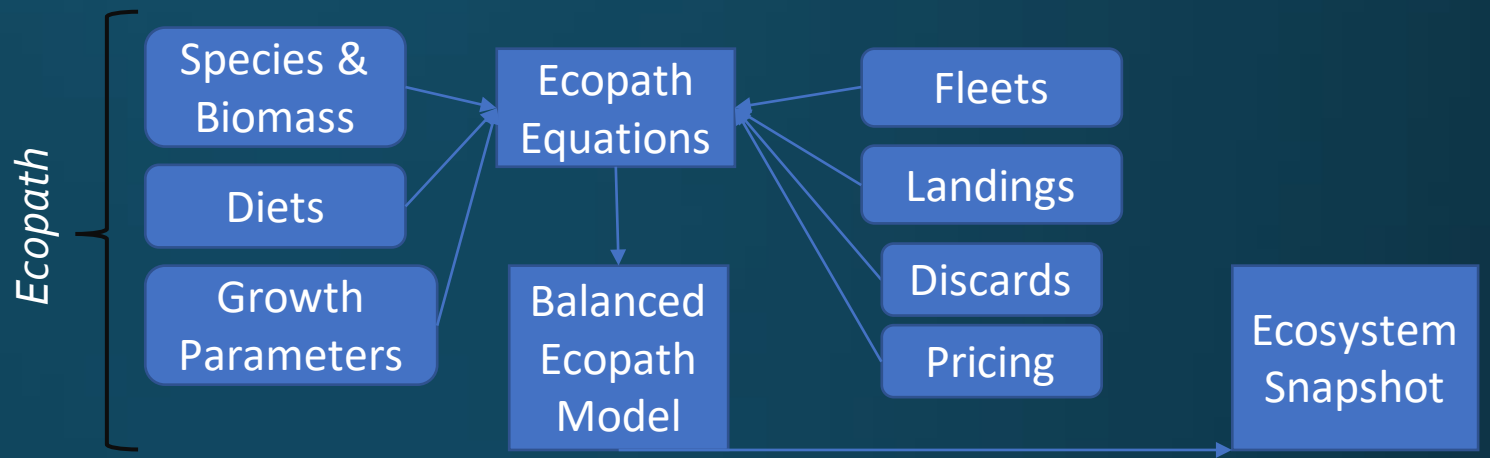
Ecopath
Mass-balance
Snapshot

Ecosim
Time
Dynamics

Ecospace
Space-Time
Dynamics



Bentley et al. 2019

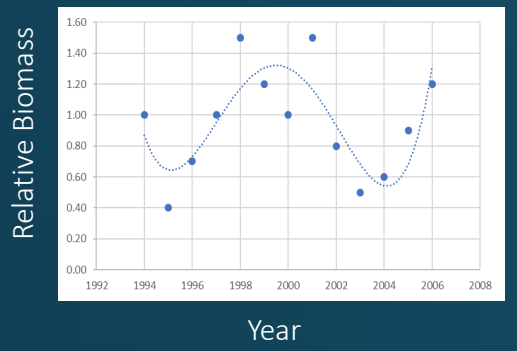


- Ecopath
  - Mass-Balance Snapshot
    - Prey mortality is predator consumption
    - Groups are linked via diet
  - Key groups, system size, flows
  - Best Practices (Link et al. 2010)
    - E.g., most biomass should be found at lower trophic levels
  - Builds the foundation for Ecosim and Ecospace

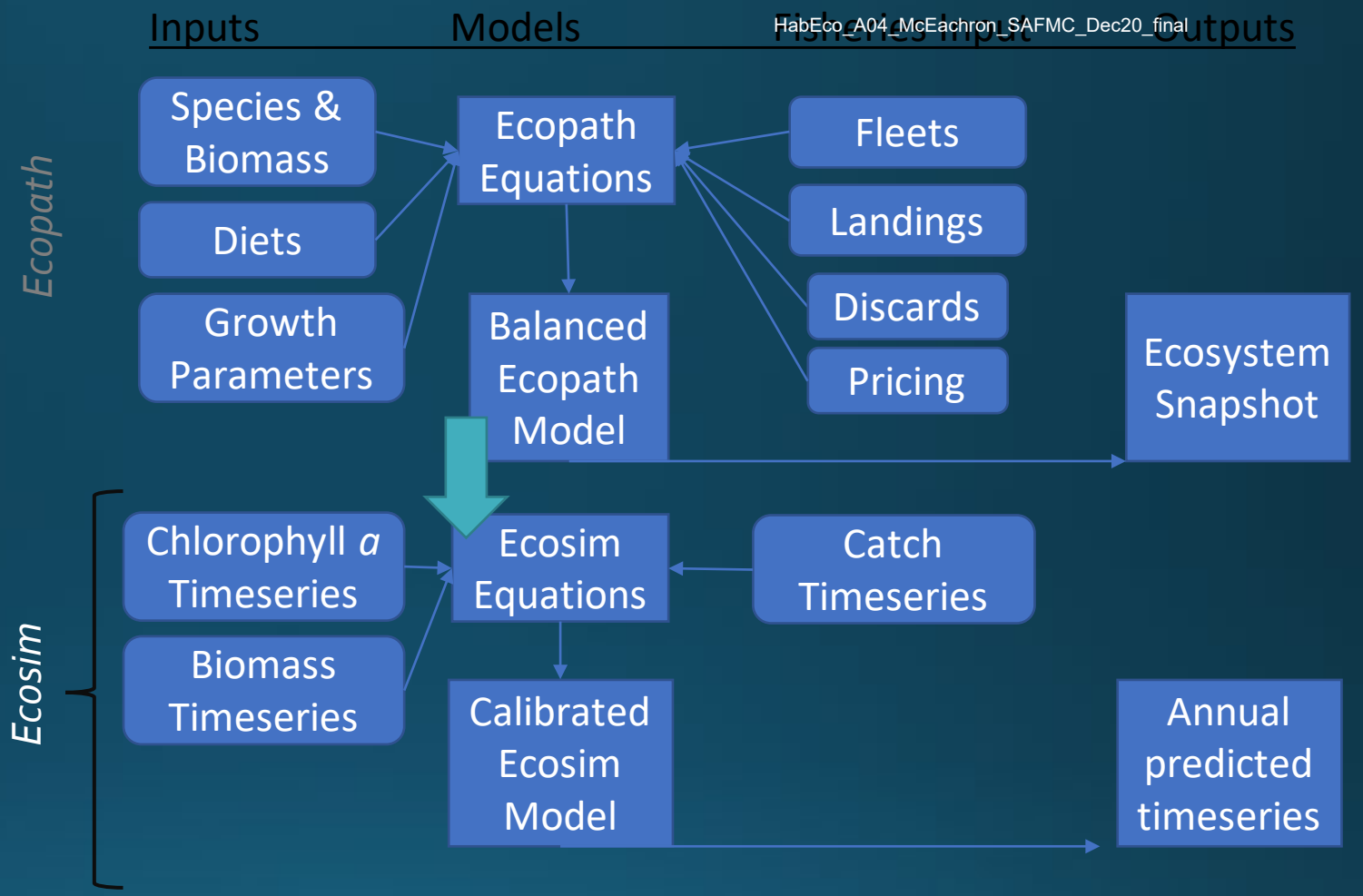
Table 1. Ecological and fisheries related indicators used in this comparison.

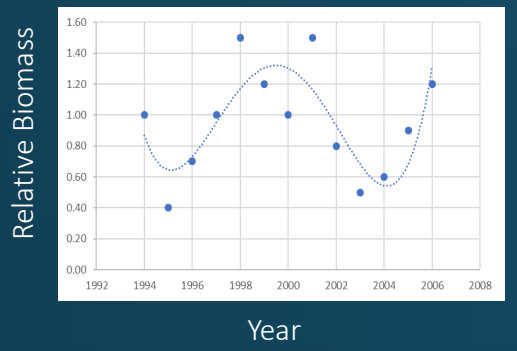
Acronym	Indicators	Units	Definition
Ecological indicators			
TST	Total System Throughput	$t \cdot km^{-2} \cdot y^{-1}$	The sum of all the flows through the ecosystem
PP/TST	Primary production/TST		Primary production over the sum of all the flows through the ecosystem
FD/TST	Flows to Detritus/TST		Flows 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.

Heymans et al. 2014



- Ecopath
- Ecosim
  - Estimate time dynamics
  - Predator-prey interactions are not random and occur in ‘arenas’
  - Only a fraction of prey is available for consumption (i.e., vulnerable)





