
MEXICO
Gulf of Mexico
CUBA
BELIZE
HONDURAS
GUATEMALA
EL SALVADOR
NICARAGUA
COSTA RICA
PANAMA
SOUTH AMERICA
Caribbean Sea

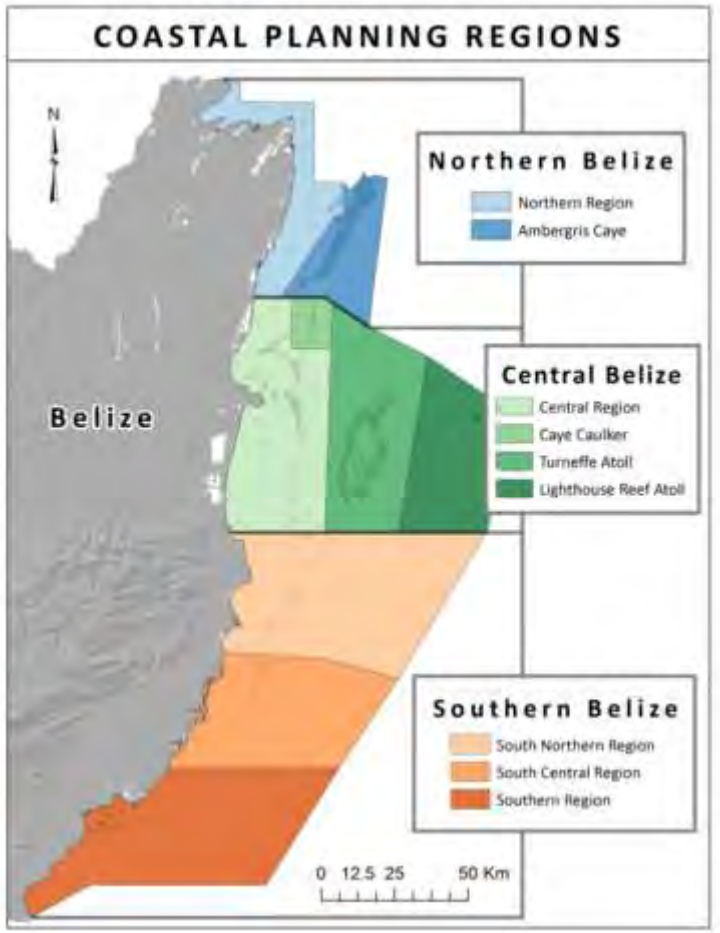
Integrated Coastal Zone Management Plan

Stakeholder engagement

Science

InVEST

integrated valuation of environmental services and tradeoffs



BELIZE COASTAL ZONE MANAGEMENT AUTHORITY & INSTITUTE

WWF

natural capital PROJECT

How did we use the InVEST models?

- Design spatial plan

Where should we site coastal and ocean uses to reduce risk to marine ecosystems and enhance the benefits they provide to people?

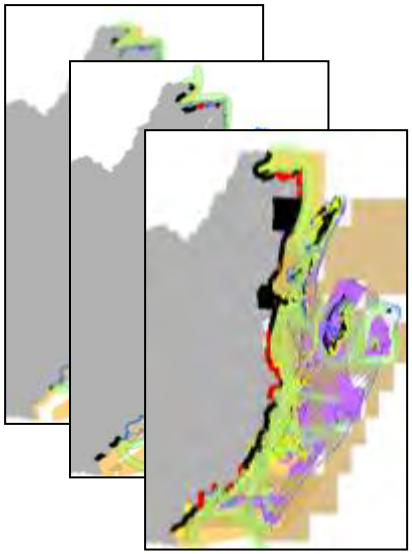
- Make the case for the plan

Which metrics for ecosystem services will resonate with stakeholders and decision-makers?

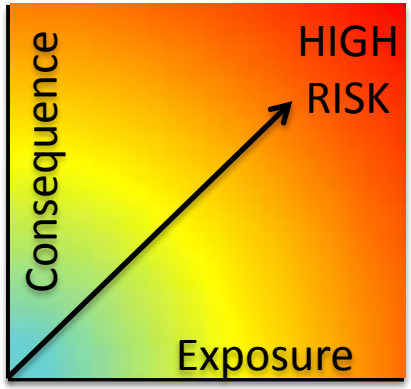
Modeling approach

Stakeholder, local scientists and government officials

Zoning Scheme



Risk to habitats



- Coral
- Mangroves
- Seagrass

Changes to magnitude and value of service

Fisheries

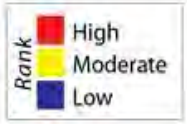
Coastal protection

Tourism opportunities

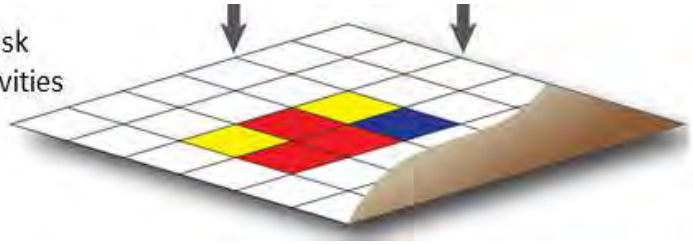
Guerry et al 2012, Clarke et al 2013

Habitat Risk Assessment

InVEST
integrated valuation of environmental services and tradeoffs



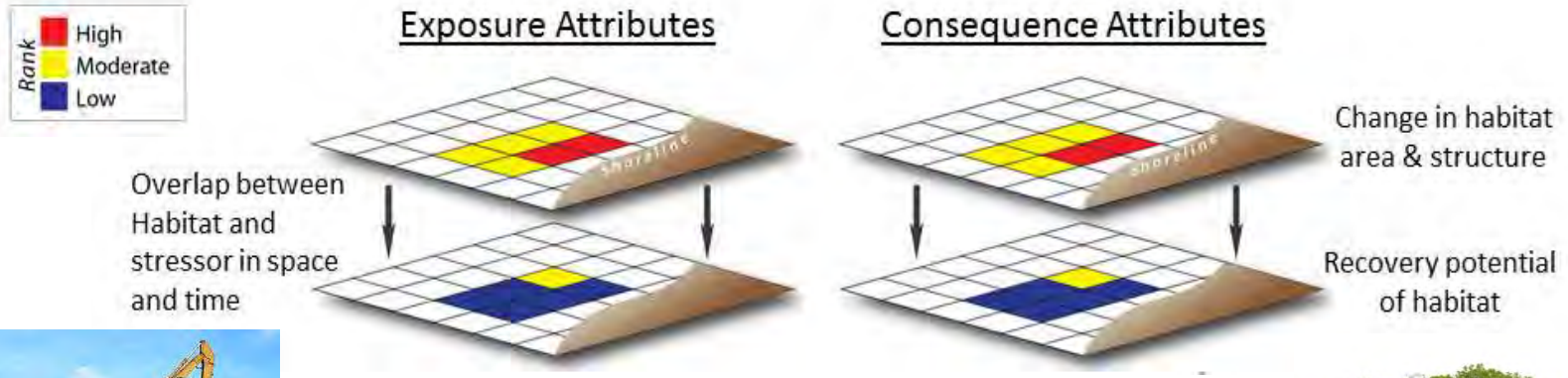
Output map of risk from human activities to habitats



Patrick et al. 2010, Samhouri & Levin 2012, Hobday et al. 2011, Arkema et al.

Habitat Risk Assessment

InVEST
integrated valuation of environmental services and tradeoffs

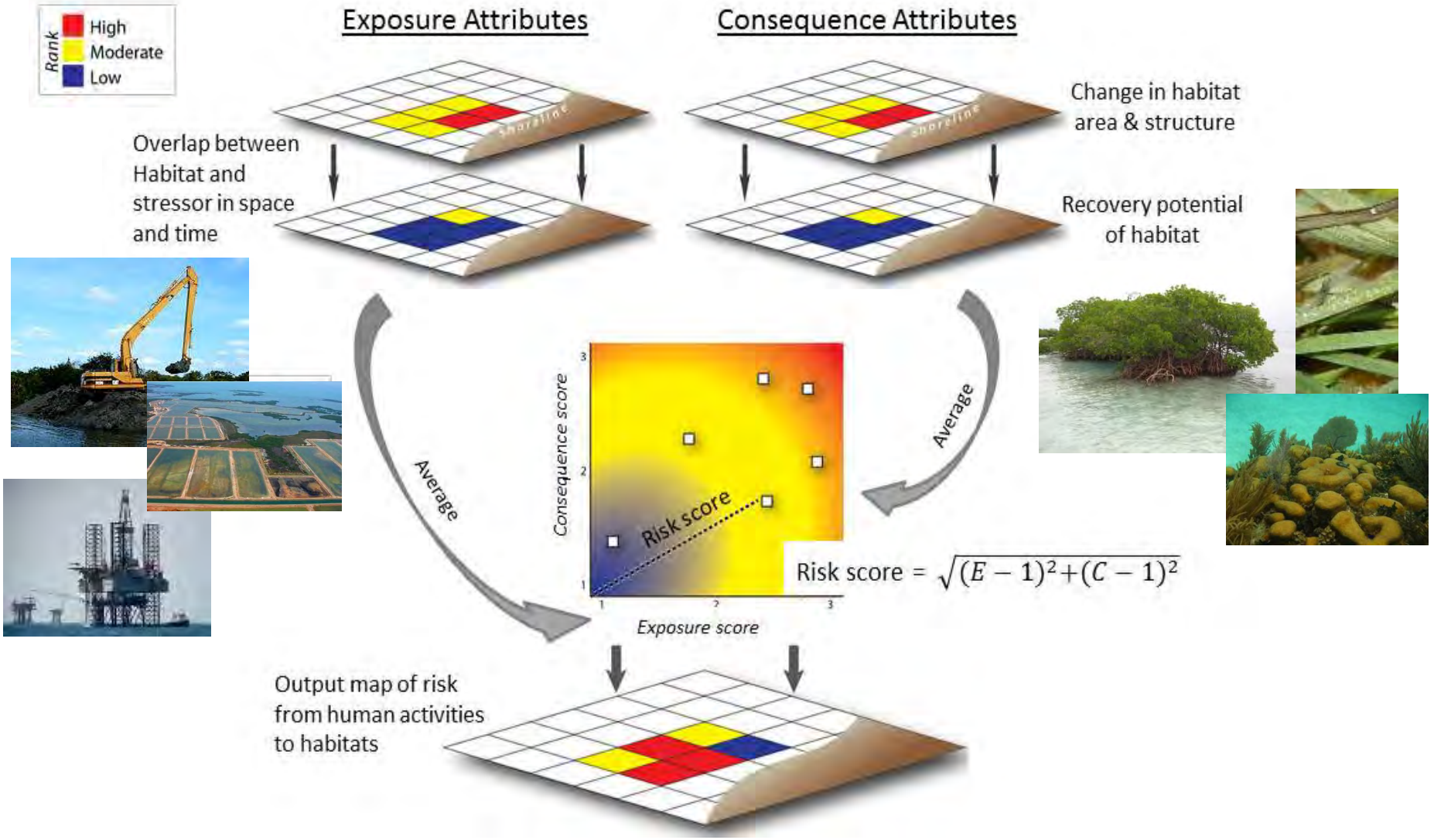


***Thalassia testudinum* 30-50%**
Zeiman 1975, Kaldy and Duncan 2000

	High (3)	Medium (2)	Low (1)
Exposure – spatial overlap	From input maps	From input maps	From input maps
Consequence – natural mortality	Low (0-20%)	Moderate (20-80%)	High (>80%)

