Integrated Ecological Modeling – Mediated Modeling and Model Development Workshops

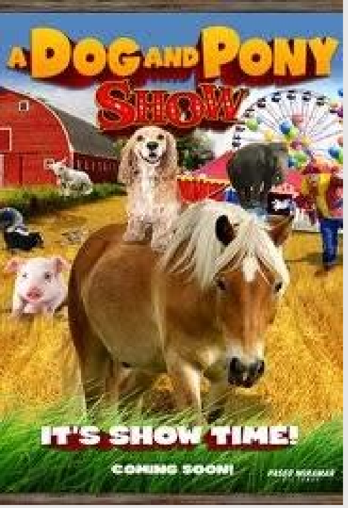
Michael E. Kjelland, S. Kyle McKay, and Todd M. Swannack

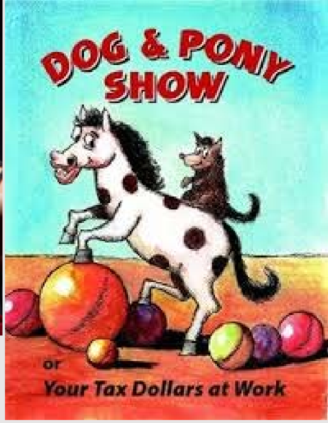
Introduction to Modeling

1) Identify the problem – Frame the question

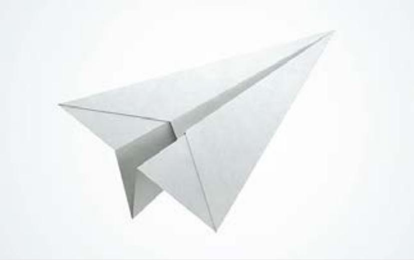
2) Identify the essential components

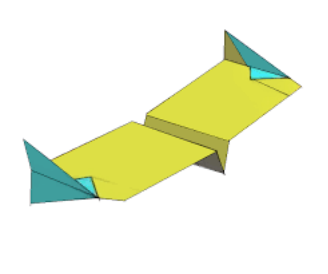
3) Determine smallest unit of time required (Δt)

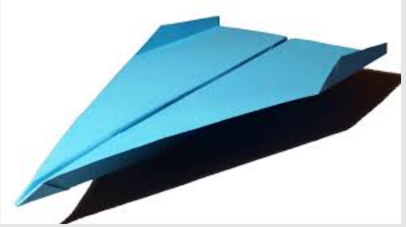


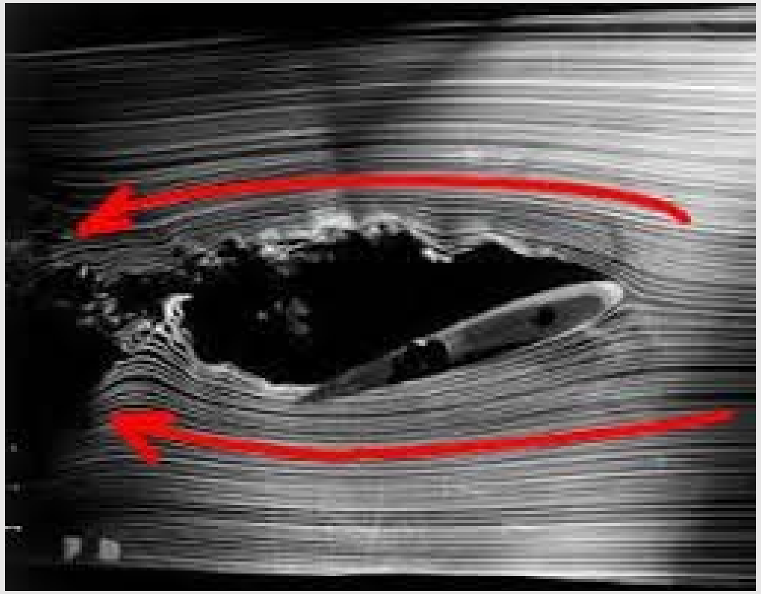


“It was a *dog-and-pony show* hiding *behind a smokescreen inside a hall of mirrors*.”





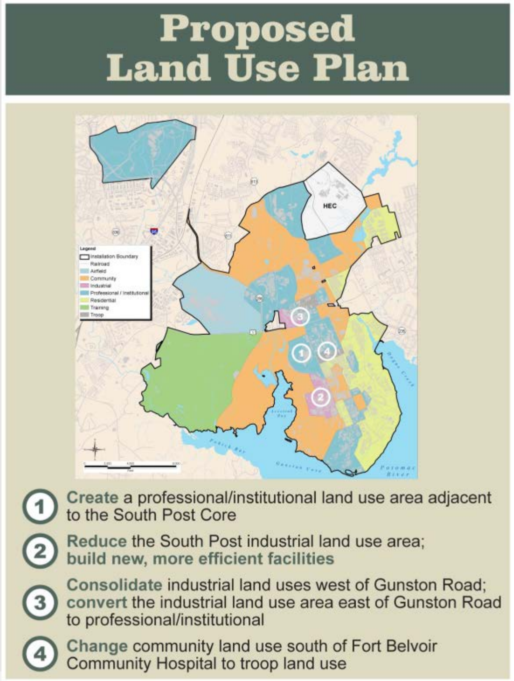


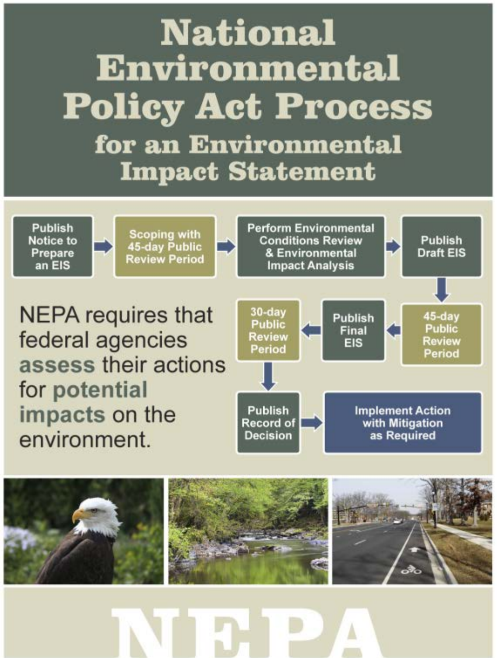


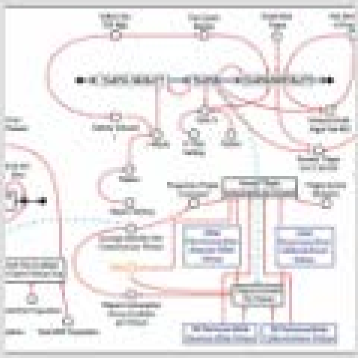

Smoke and Tufts
Smoke Injection
Surface Tufts

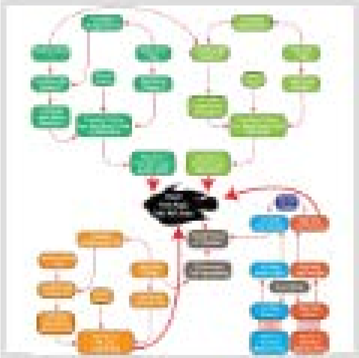

B61-7
B83-1
B61-11


alamy stock photo

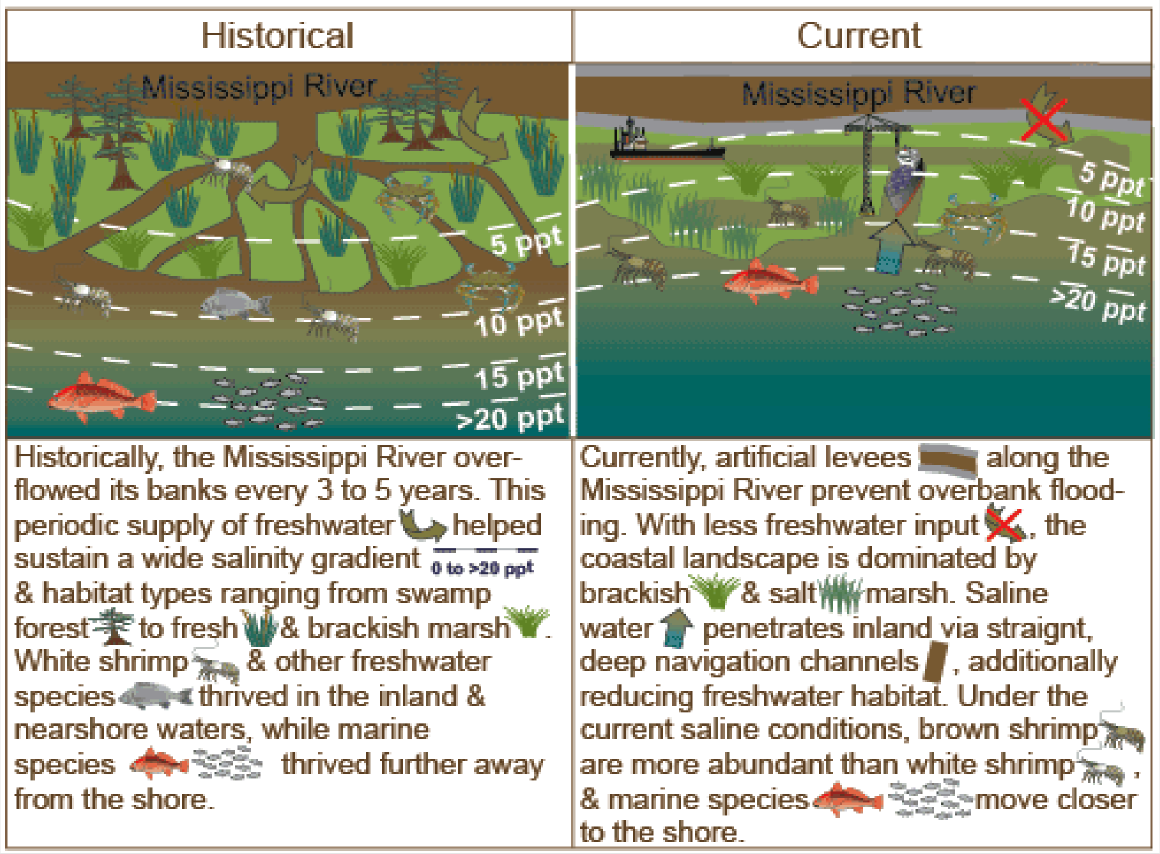

Proposed
Land Use Plan
1 Create a professional/institutional land use area adjacent to the South Post Core
2 Reduce the South Post industrial land use area; build new, more efficient facilities
3 Consolidate industrial land uses west of Gunston Road; convert the industrial land use area east of Gunston Road to professional/institutional
4 Change community land use south of Fort Belvoir Community Hospital to troop land use


National Environmental Policy Act Process
for an Environmental Impact Statement
Publish Notice to Prepare an EIS
Scoping with 45-day Public Review Period
Perform Environmental Conditions Review & Environmental Impact Analysis
Publish Draft EIS
45-day Public Review Period
Publish Final EIS
30-day Public Review Period
Publish Record of Decision
Implement Action with Mitigation as Required
NEPA requires that federal agencies assess their actions for potential impacts on the environment.
NEPA





Conceptual Models describe general functional relationships among essential ecosystem components. They tell the story of "how the system works."

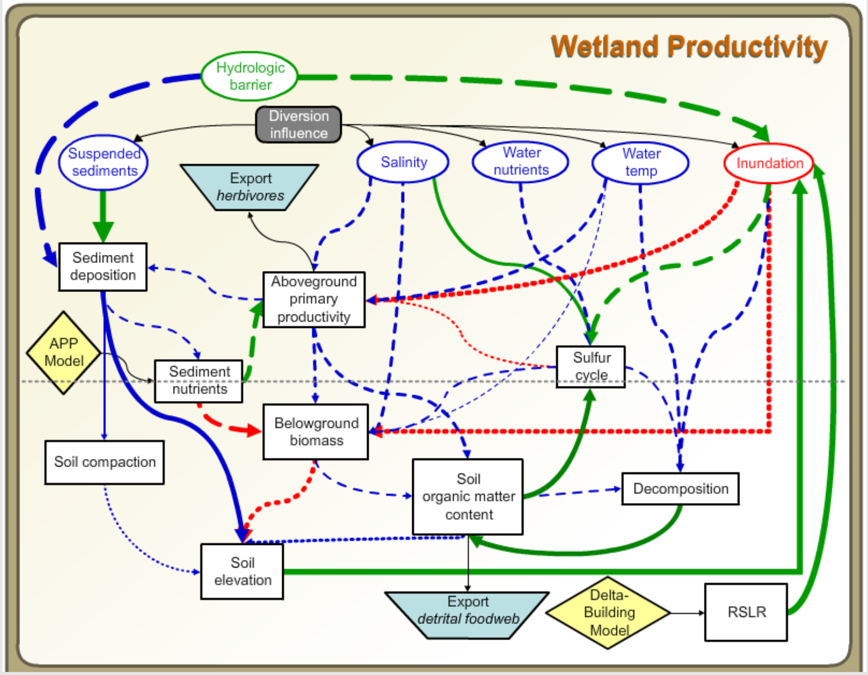


One of my favorite examples!

http://lacoast.gov/crms2/WetlandProd.aspx

How are conceptual models used in ecological model development?