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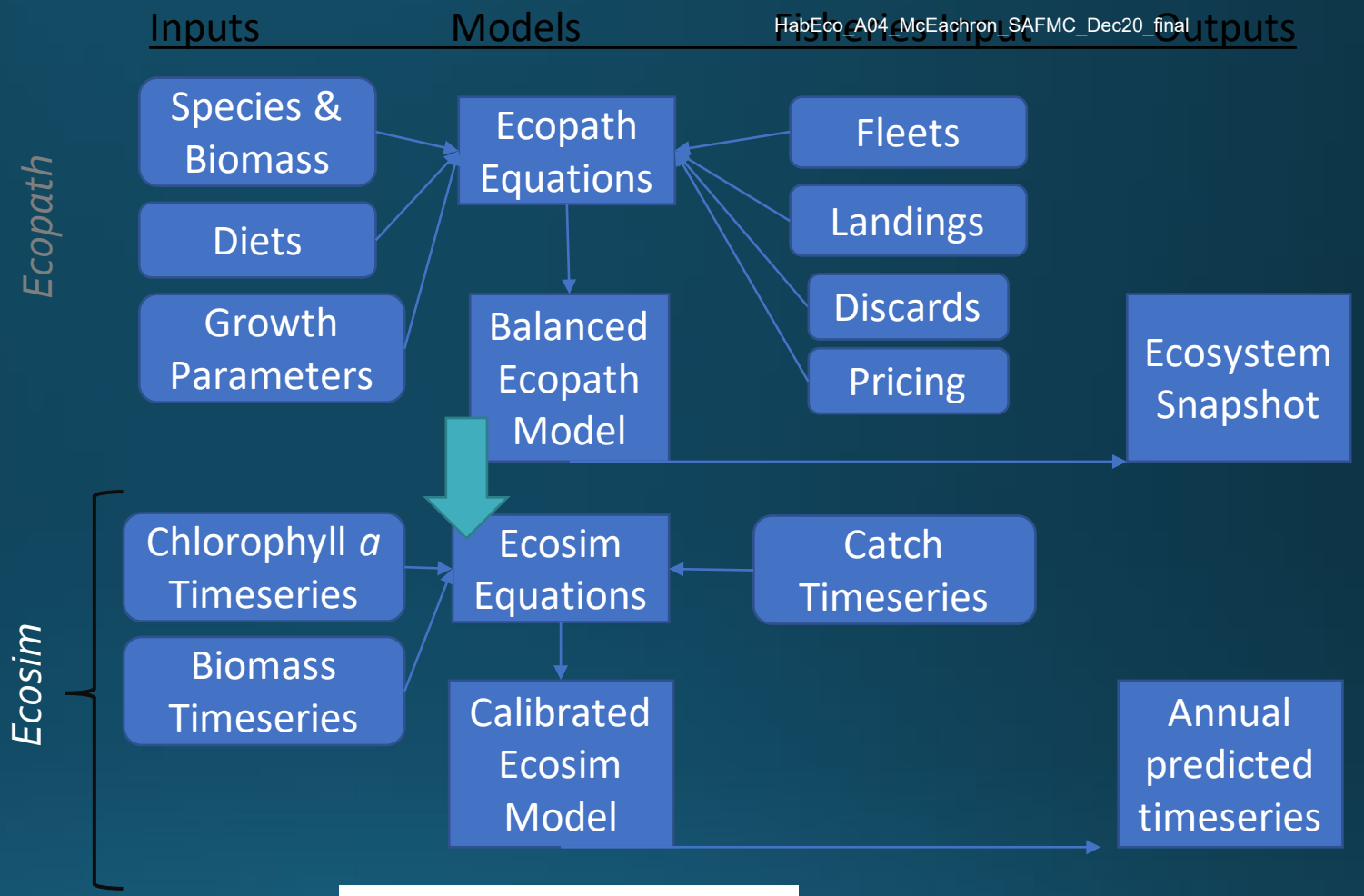
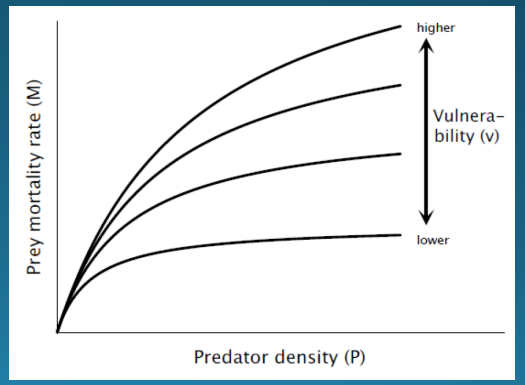
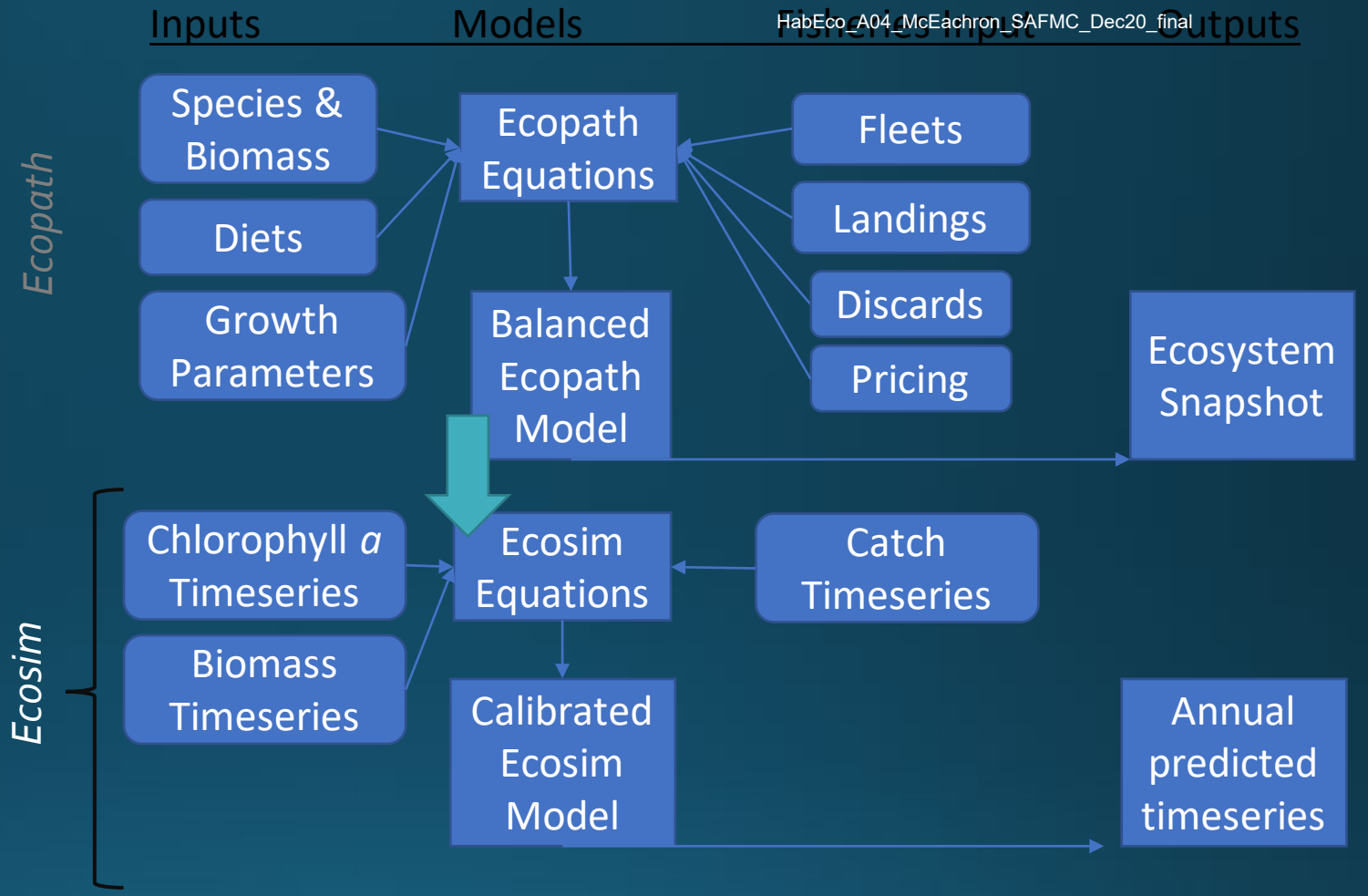




- Ecopath
- Ecosim
  - Chagaris et al. 2017

(1) estimate the effects of lionfish on the native reef fish community of the WFS

(2) assess the efficacy of direct lionfish harvest to mitigate those impacts



- Ecopath
- Ecosim
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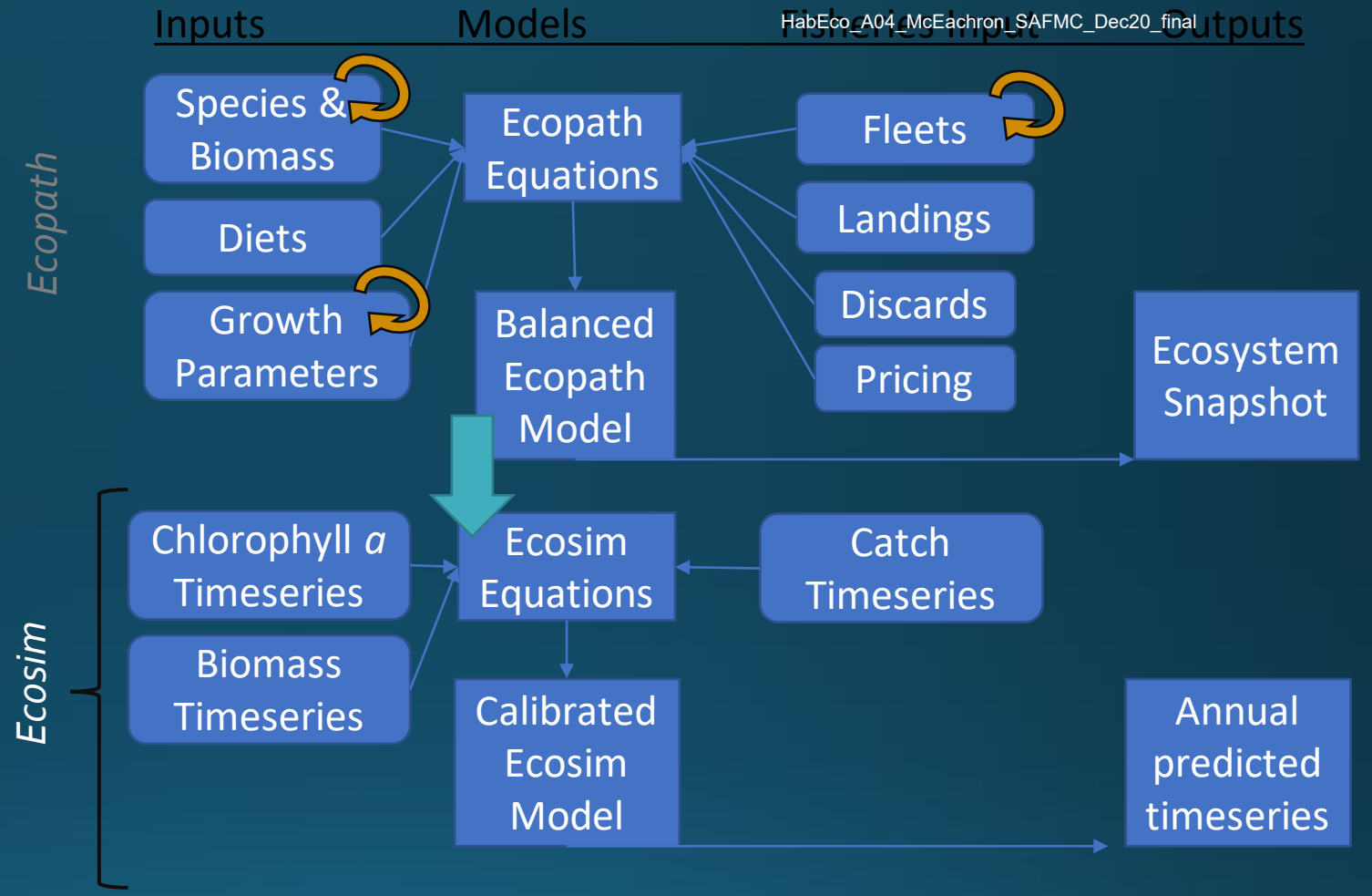
1. Added Lionfish to existing model

