# Estimating Impacts of Cumulative Stressors on Fisheries Production in the Chesapeake Bay with Atlantis

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Modeling Quarterly Review
1 October, 2014

*The Commonwealth Scientific and Industrial Research Organisation*

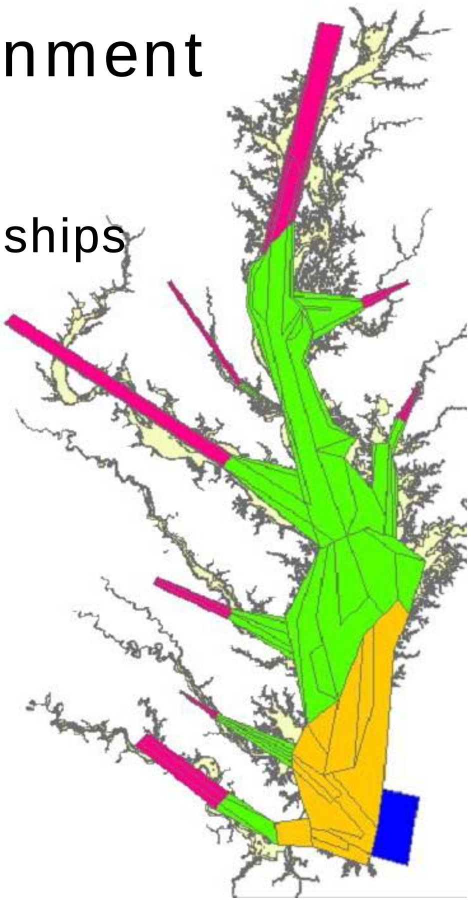
# *Atlantis*

Beth Fulton

# The Atlantis Model

## A Holistic Ecosystem Model

*Incorporating:*



### Biological environment
✓Primary production
✓Trophic interactions
✓Recruitment relationships
✓Age structure
✓Size structure
✓Life History
✓Refuge Habitat

### Fisheries
✓Multiple sectors
✓Gears
✓Seasons
✓Spatially explicit

### Physical environment
✓Geology
✓Chemistry
✓Circulation & currents
✓Temperature
✓Salinity
✓Water clarity
✓Climate variability

### Nutrient Inputs
✓Currency is Nitrogen
✓Oxygen
✓Silica
✓3 forms of detritus
✓Bacteria-mediated recycling

# Goals

## *Atlantis:*

- To model important populations in context of their ecosystem
  - Predators & Prey
  - Water quality, habitat
  - Management change of other species
  - Ecosystem change (e.g., habitat loss, migration patterns)
  - Cumulative effects of multiple stressors
    - Kaplan et al., 2010
    - Nye et al., 2012
- Complements single species assessments
- Strategic not tactical
  - Quantitative prediction
  - Relative to other scenarios
- Understand ecosystem function
  - Early warning of tipping points
  - Identify priority research gaps, where expensive field study should yield greatest “bang for the buck”

# Goals

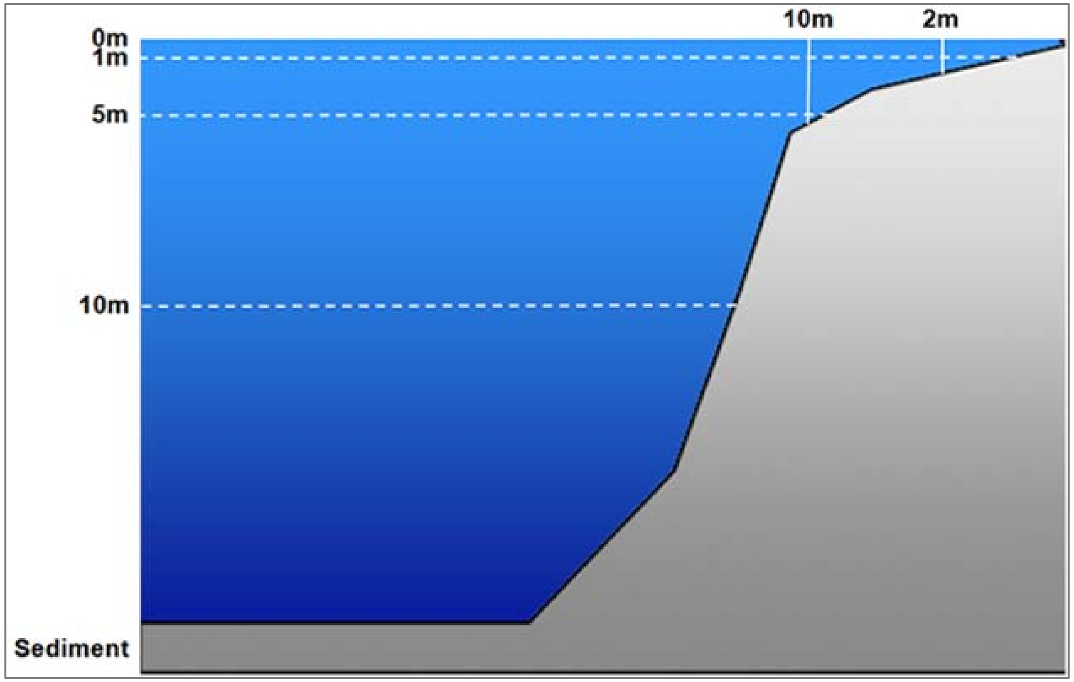
## *Chesapeake Atlantis Model (CAM):*

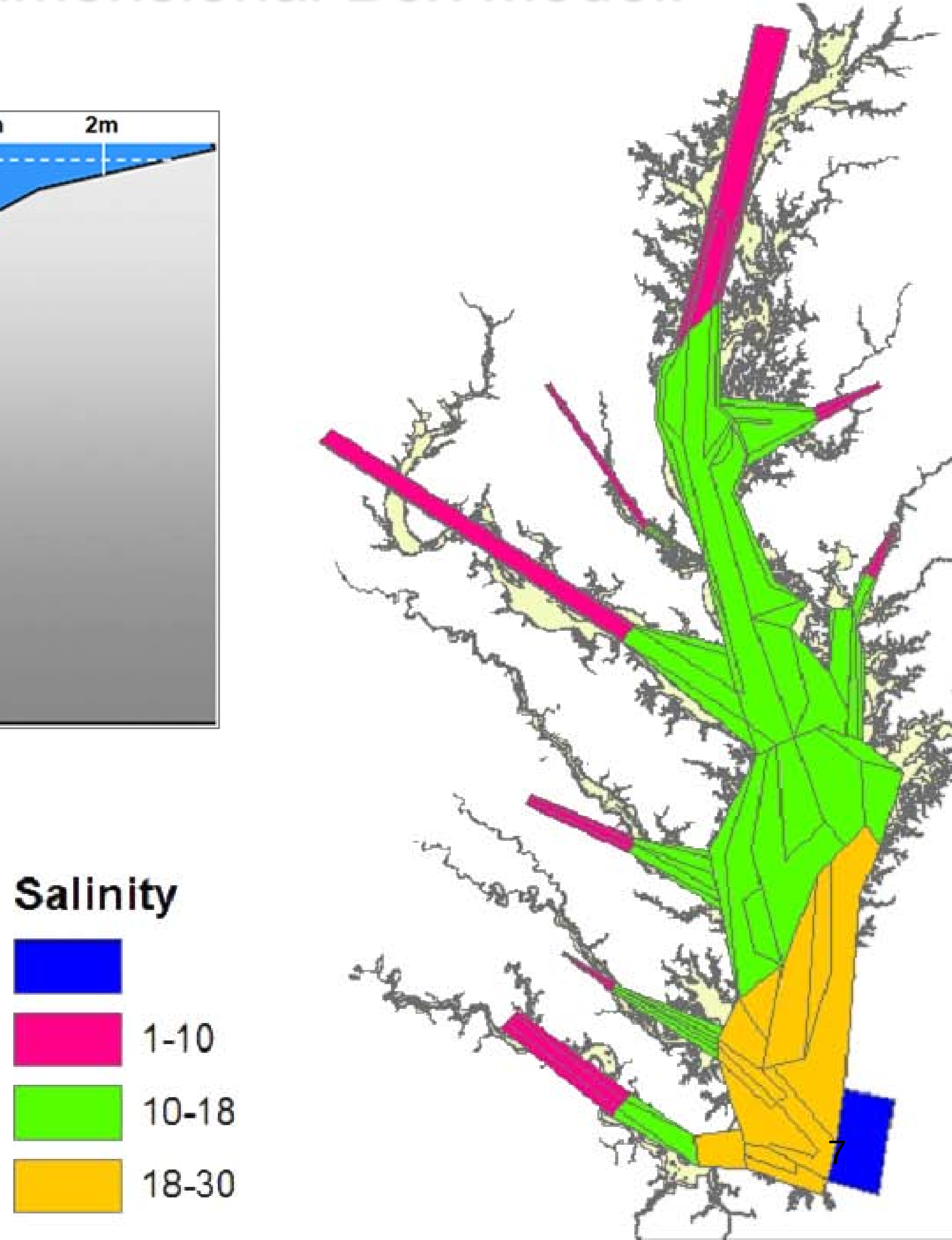
- A virtual Chesapeake for managers & biologists to explore important questions
- Integrates best available data - multiple disciplines & scales
- Identify tipping points, data gaps & research priorities
- Compare trade-offs of multiple management options