Habitat Risk Assessment

InVEST
integrated valuation of environmental services and tradeoffs



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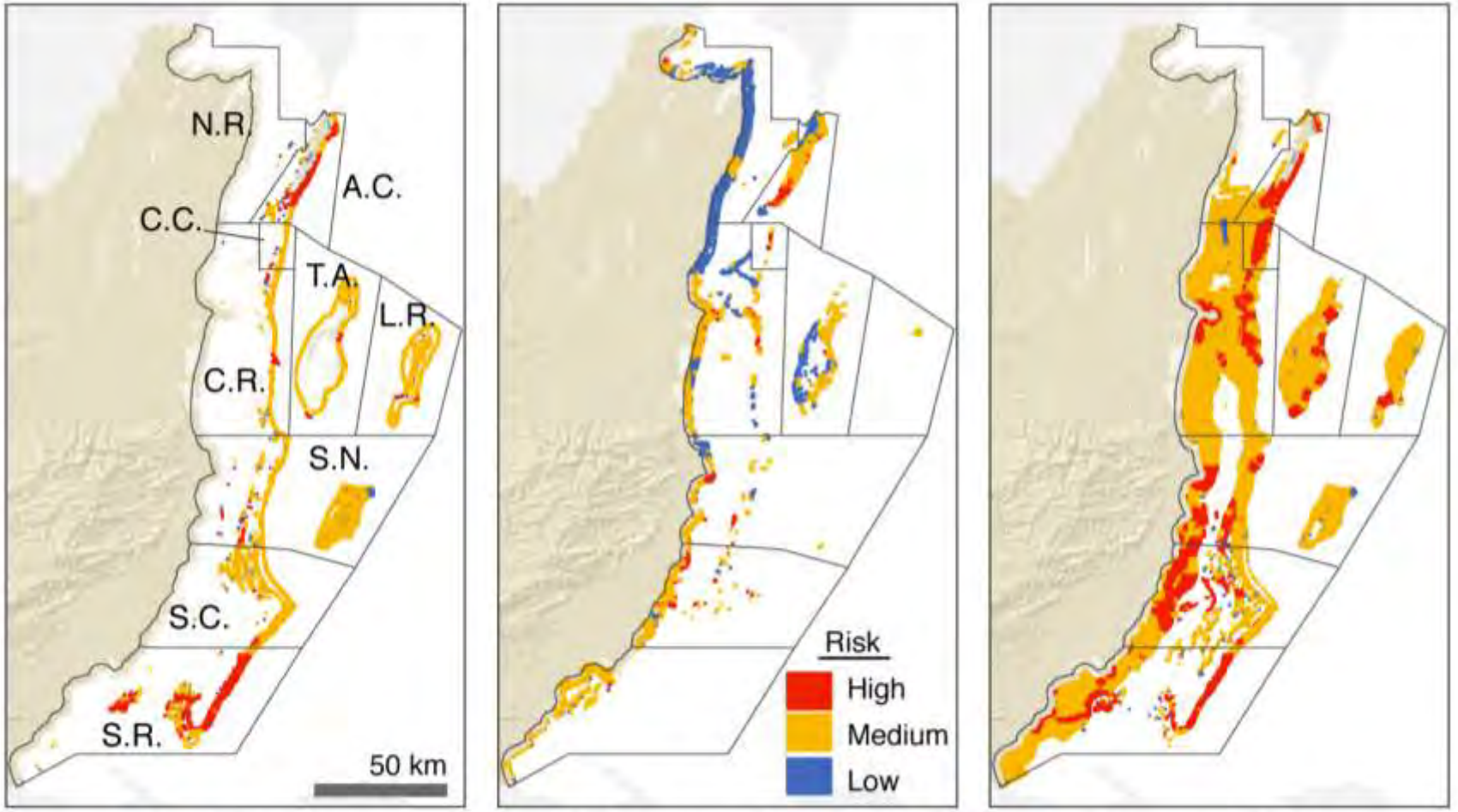
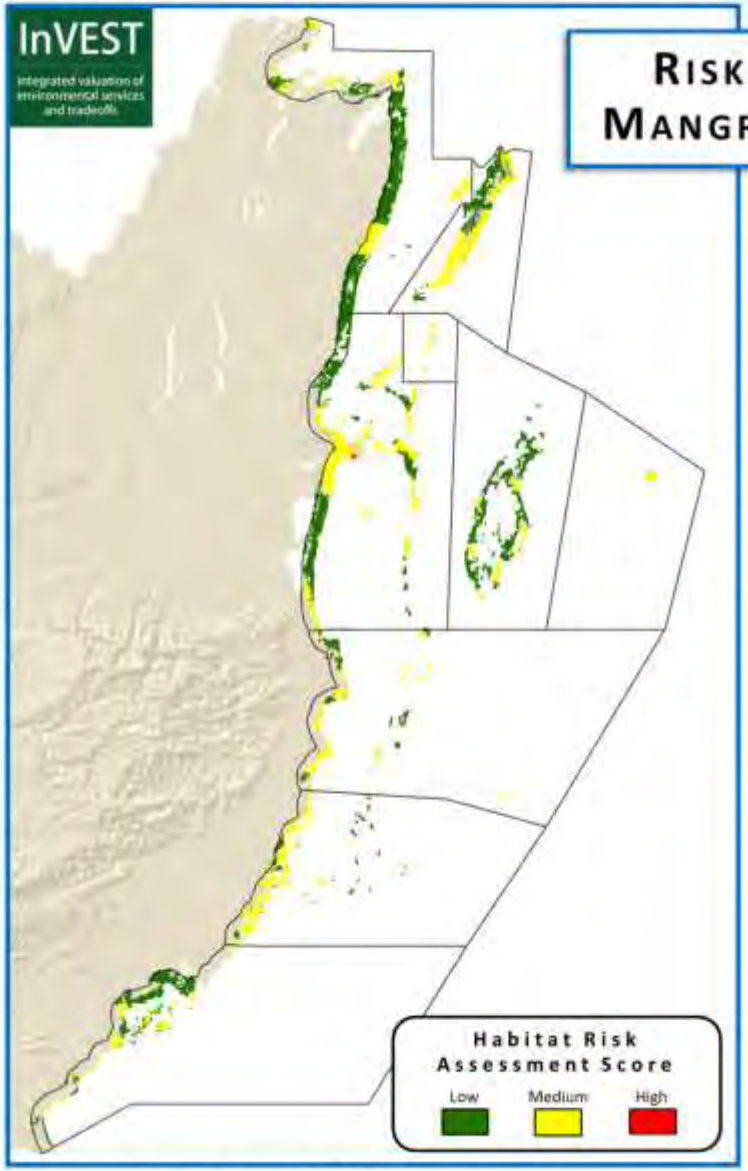
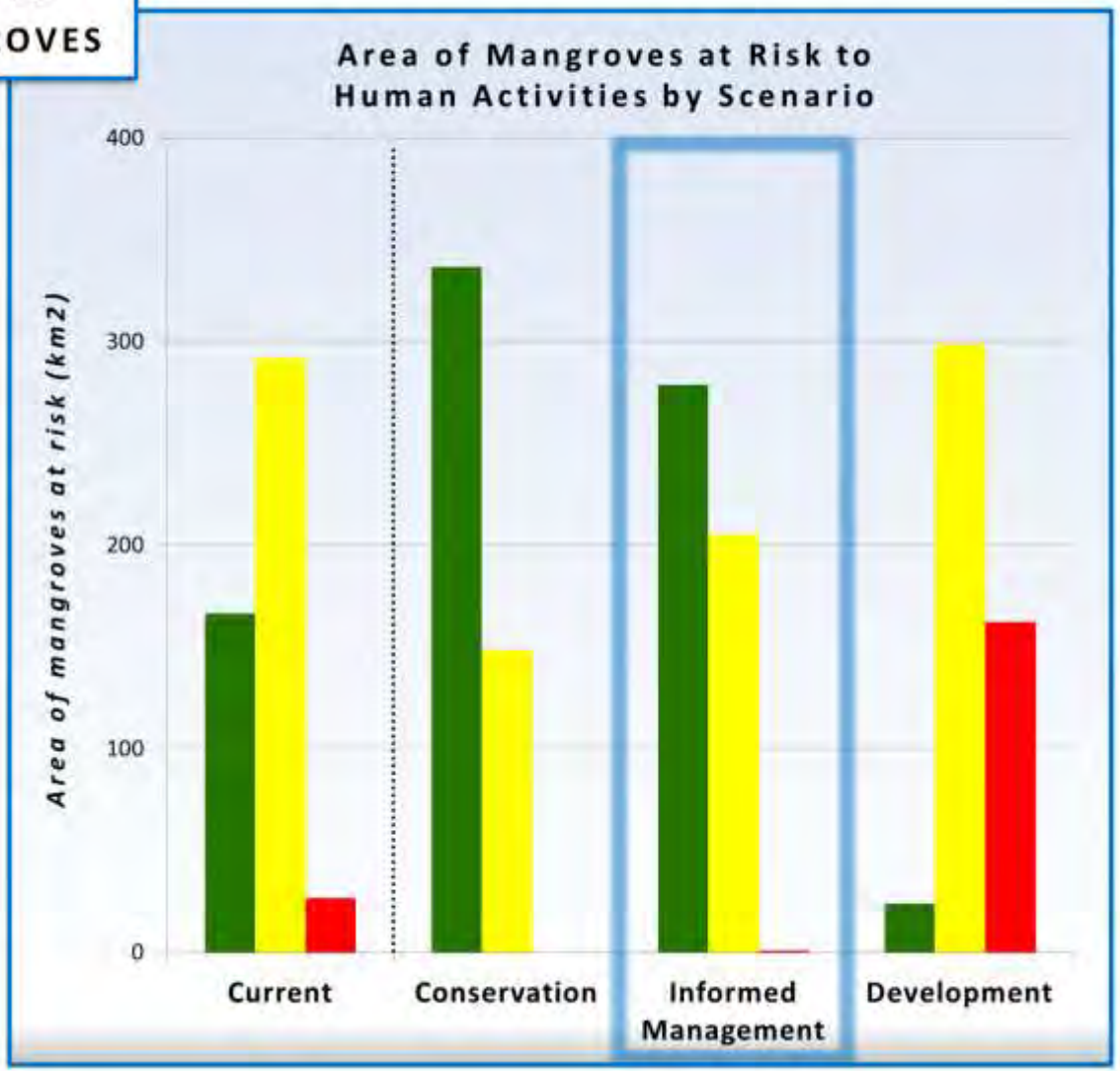

N.R.
A.C.
C.C.
T.A.
L.R.
C.R.
S.N.
S.C.
S.R.
50 km
Risk
High
Medium
Low
Coral reefs
Mangrove forests
Seagrass beds

Arkema et al.



INFORMED MANAGEMENT

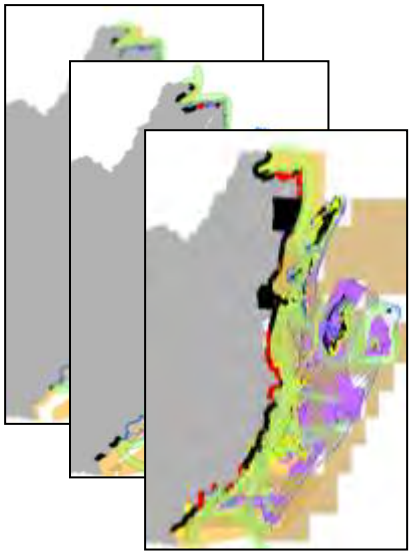


Clarke et al 2013

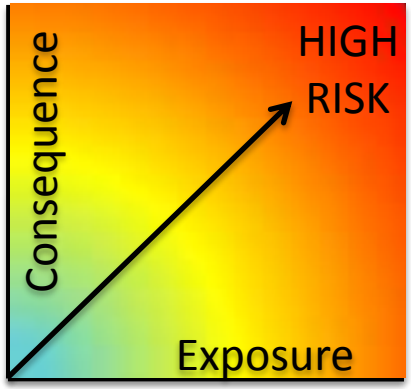
Modeling approach

Stakeholder, local scientists and government officials

Zoning Scheme



Risk to habitats



- Coral
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Changes to magnitude and value of service

Fisheries

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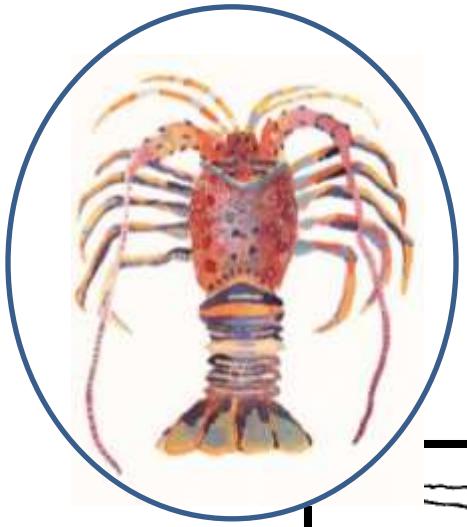
Guerry et al 2012, Clarke et al 2013

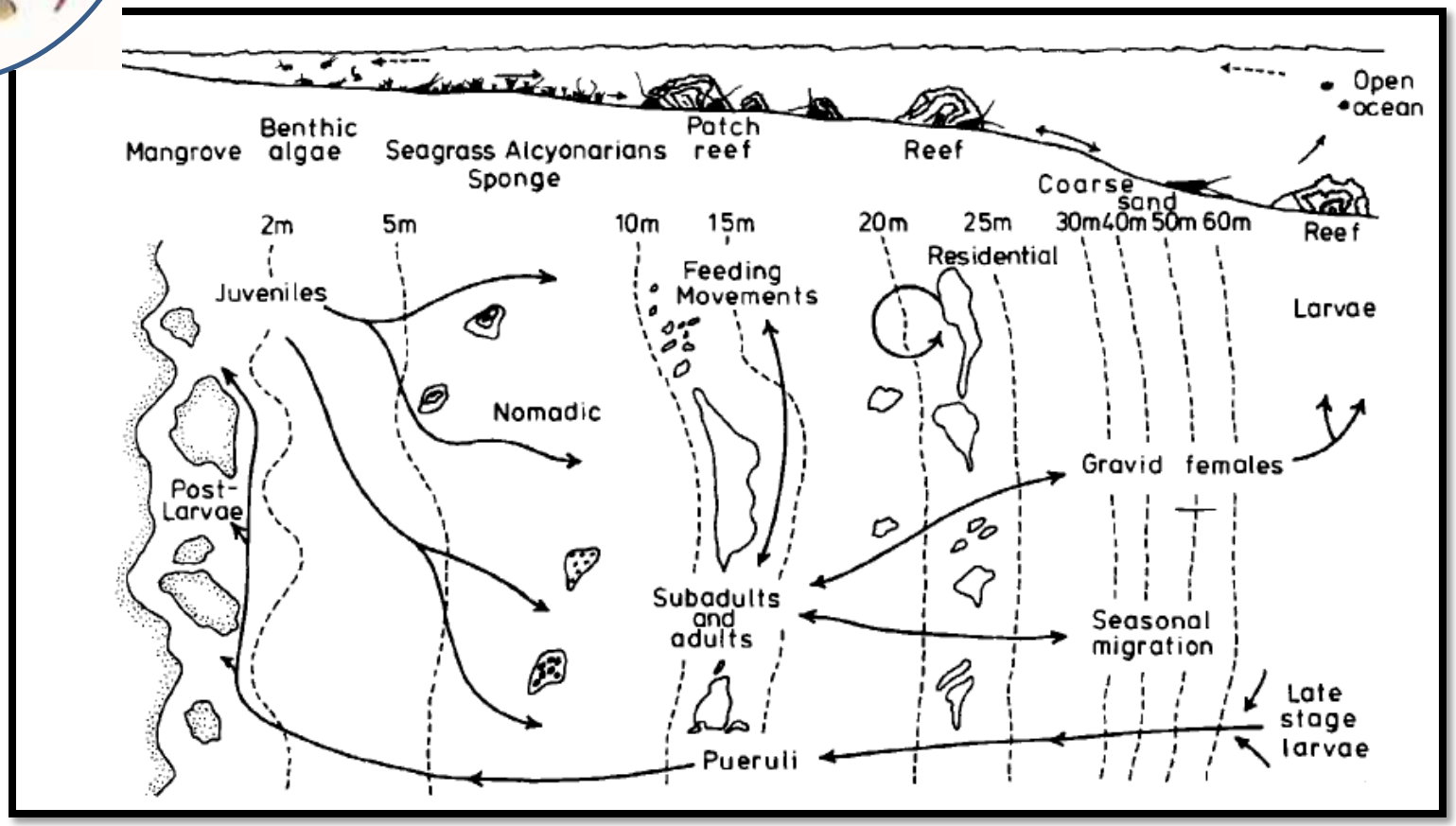
InVEST Tier 1 Fisheries Models

- **Objective:** model population response of individual species to change in habitat, environmental conditions and/or fishing pressure.

- Best used for relative comparison between scenarios

- The Library approach:
  1. Dungeness crab (Hood Canal, WA)
  2. blue crab (Galveston Bay, TX)
  3. white shrimp (Galveston Bay, TX)
  4. Sockeye salmon (Barkley Sound, BC)
  5. Caribbean spiny lobster (Belize)




Open ocean
Mangrove
Benthic algae
Seagrass
Alcyonarians
Sponge
Patch reef
Reef
Coarse sand
Reef
2m
5m
10m
15m
20m
25m
30m
40m
50m
60m
Residential
Juveniles
Feeding Movements
Larvae
Nomadic
Post-Larvae
Gravid females
Subadults and adults
Seasonal migration
Late stage larvae
Pueruli

Spiny lobster catch and revenue

InVEST
integrated valuation of environmental services and tradeoffs

INPUTS

Habitat
Where? How much?

Life history
survivorship,
growth, recruitment

Fishing zone
Where do people catch lobster?

Fishing pressure
How much do people fish?