2. Created high initial fishing mortality to suppress starting biomass



- Ecopath
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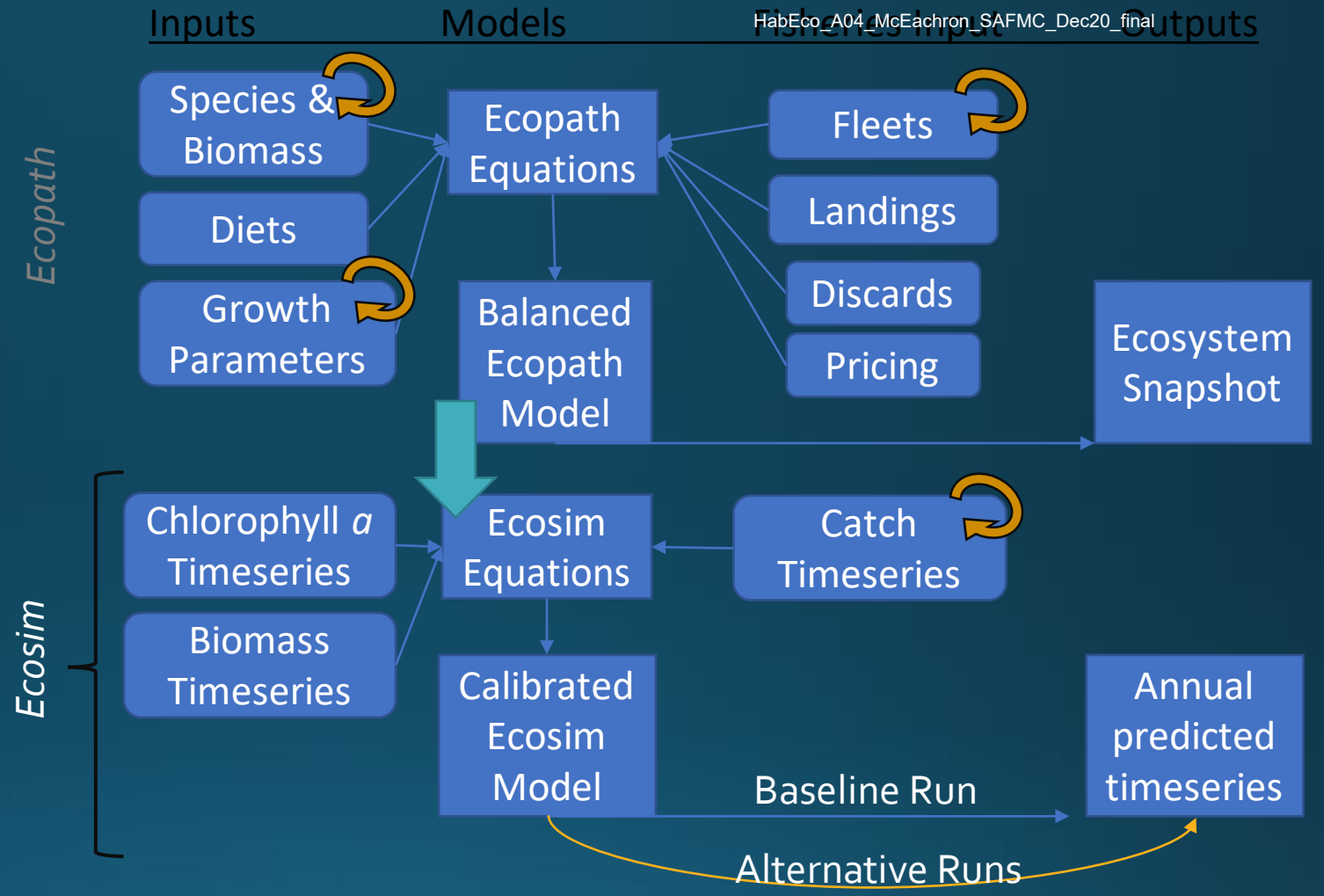
1. Added Lionfish to existing model

2. Created high initial fishing mortality to suppress starting biomass

3. In Ecosim, explored harvest strategies by adjusting effort



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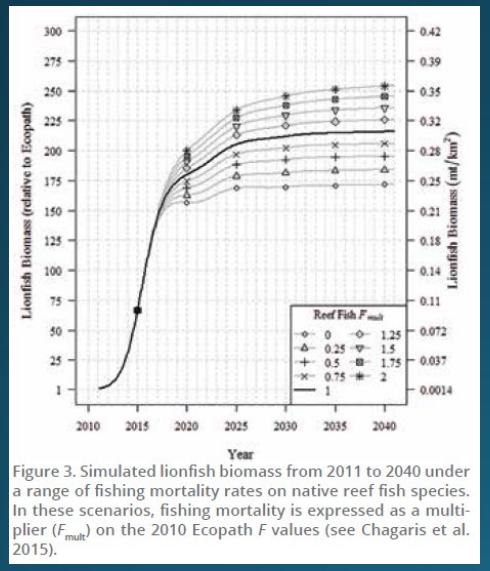
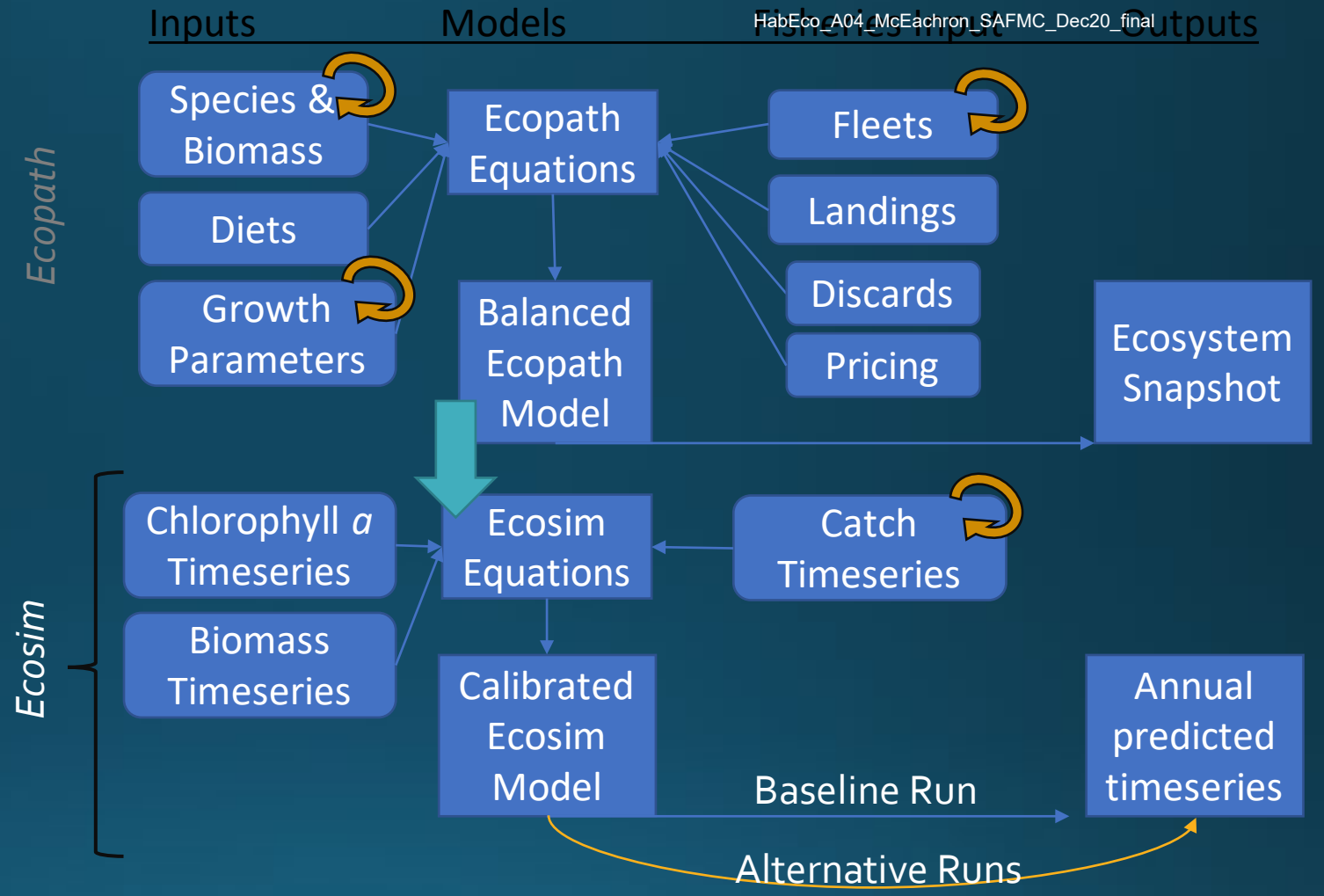


Figure 3. Simulated lionfish biomass from 2011 to 2040 under a range of fishing mortality rates on native reef fish species. In these scenarios, fishing mortality is expressed as a multiplier (F_{mult}) on the 2010 Ecopath *F* values (see Chagaris et al. 2015).