# The Chesapeake Atlantis Model

# Design

# CAM Design: 3-Dimensional Box Model:

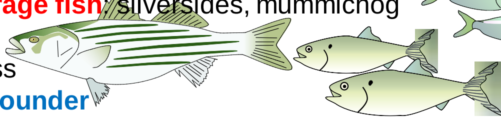
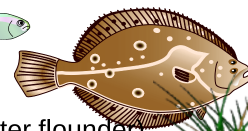
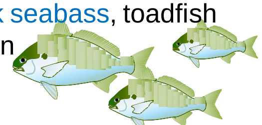


# Ecological Groups: Federal fisheries, Forage, Protected, Habitat

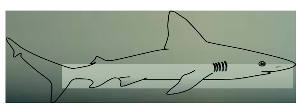
## Finfish



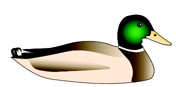
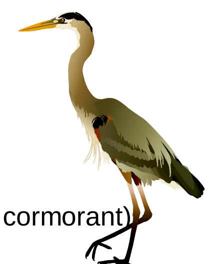
- **Alosines** (Amer.Shad, Hickory Shad, Alewife & Herring)
- Atlantic Croaker
- **Bay anchovy**
- Black drum
- **Bluefish**
- **Butterfish**, harvestfish ("Jellivores")
- Catfish
- Gizzard shad
- **Littoral forage fish**: silversides, mummichog
- **Menhaden**
- Striped bass
- **Summer flounder**
- Other flatfish (hogchoker, tonguefish, window pane, winter flounder)
- **Panfish**:
  Euryhaline: Spot, silver perch; FW to 10ppt: yellow perch, bluegill
- **Reef assoc. fish**: spadefish, tautog, black seabass, toadfish
- Spotted hake, lizard fish, northern searobin
- Weakfish
- White perch

## Elasmobranchs



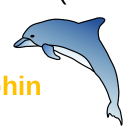
- Cownose ray
- Dogfish, smooth
- **Dogfish, spiny**
- Sandbar shark

## Birds

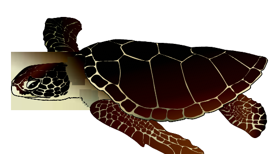
- **Bald Eagle**
- Piscivorous birds (osprey, great blue heron, brown pelican, cormorant)
- Benthic predators (diving ducks)
- Herbivorous seabirds (mallard, redhead, Canada goose, & swans)

## Mammals



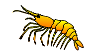
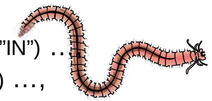
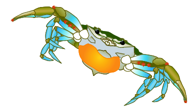
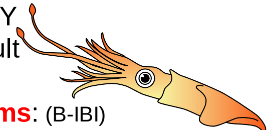
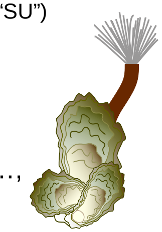
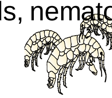
- **Bottlenose dolphin**

## Reptiles

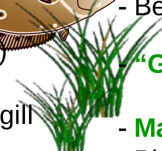
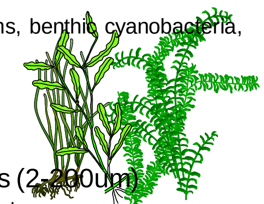
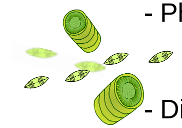
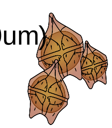
- **Diamond-back Terrapin**
- **Seaturtles**

## Invertebrates

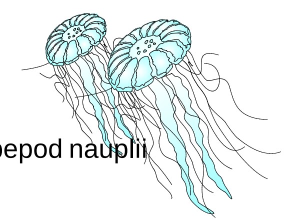
- **Benthic feeders**: (B-IBI "CO"+"IN") …
- **Benthic predators**: (B-IBI "P") …,
- **Benthic suspension feeders**: (B-IBI "SU")
- Blue crab YOY
- Blue crab adult
- **Brief squid**
- **Macoma clams**: (B-IBI)
- **Meiofauna**: copepods, nematodes, …,
- **Oysters**

## Primary Producers

- Benthic microalgae ("microphytobenthos" benthic diatoms, benthic cyanobacteria, & flagellates)
- **"Grasses:"**
  **SAV** – type varies with salinity
- **Marsh grass**
- Phytoplankton – Large: diatoms & silicoflagellates (2-200um)
- Phytoplankton – Small: nannoplankton, ultraplankton,
  aka "picoplankton" or "picoalgae" (0.2-2um),
  cyanobacteria included (2um)
- Dinoflagellates (mixotrophs) (5-2,000um)

## ZooPlankton



- Ctenophores
- Sea nettles
- Microzooplankton (.02-.2mm): rotifers, ciliates, copepod nauplii
- Mesozooplankton (.2-20mm): copepods, etc.

## Detritus

- Carrion
- Carrion (sediment)
- Labile
- Labile (sediment)
- Refractory
- Refractory (sediment)

## Bacteria (.2-2 um [.002 mm] - feed microzooplankton food chain)

- Benthic Bacteria (sediment)
- Pelagic Bacteria: (free-living)