OUTPUTS

Catch of spiny lobster
(lbs./m^2/yr)

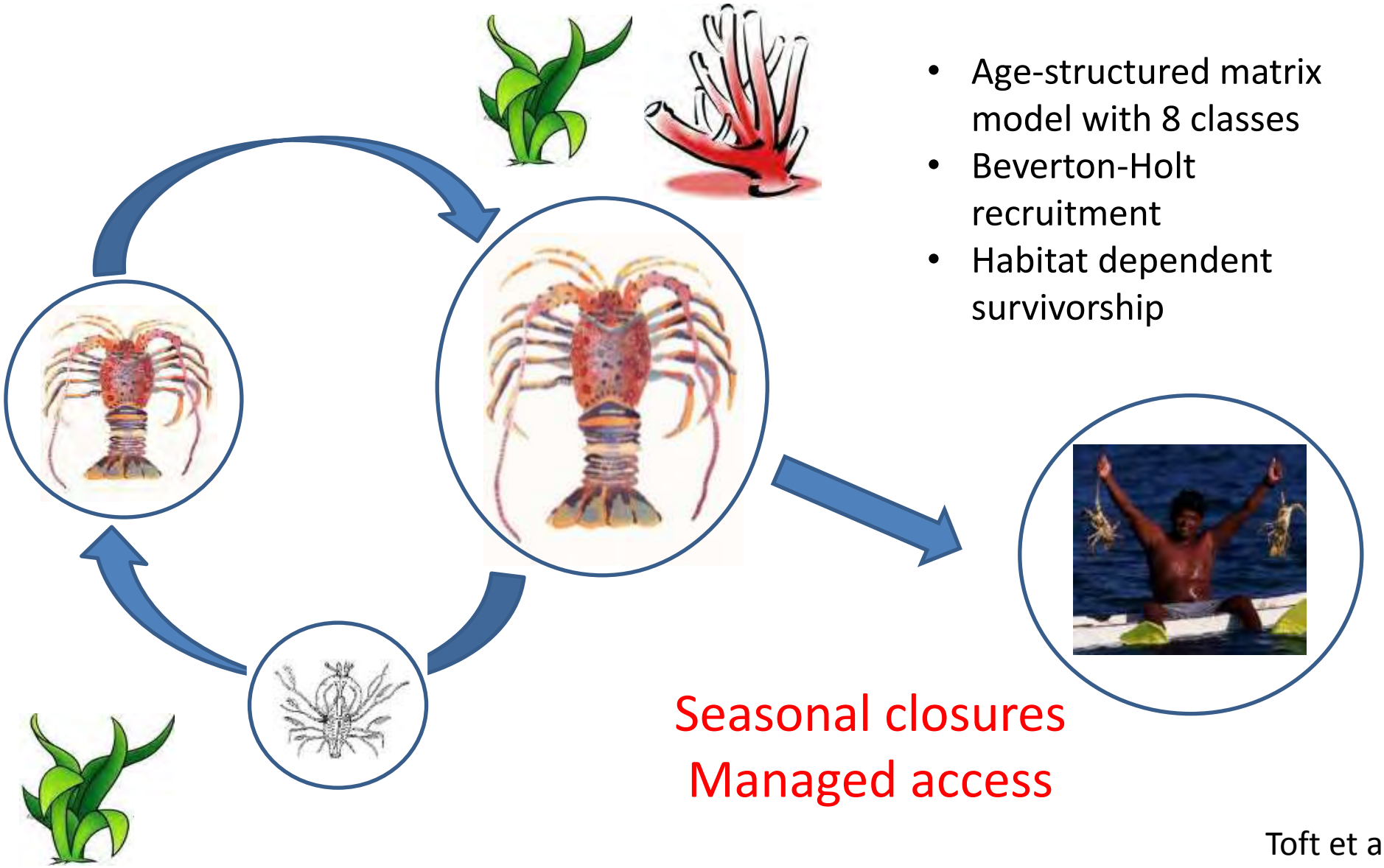
Market value of catch ($BZ/$m^2$/yr)
NPV of harvest

Value of habitats
that support lobster

Toft et al.

Spiny lobster catch and revenue

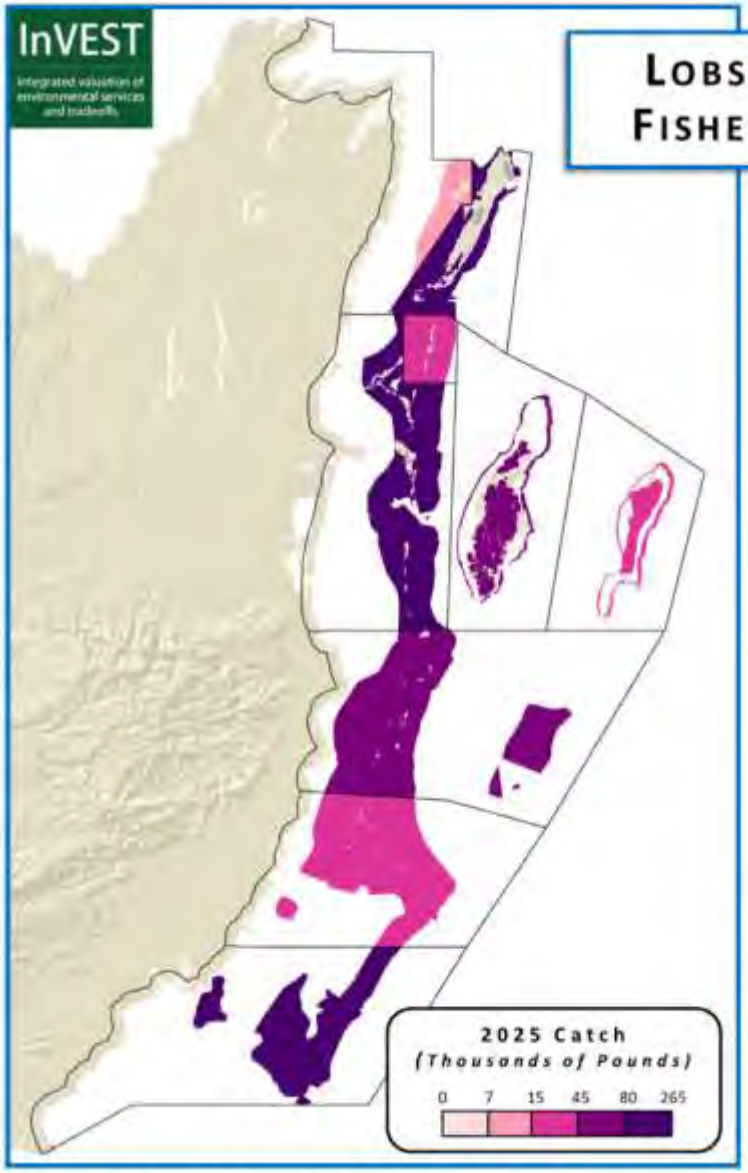
InVEST
integrated valuation of environmental services and tradeoffs



- Age-structured matrix model with 8 classes
- Beverton-Holt recruitment
- Habitat dependent survivorship

Seasonal closures
Managed access

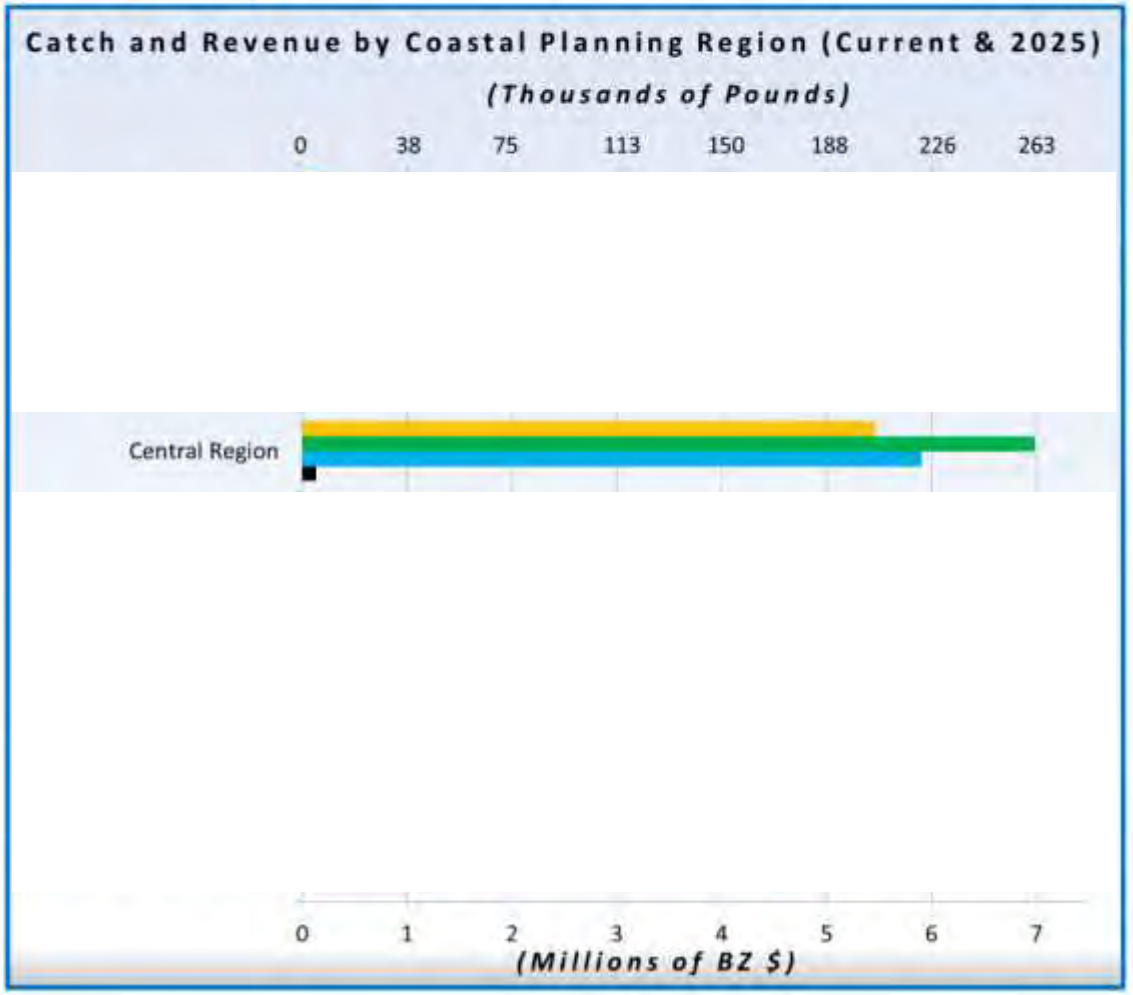
Toft et al.

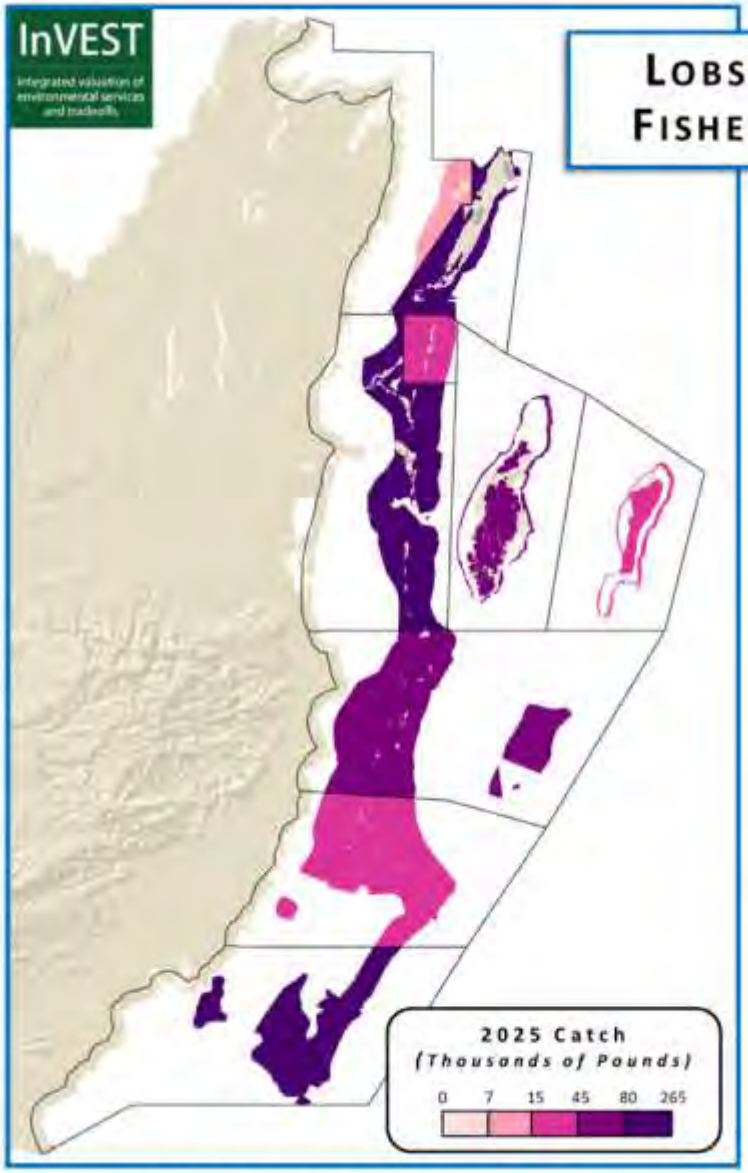


INFORMED MANAGEMENT

SCENARIOS

- Current
- Conservation
- Informed Management
- Development





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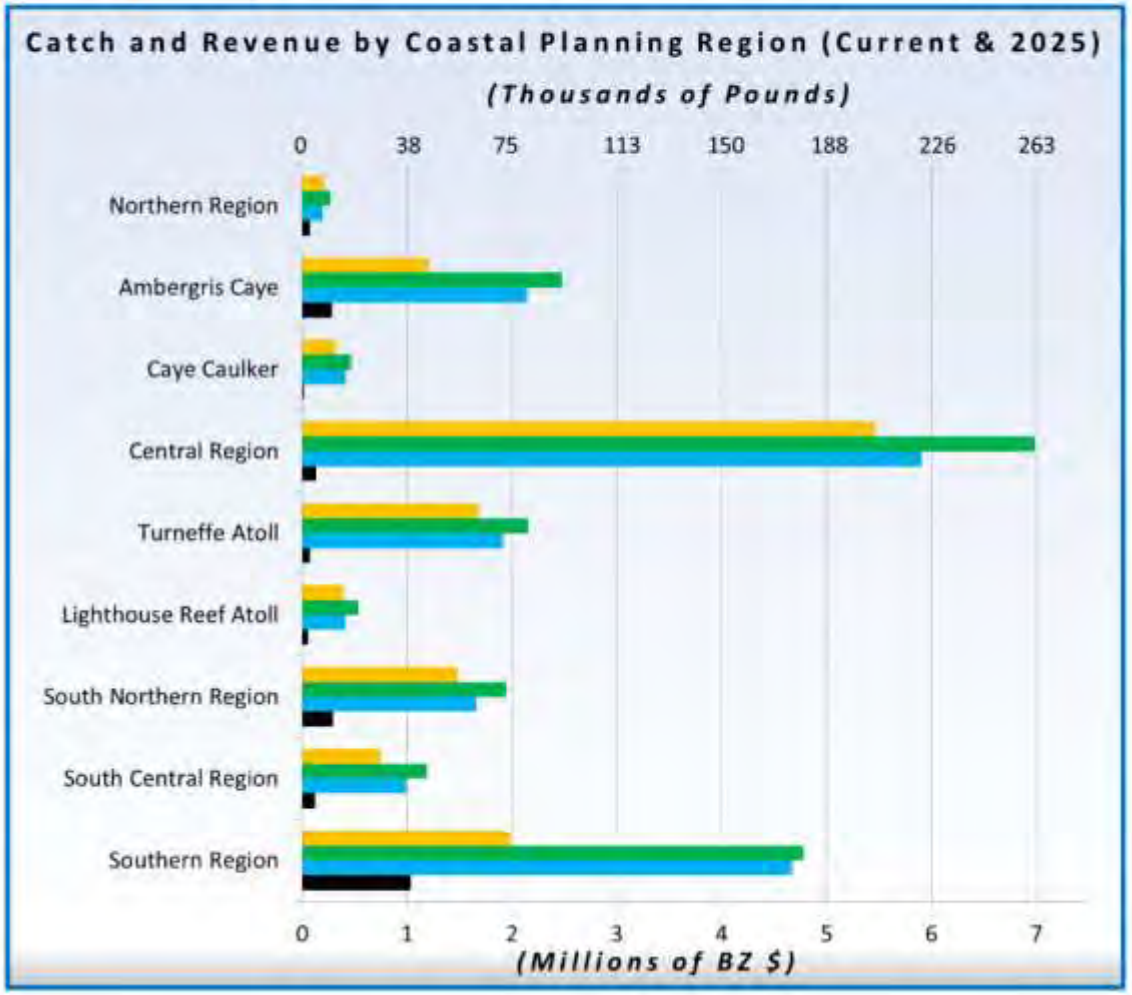
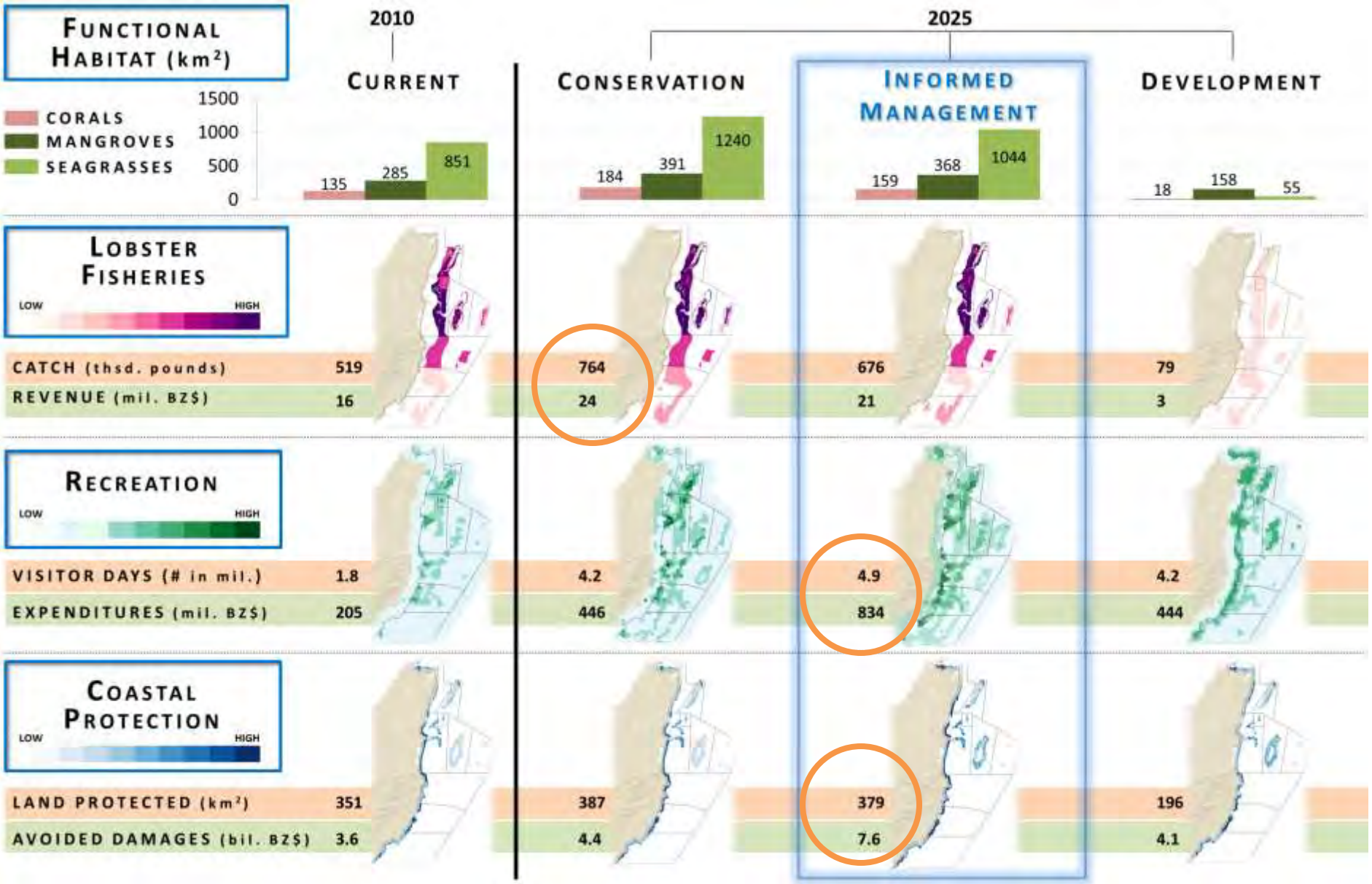