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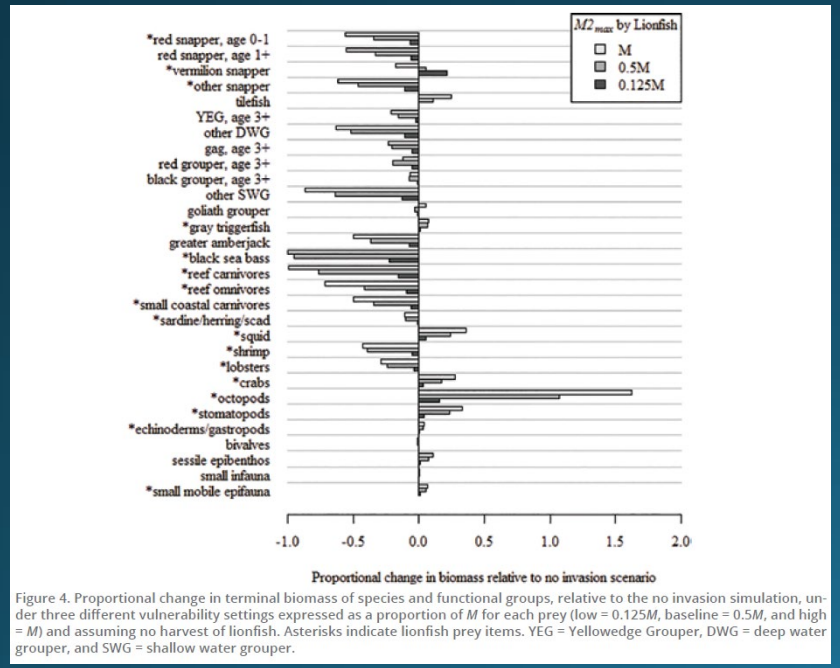
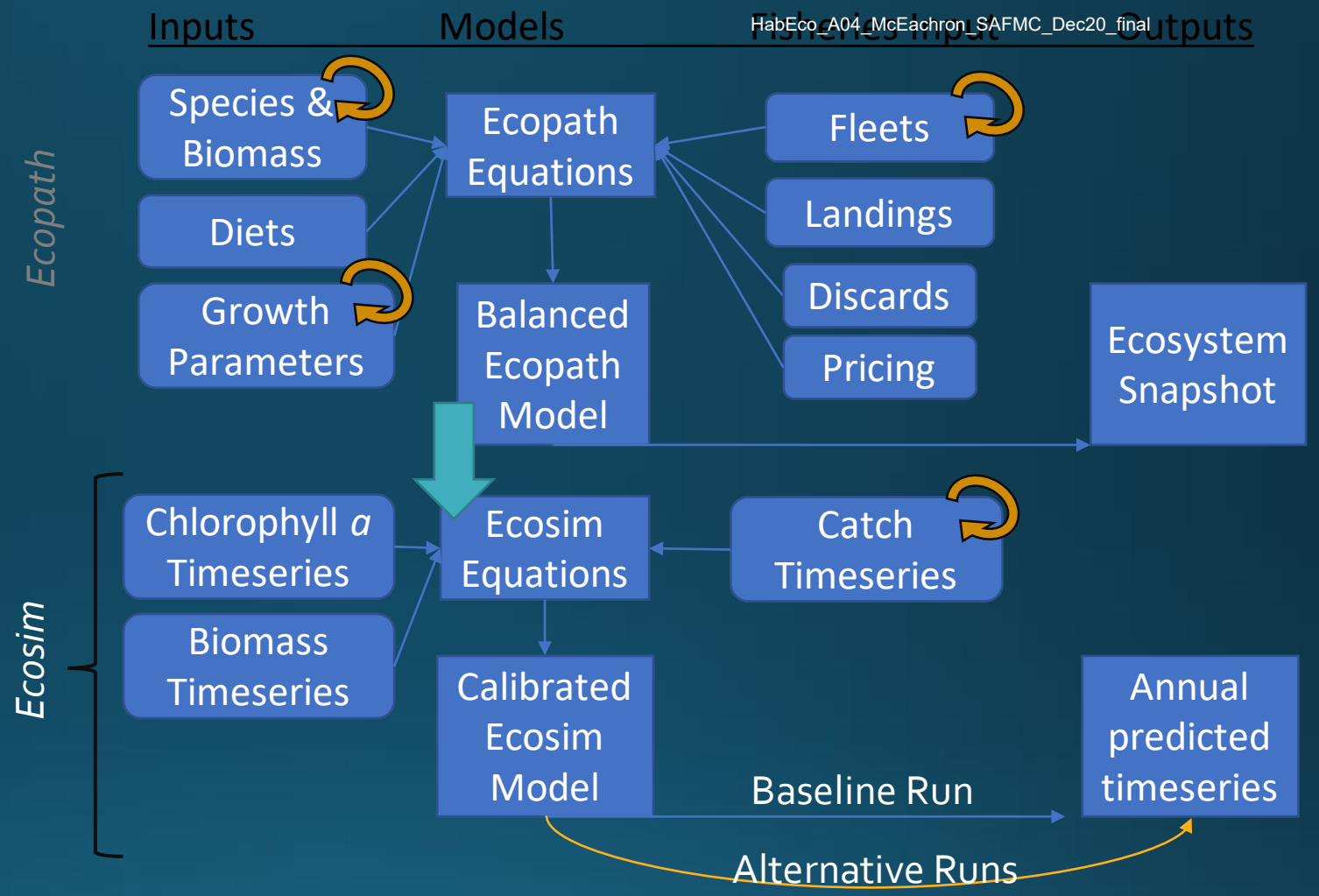
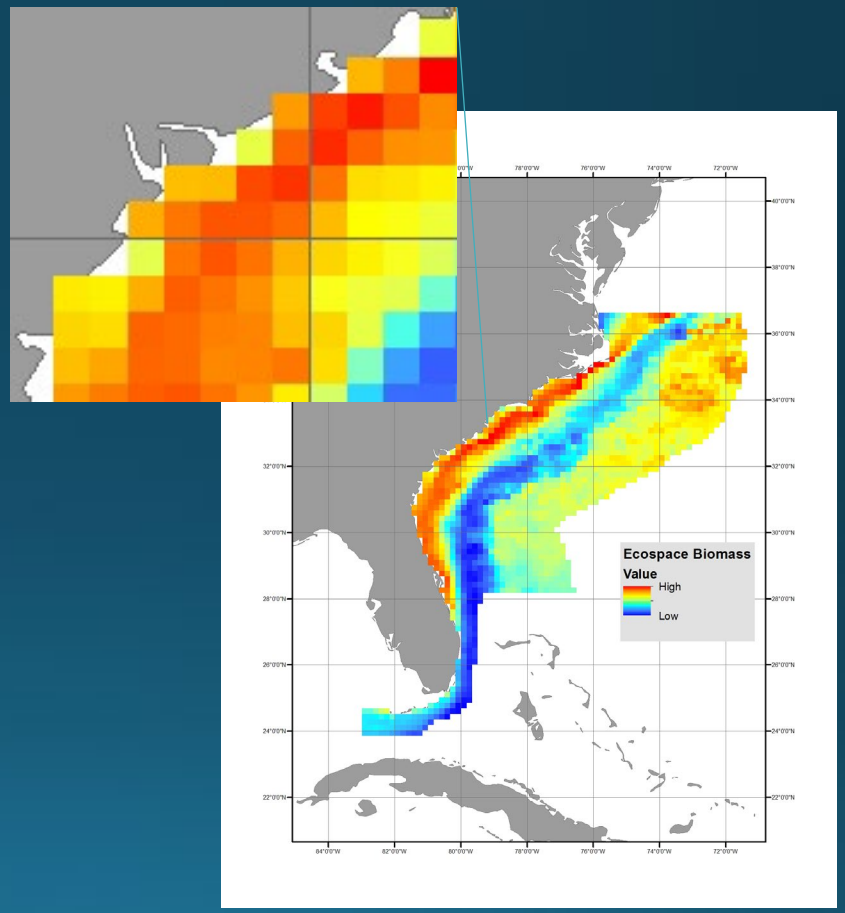


Figure 4. Proportional change in terminal biomass of species and functional groups, relative to the no invasion simulation, under three different vulnerability settings expressed as a proportion of *M* for each prey (low = 0.125*M*, baseline = 0.5*M*, and high = *M*) and assuming no harvest of lionfish. Asterisks indicate lionfish prey items. YEG = Yellowedge Grouper, DWG = deep water grouper, and SWG = shallow water grouper.



- Ecopath
- Ecosim
- Ecospace
  - Replicates Ecosim dynamics as varying with space
  - Produces monthly distribution maps for every group



- Ecopath
- Ecosim
- Ecospace
  - Replicates Ecosim dynamics as varying with space
  - Produces monthly distribution maps for every group
  - Predator-prey distributions are a function of:
    - Environmental preference functions that define habitat capacity (“arena size”)
      - Habitat capacity is multiplicative
      - More environmental layers are not necessarily better
        - Temperature, Depth, Chlorophyll *a*, velocity

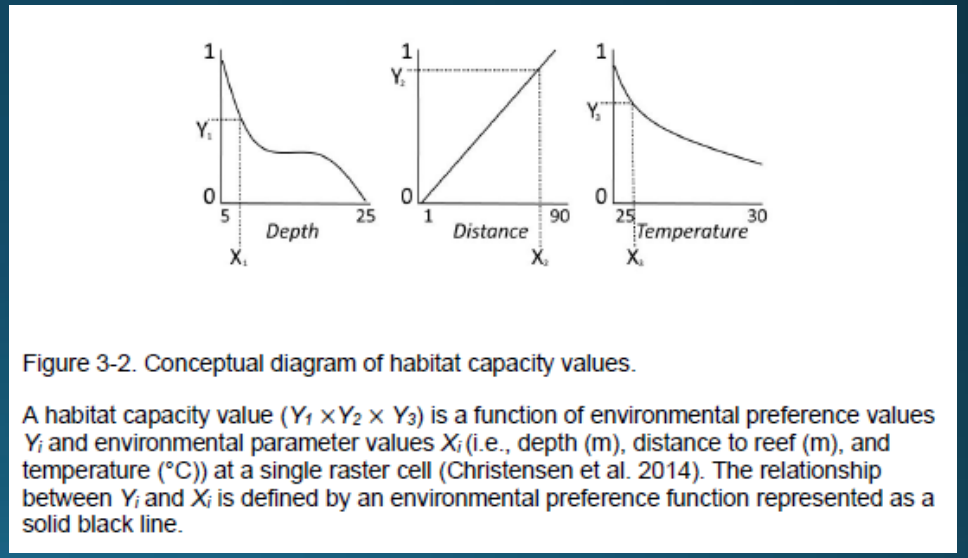


Figure 3-2. Conceptual diagram of habitat capacity values.

A habitat capacity value ($Y_1 \times Y_2 \times Y_3$) is a function of environmental preference values Y_i and environmental parameter values X_i (i.e., depth (m), distance to reef (m), and temperature (°C)) at a single raster cell (Christensen et al. 2014). The relationship between Y_i and X_i is defined by an environmental preference function represented as a solid black line.

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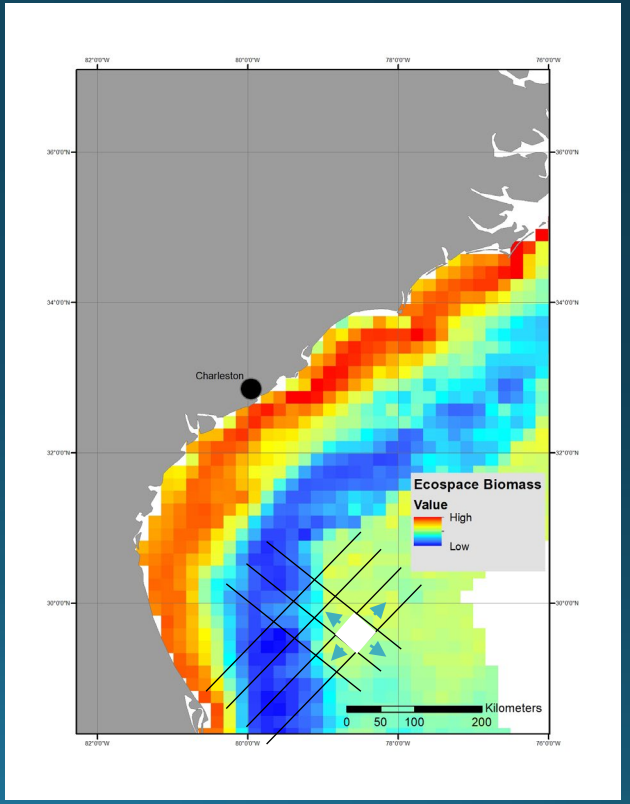
- Ecopath
- Ecosim
- Ecospace
  - Replicates Ecosim dynamics as varying with space
  - Produces monthly distribution maps for every group
  - Predator-prey distributions are a function of:
    - Environmental preference functions that define habitat capacity (“arena size”)
      - Habitat capacity is multiplicative
    - Dispersal is user defined, modified by habitat capacity
    - Fishing effort distributed by a gravity model (Revenue/Cost; Port locations)