- Team building
- Communication and understanding
- Translation of concepts into quantifiable processes
- Multiple models are often helpful
  - A simplified model for public communication
  - A complex model capturing all processes
  - A simplified model as a basis for quantification



Conceptual Model Development

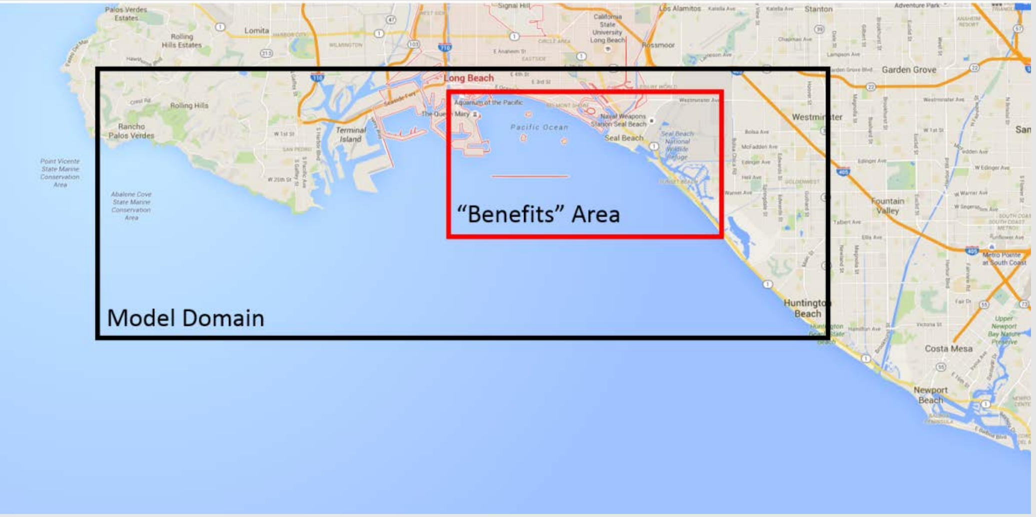
Seven step process (Fischenich 2008):

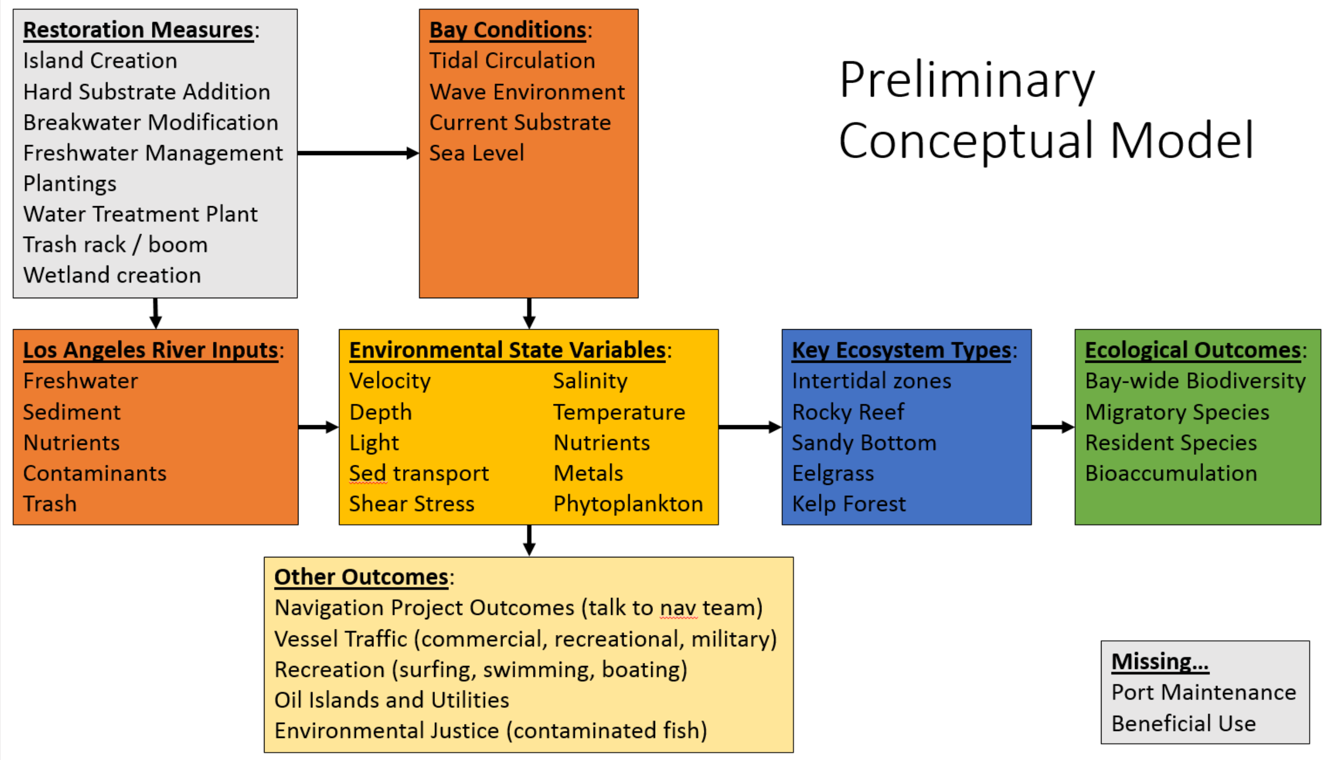
1. State the model objectives.
2. Bound the system of interest.
3. Identify critical model components within the system of interest.
4. Articulate the relationships among the components of interest.
5. Represent the conceptual model.
6. Describe the expected pattern of model behavior.
7. Test, review, and revise as needed.

Development tips (Casper et al. 2010):

- Combine graphical and narrative descriptions
- Align boxes, both horizontally and vertically
- Maximize content with weights, shapes, and colors
- Be aware that B&W printing and color-blindness can impact understanding
- Aggregate lines when possible
- Adapt to target audience and presentation medium
- Develop iterative with **quiet reflection** as a key step
- Post-its are fun for sorting through ideas

East San Pedro Bay

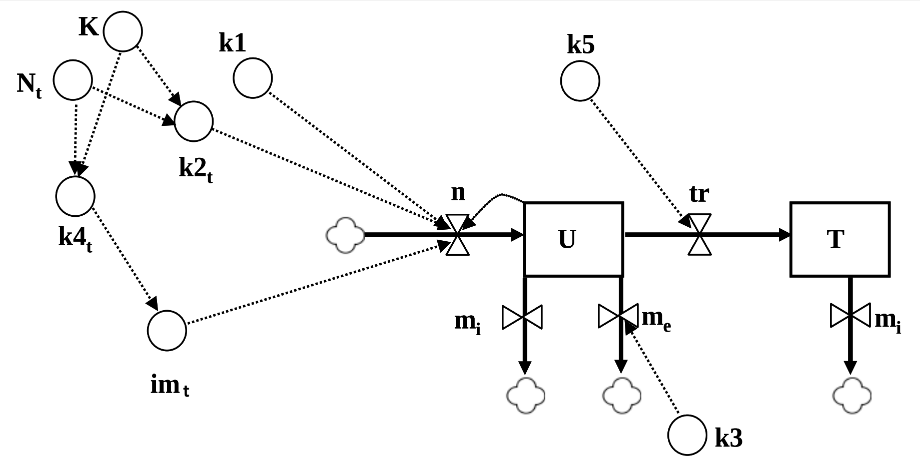




Quantification

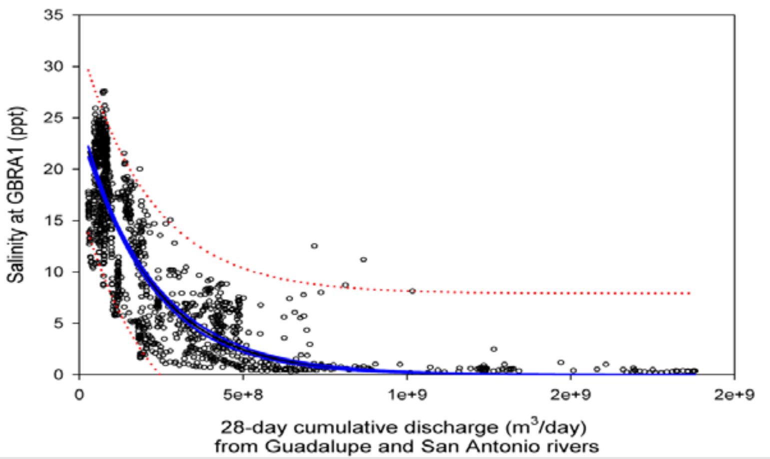
- **Quantifying models provides ability to understand numerical consequences of ideas, scenarios, system dynamics, etc..**

- **Conceptual Model should be used a template**
  - Equations should be tightly coupled with conceptual model
  - Helps with communication and transparency
  - Don't hide behind the math/code
- **In Theory:**
  - Results should not depend on software or advanced math
  - What is important is that the critical processes are captured



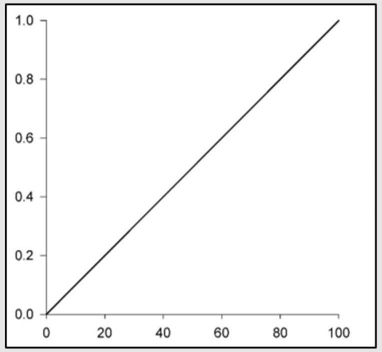
Functional Forms of Equations

How should relationships be quantified?

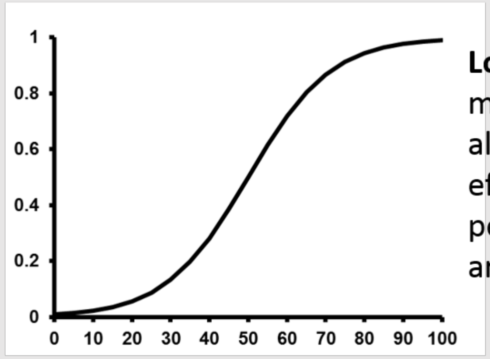


$$p(j) = \frac{e^{V_j/\theta_k} \cdot \left(\sum_{i \epsilon C_k} e^{V_i/\theta_k}\right)^{\delta_k - 1}}{\sum_{k'} \left(\sum_{i \epsilon C_{k'}} e^{V_i/\theta_{k'}}\right)^{\delta_{k'}}}$$

What about unknown relationships?



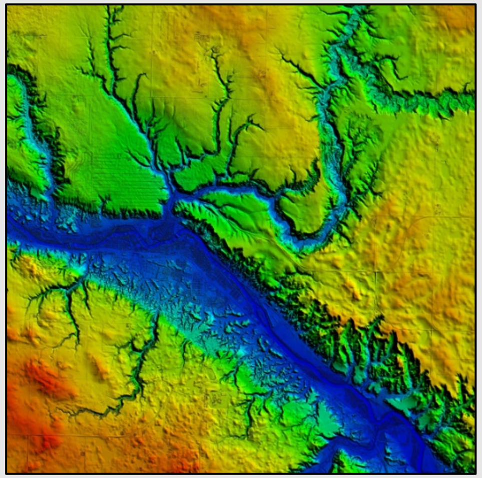
Linear functions: simplest relationship; the general relationship between two variables is understood (e.g., variable A increases when variable B decreases), but the exact form is not

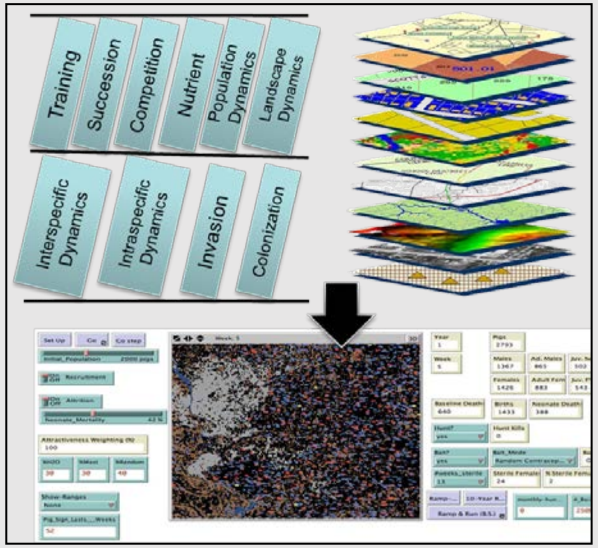


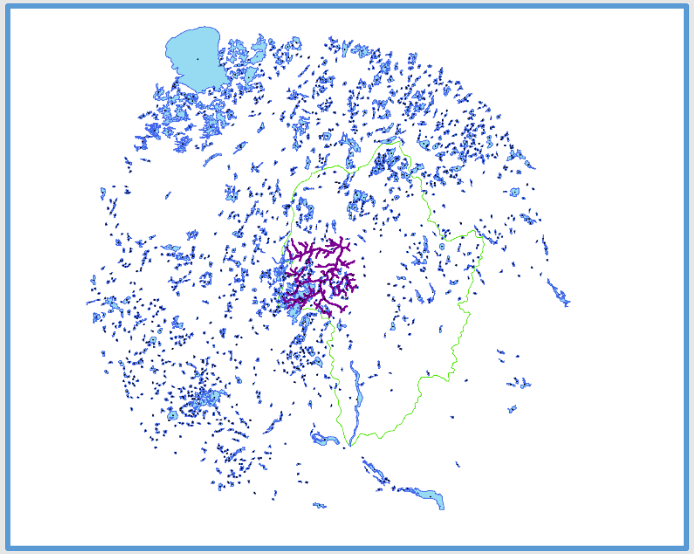
Logistic functions: more complex; allows threshold effects, and periods of stasis and rapid change

Types of data and parameterizations

- **Quantitative Data**
  - Field work
  - Remotely sensed
  - Other models
  - Literature
  - Theory
- **Qualitative data**
  - Expert opinion
  - Hypotheses
- **The model itself**
  - Experimenting with model can reveal trends and patterns