# Simple Experimental Plan

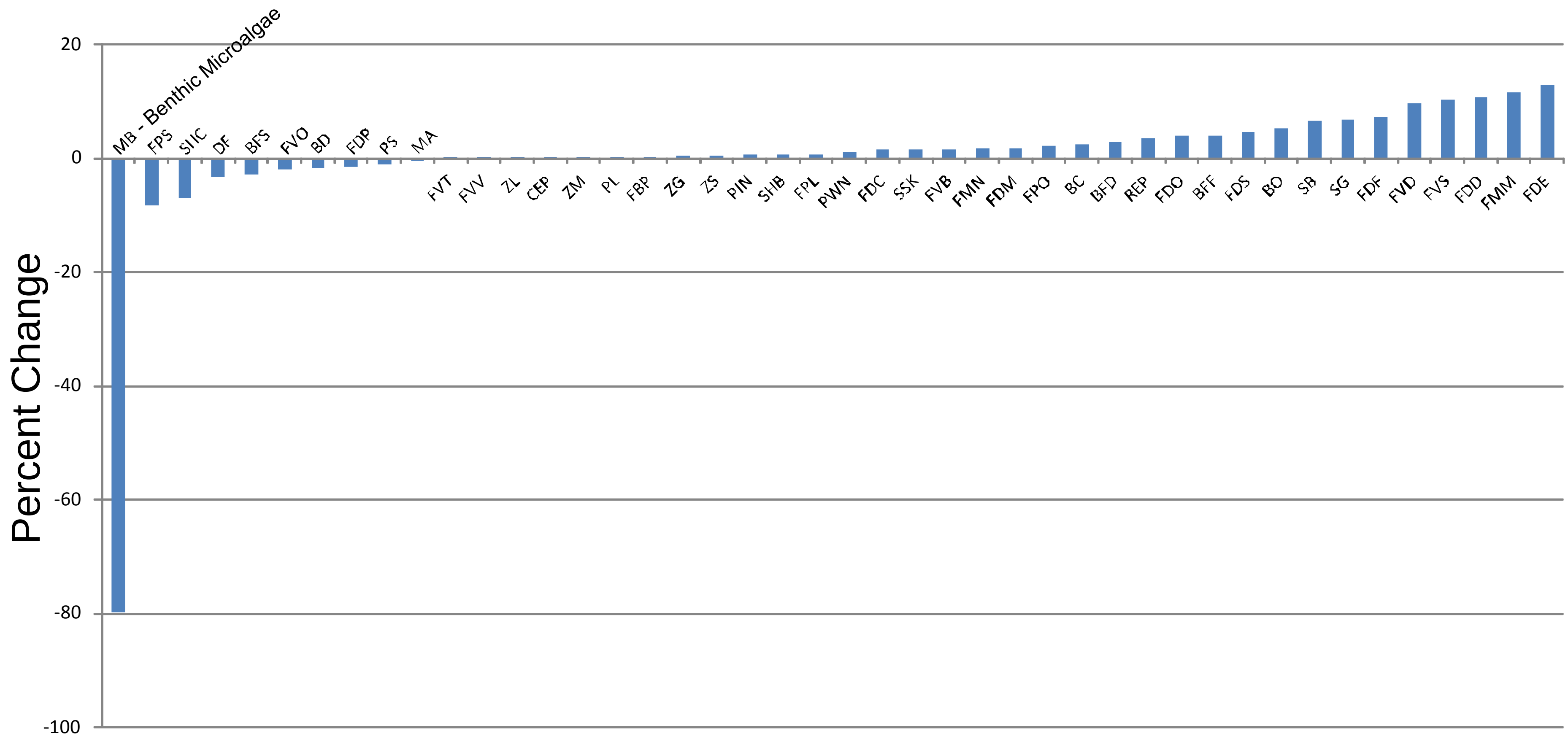
## Change predicted with full implementation Of TMDL (Total Maximum Daily Load, EPA)

# Results

# Productivity Change under TMDL Nutrient and Sediment Conditions Predicted with CAM

## Median Difference

(Simulation Years 40 – 50)



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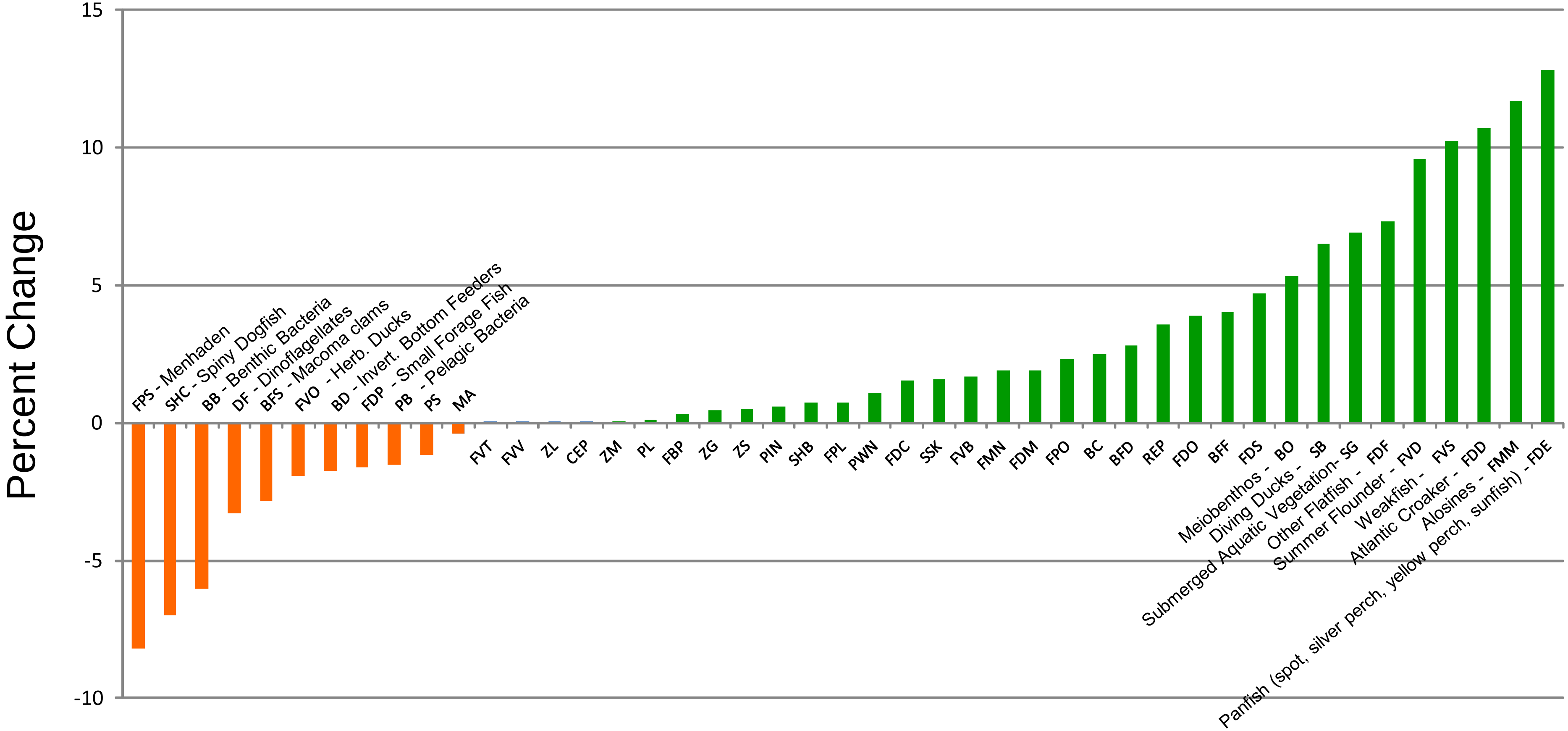

# Summary

*General:*

- Atlantis integrates a wide variety of data across disciplines & scales
- 3D "box" model – CAM spatially structured by salinity & depth characteristics
- Useful for planning for system change/ management change in the Chesapeake system

*Habitat Scenario (TMDL):*

- CAM predicts reducing nitrogen & sediment inputs will benefit medium-large forage groups (alosines, "panfish", small flatfish, croaker) and some large predatory fish (summer flounder, weakfish) most
- Likewise, model captures unintended consequences of management change that might otherwise surprise us
  - Predicted decrease in menhaden