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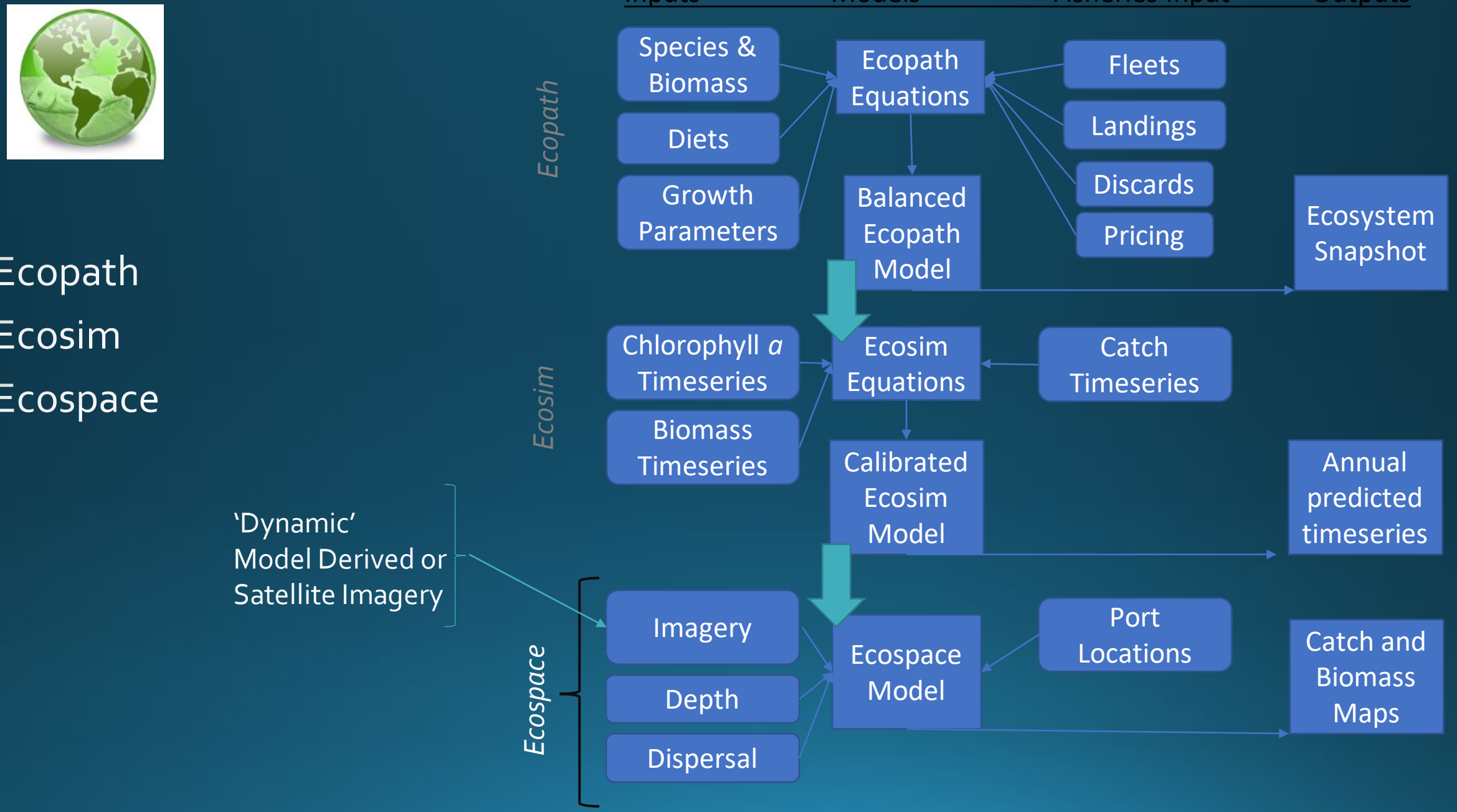
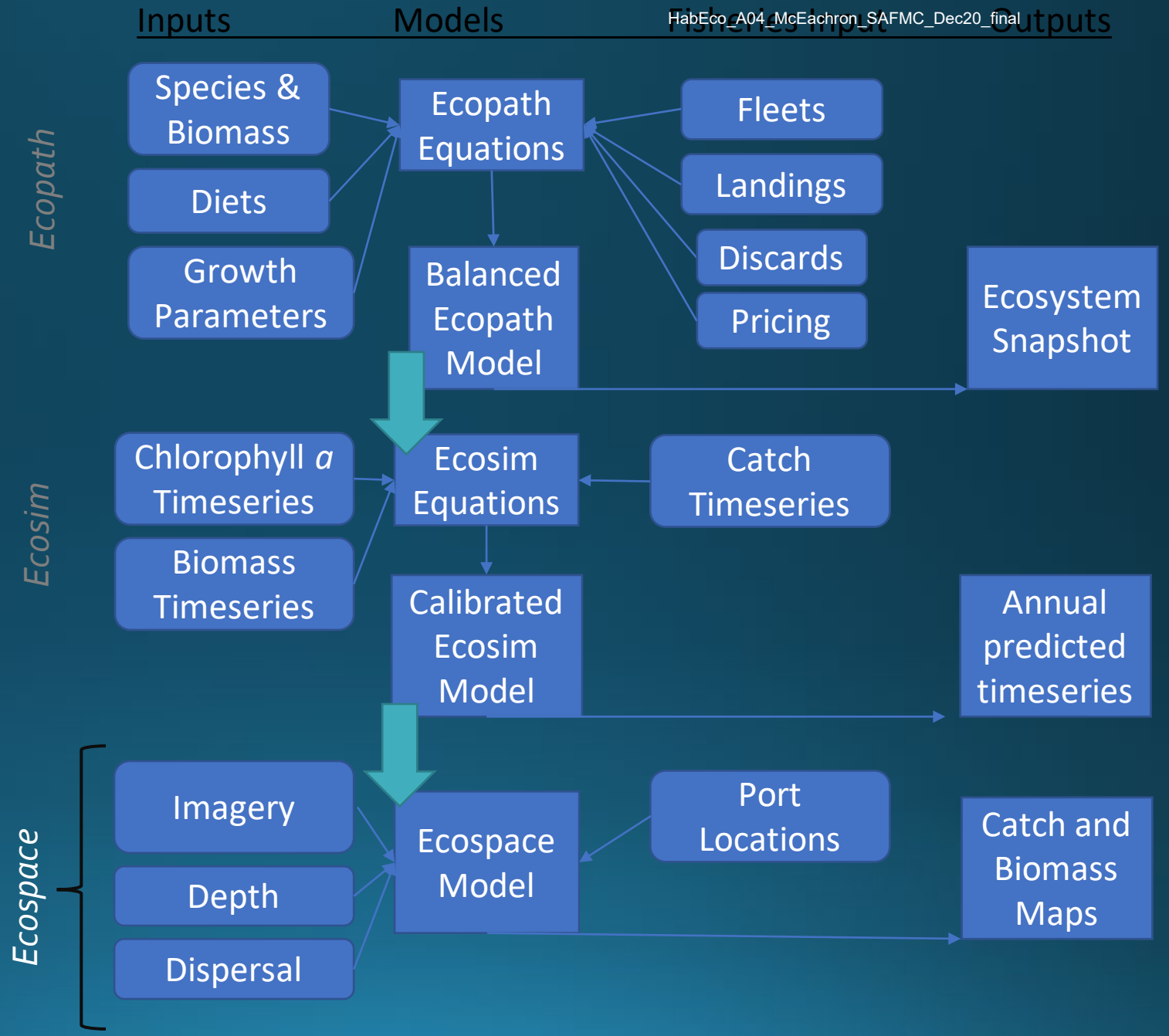


- Ecopath
- Ecosim
- Ecospace
  - de Mutsert et al. 2016

(1) Analyze effects of hypoxia on fish and fisheries through ecosystem model simulations

(2) Should we restrict effort during hypoxic events?



- Ecopath
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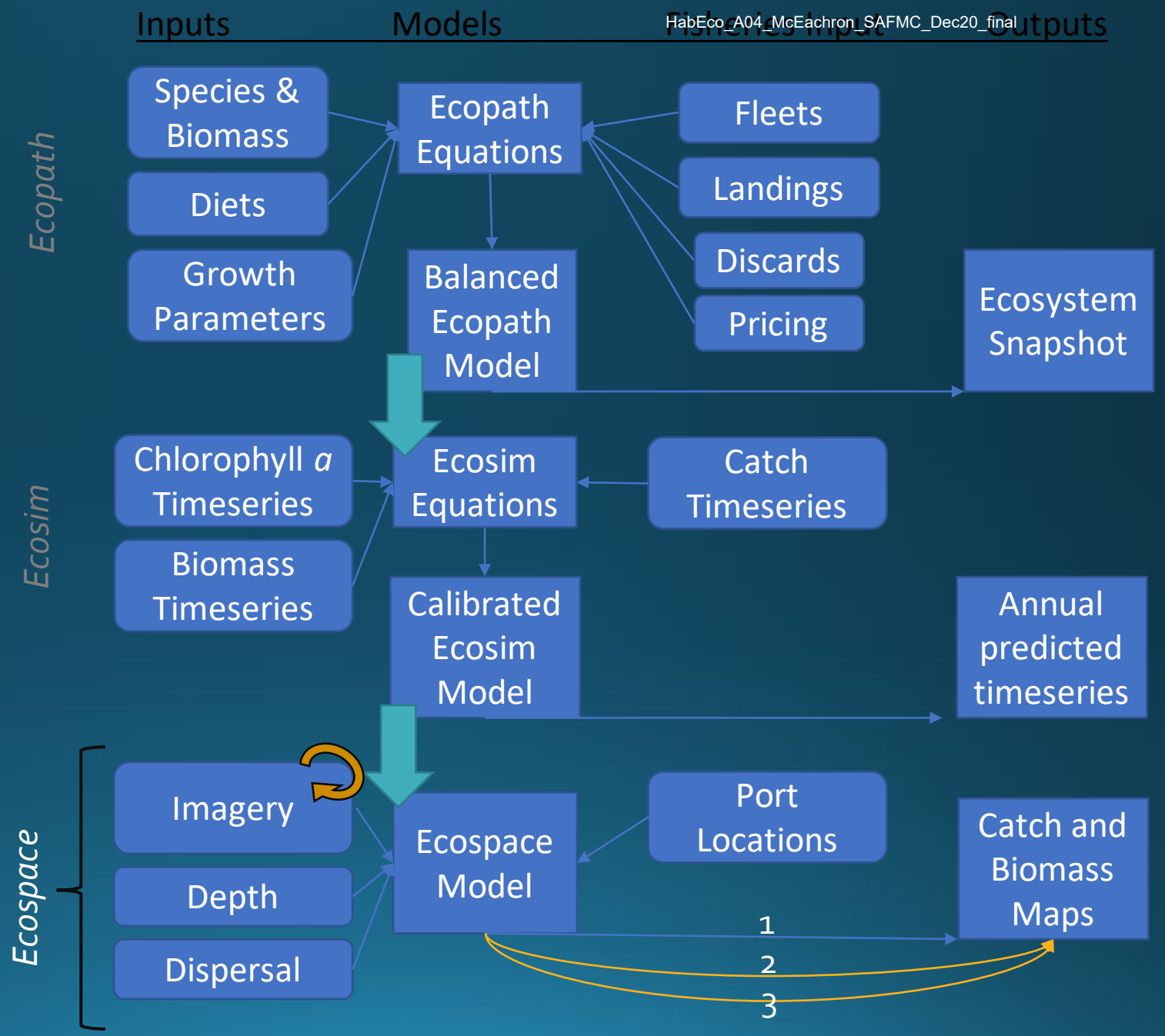
1. 'no forcing'
2. 'enrichment only', which simulated Chl a loading effects on primary productivity
3. 'enrichment + hypoxia', which included primary productivity forcing, and effects of DO on fish biomass.