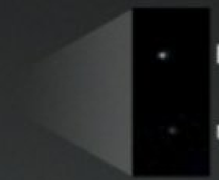






Spatial Considerations

Things to think about when incorporating space

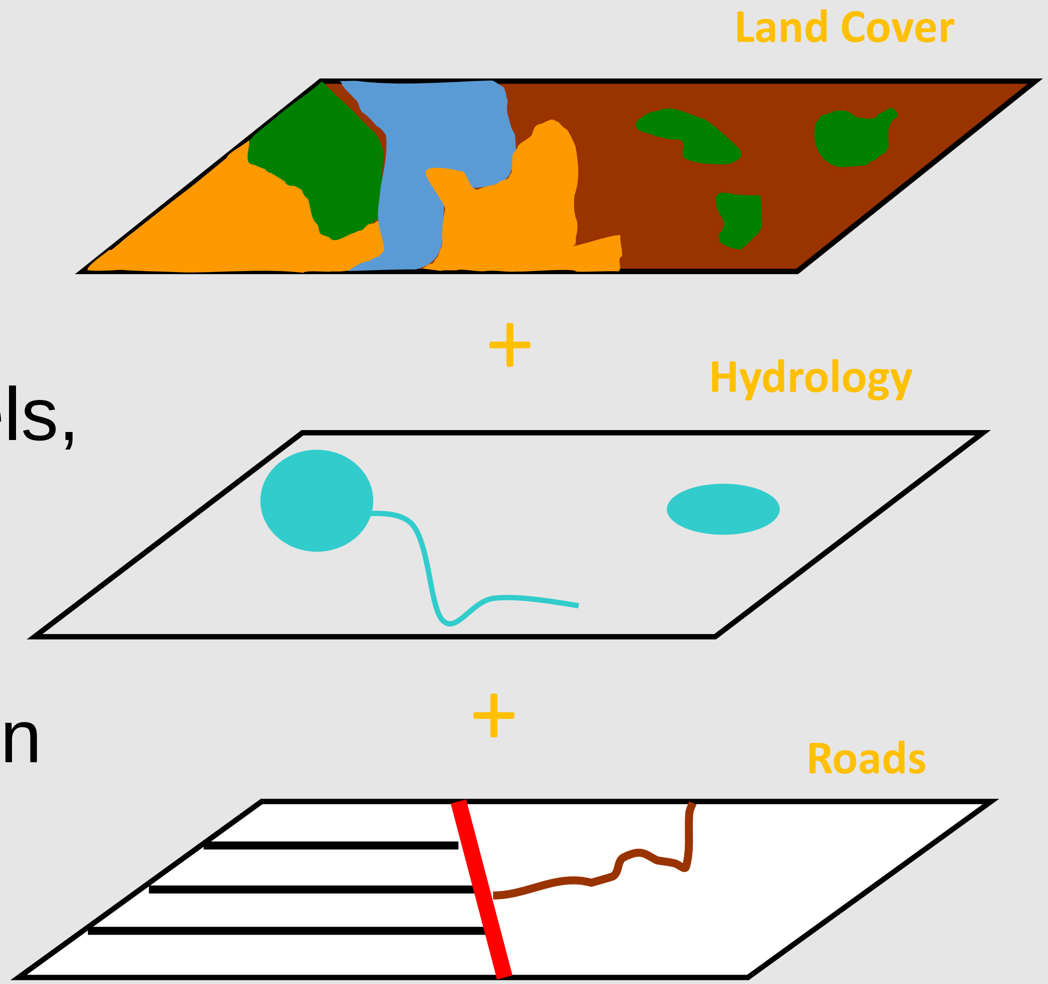


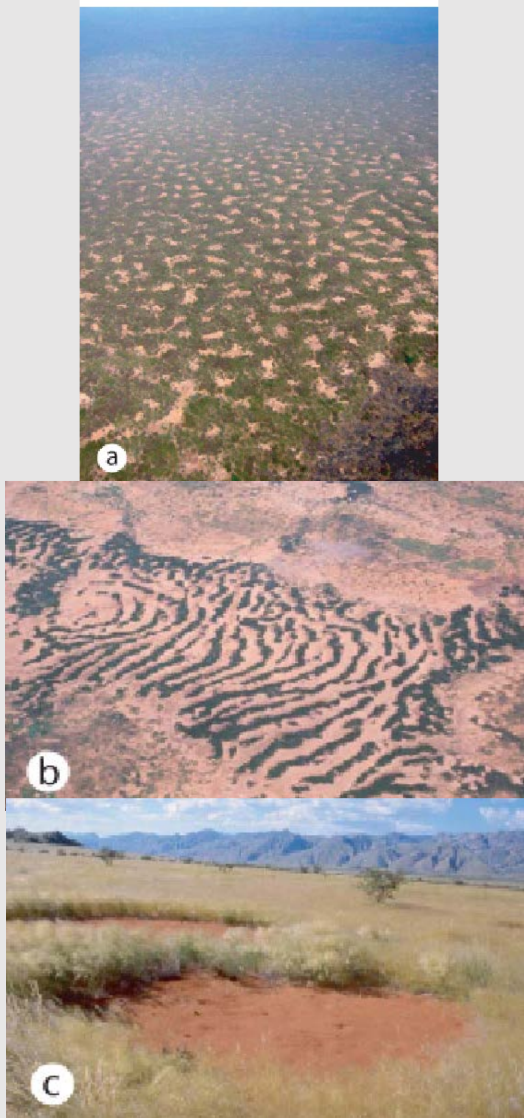
"Spatial analysis is how we understand our world - mapping where things are, how they relate, what it all means, and what actions to take."

Ecological modeling - *Spatial components*

- Can be combined to determine habitat quality, used as foundation for spatially-based simulations:
- agent-based models,
- land use change models,
- landscape evolution models

- Must consider scale
  - What spatial scale do processes occur?



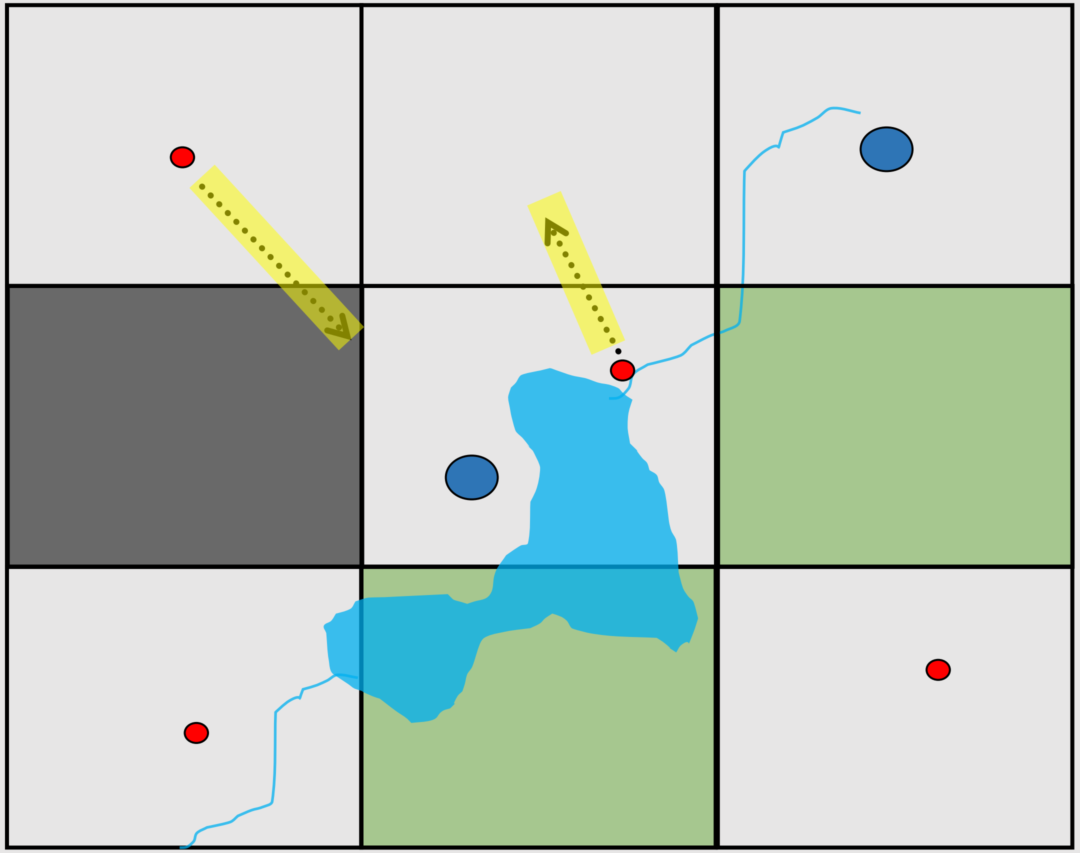


Working with spatial models

Considerations:

- Generally a grid-based approach
  - Each cell has same conditions applied per time step
  - Cells can be different (e.g., weather)

- What spatial scale is relevant?
  - Link ecological processes to grid/mesh size
  - Generally want the grid size to be no larger than species can move in one time step



Evaluation

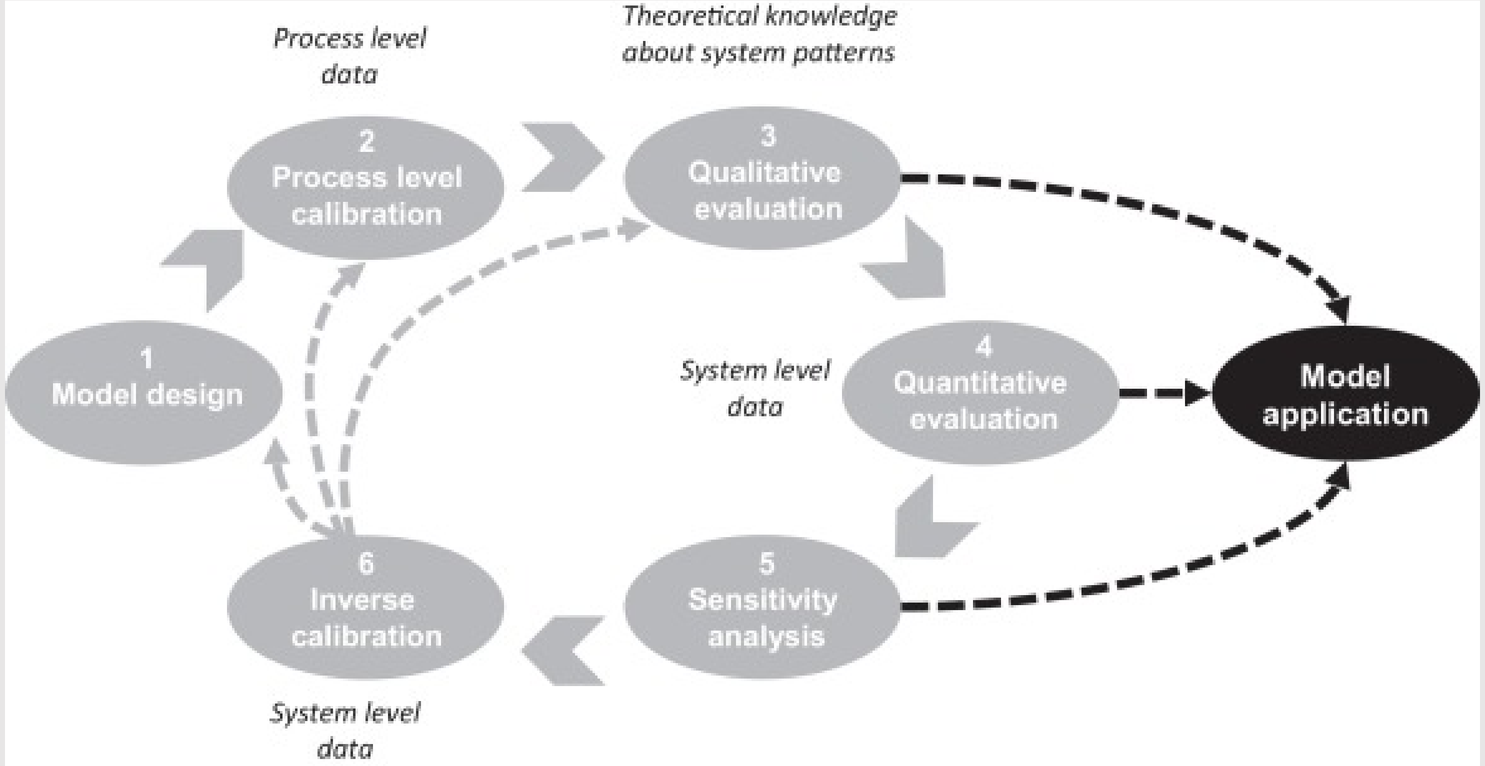
- Process of rigorously assessing model components, structure, parameter values, assumptions, but not scenario results
- Commonly called *model validation*
  - Models represent a point of view of a system. Validation probably not the best term b/c it indicates a model can be true. Are opinions true?
  - Evaluation captures the essence of validation without connoting that the model is true
- Process needs to ensure scientific defensibility and transparency

Evaluation is often not Rigorous

- Detailed evaluation is rare
  - Overly rely on software
  - Don’t have time
  - Aren’t concerned with recreatability
  - Discipline hasn’t required it
    - Small field & modeling was esoteric
    - But most agencies rely on models now
    - Increased need for scientifically-defensible and detailed documentation
    - TRACE (Transparent and comprehensive model evaluation)

Problems with evaluation

- Biggest issue is failure to document entire evaluation process
- Iterative approach
- Evaluation occurs throughout the modeling process, but is rarely documented thoroughly. Need to document each cycle.



Application

Chesapeake Bay Oyster Population Model (CBOPM)

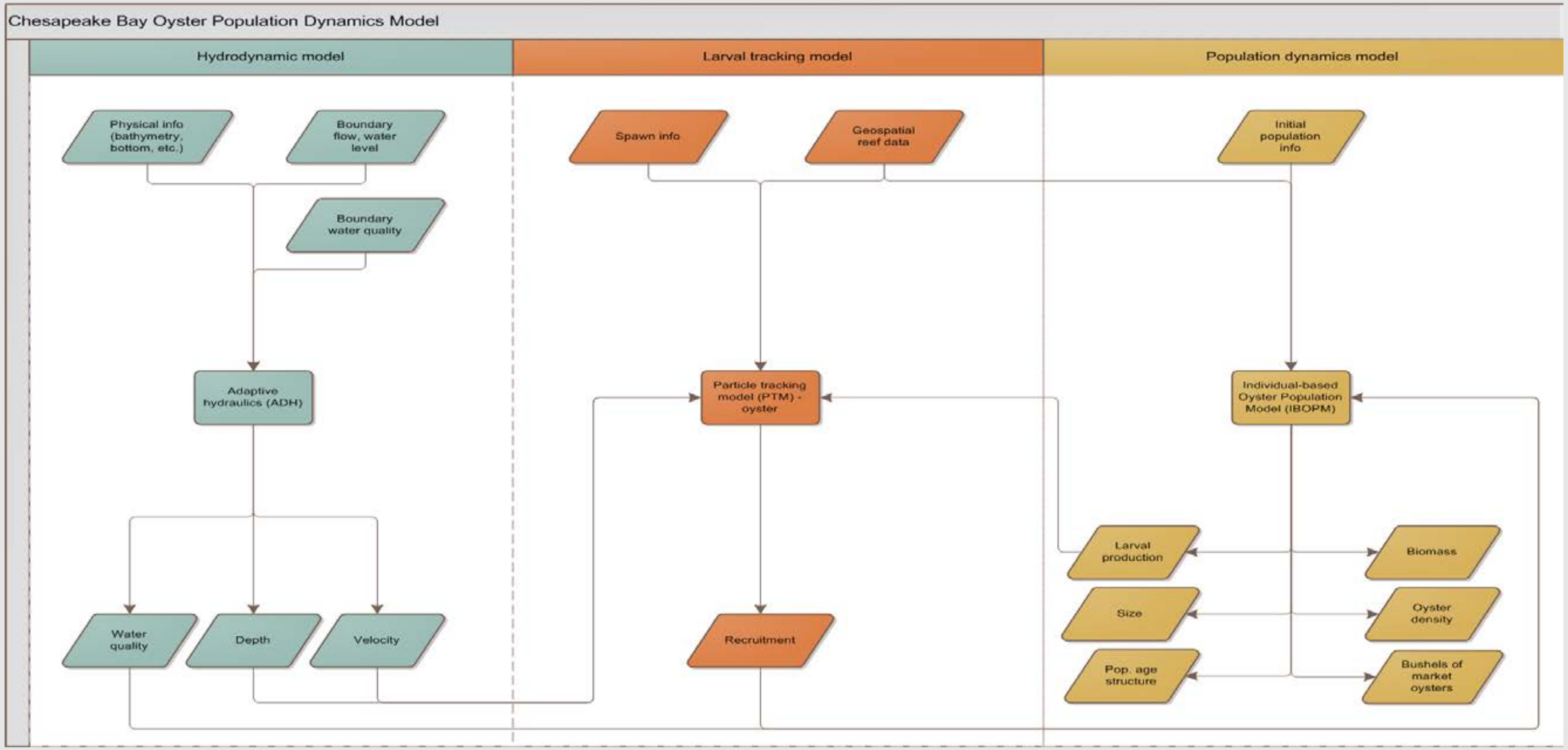
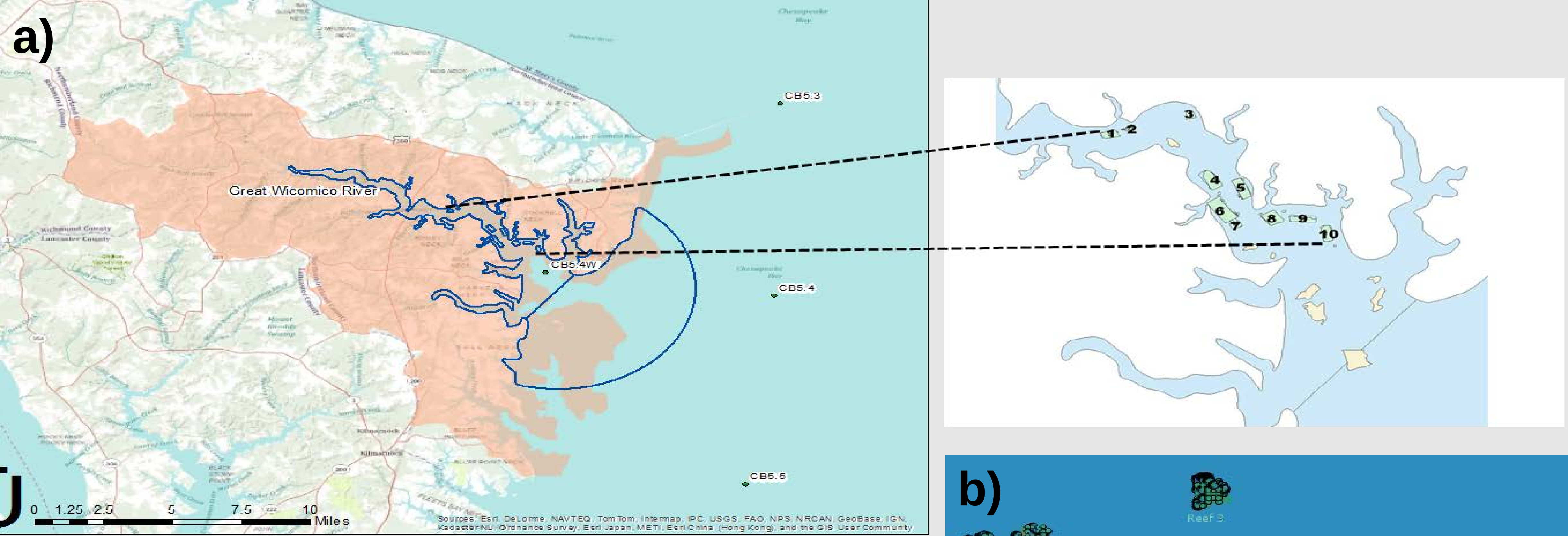