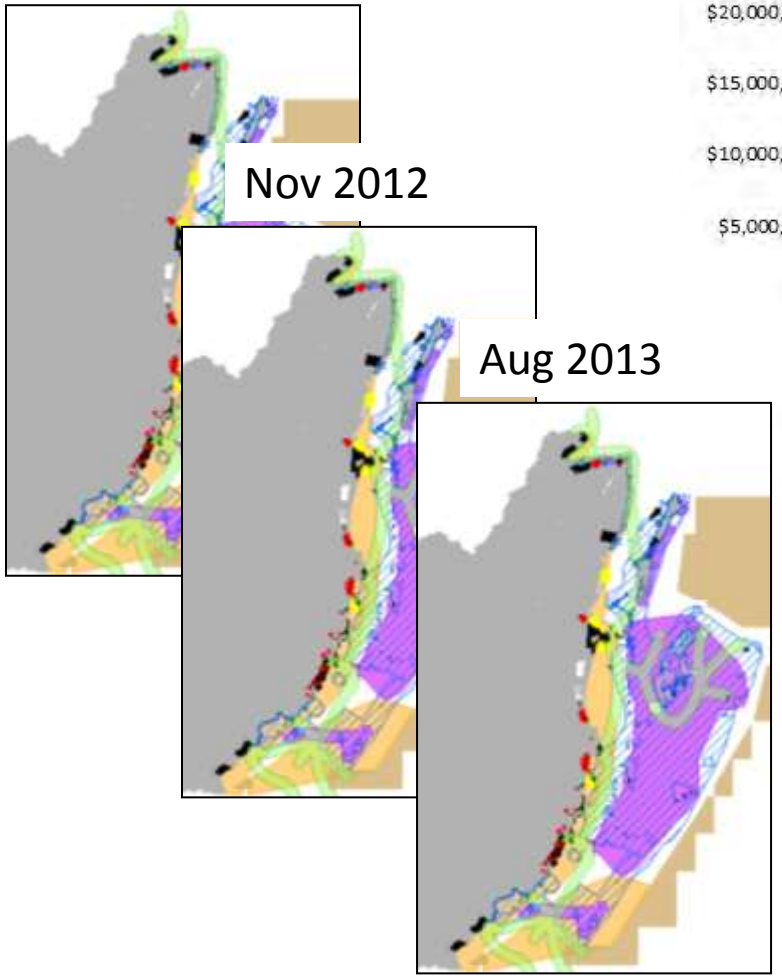
Making the case to balance conservation and development

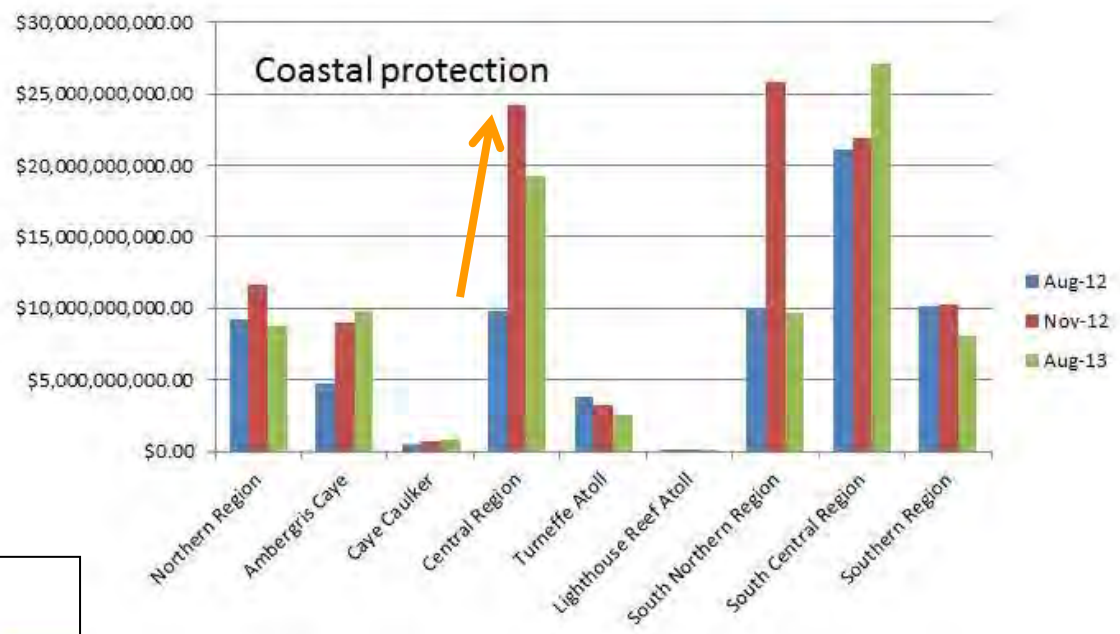


Reconfigure zoning scheme based on iteration

Informed Management

August 2012





natural capital PROJECT

BELIZE COASTAL ZONE MANAGEMENT AUTHORITY & INSTITUTE

WWF

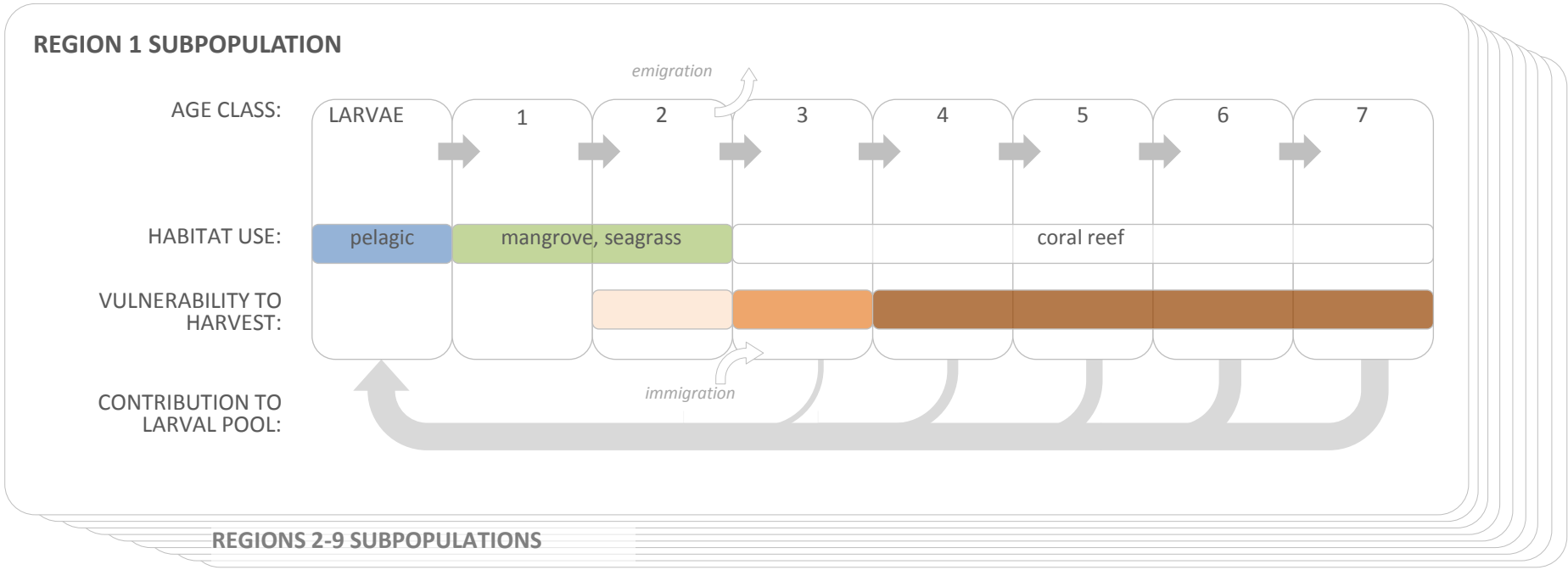
Healthy Reefs for healthy people

TOLEDO INSTITUTE FOR DEVELOPMENT AND ENVIRONMENT
TIDE

WILDLIFE CONSERVATION SOCIETY

SEA BELIZE

BELIZE FISHERIES DEPARTMENT

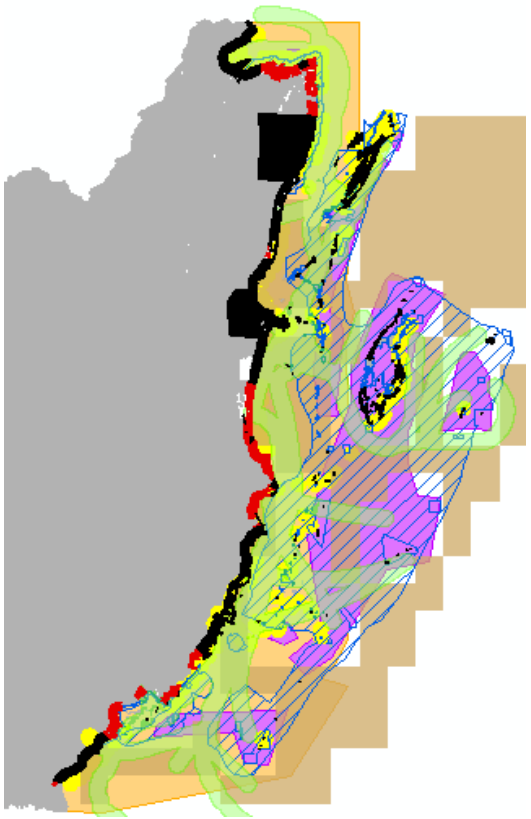

REGION 1 SUBPOPULATION
emigration
AGE CLASS:
LARVAE
1
2
3
4
5
6
7
HABITAT USE:
pelagic
mangrove, seagrass
coral reef
VULNERABILITY TO HARVEST:
CONTRIBUTION TO LARVAL POOL:
immigration
REGIONS 2-9 SUBPOPULATIONS