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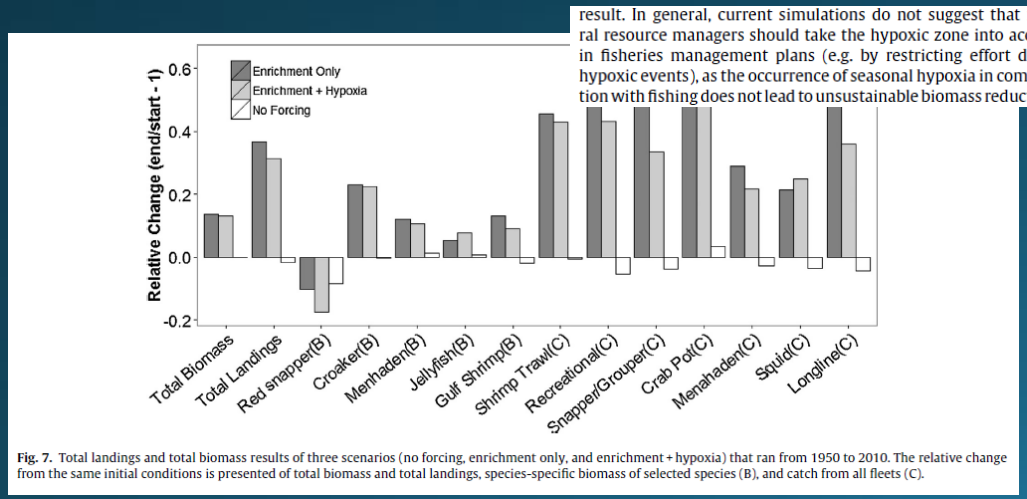
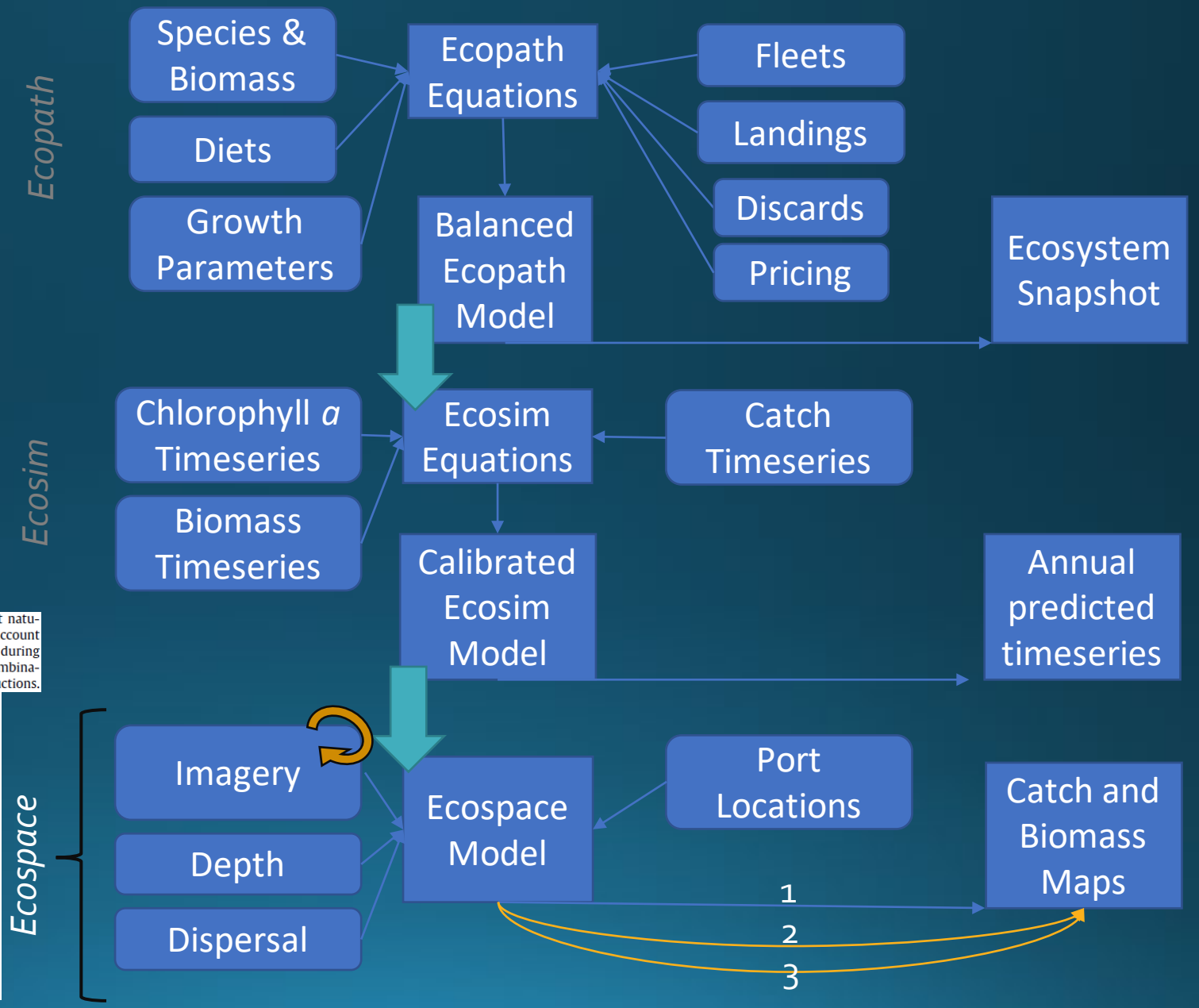


result. In general, current simulations do not suggest that natural resource managers should take the hypoxic zone into account in fisheries management plans (e.g. by restricting effort during hypoxic events), as the occurrence of seasonal hypoxia in combination with fishing does not lead to unsustainable biomass reductions.

Fig. 7. Total landings and total biomass results of three scenarios (no forcing, enrichment only, and enrichment + hypoxia) that ran from 1950 to 2010. The relative change from the same initial conditions is presented of total biomass and total landings, species-specific biomass of selected species (B), and catch from all fleets (C).



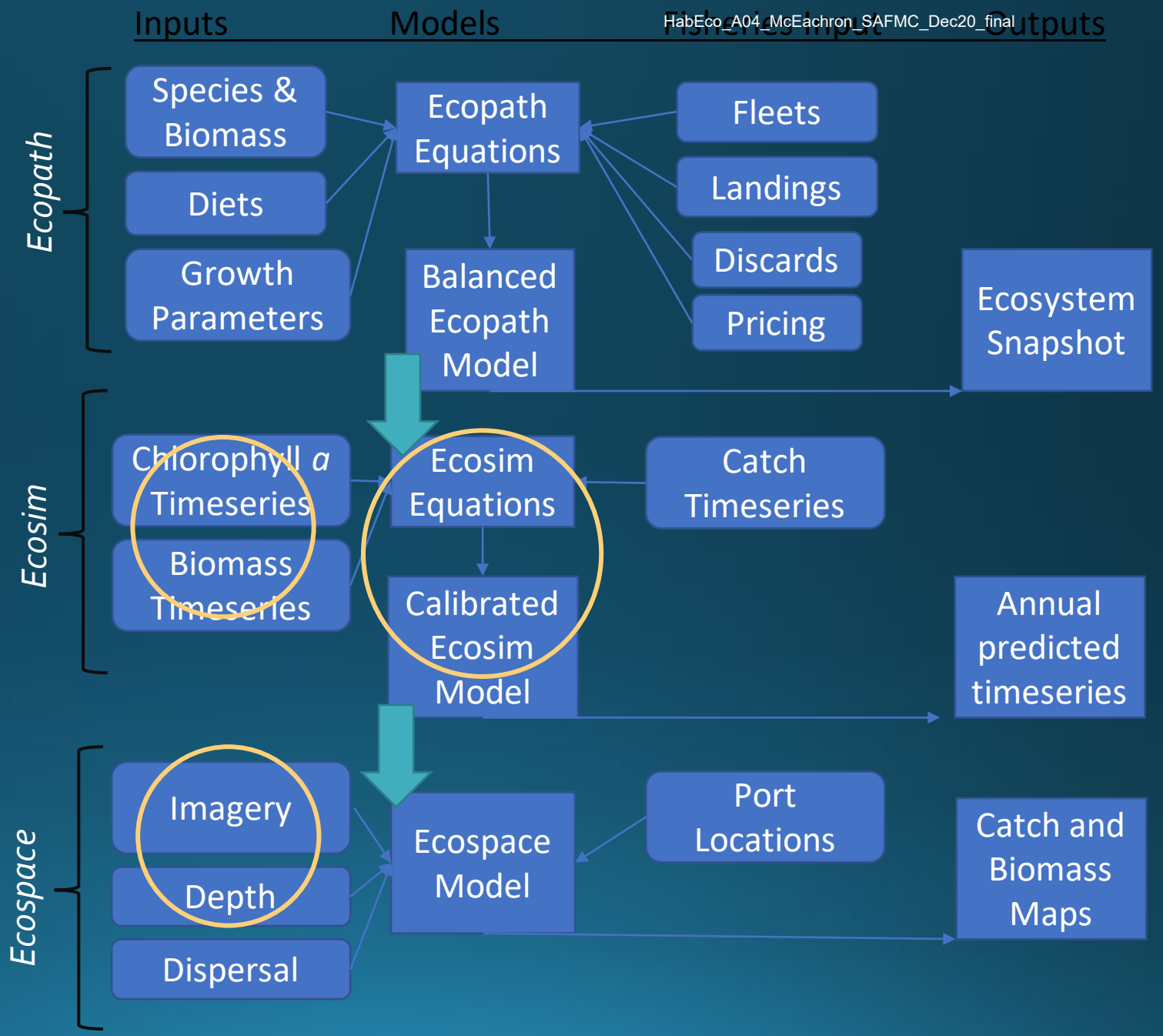
Applications

- Where are we (FWC & SAFMC)?