Figure 2. Conceptual model of the integrated Chesapeake Bay Oyster Population Model (CBOPM). CBOPM consists of three models: a hydrodynamic model (left panel), Larval transport model (middle panel) and a spatially-explicit agent based population dynamics model (right panel). Initialization requirements are along the top row, the specific models used are located in the middle, and the bottom row represents the outputs of each models. Arrows indicate the directions of input/output linkages among the models.



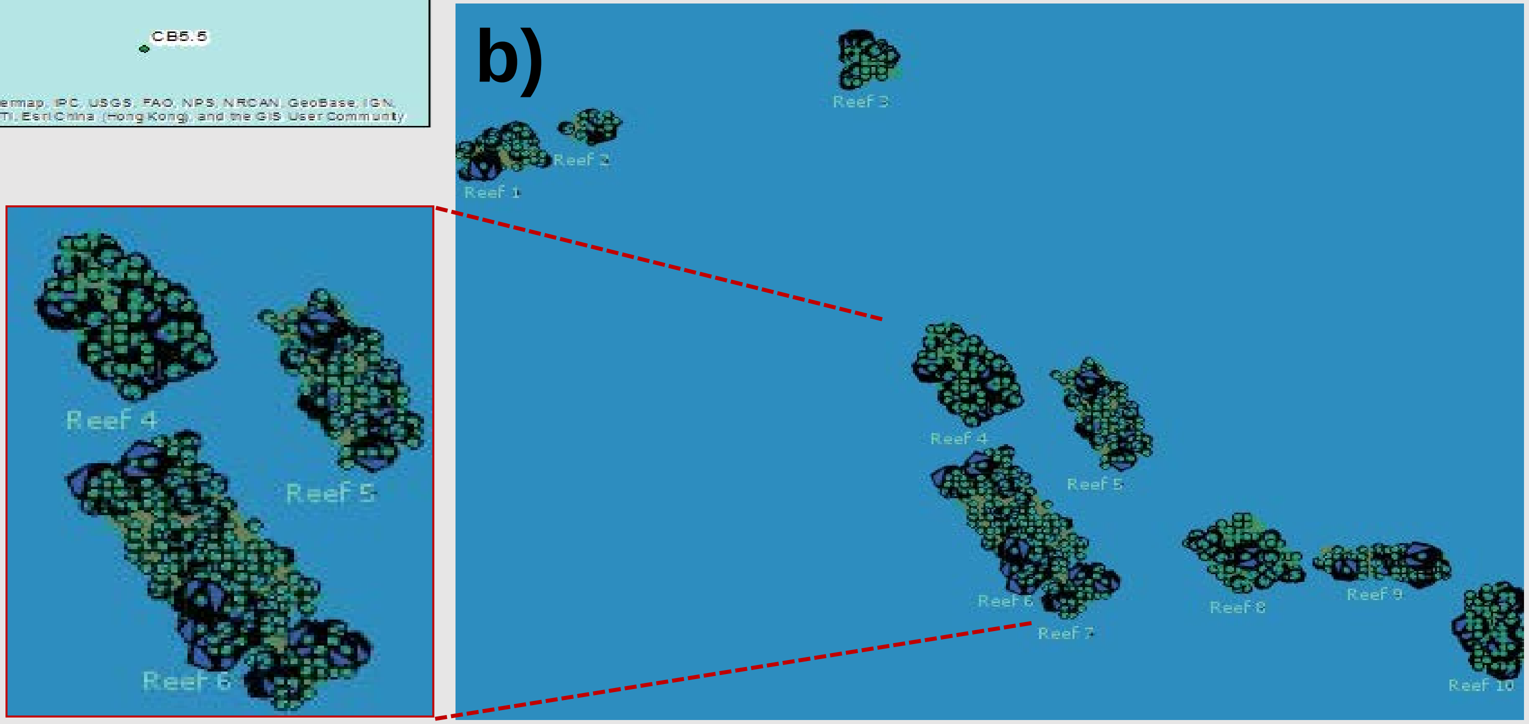
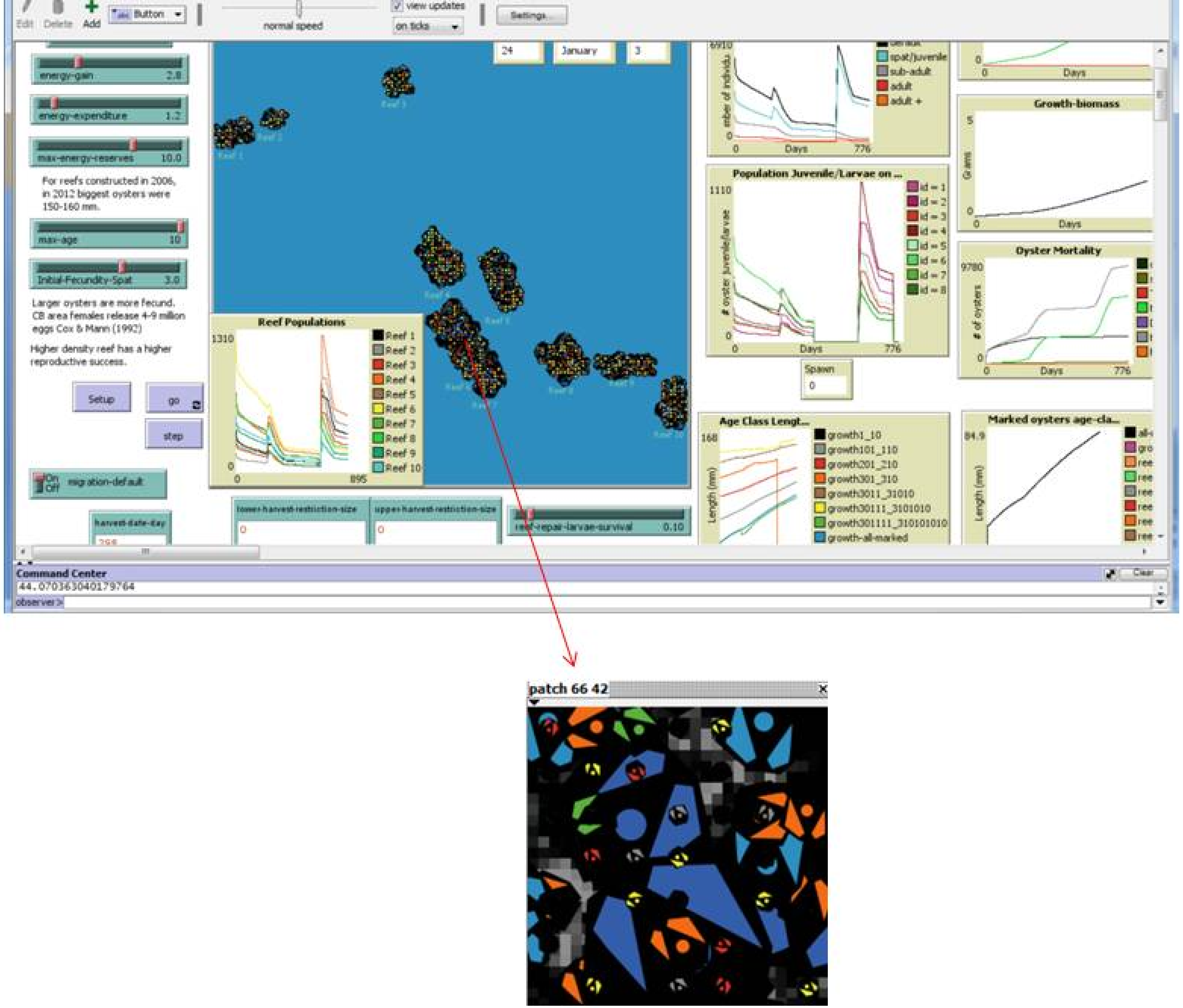
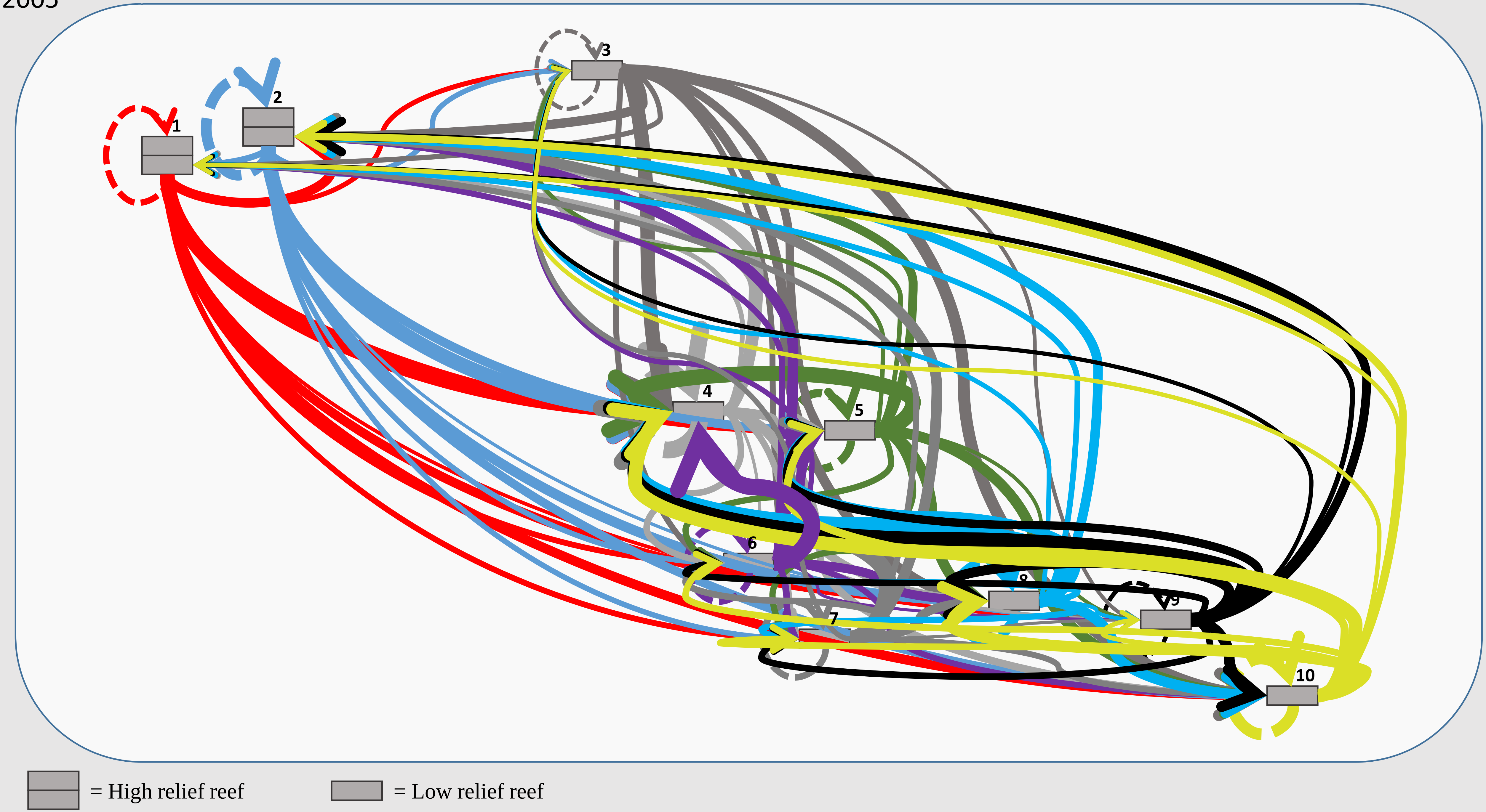