Zoning Scheme

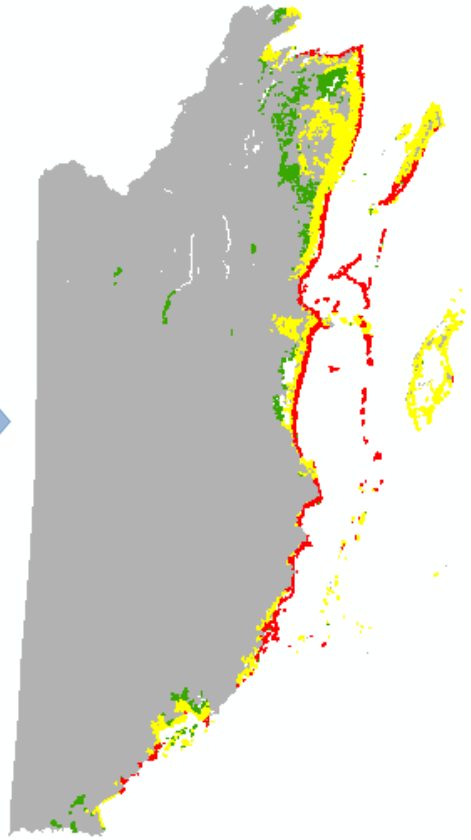
Risk to habitats

Changes to magnitude and value of service

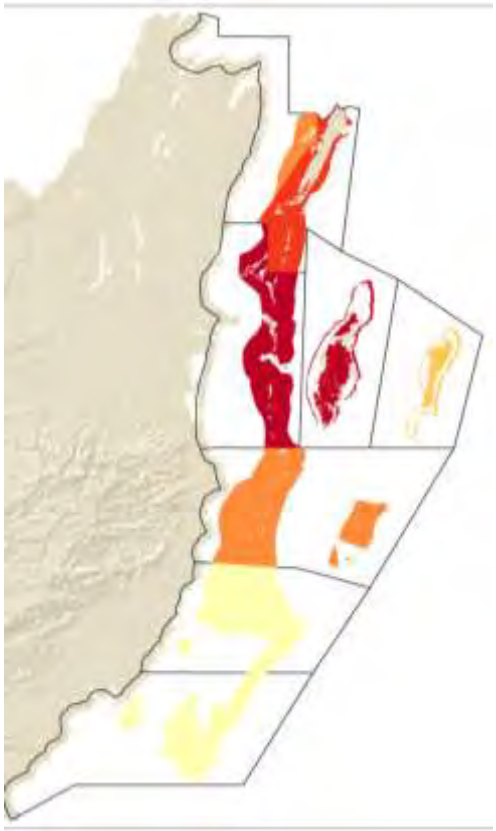
Development



Risk to mangroves



Lobster catch & revenue



natural capital PROJECT

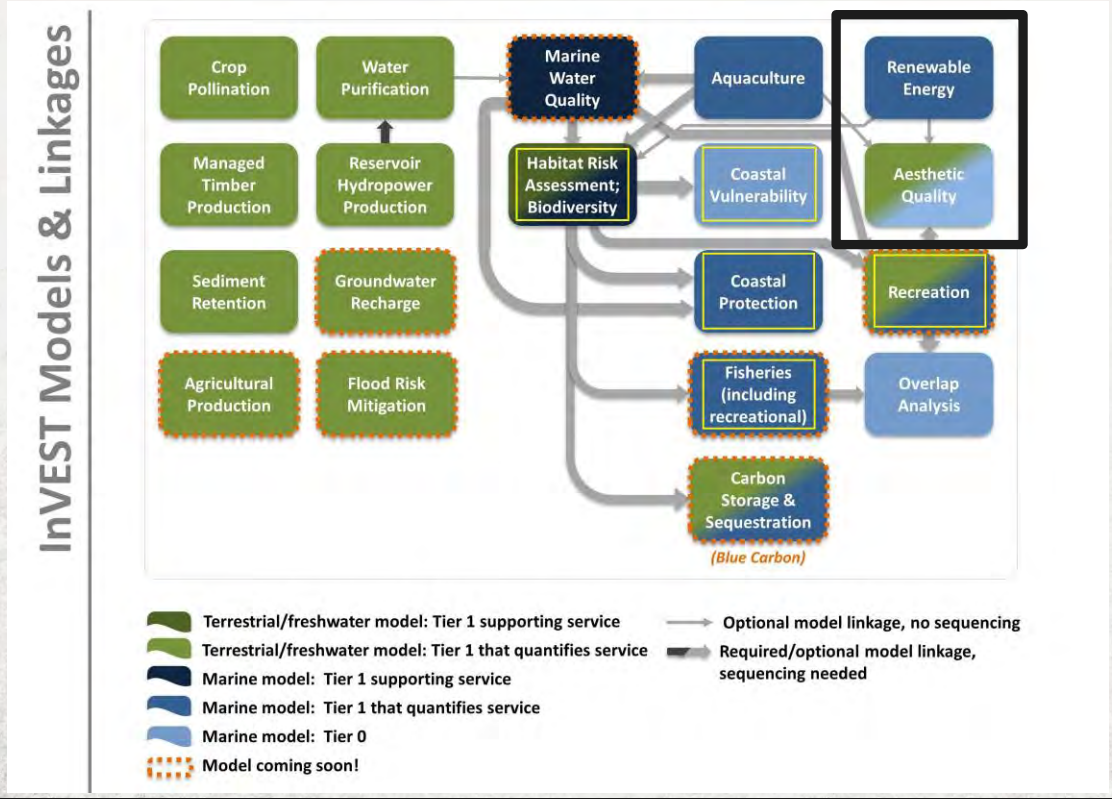
ECOSYSTEM SERVICE TRADE-OFFS

- Renewable Energy (Wave and Wind)
- Scenic Quality

Gregg Verutes, CK Kim, Doug Denu, Nic Chaumont , Rob Griffin

APPLICATION
SITES

MODEL LINKAGE
RENEWABLE ENERGY & SCENIC QUALITY



RENEWABLE ENERGY

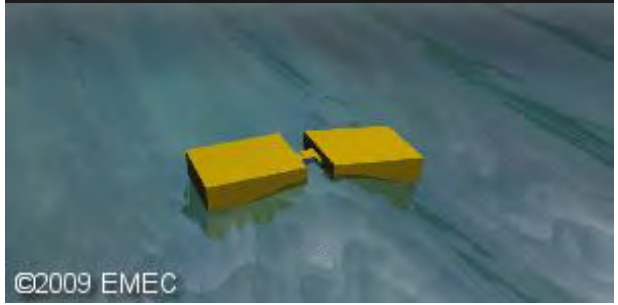
OFFSHORE WIND AND WAVE

RENEWABLE ENERGY

WIND AND WAVE DEVICES

natural capital PROJECT

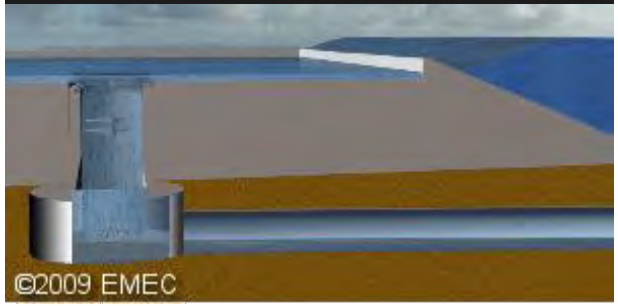
Attenuator



Point Absorber

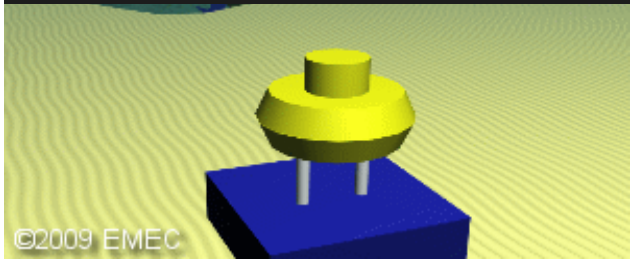
Oscillating Water Column

Overtopping Device



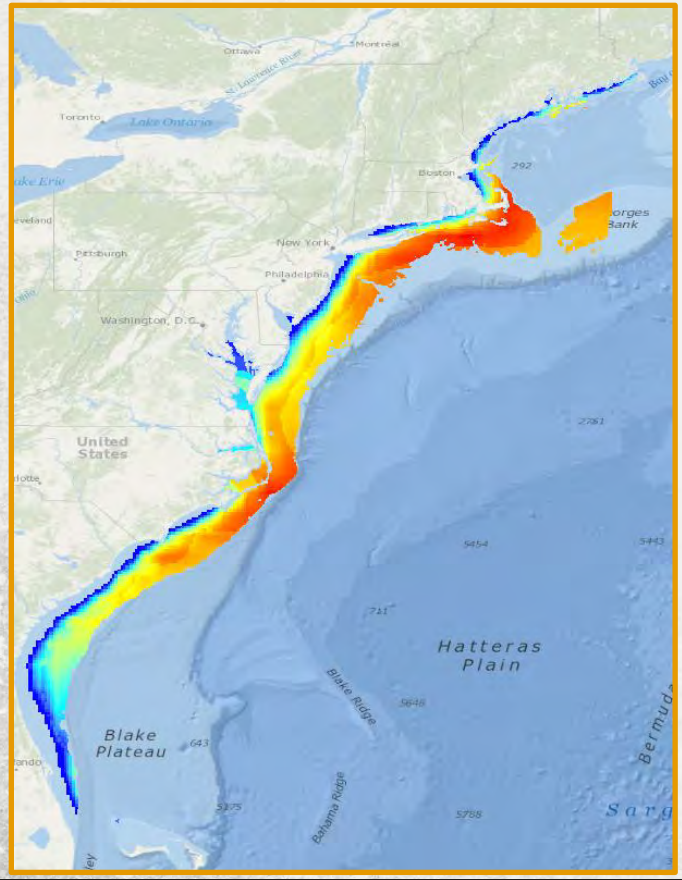
Oscillating Wave Surge Converter

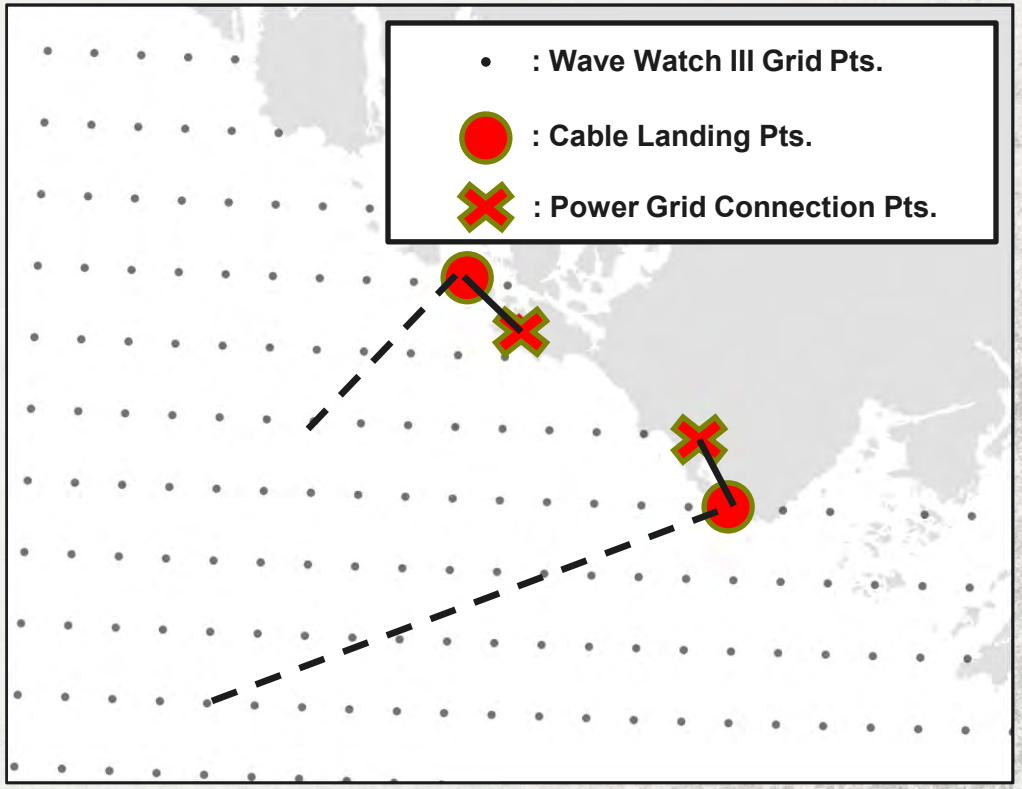
Submerged Pressure Differential



RENEWABLE ENERGY MODELS

THE BASICS





RENEWABLE ENERGY MODELS
INPUTS AND OUTPUTS

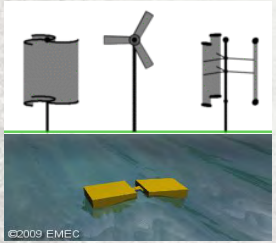
InVEST integrated valuation of environmental services and tradeoffs

natural capital PROJECT

Inputs

Sea state or wind conditions

wave height / period
wind velocity



Device operation

performance, limitations

Economic values

cost of device, electricity, maintenance, accessibility of grid

Outputs

Energy produced

Value of energy

TRADEOFF ANALYSIS

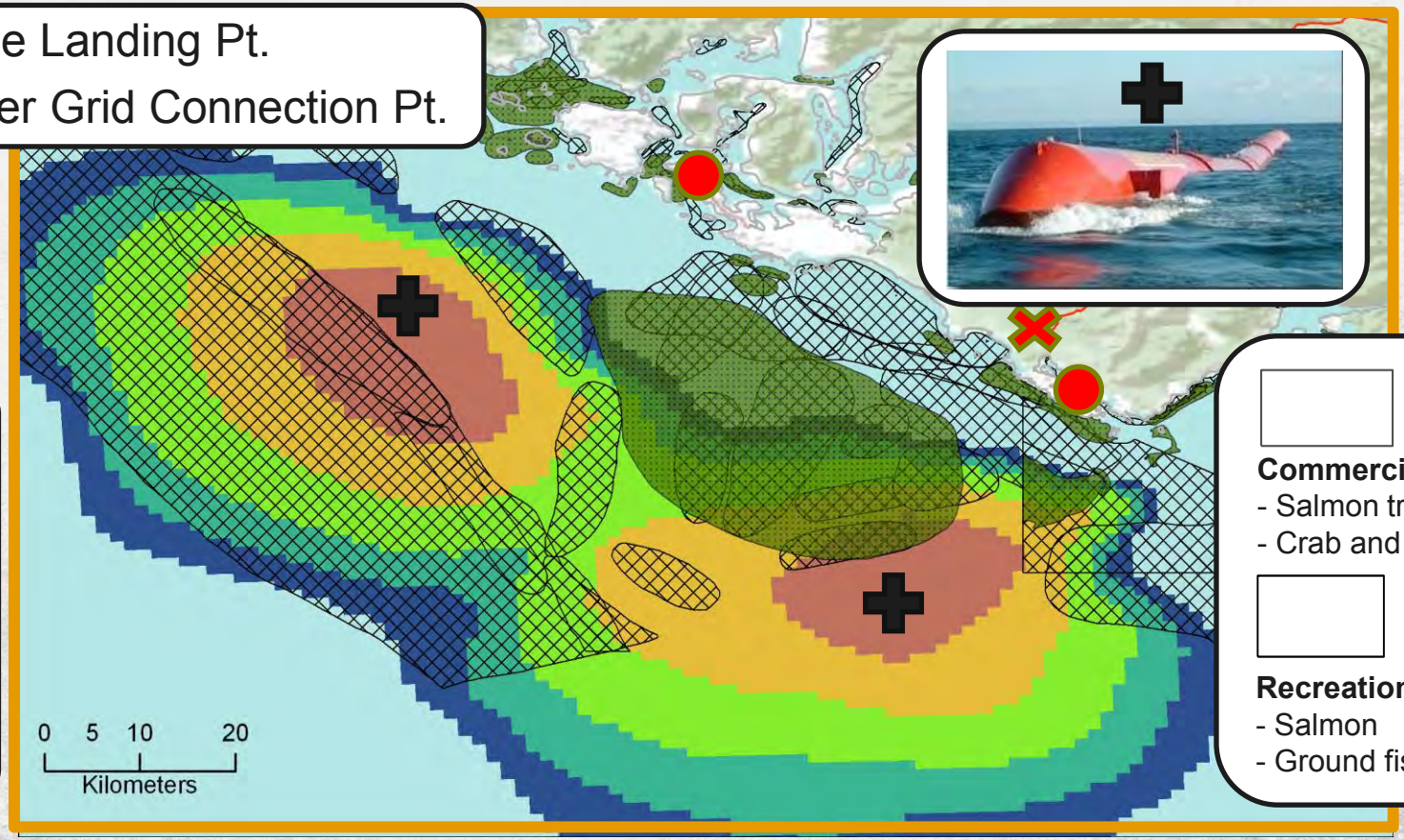
VANCOUVER ISLAND, CANADA

Kim et al. (PLOS One 2012)

natural capital PROJECT

: Cable Landing Pt.

: Power Grid Connection Pt.