# *Thanks to:*

NOAA OFFICE OF SCIENCE AND TECHNOLOGY
NATIONAL MARINE FISHERIES SERVICE

NOAA HABITAT CONSERVATION
NATIONAL MARINE FISHERIES SERVICE

National Science Foundation
WHERE DISCOVERIES BEGIN

CSIRO **Marine and Atmospheric Research**

*Northwest Fisheries Science Center*
*NOAA Fisheries Service*

Northeast Fisheries Science Center

NOAA Chesapeake Bay Office
& Cooperative Oxford Laboratory

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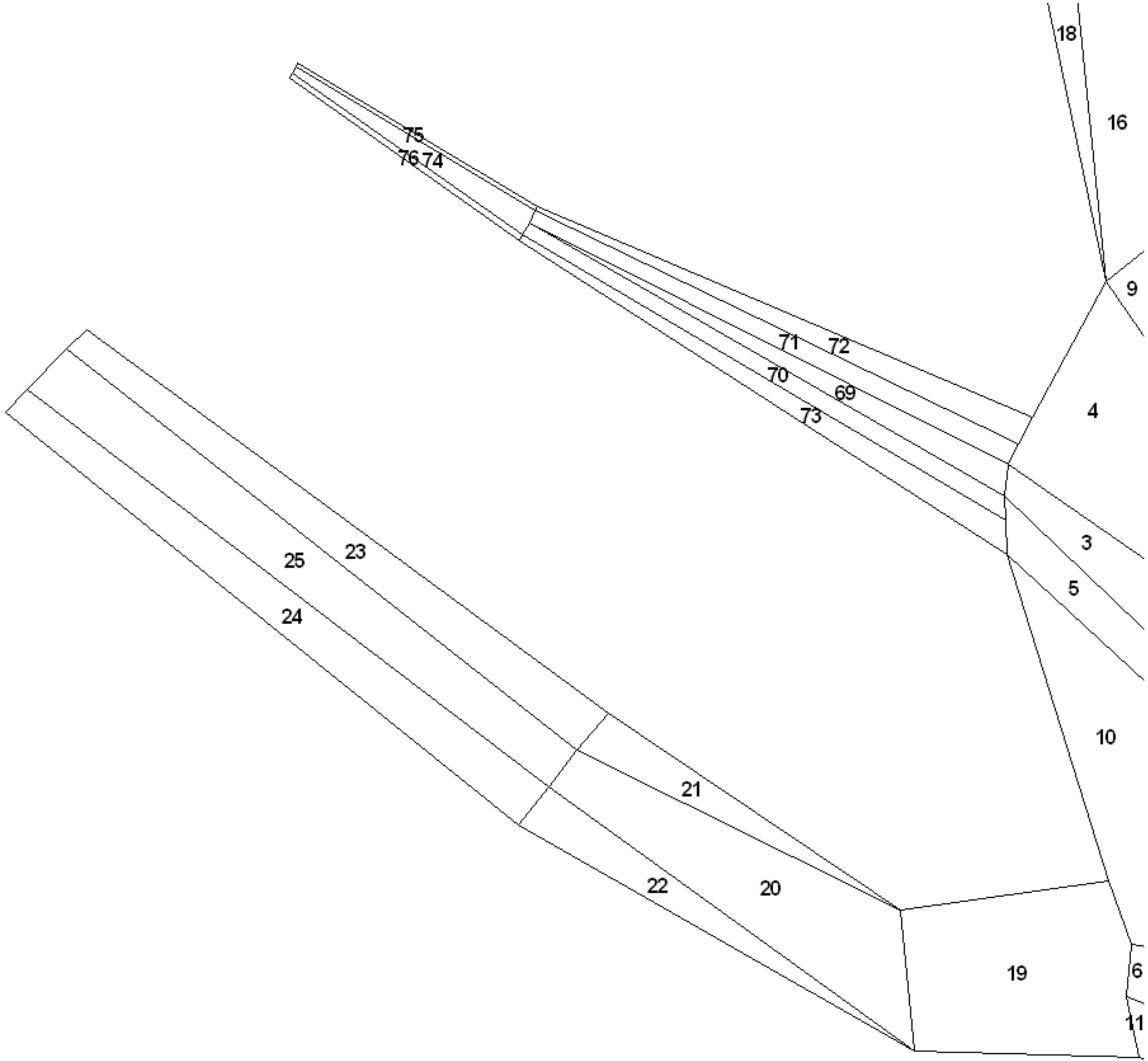
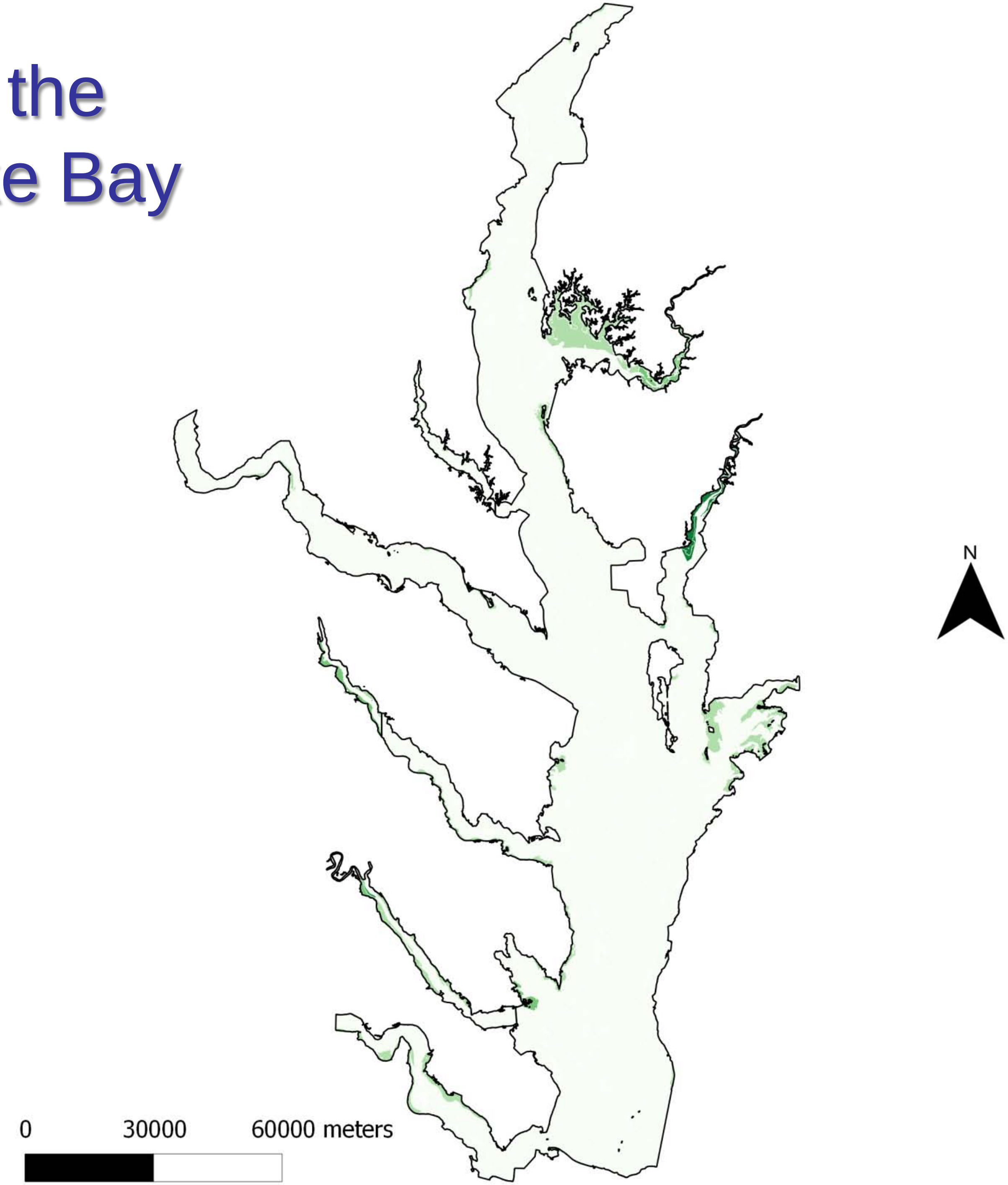
# EXTRA SLIDES