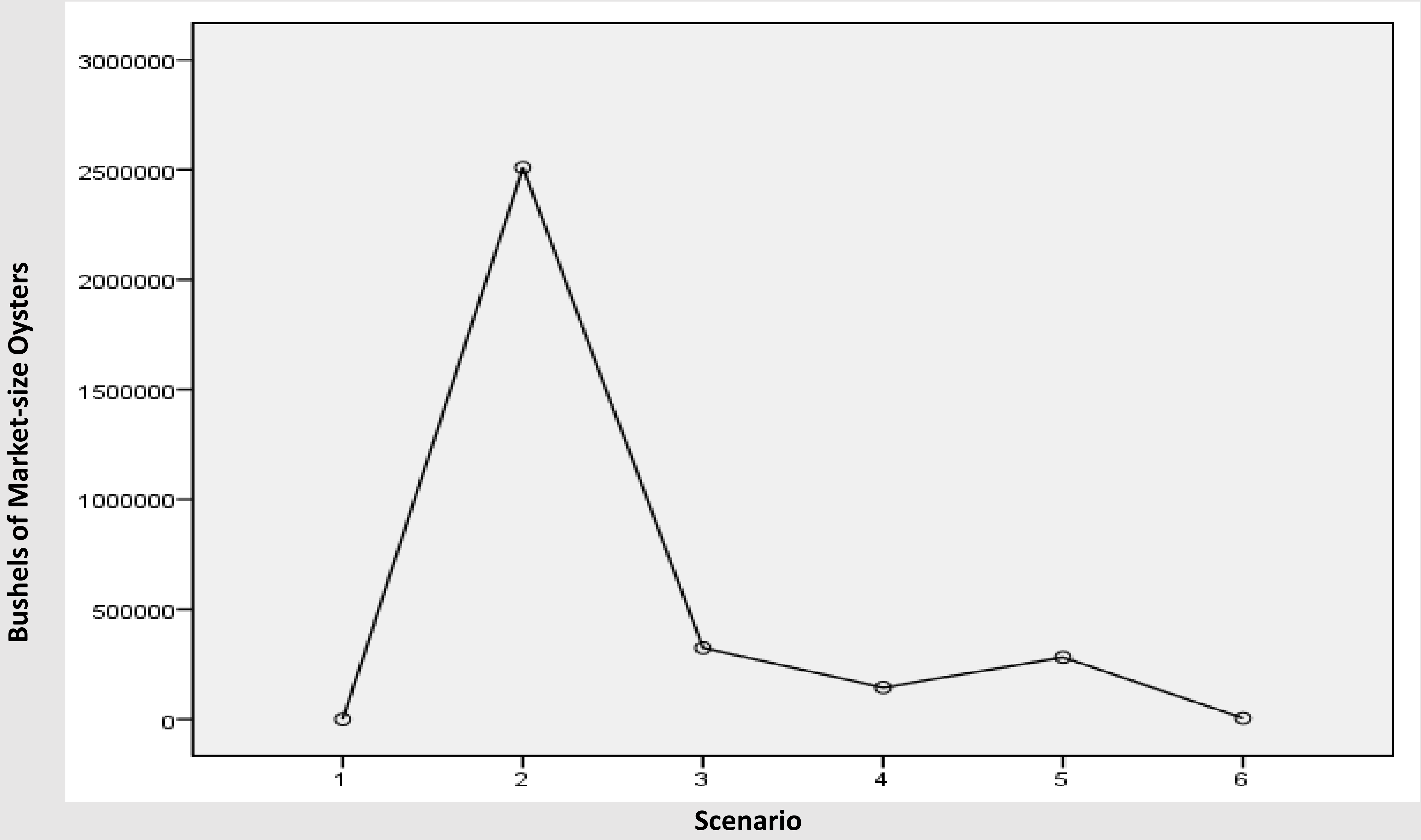
Figure 1. Map of Great Wicomico River watershed and ADH model domain. (A) Orange shaded area is the watershed drainage area, blue outlined area is ADH model boundaries and material types, and green points are Chesapeake Bay Program long term monitoring stations (B) enlarged view of location of 10 geo-referenced oyster reefs used for larval tracking and population dynamics models. Reefs are numbered for simplicity.



Edit
Delete
Add
Button
normal speed
view updates
on ticks
Settings...
24
January
3
energy-gain 2.8
energy-expenditure 1.2
max-energy-reserves 10.0
For reefs constructed in 2006, in 2012 biggest oysters were 150-160 mm.
max-age 10
Initial-Fecundity-Spat 3.0
Larger oysters are more fecund. CB area females release 4-9 million eggs Cox & Mann (1992)
Higher density reef has a higher reproductive success.
Setup
go
step
migration-default
harvest-date-day
Reef Populations
Reef 1
Reef 2
Reef 3
Reef 4
Reef 5
Reef 6
Reef 7
Reef 8
Reef 9
Reef 10
lower-harvest-restriction-size
upper-harvest-restriction-size
reef-repair-larvae-survival 0.10
spat/juvenile
sub-adult
adult
adult +
Days
Population Juvenile/Larvae on ...
# oyster juvenile/larvae
id = 1
id = 2
id = 3
id = 4
id = 5
id = 6
id = 7
id = 8
Spawn
Age Class Lengt...
Length (mm)
growth1_10
growth101_110
growth201_210
growth301_310
growth3011_31010
growth30111_3101010
growth301111_310101010
growth-all-marked
Growth-biomass
Grams
Oyster Mortality
# of oysters
Marked oysters age-cla...
Command Center
44.070363040179764
observer>
Clear
patch 66 42

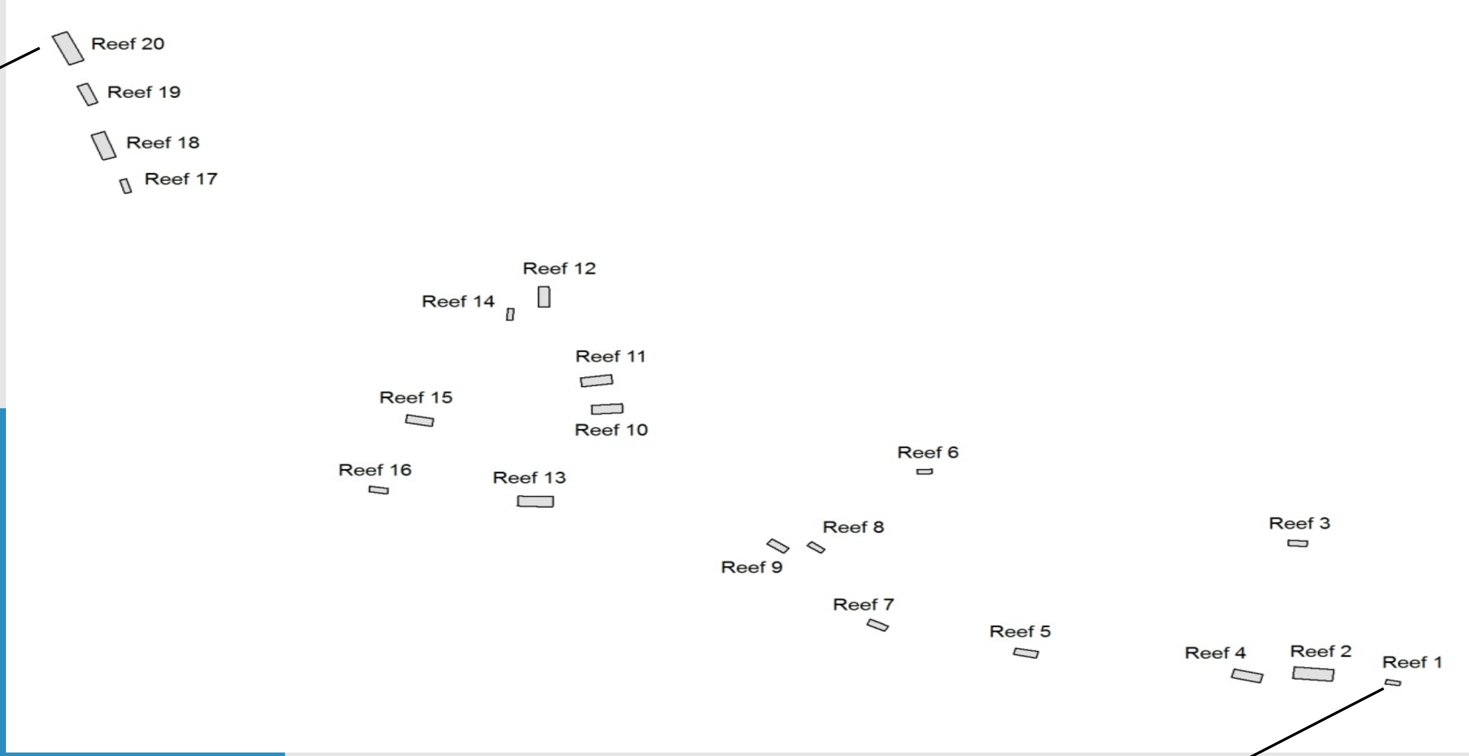
2005

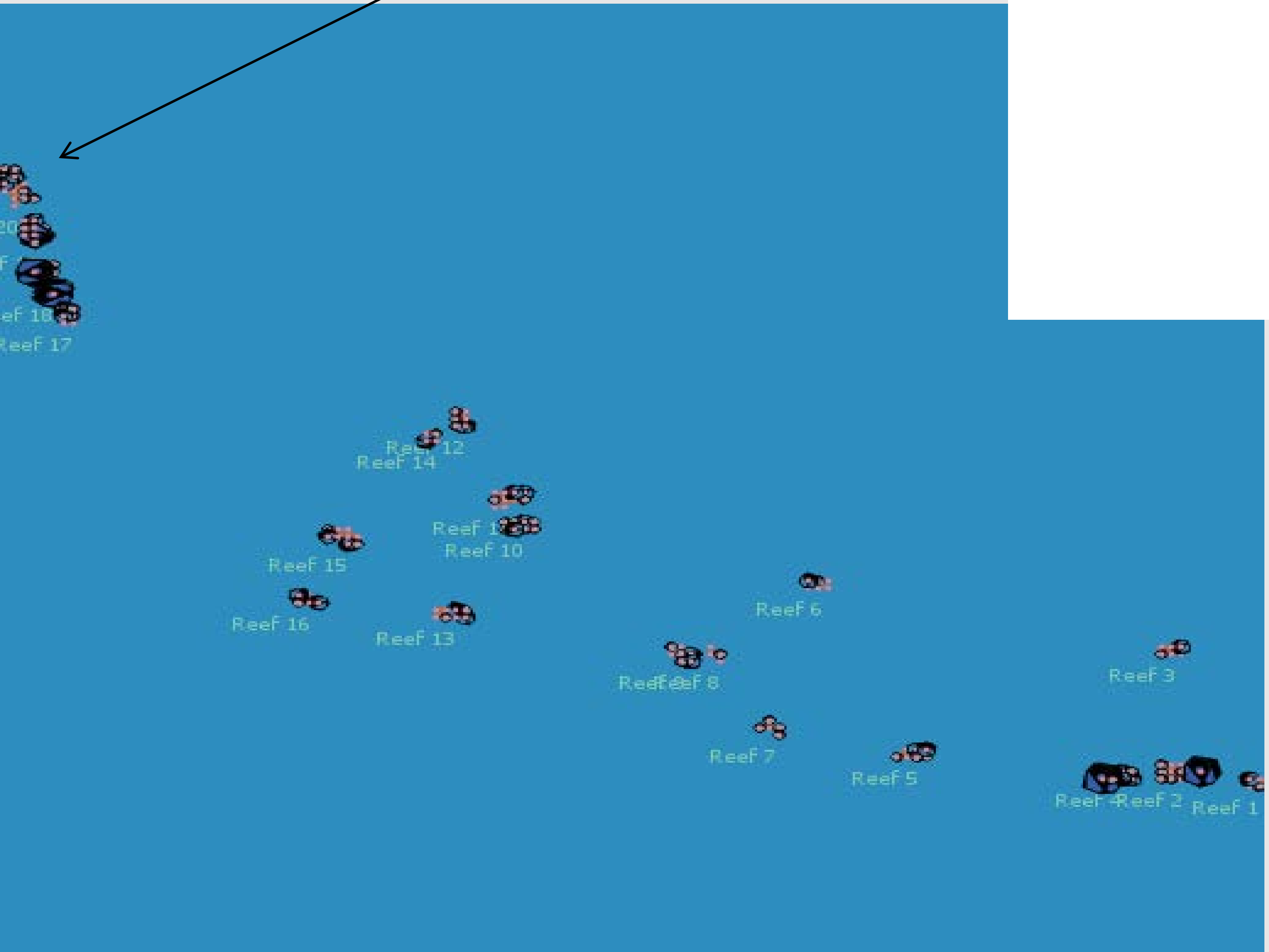




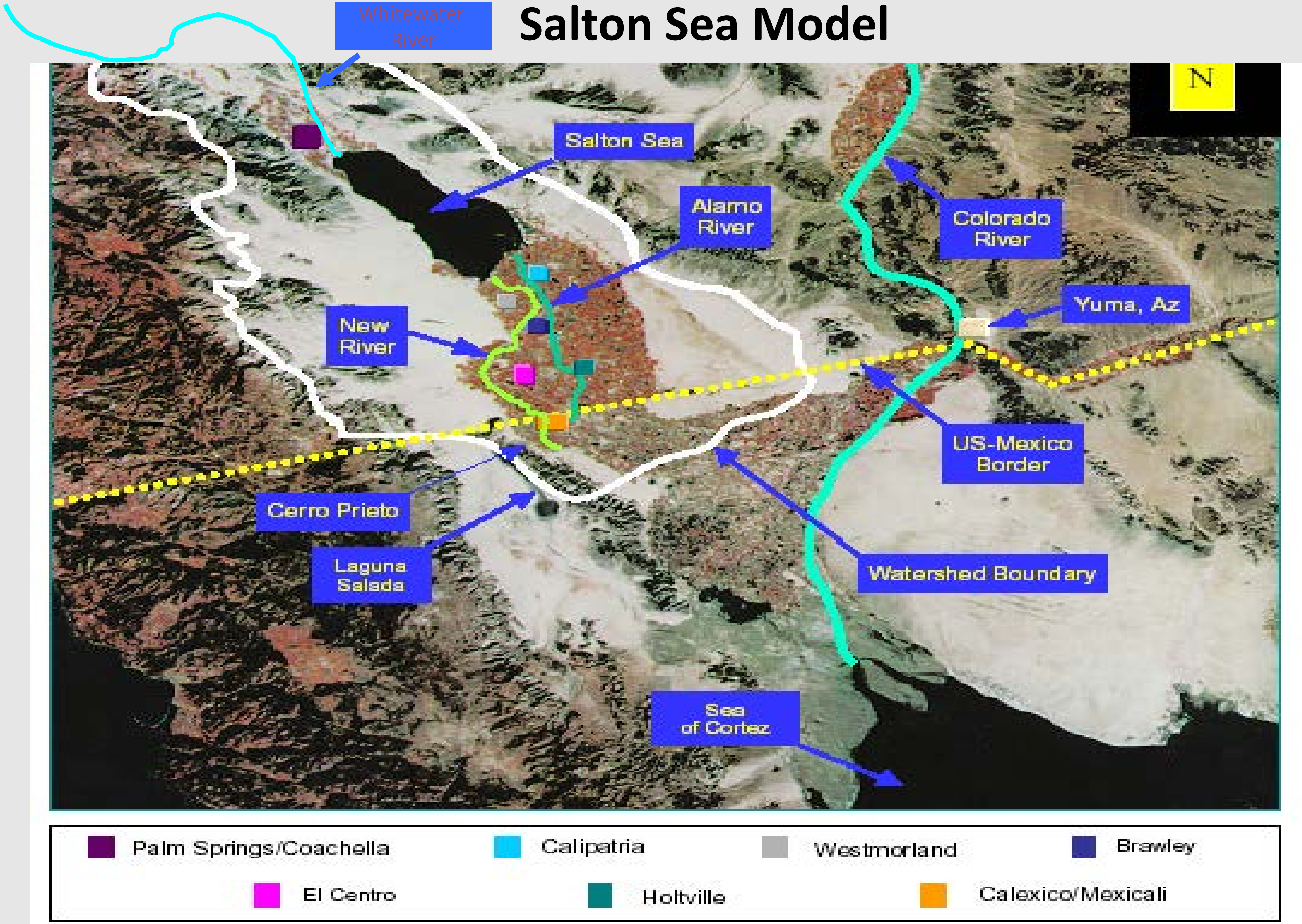
Bushels of Market-size Oysters
3000000
2500000
2000000
1500000
1000000
500000
0
1
2
3
4
5
6
Scenario