NPV ($ mil)

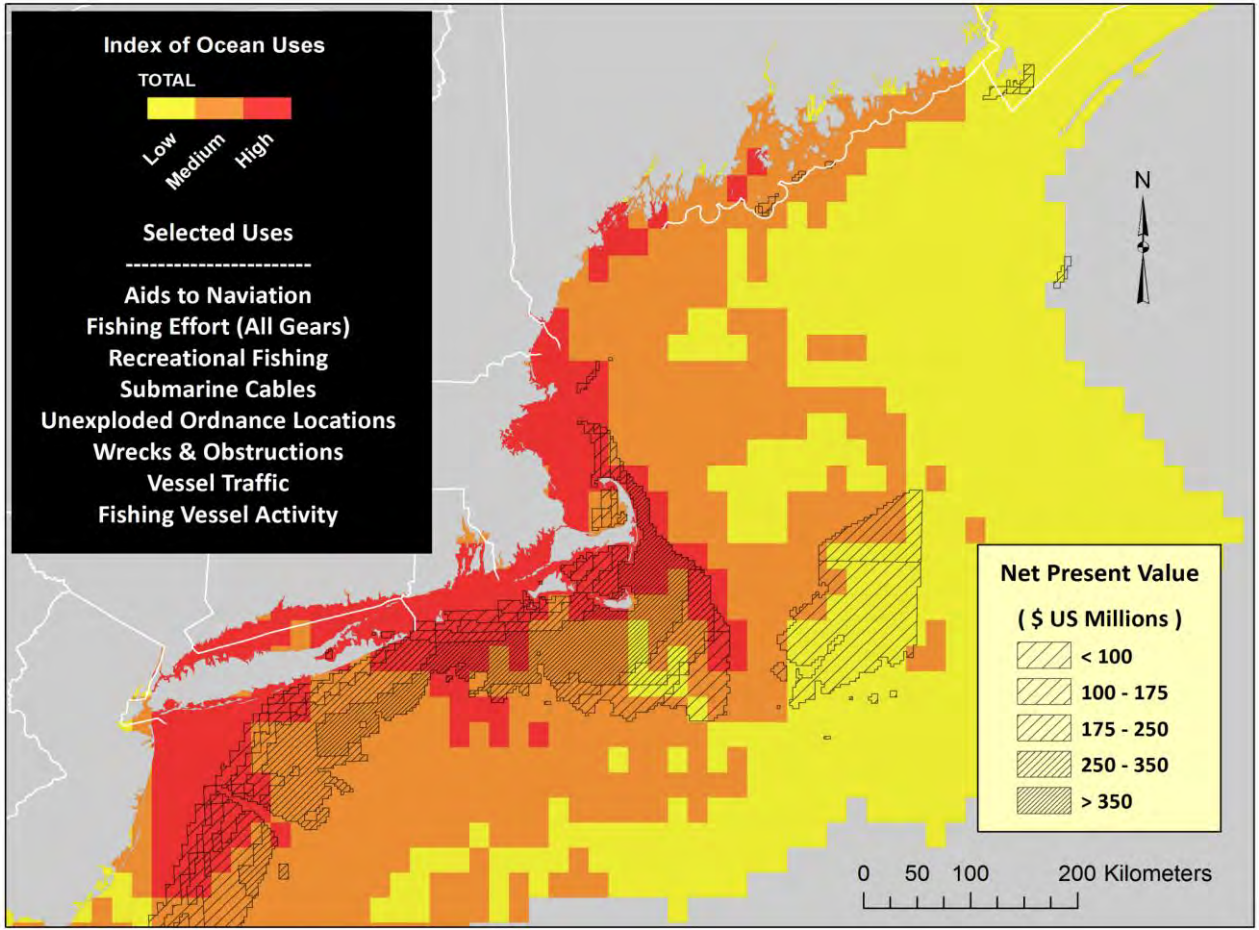
- 0 - 1.5
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0 - 7.5

REC_FI

Commercial Fishery
- Salmon troll & net
- Crab and Shrimp

COM_SA

Recreational Fishery
- Salmon
- Ground fish



Overlap Analysis

- Location:
  New England, USA
- Task: Wind Energy Area Siting
- Concerns
  - Efficient location of wind
  - Ocean Uses
- Data:

  northeastoceandata.org

SPATIAL PLANNING
"WHERE TO PUT THINGS?"

Competing Uses

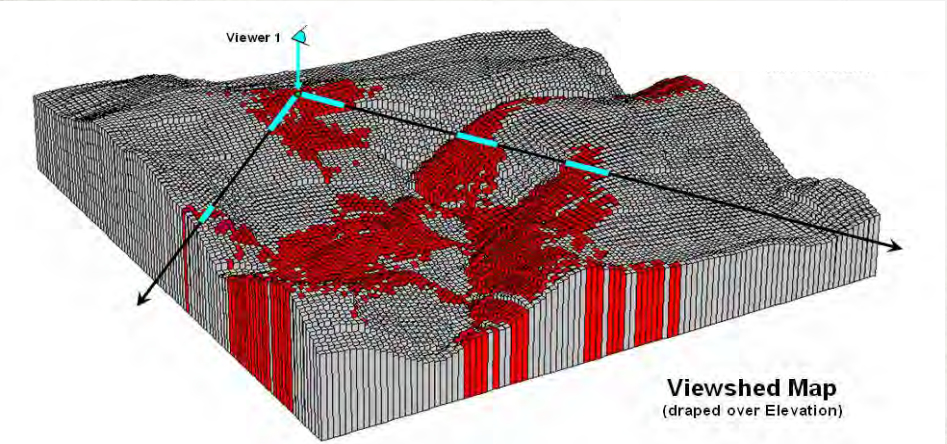
- Fishing / Vessel Activity
- Shipping
- Recreation
- Wrecks and Obstructions
- Aquaculture
- and **SCENIC QUALITY!**

SCENIC QUALITY

AESTHETICS (VIEWSHED ANALYSIS)

INVEST SCENIC QUALITY MODEL
THE BASICS

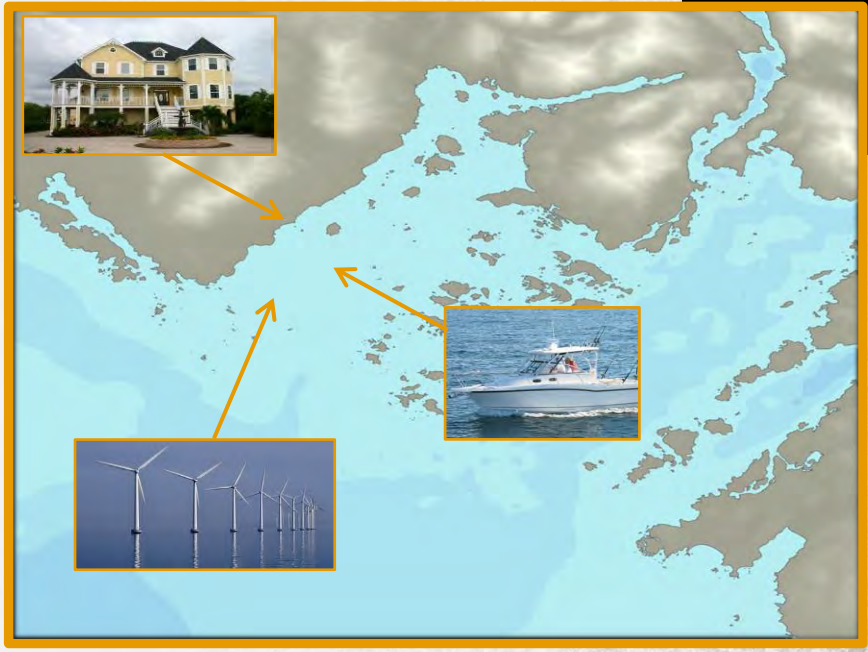
- A **viewshed** is an area that is visible from a specific location.
- This type of analysis is common functionality available within most GIS software.

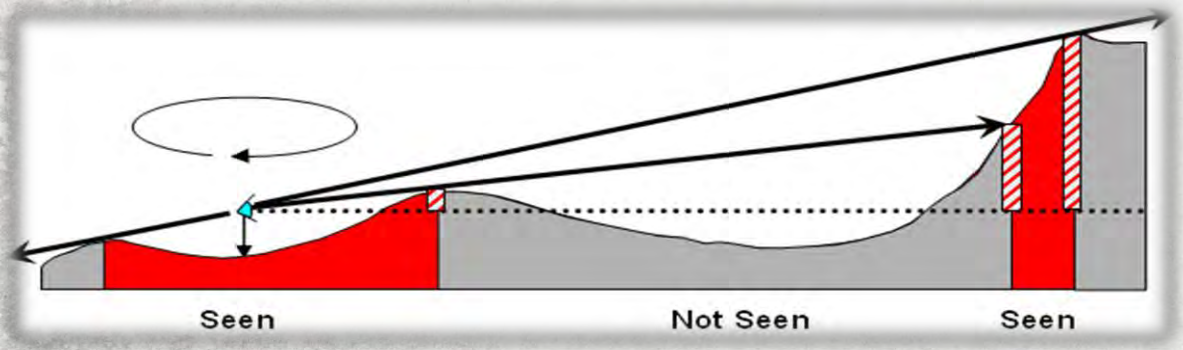


- Viewshed analysis uses the elevation value of each cell of a DEM to determine visibility to or from a particular cell.
- Application example:
  Locations on land where five new offshore wind turbines are visible

SCENIC QUALITY
HOW IT WORKS

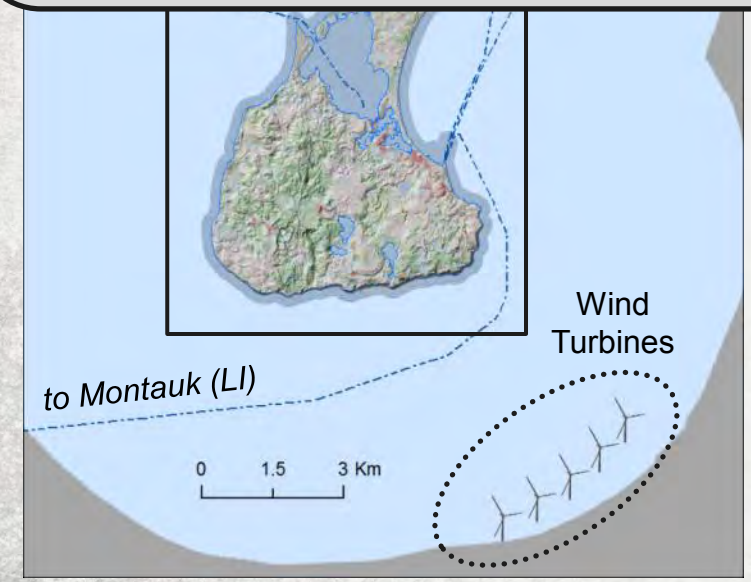
- *Input:* Digital Elevation Model (DEM)
  1. Resample / Clip
  2. Flatten bathymetry
  3. Calculate viewshed

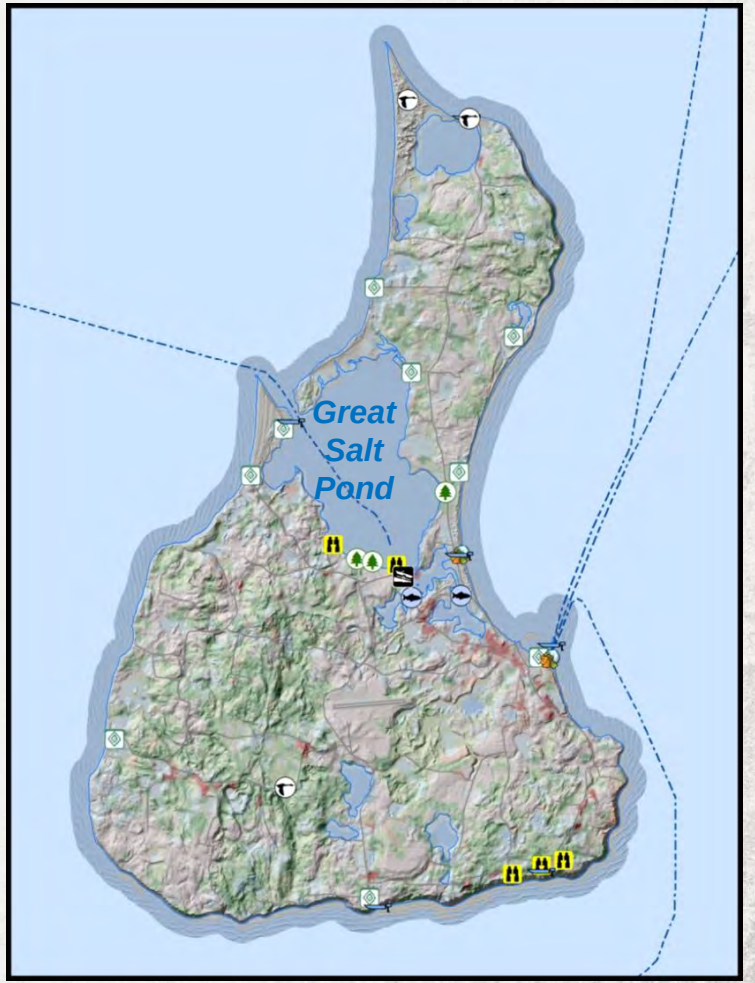




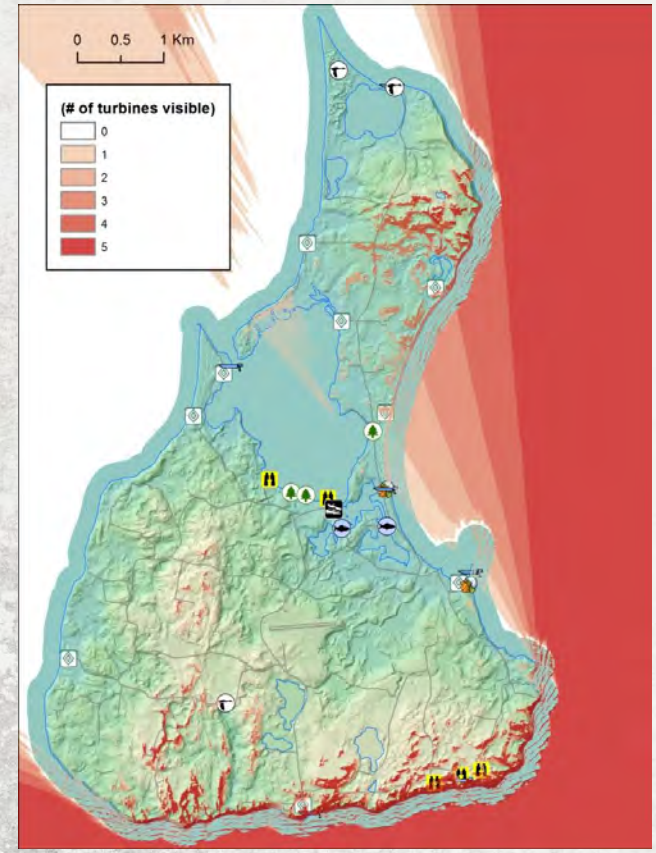
PRIMARY USE

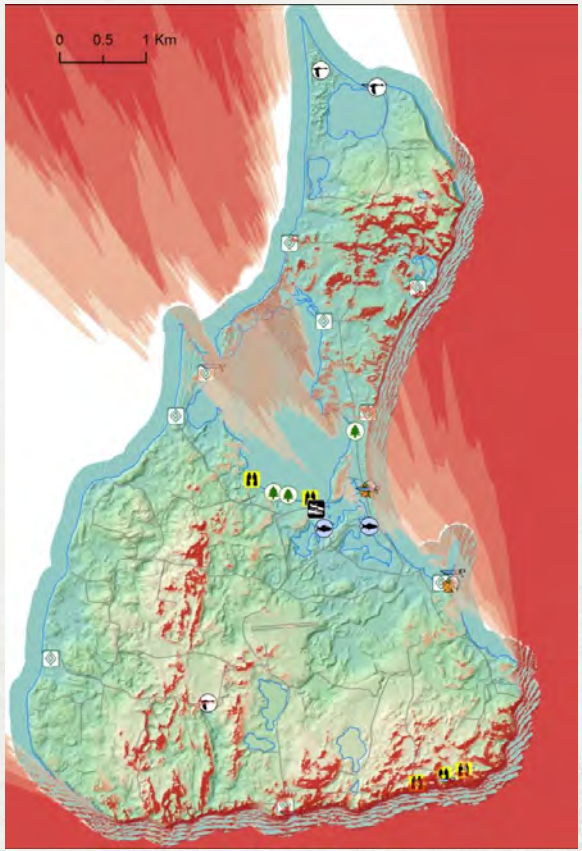
- Path to shore
- Beach w/ lifeguard
- Conservation area/ wildlife refuge
- Scenic view
- Boat ramp
- Fishing / boating access
- Fishing site
- Ferry route (approx.)