# CAM: River Box Structure



# Marsh in the Chesapeake Bay



# Marsh in the Chesapeake Bay

# Productivity Change under TMDL Nutrient and Sediment Conditions Predicted with the Chesapeake Atlantis Model (CAM)

| Percent difference (range) | Number of groups increase | Number of groups decrease | | Groups: (+) Production increase: | Groups: (-) Production loss: |
|---|---|---|---|---|---|
| 0 - 1 % | 11 | 1 | 25 | ***Verts:*** Gizzard Shad, Bluefish, Striped Bass, Terrapin, Bald Eagles, ***Inverts:*** Lg.Phytoplank, MicroZooplank, MesoZooplank, SeaNettles, Ctenophores, Brief Squid | Marshgrass |
| > 1 - 3 % | 8 | 5 | | ***Verts:*** Bay Anchovy, Catfish, Butterfish, Reef fish, Bottom fish Cownose Rays; ***Inverts:*** Sm.Phytoplank, Blue Crab, Benthic carnivores Bottom Feeders, Macoma Sps. | Sm.ForageFish, Herb.Ducks |
| > 3 - 5 % | 5 | 1 | 11 | ***Verts:*** White Perch, Black Drum, SeaTurtles ***Inverts:*** Oysters | Dinoflagellates |
| > 5 - 7 % | 4 | 1 | | ***Verts:*** Smooth Dogfish, Diving Ducks ***Inverts:*** SeaGrass, Meiobenthos | Spiny Dogfish |
| > 7 - 9 % | 0 | 1 | 5 | - - - | Menhaden (-8%) |
| > 9 - 11 % | 4 | 0 | | ***Verts:*** Summer Flounder (+10%), Weakfish (+10%), Atl.Croaker (+11%), Other Flatfish (hogchoker, tonguefish, window pane, winter flounder) +7% | - - - |
| > 11 % | 2 | 1 | 3 | ***Verts:*** Alosines (American shad, Alewife, Blueback shad, Hickory shad) +12%, Panfish (spot, silver perch, yellow perch, sunfish) +13% | Benthic algae (-80%) |
| Totals: | 34 | 10 | | | |

# Biological Change under TMDL Nutrient and Sediment Conditions Predicted with the Chesapeake Atlantis Model (CAM)

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- Likewise, model captures unintended consequences of management change that might otherwise surprise us.
  - Predicted decrease in menhaden

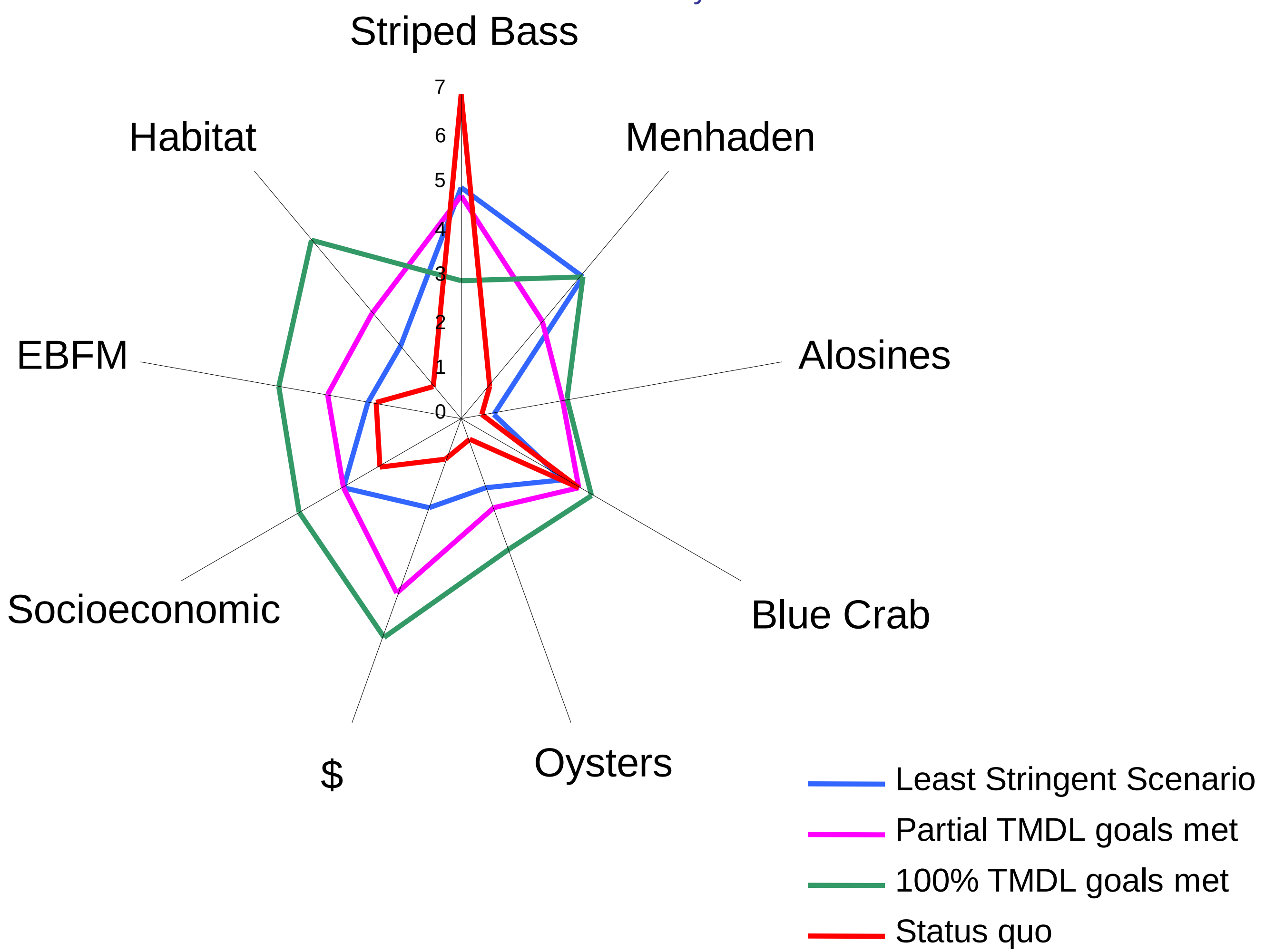
*Closing Thoughts:*

- Atlantis enables us to address a broad range of questions; fish production under projected environmental conditions outside of past observations (e.g., climate change)
- Atlantis application in the coastal system underscores the importance of close collaboration with state & regional partners; connects coastal habitat decisions (e.g., marsh, land use, fish harvest, water quality) to fish production