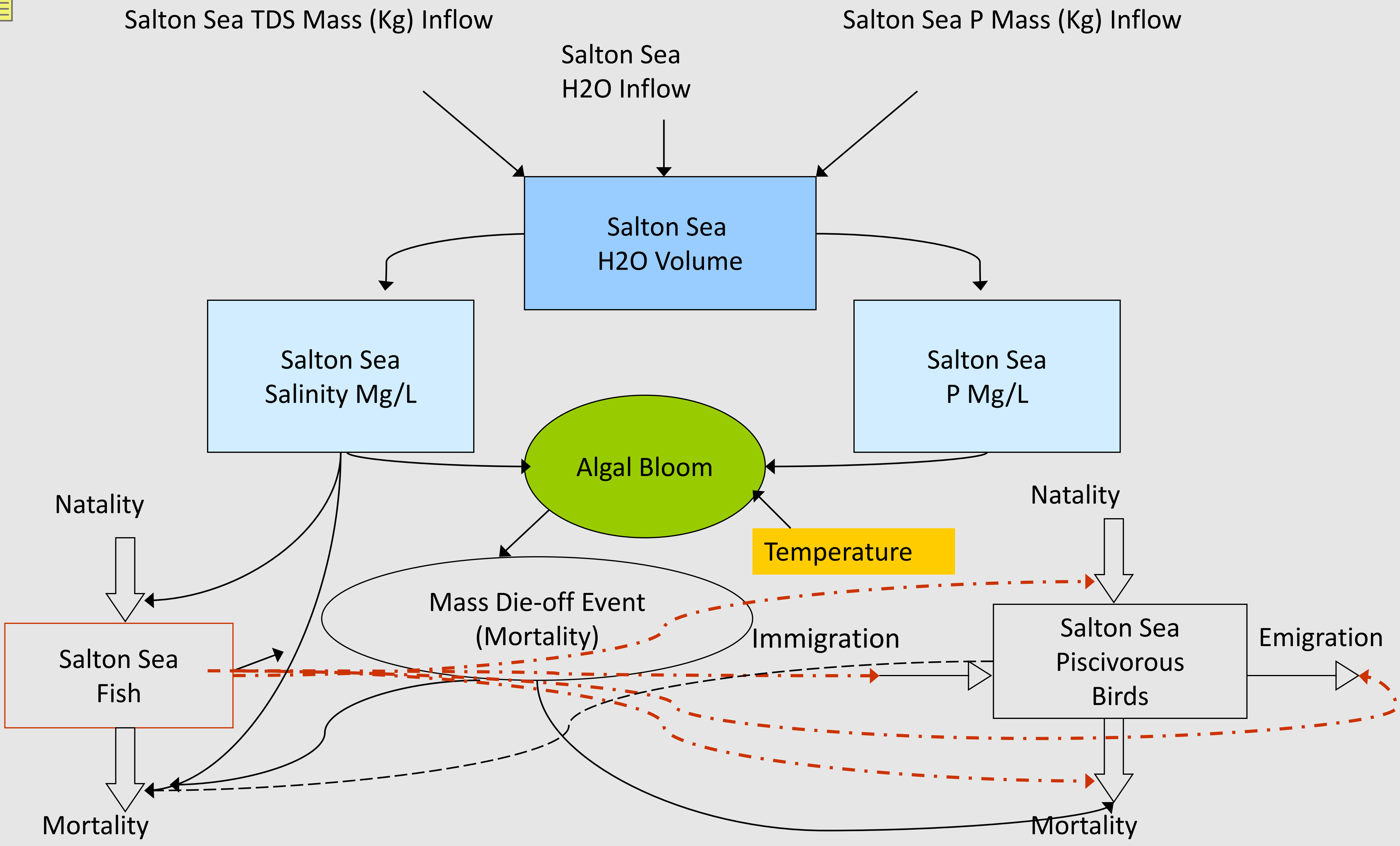
Rappahannock River

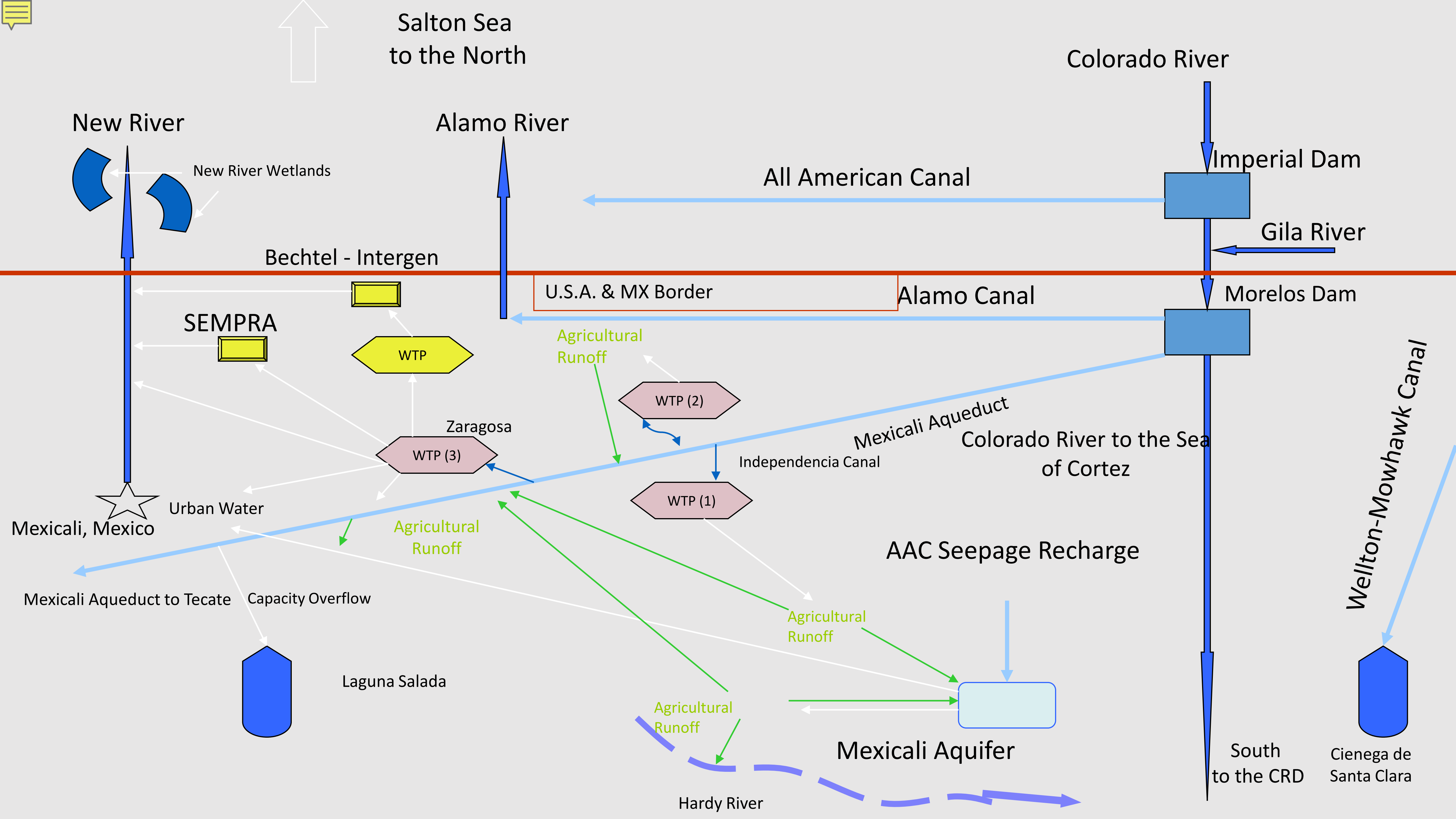




Salton Sea Model

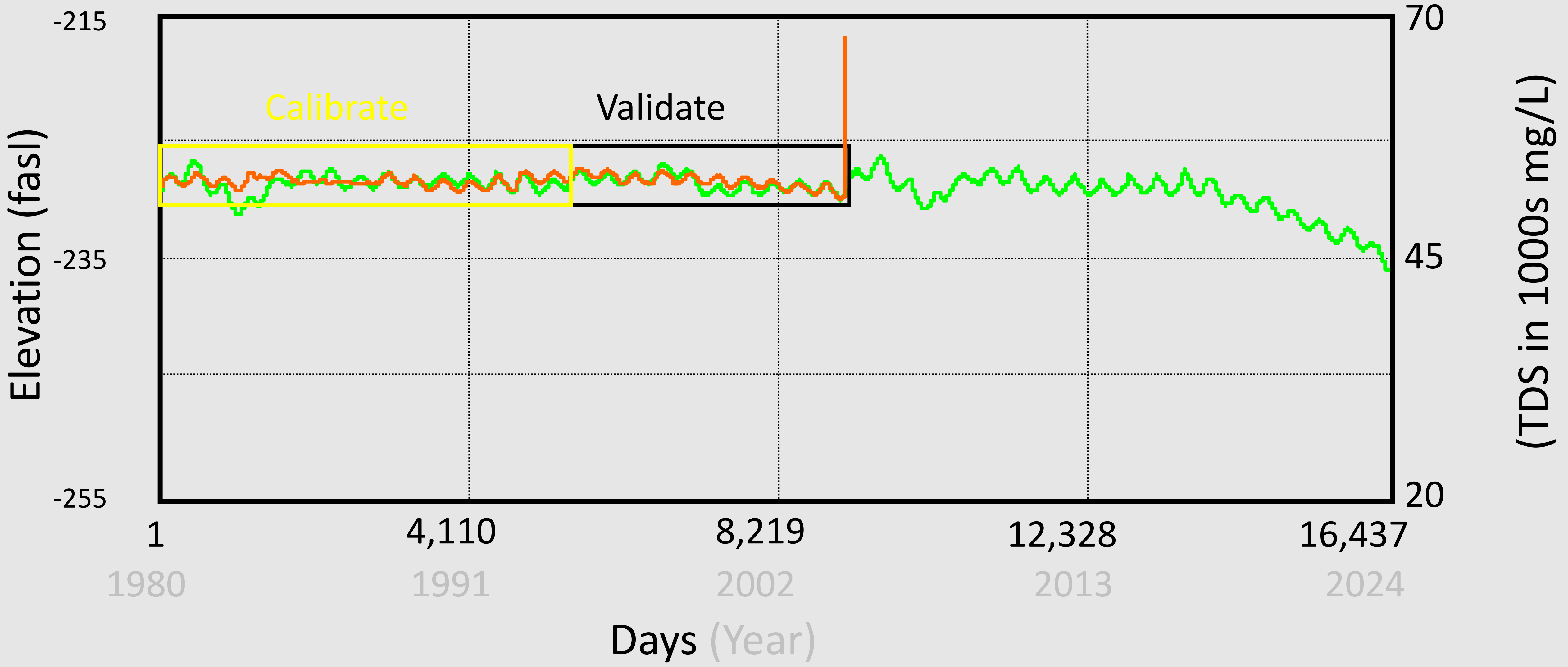



Salton Sea TDS Mass (Kg) Inflow
Salton Sea H2O Inflow
Salton Sea P Mass (Kg) Inflow
Salton Sea H2O Volume
Salton Sea Salinity Mg/L
Salton Sea P Mg/L
Algal Bloom
Temperature
Natality
Natality
Mass Die-off Event (Mortality)
Salton Sea Fish
Immigration
Salton Sea Piscivorous Birds
Emigration
Mortality
Mortality