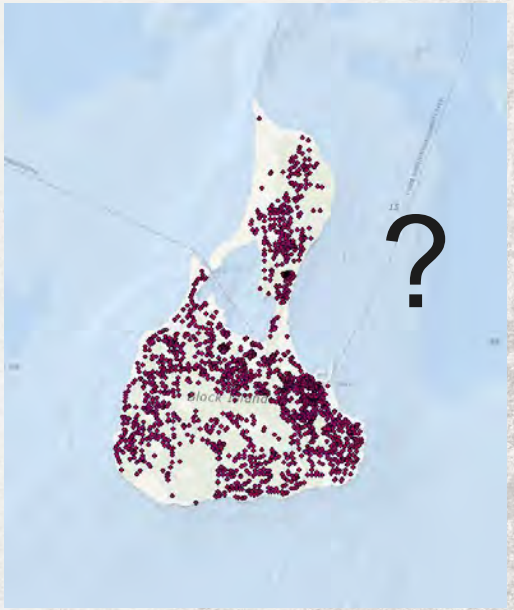


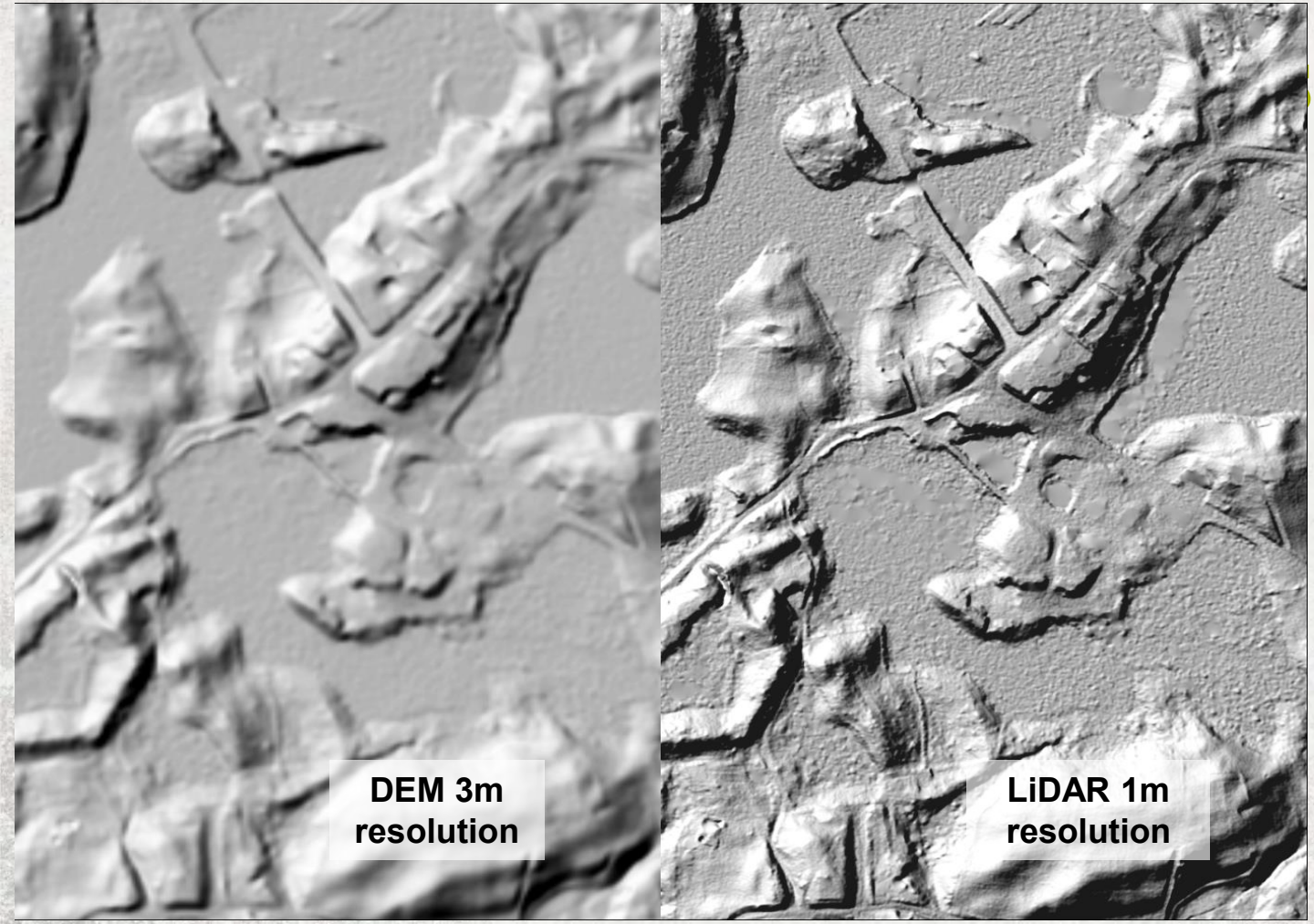


VIEWSHED RESULTS








DEM 3m resolution
LiDAR 1m resolution

TRADE-OFFS
REPRISE

Competing Uses

- Controversial
- Often difficult to map and value
- Spatially-explicit information can help identify and weigh tradeoffs

COASTAL PROTECTION

PROTECTING PEOPLE AND INFRASTRUCTURES FROM COASTAL HAZARDS

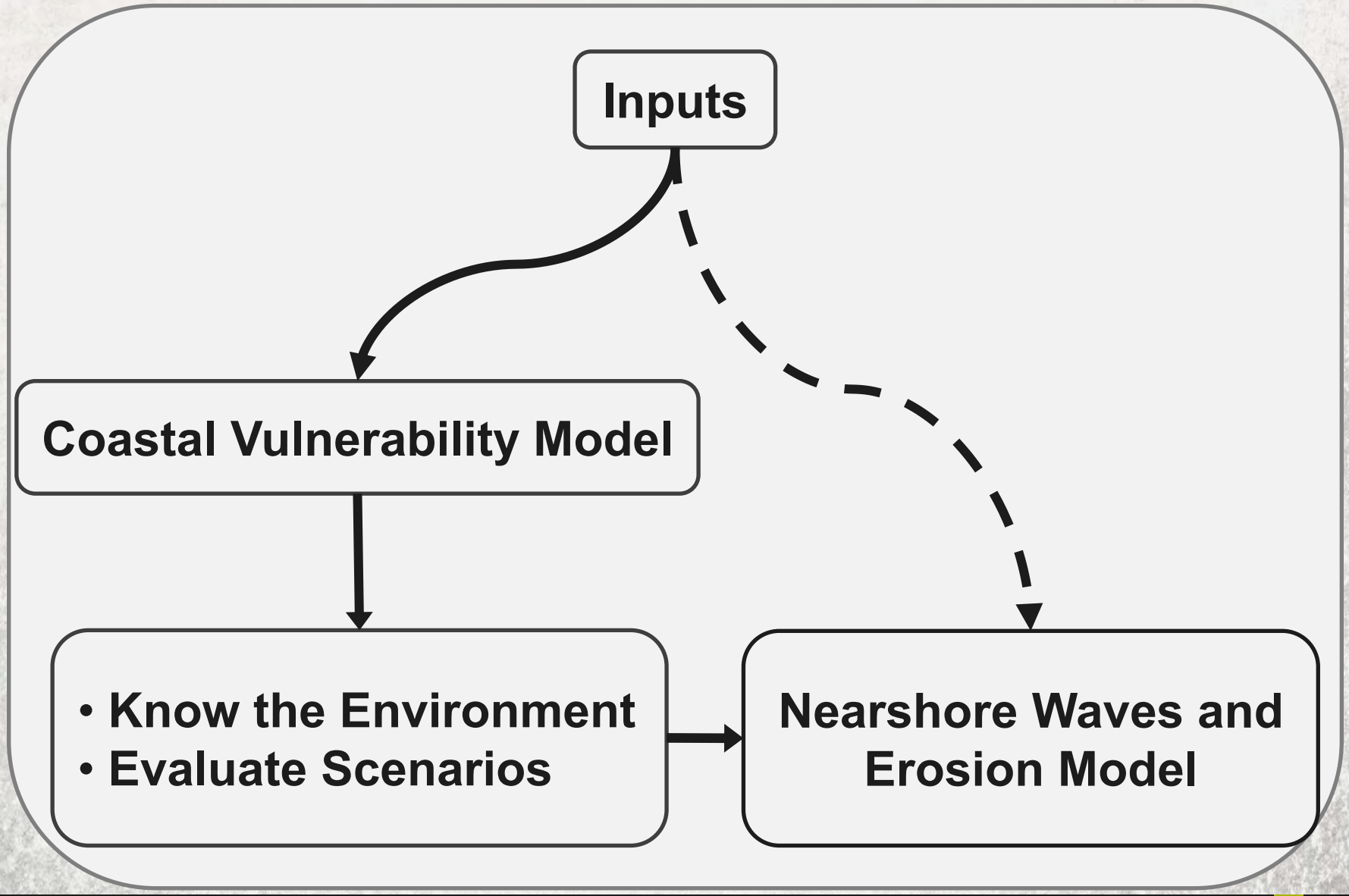
March 27-28, 2014

Greg Guannel
gguannel@stanford.edu
8008-563-0434


WILD
SINGAPORE
www.wildsingapore.com

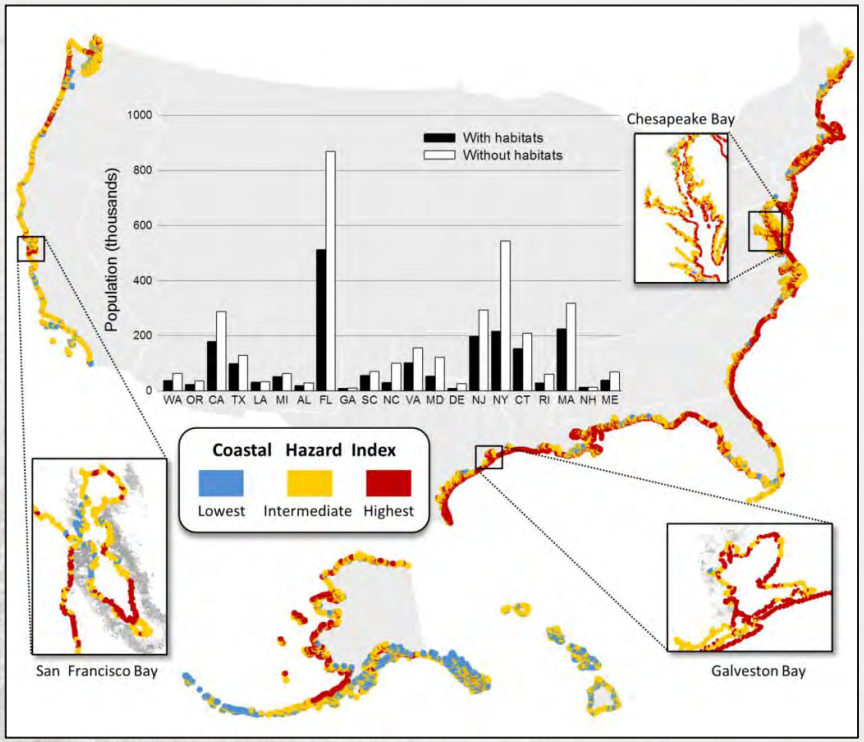
1. Where do habitats protect the most?
2. What is their $ value?