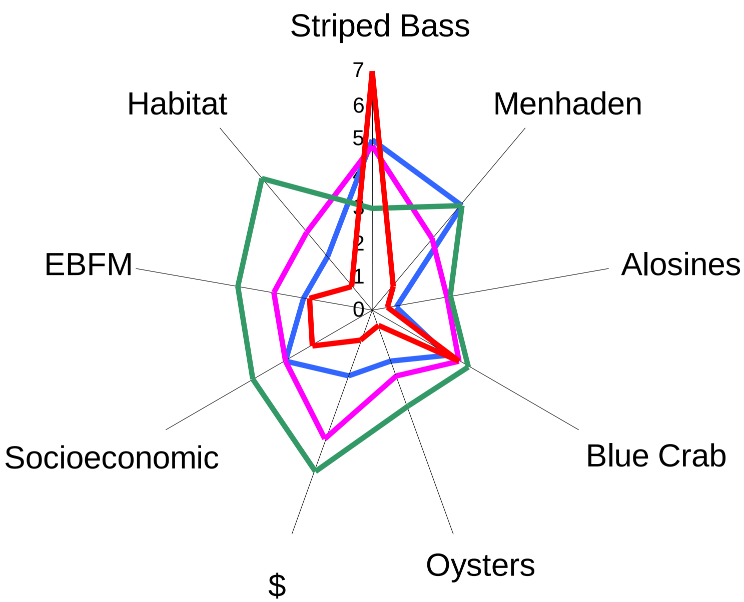
# Tradeoffs - *Hypothetical*

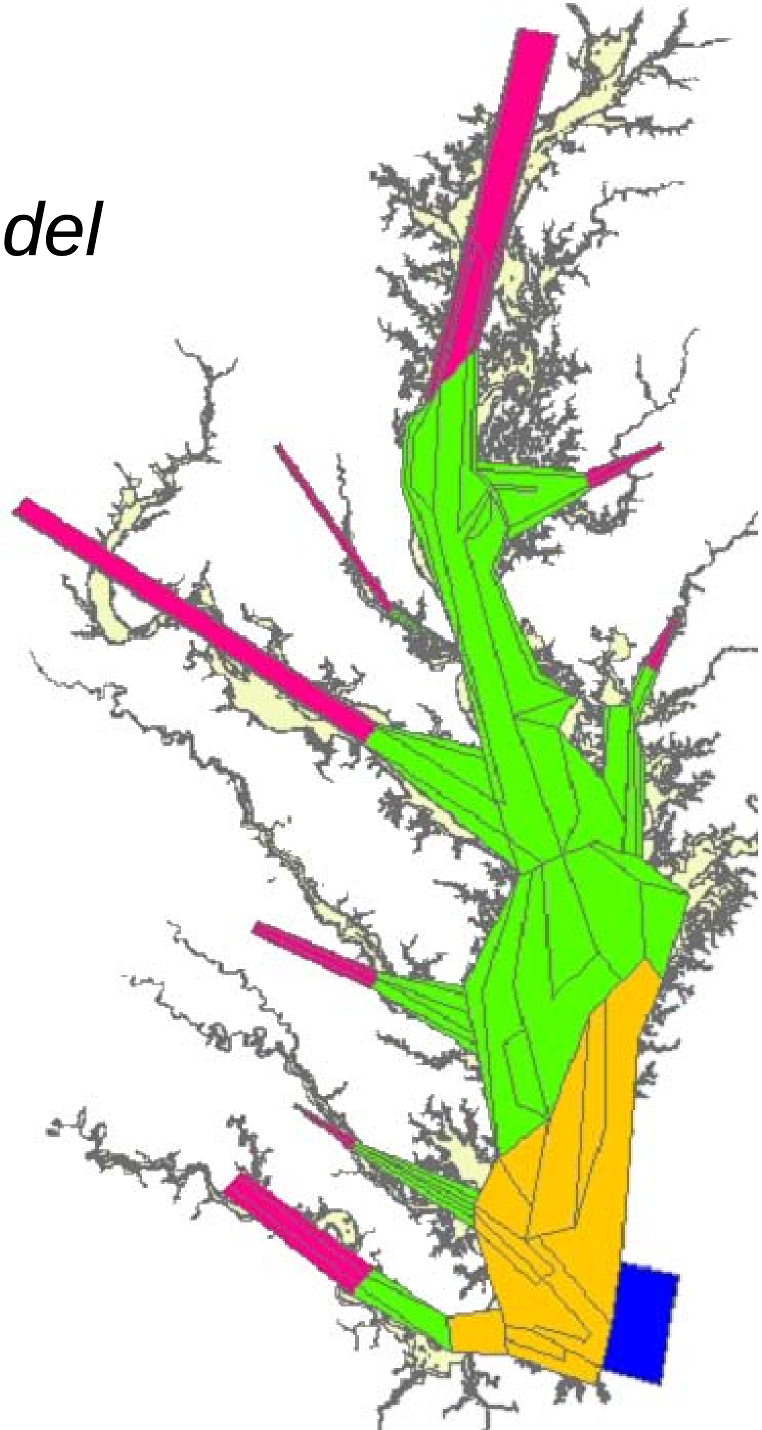
CAM Output

20 year Simulation



# *Chesapeake Atlantis Model*



# Tradeoffs

## CAM Output

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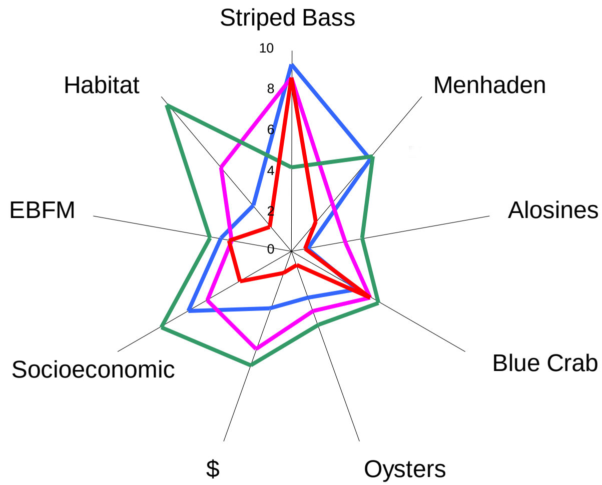
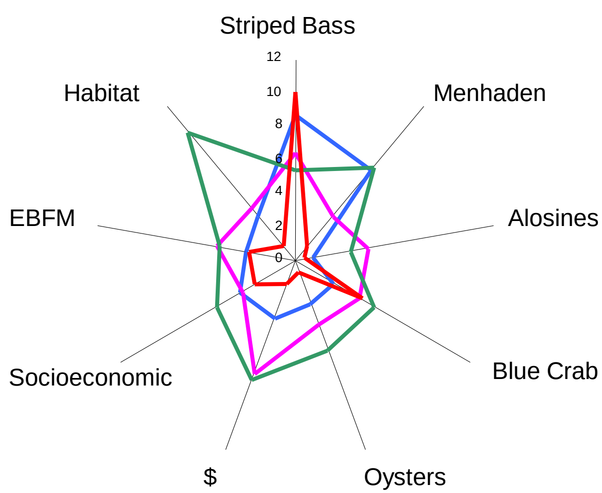
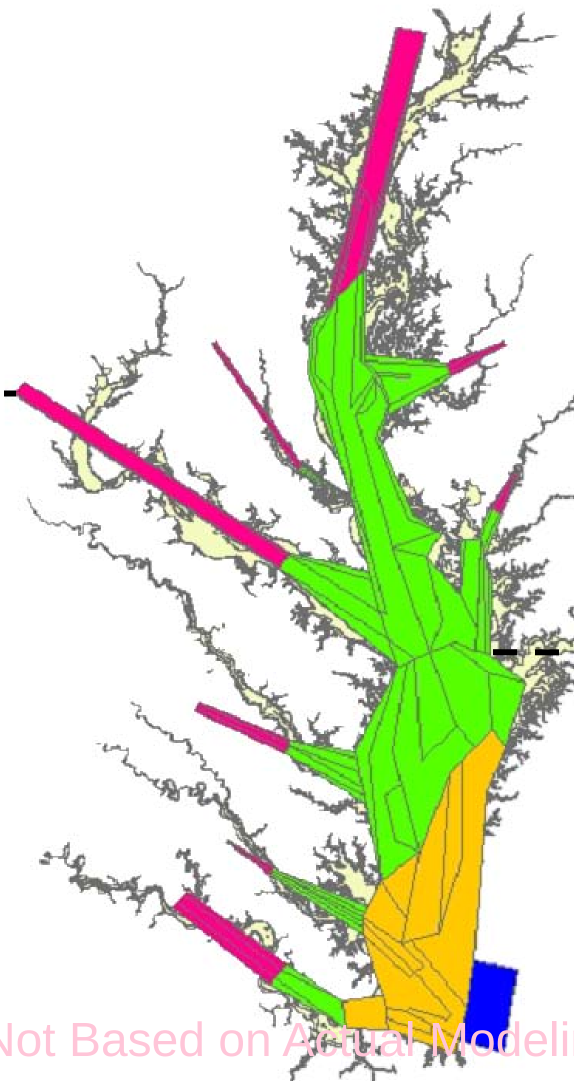