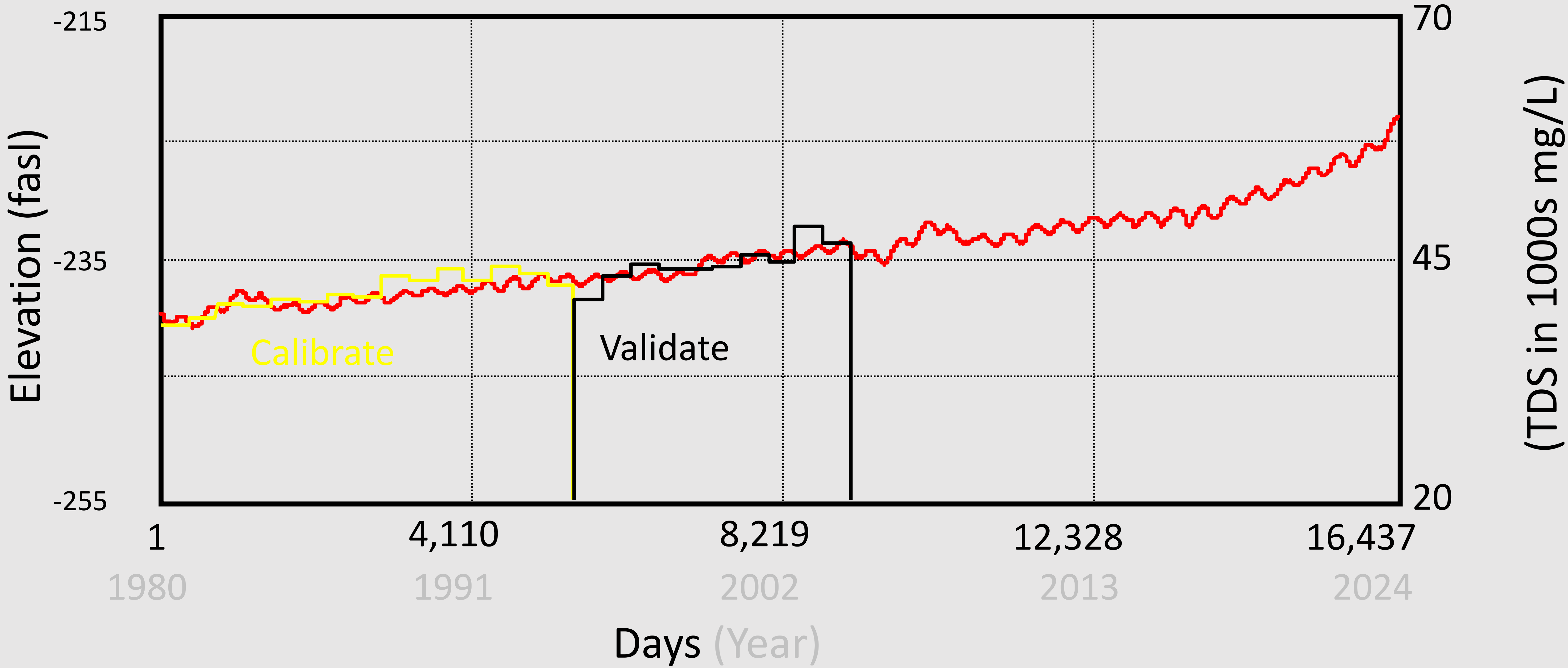


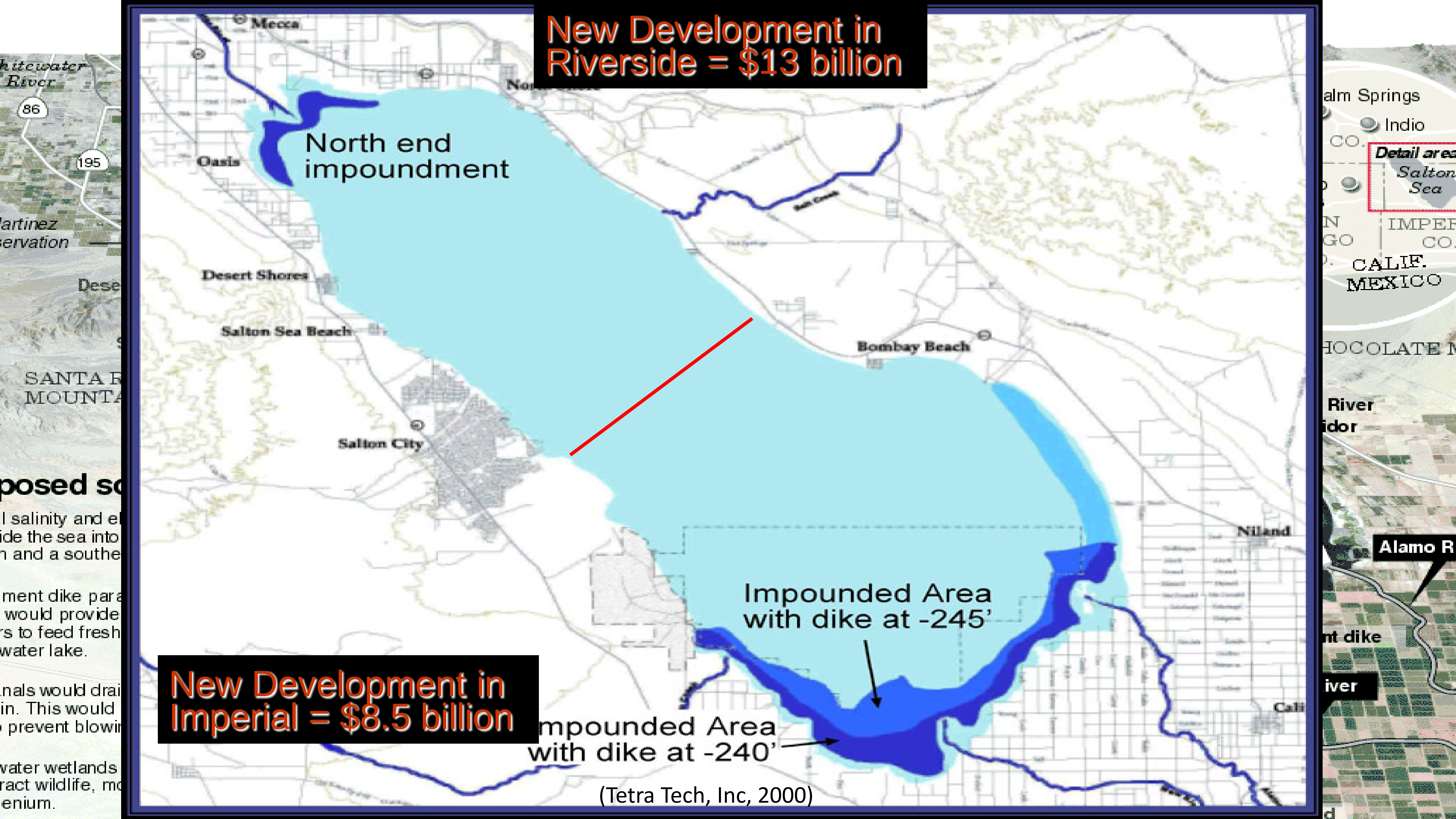
Salton Sea
to the North
Colorado River
New River
Alamo River
New River Wetlands
Imperial Dam
All American Canal
Gila River
Bechtel - Intergen
U.S.A. & MX Border
Alamo Canal
Morelos Dam
SEMPRA
WTP
Agricultural
Runoff
WTP (2)
Wellton-Mowhawk Canal
Mexicali Aqueduct
Zaragosa
Colorado River to the Sea
of Cortez
WTP (3)
Independencia Canal
WTP (1)
Urban Water
Mexicali, Mexico
Agricultural
Runoff
AAC Seepage Recharge
Mexicali Aqueduct to Tecate
Capacity Overflow
Agricultural
Runoff
Laguna Salada
Agricultural
Runoff
Mexicali Aquifer
South
to the CRD
Cienega de
Santa Clara
Hardy River

Sea Baseline Elevation: Calibrate & Validate

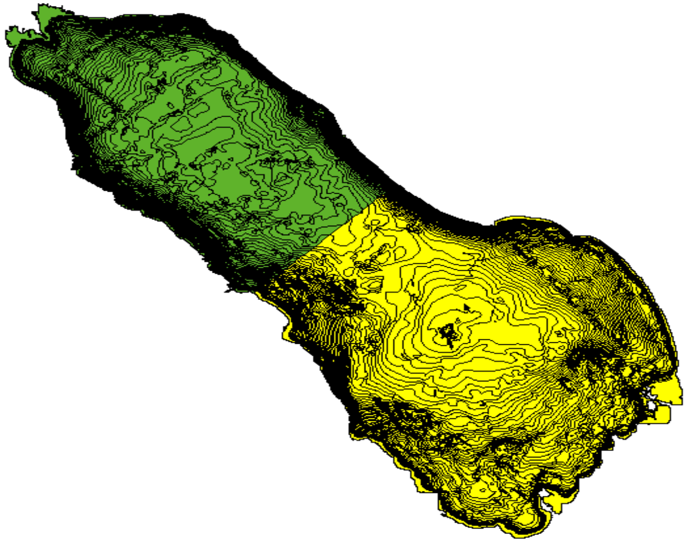


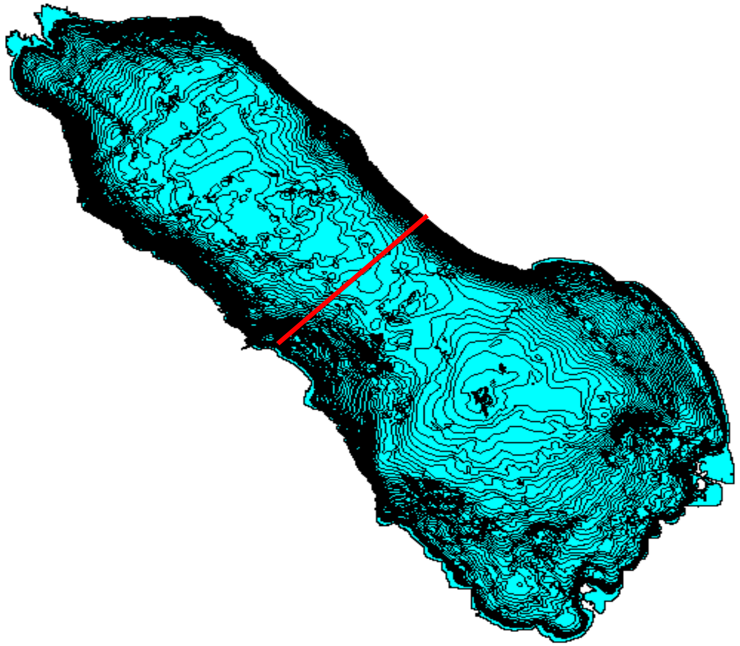
Sea Baseline Salinity: Calibrate & Validate

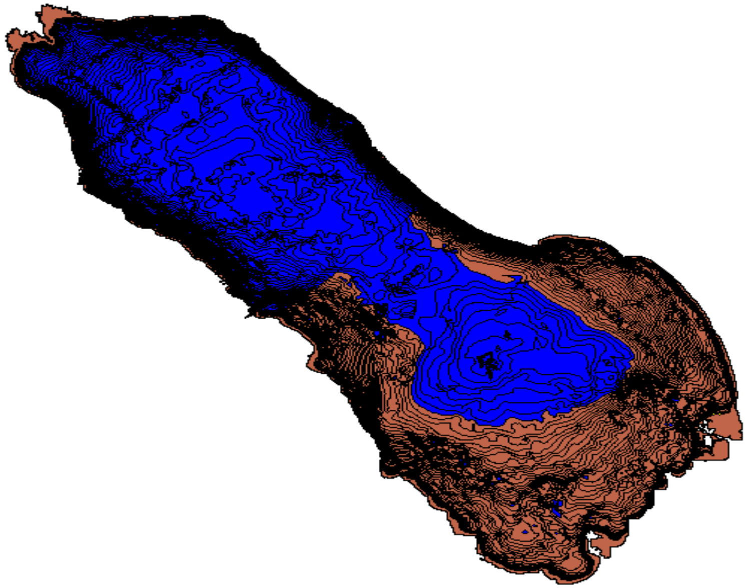


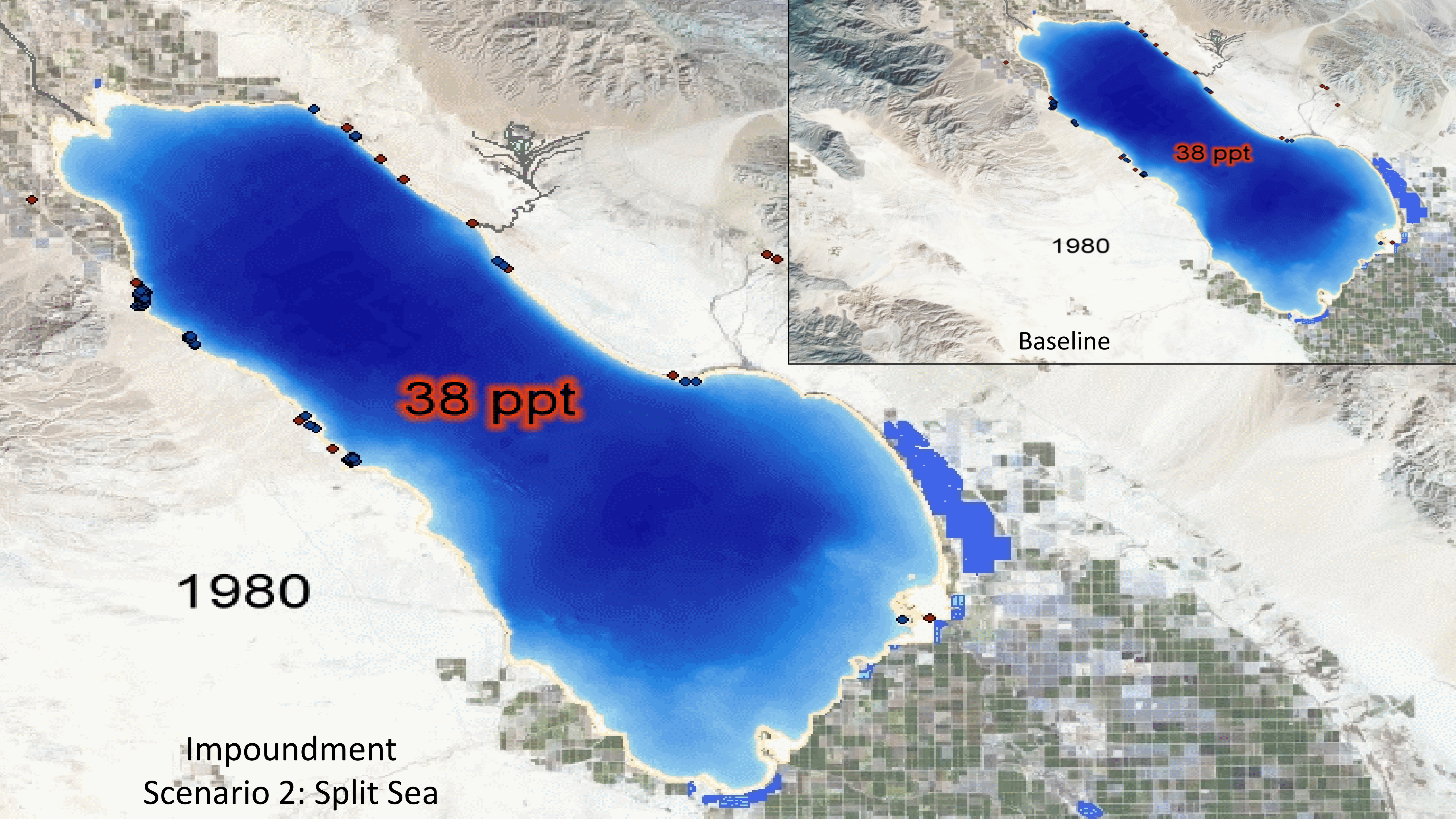


(Tetra Tech, Inc, 2000)








38 ppt
1980
Baseline
38 ppt
1980
Impoundment
Scenario 2: Split Sea

NEW RIVER WETLANDS PROJECT

California's Wetlands:

1780: 5 million acres

1999: 450,000 acres

www.newriverwetlands.com

NEW RIVER WETLANDS PROJECT

Site	Water Volume	Wet Acres	Retention Time	Flow Rate	Max. Depth
Imperial	127 Acre ft	22.7	18 days	4 cfs	Sed: 14 ft
					cells: 4 ft
Brawley	21 Acre ft	6	9 days	1 cfs	Sed: 10 ft
					cells: 4 ft

NEW RIVER WETLANDS PROJECT

DO = Dissolved Oxygen

N = Nitrogen

P = Phosphorus

BOD = Biochemical Oxygen Demand

TSS = Total Suspended Solids

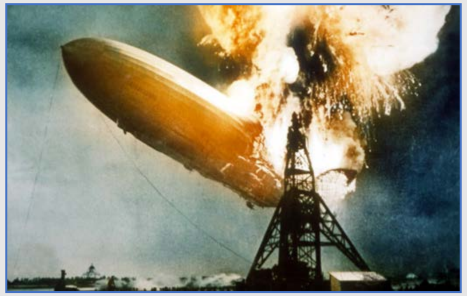
Imperial Site Monitoring Summary (Averages) 2001

	Inlet(Mg/L)	Outlet(Mg/L)	% Change
DO	7.92	10.95	28% Incr.
Total N	5.8	3.5	40% Decr.
Total P	1.95	0.57	71% Decr.
Selenium	0.007	0.005	29% Decr.
BOD	20	15	25% Decr.
Fecal Coliform	1,998	76	96% Decr.
TSS	179	19	89% Decr.