Ecopath
Mass-balance
Snapshot

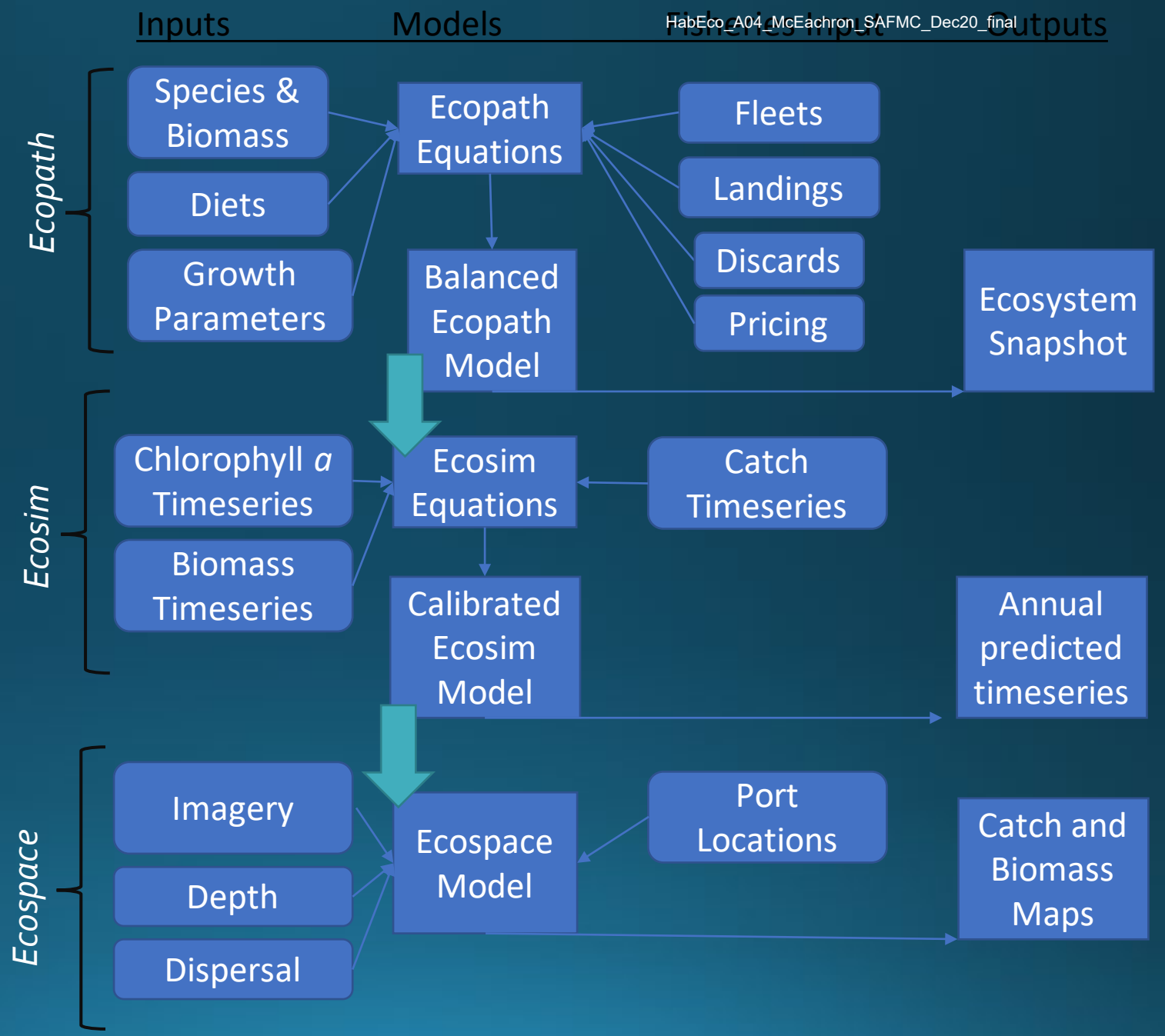
Ecosim
Time
Dynamics

Ecospace
Space-Time
Dynamics



Applications

- Where are we?
- Where can we go from here?
  - Recruitment
  - Discards
  - Climate Change



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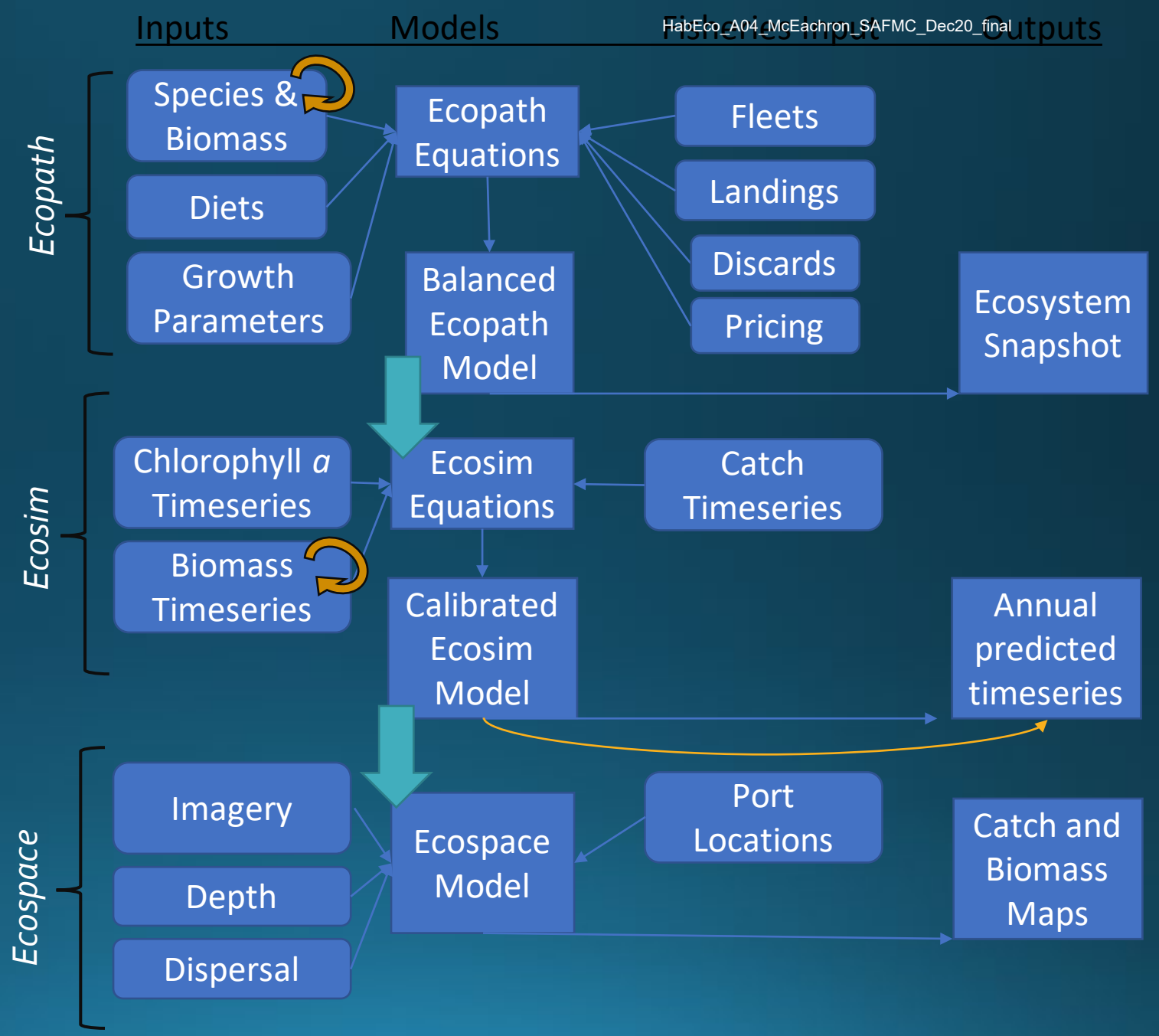

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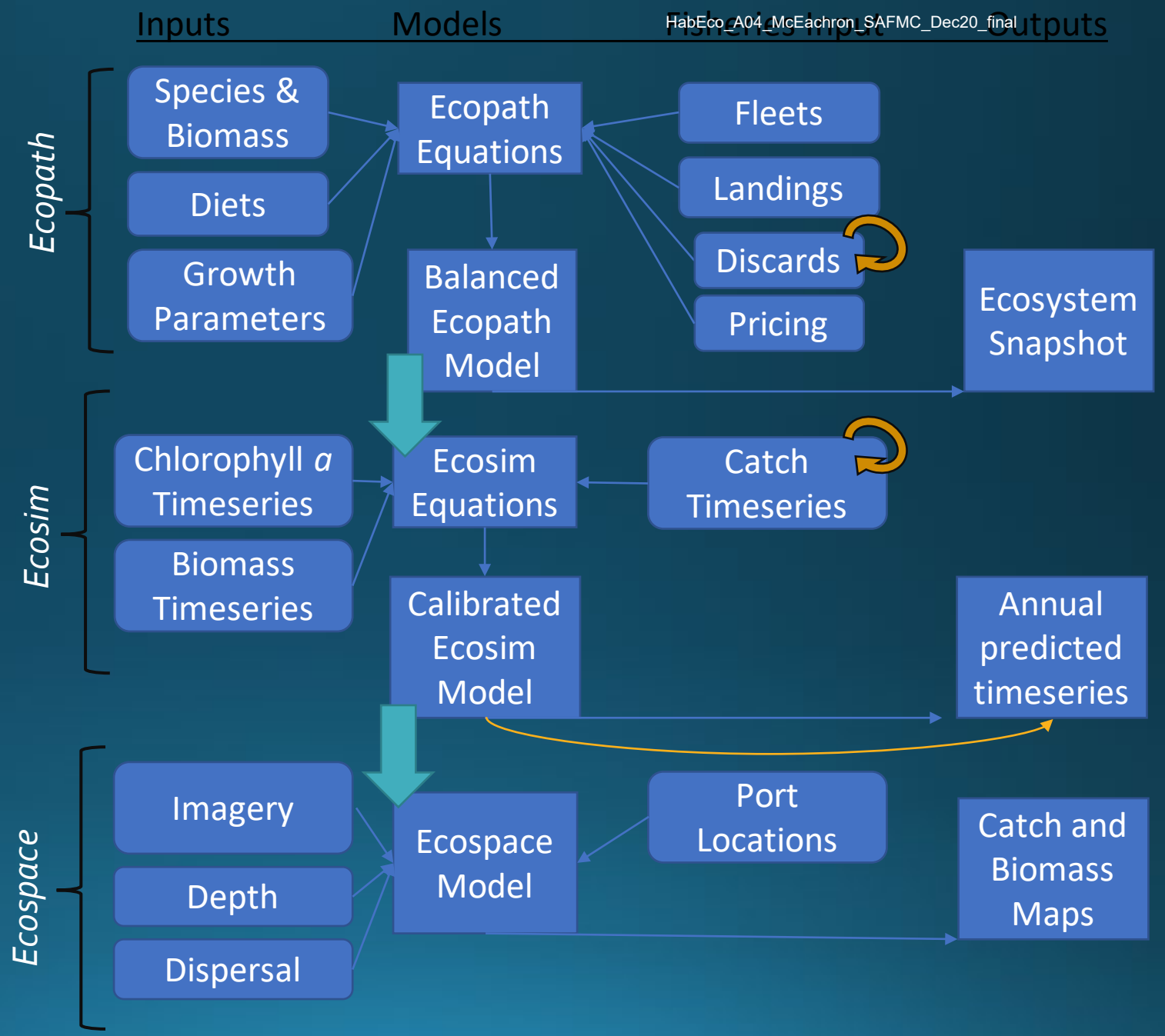