MD

VA



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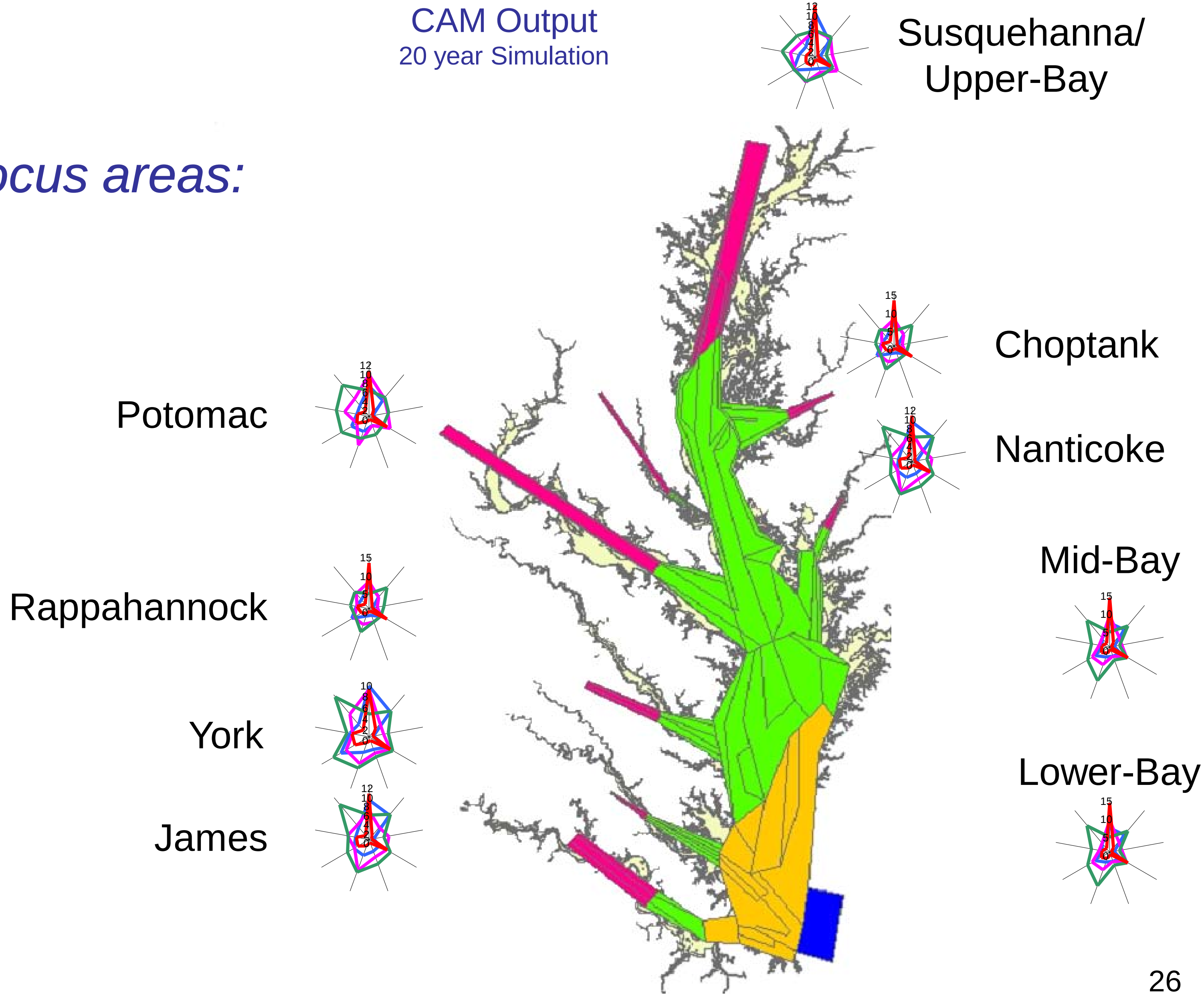
# Tradeoffs

CAM Output

20 year Simulation

*Focus areas:*



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# Atlantis

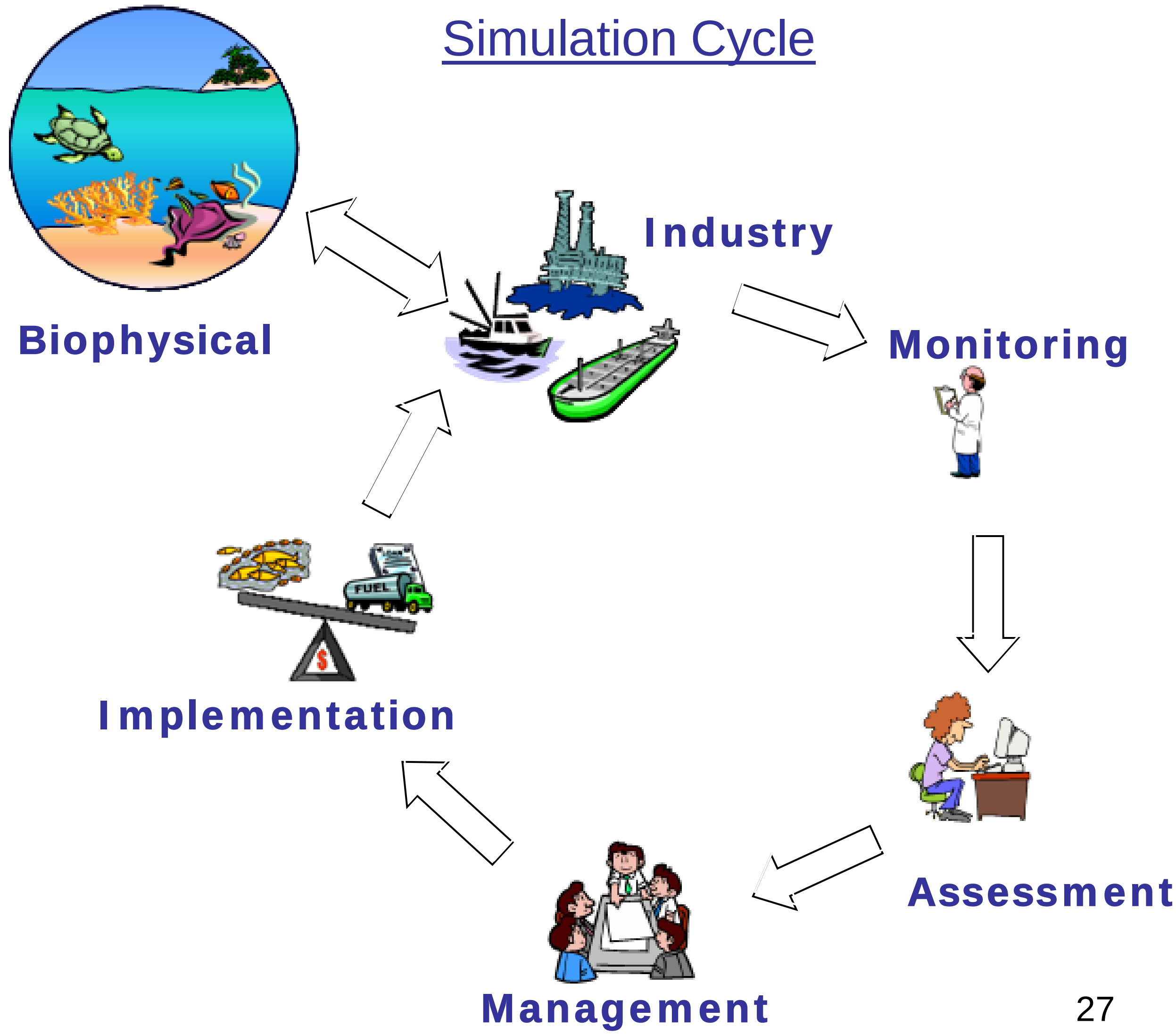
## Management Strategy Evaluation (MSE)