Brawley Site Monitoring Results (Averages) 2001

	Inlet (Mg/L)	Outlet (Mg/L)	% Change
DO	3.67	10.83	66% Incr.
Total N	0.9	0.9	0
Total P	1.59	0.73	54% Decr.
Selenium	0.011	0.008	27% Decr.
BOD	16	13	19% Decr.
Fecal Coliform	151,664	274	99.8% Decr.
TSS	543	13	98% Decr.

Model Communication...a Disaster!



The problem with communication

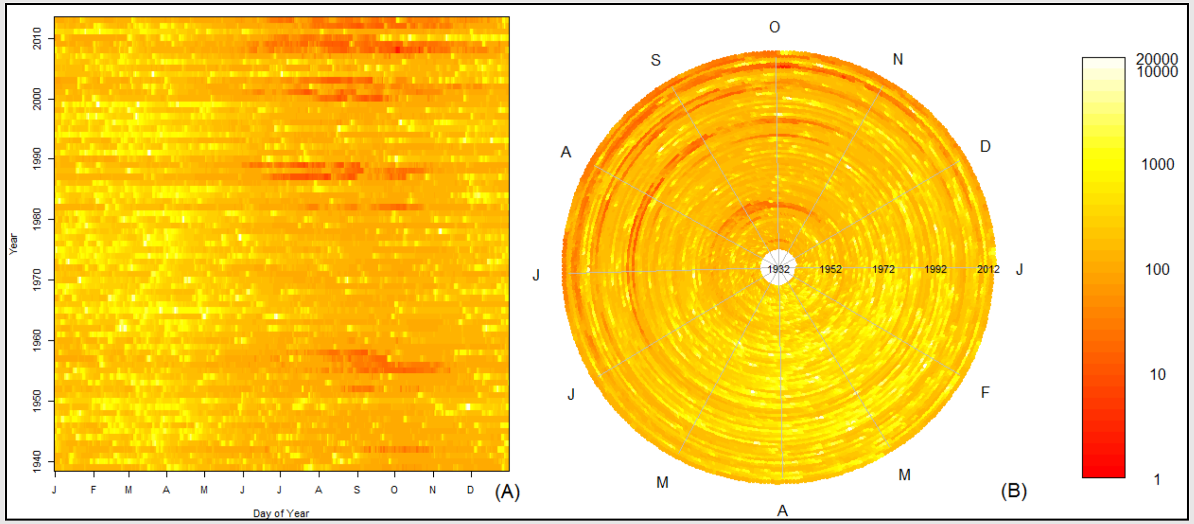
- Most ignored aspect of modeling
- Confusion over the meaning of "model"
- Preexisting notions prevent audience from understanding objective
- Very rarely do we
  - Analyze audience
  - Anticipate potential obstacles

Communicate twice (at least)

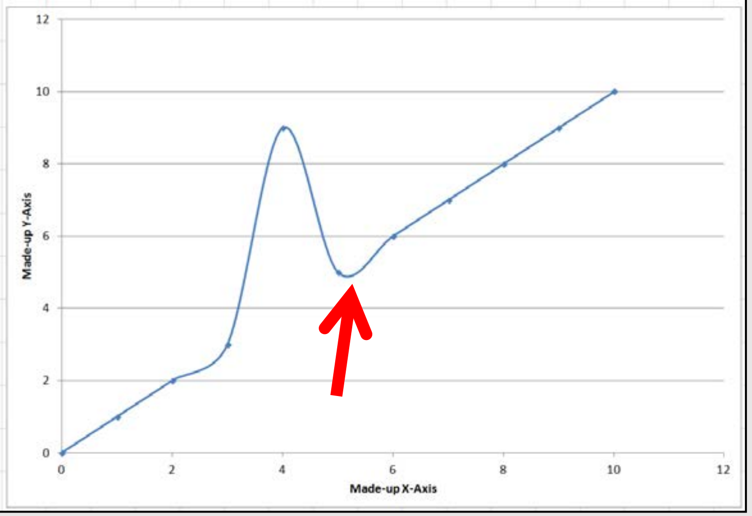
- Development document
  - The team may need a model document, code document, separate set of visualization, etc.
- Technical documentation
  - Each stage of model development should be thoroughly documented, including equations and assumptions
- Communicating to non-technical audiences
  - How do we communicate to non-modelers, stakeholders, general public, etc...

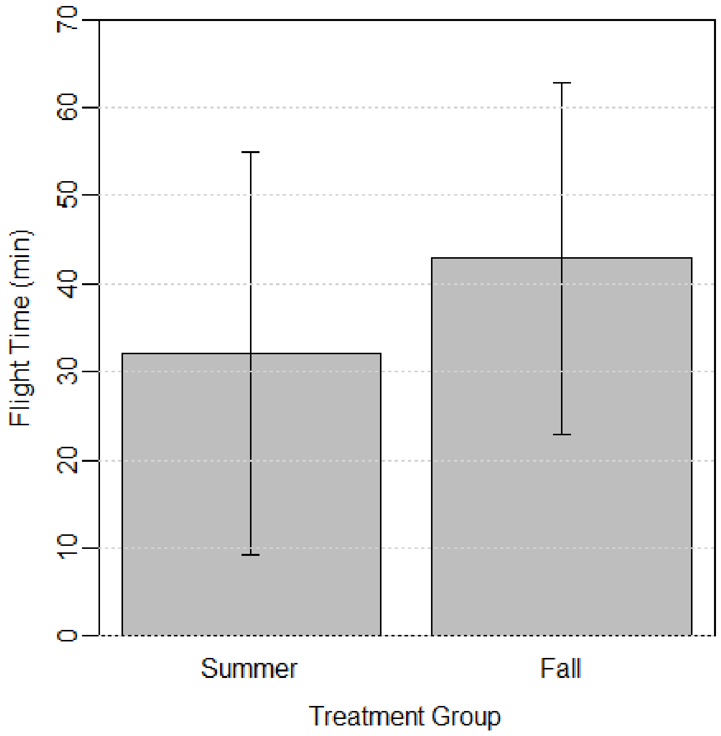
Communication

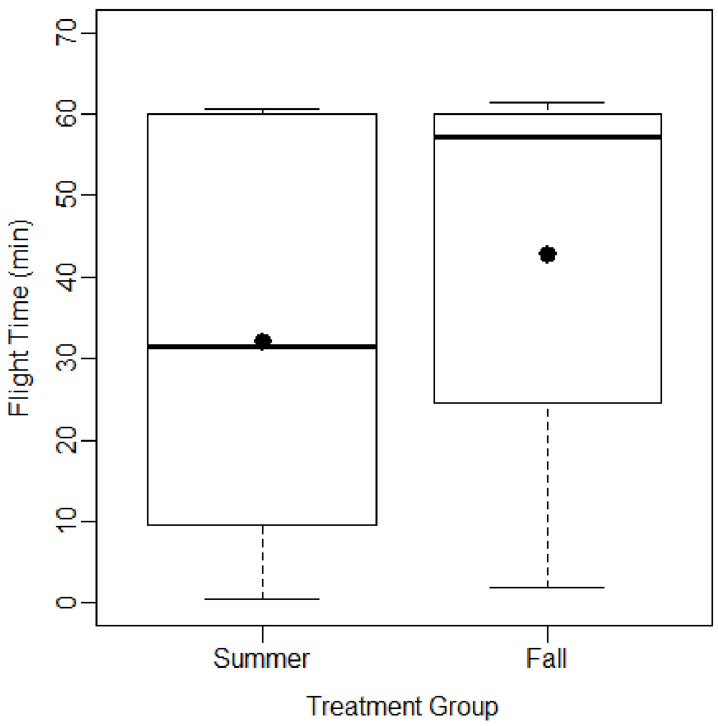
- Telling your story is as (or more) important than having a great model
- Think about what details should (and should not) be passed along
  - e.g., basic ecological premise v. looping structure
- Plots require thinking, not just throwing the data into Excel haphazardly
  - There are more techniques than line plots
  - Choose the right plot for the job
  - Never use the “smooth” line function

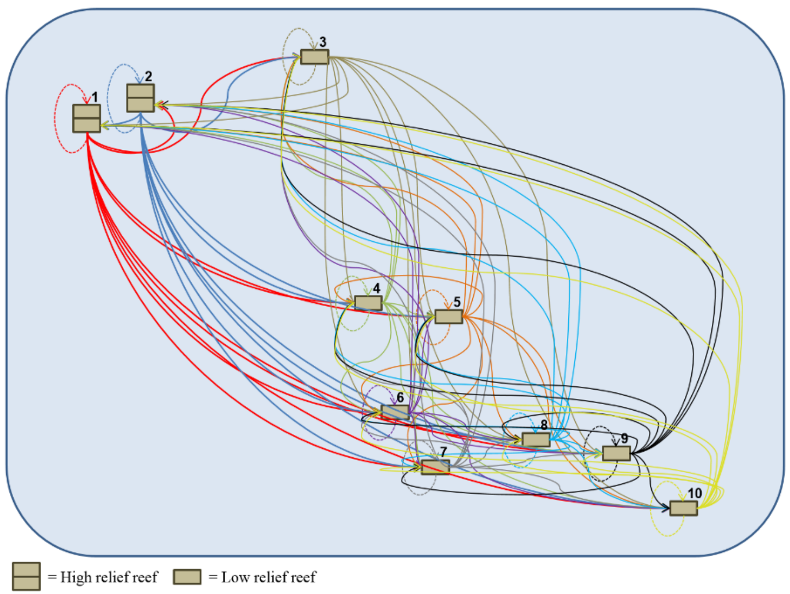


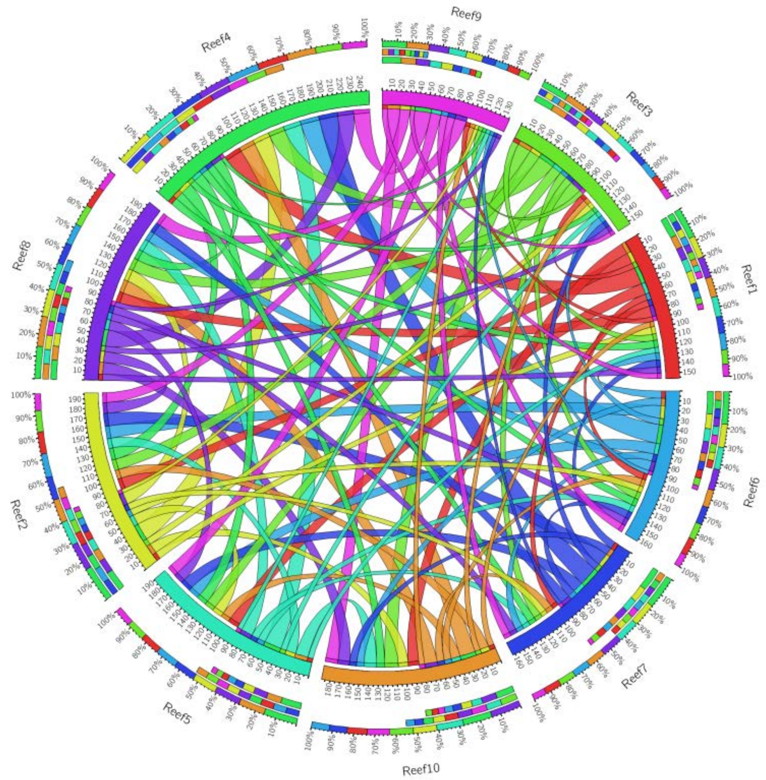
x	y
0	0
1	1
2	2
3	3
4	9
5	5
6	6
7	7
8	8
9	9
10	10




Flight Time (min)
0
10
20
30
40
50
60
70
Summer
Fall
Treatment Group


Flight Time (min)
0
10
20
30
40
50
60
70
Summer
Fall
Treatment Group


1
2
3
4
5
6
7
8
9
10
= High relief reef
= Low relief reef


Reef9
Reef3
Reef1
Reef6
Reef7
Reef10
Reef5
Reef2
Reef8
Reef4

CONCLUSIONS: FANTASTIC MODELS AND WHERE TO FIND THEM

ELSEVIER

Ecological Informatics

Available online 21 June 2017

In Press, Accepted Manuscript

Salton Sea days of future past: Modeling impacts of alternative water transfer scenarios on fish and bird population dynamics

Michael E. Kjelland[a], Todd M. Swannack[a, b]

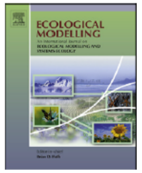
Ecological Modelling 360 (2017) 244–251

ELSEVIER

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel



Beyond graphs and tables: Enhancing explanatory power of complex environmental simulations through 3D printed model output

CrossMark

Michael E. Kjelland[a,*], Candice D. Piercy[a], Todd M. Swannack[a,b]

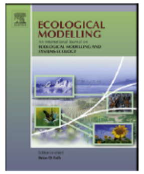
Ecological Modelling 308 (2015) 45–62

ELSEVIER

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel



An integrated modeling approach for elucidating the effects of different management strategies on Chesapeake Bay oyster metapopulation dynamics

CrossMark

Michael E. Kjelland[a], Candice D. Piercy[a], Tahirih Lackey[a], Todd M. Swannack[a,b,*]

Table of Contents | Author Guidelines | Submit a Manuscript

Advances in Meteorology

Volume 2014 (2014), Article ID 135012, 15 pages

http://dx.doi.org/10.1155/2014/135012

Research Article

A System Dynamics Approach to Modeling Future Climate Scenarios: Quantifying and Projecting Patterns of Evapotranspiration and Precipitation in the Salton Sea Watershed

Michael E. Kjelland,[1,2] Todd M. Swannack,[1] and William E. Grant[2]

[1]U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS 39180-6199, USA

[2]Department of Wildlife & Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA

FANTASTIC BEASTS AND WHERE TO FIND THEM

Acknowledgements: This webinar was made possible through funding by the Water Operations Technical Support Program (WOTS).

https://wots.el.erdc.dren.mil/