Applications

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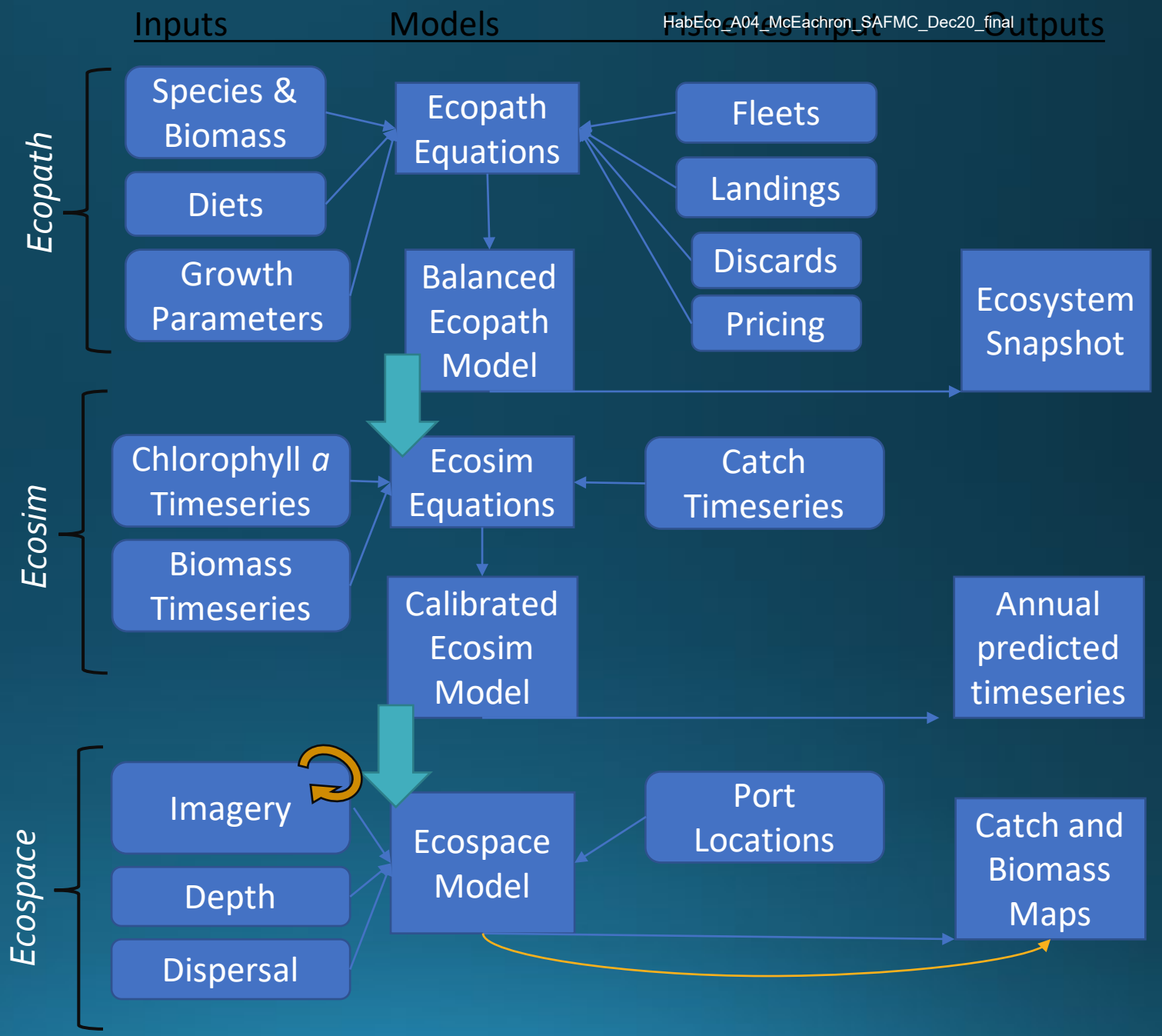
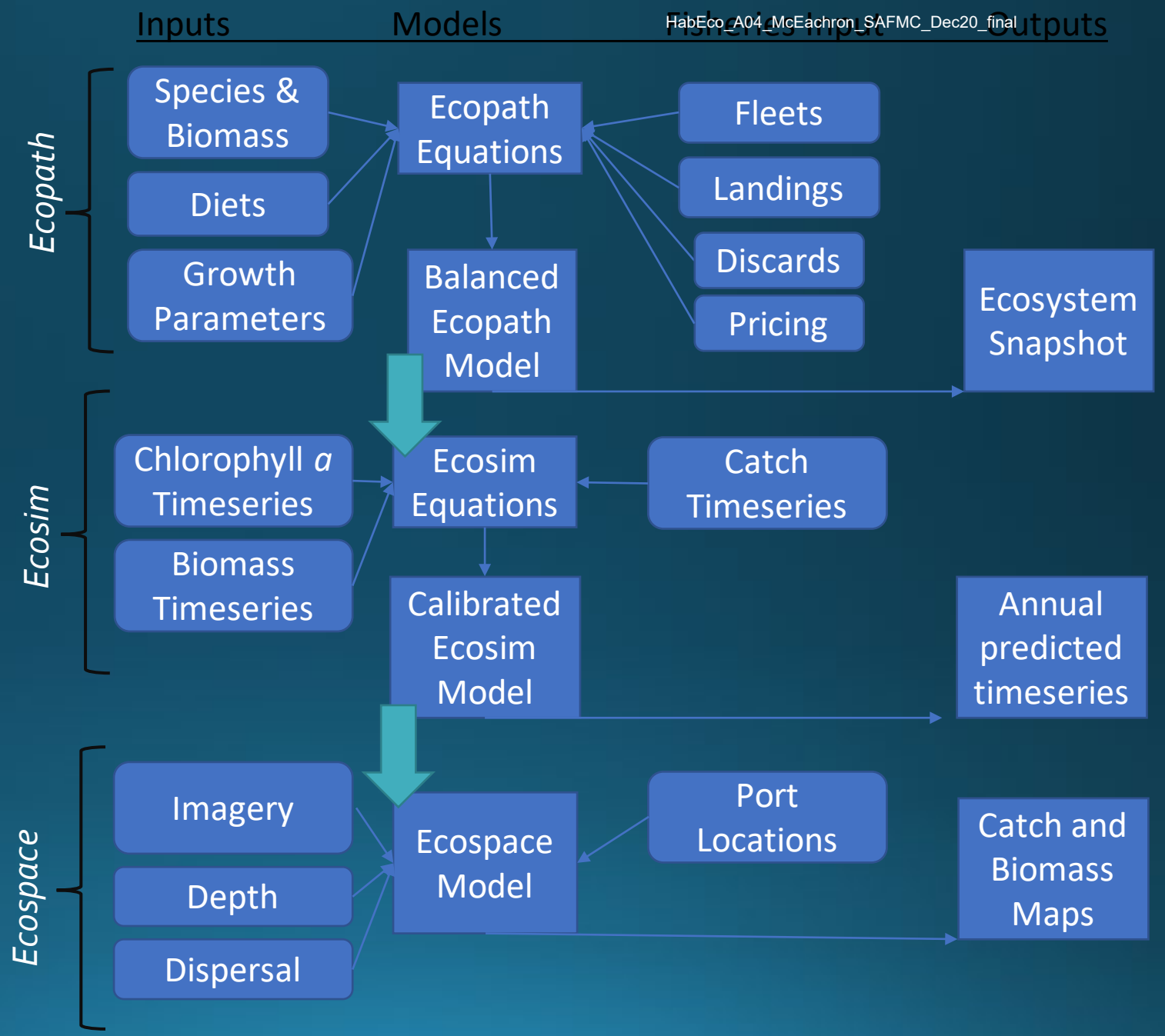
  - Climate Change

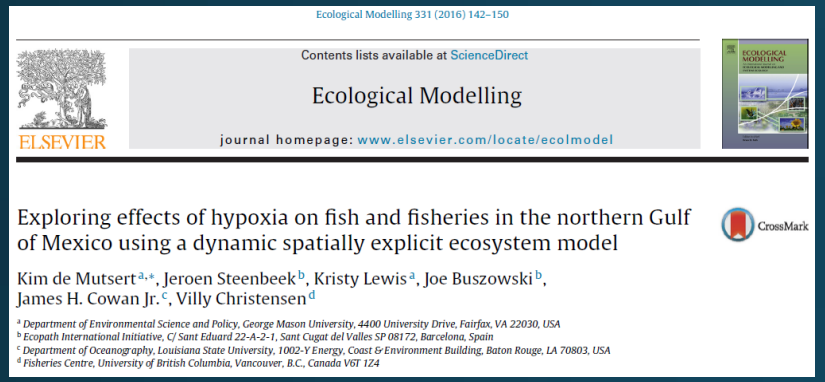


Applications

- Where are we?
- Where can we go from here?
- What do we get?
  - Indirect effects
  - Change, or no change
  - We don't start from scratch



Citations



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Exploring effects of hypoxia on fish and fisheries in the northern Gulf of Mexico using a dynamic spatially explicit ecosystem model

Kim de Mutsert[a,*], Jeroen Steenbeek[b], Kristy Lewis[a], Joe Buszowski[b], James H. Cowan Jr.[c], Villy Christensen[d]

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Fisheries

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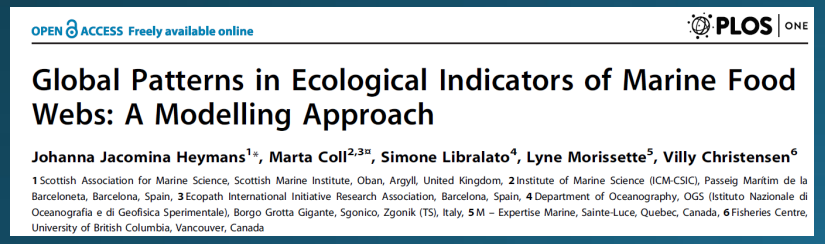
An Ecosystem-Based Approach to Evaluating Impacts and Management of Invasive Lionfish

David Chagaris, Samantha Binion-Rock, Alex Bogdanoff, Kristen Dahl, Jennifer Granneman, Holden Harris, John Mohan, Merrill B. Rudd, Mary Kate Swenarton, Rob Ahrens, William F. Patterson III, James A. Morris Jr. & Micheal Allen



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Global Patterns in Ecological Indicators of Marine Food Webs: A Modelling Approach

Johanna Jacomina Heymans[1]*, Marta Coll[2,3¤], Simone Libralato[4], Lyne Morissette[5], Villy Christensen[6]

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