### Manager Roles

DEFINE
OBJECTIVES

PERFORMANCE
MEASURES

### Simulation Cycle






Modified from E. Fulton

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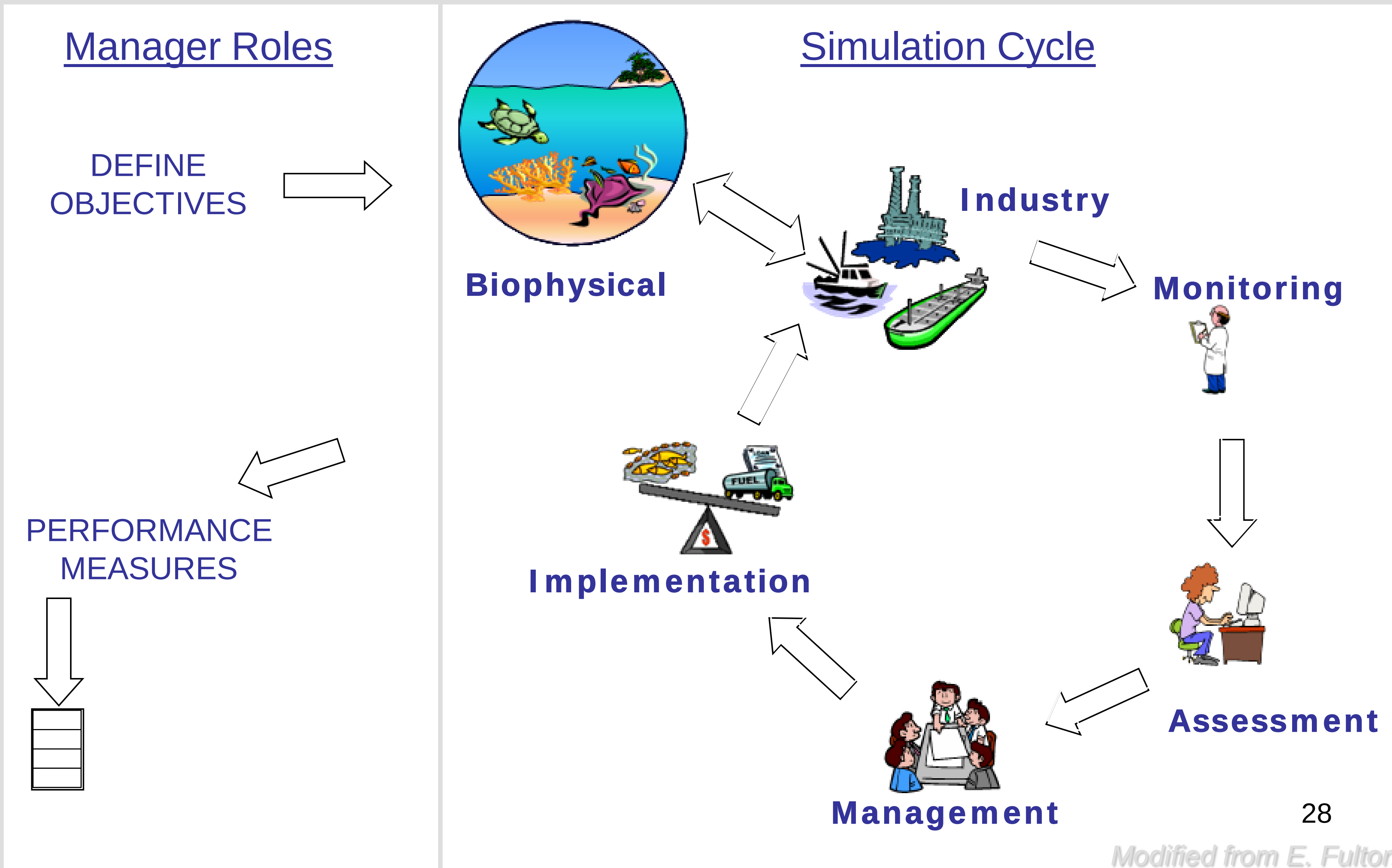




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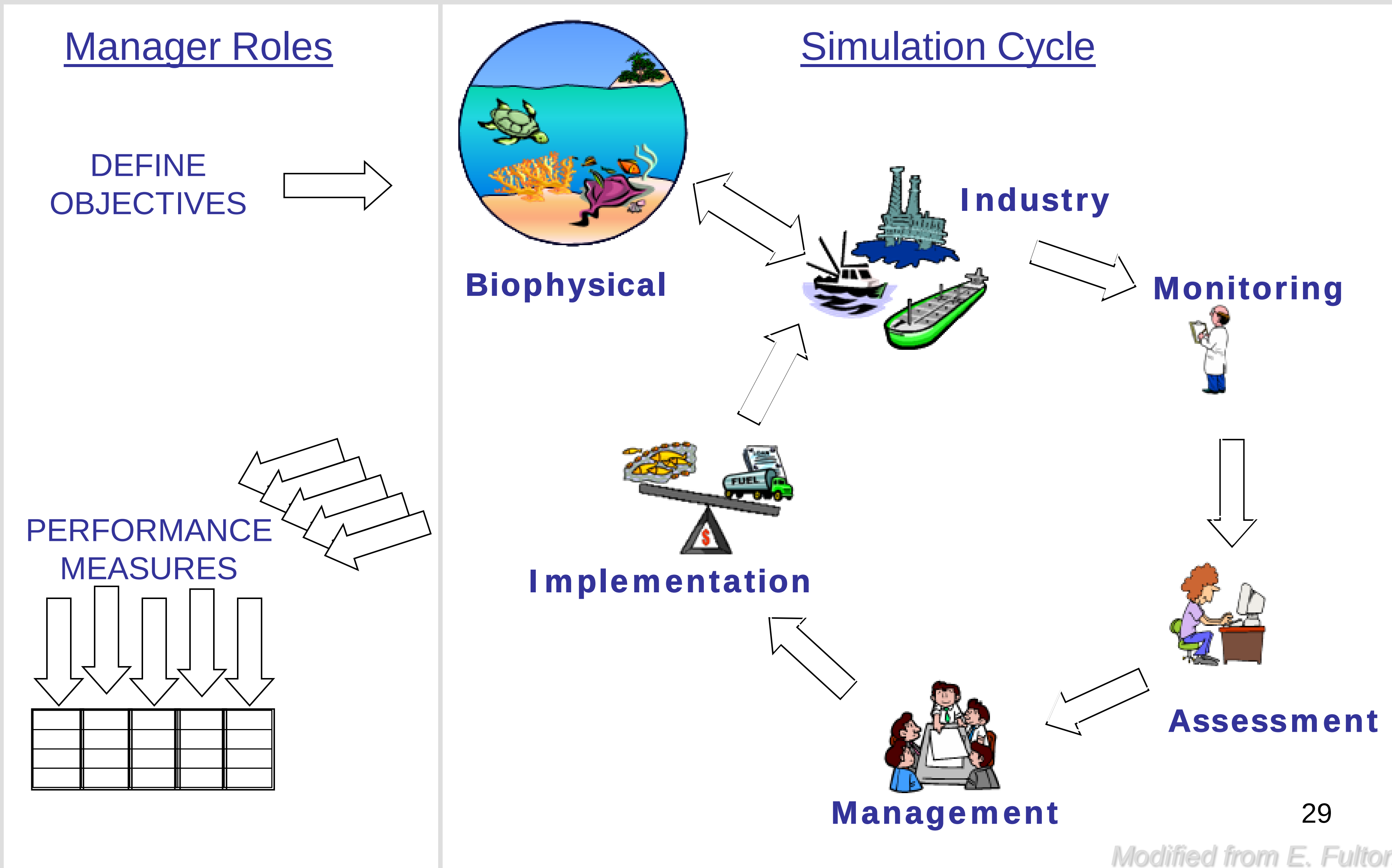

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