COASTAL PROTECTION

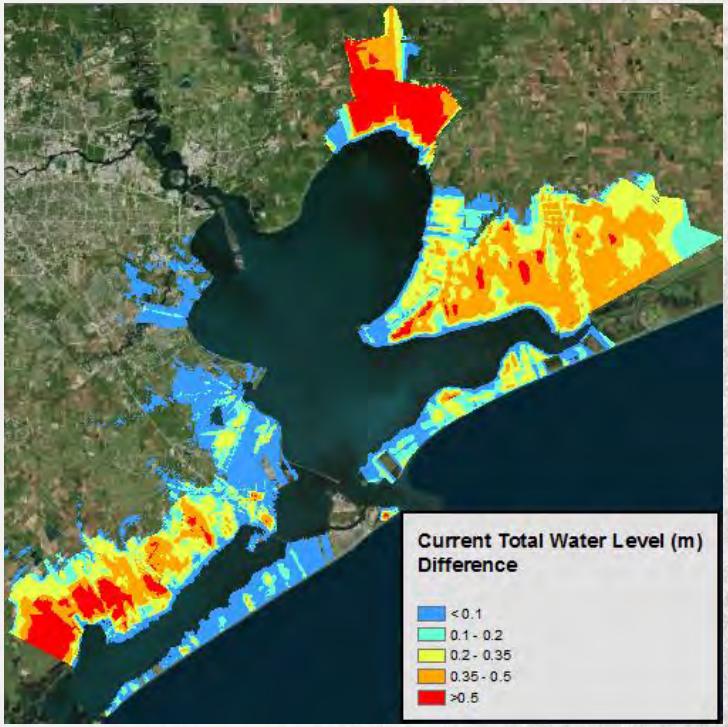


COASTAL PROTECTION

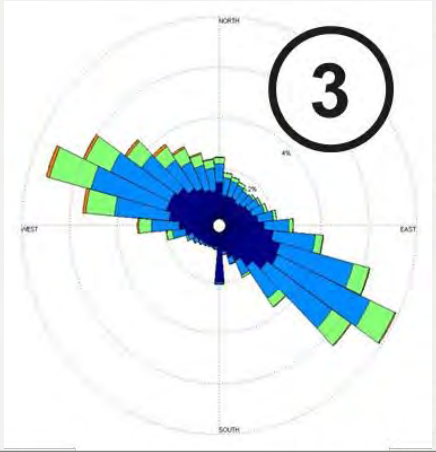
Coastal Vulnerability



Nearshore Waves



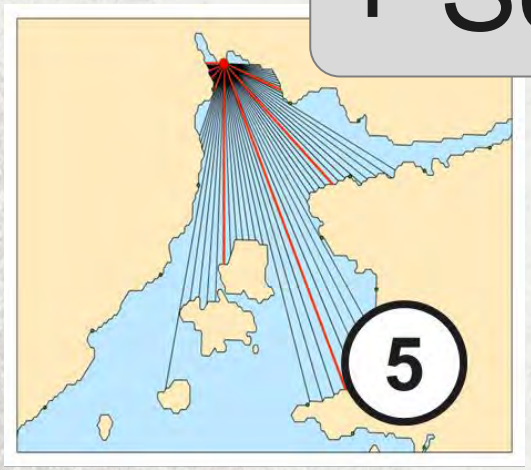
COASTAL VULNERABILITY



GEOMORPHOL

+ Social Metrics

OTENTIAL

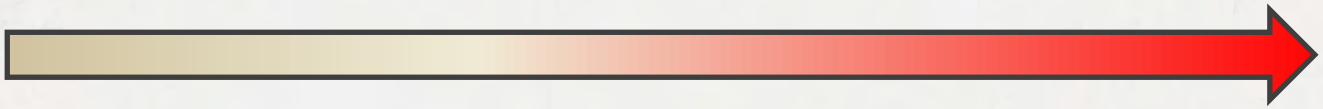


WAVE EXPOSURE

RELIEF

SEA LEVEL RISE

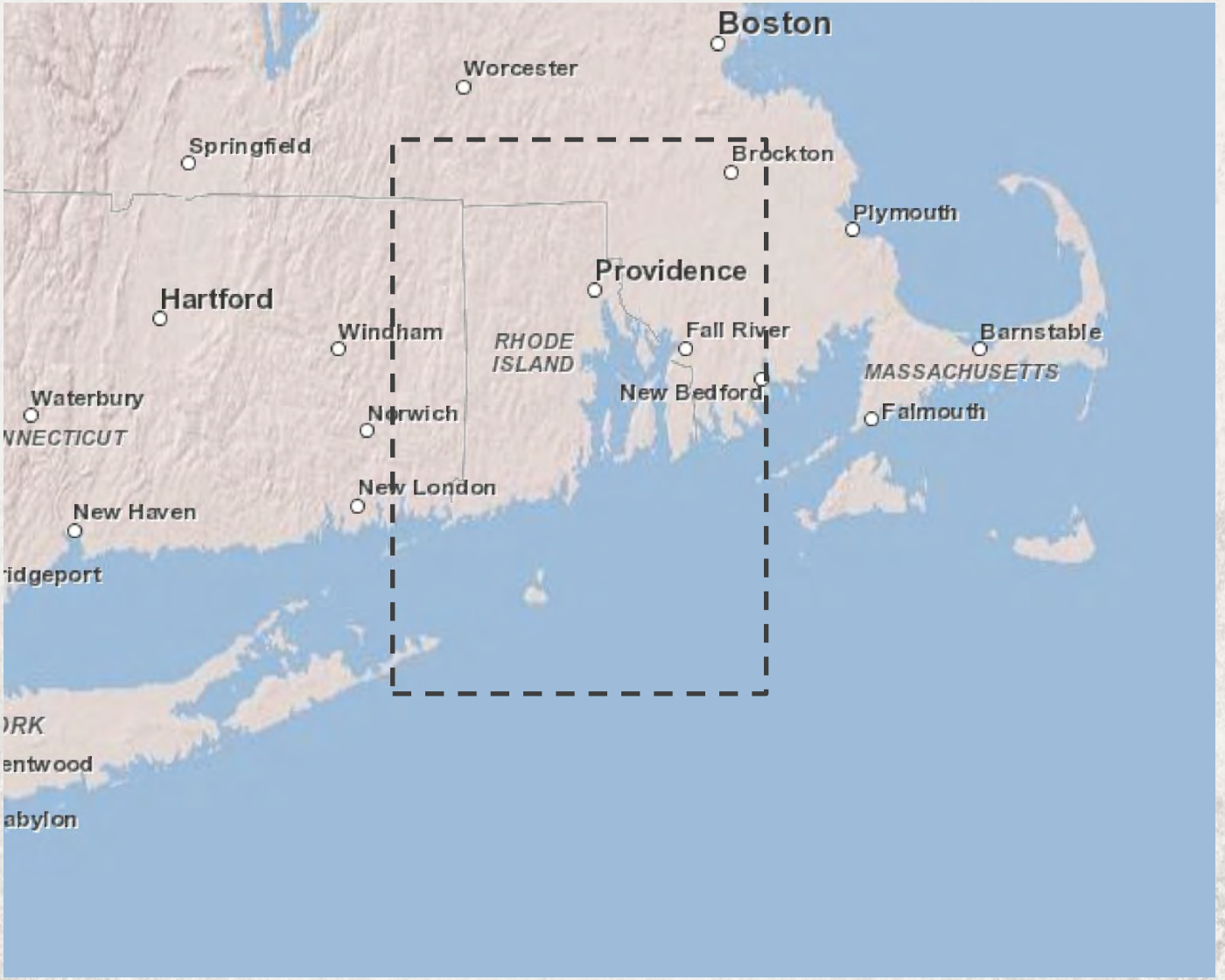
COASTAL EXPOSURE INDEX



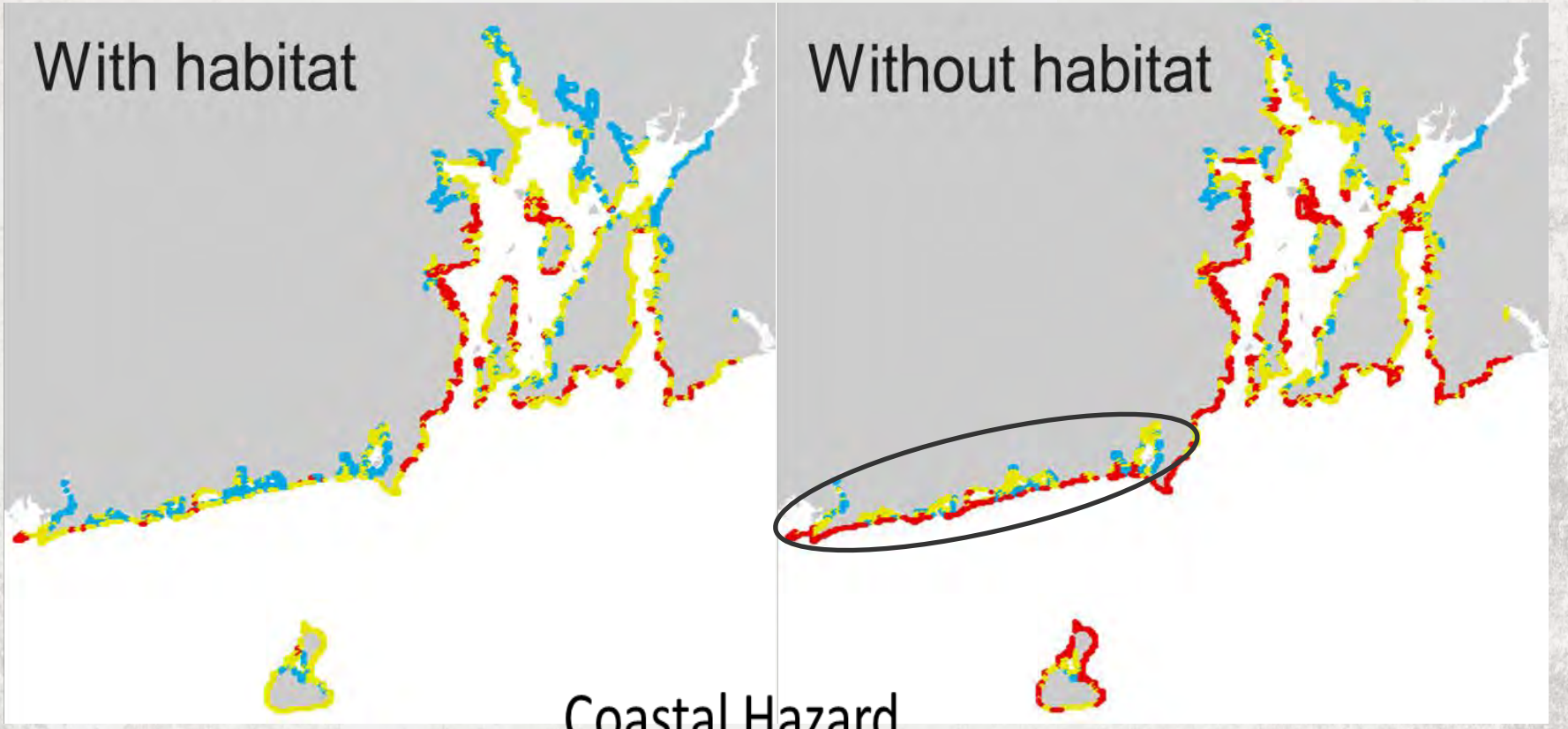
Rank	Very Low	Low	Moderate	High	Very High
	1	2	3	4	5
Geomorphology	Rocky; high cliffs; fiord; fiard	Medium cliff; indented coast	Low cliff; glacial drift; alluvial plain	Cobble beach; estuary; lagoon; bluff	Barrier beach; sand beach; mud flat; delta
Relief	> 90th Percentile	> 75th Percentile	Average value	< 25th Percentile	< 10th Percentile
Natural Habitats	Coral reef; mangrove; coastal forest	High dune; marsh	Low dune; oyster reef	Seagrass; kelp	No habitat
Sea Level Change	< 10^{th} Percentile	< 25^{th} Percentile	Average value	> 75^{th} Percentile	> 90^{th} Percentile
Wind Exposure	< 10^{th} Percentile	< 25^{th} Percentile	Average value	> 75^{th} Percentile	> 90^{th} Percentile
Wave Exposure	< 10^{th} Percentile	< 25^{th} Percentile	Average value	> 75^{th} Percentile	> 90^{th} Percentile
Surge Potential	No exposure	< 25^{th} Percentile	Average value	> 75^{th} Percentile	> 90^{th} Percentile

Qualitative assessment of vulnerability based on mixture of relative and absolute rankings

RHODE ISLAND EXAMPLE



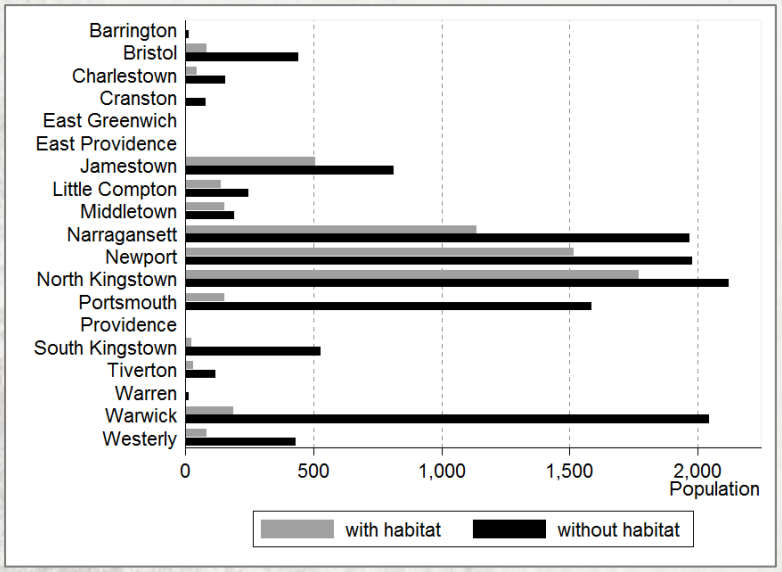
COASTAL EXPOSURE INDEX

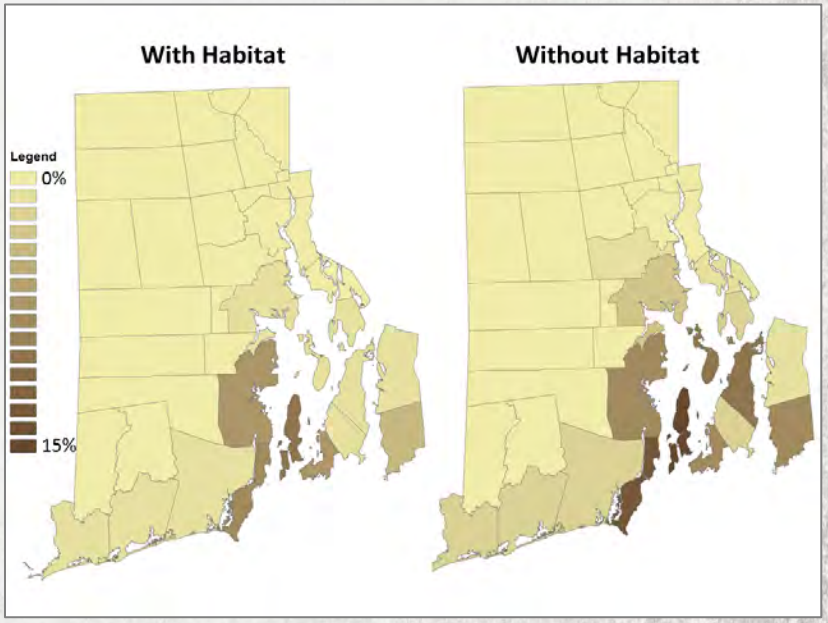


SOCIAL METRICS

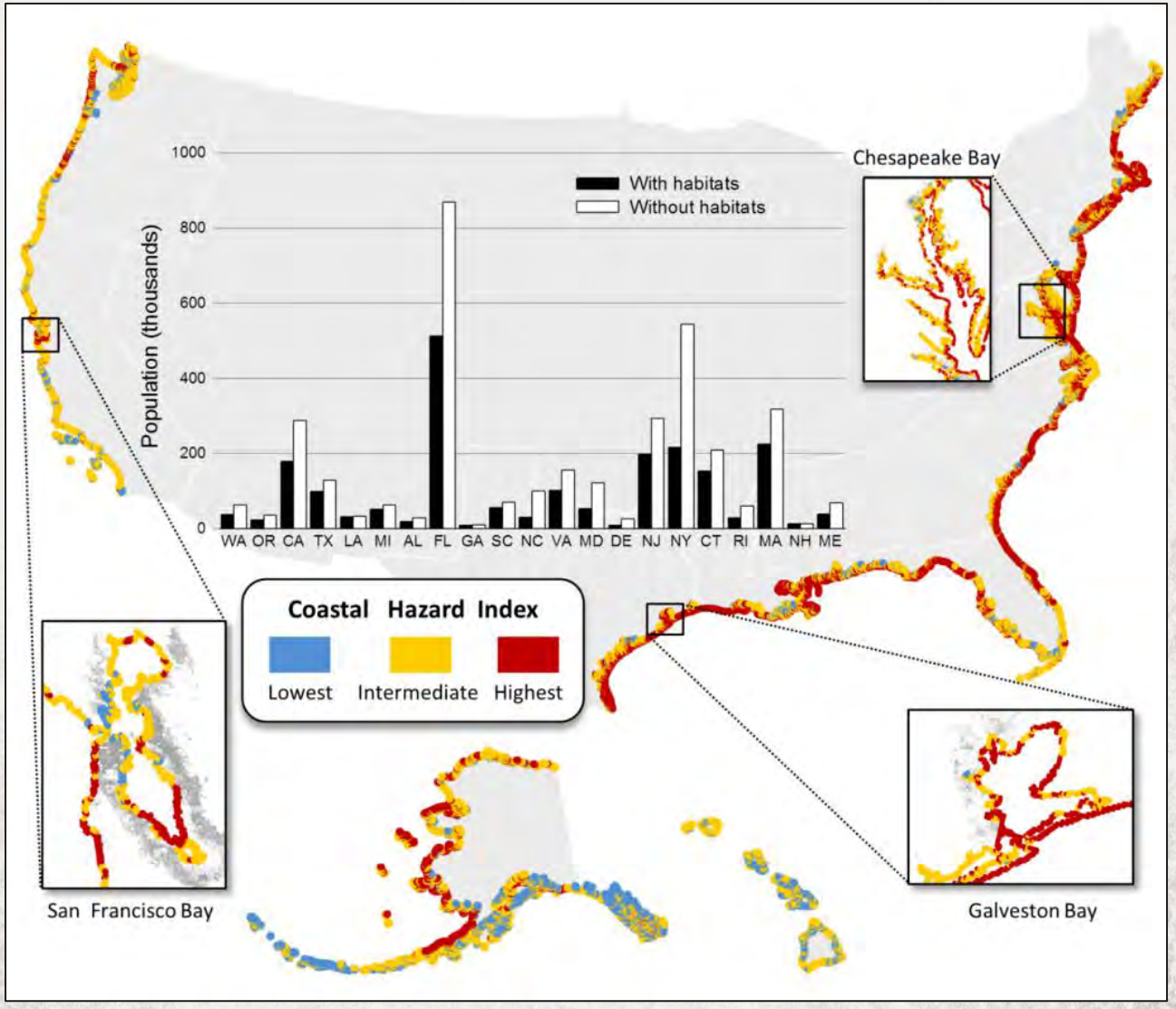
American Community Survey
(2006 – 2010, 5 yr. estimates)

- Total Population
- People Age 65+
- Families Below the Poverty Line

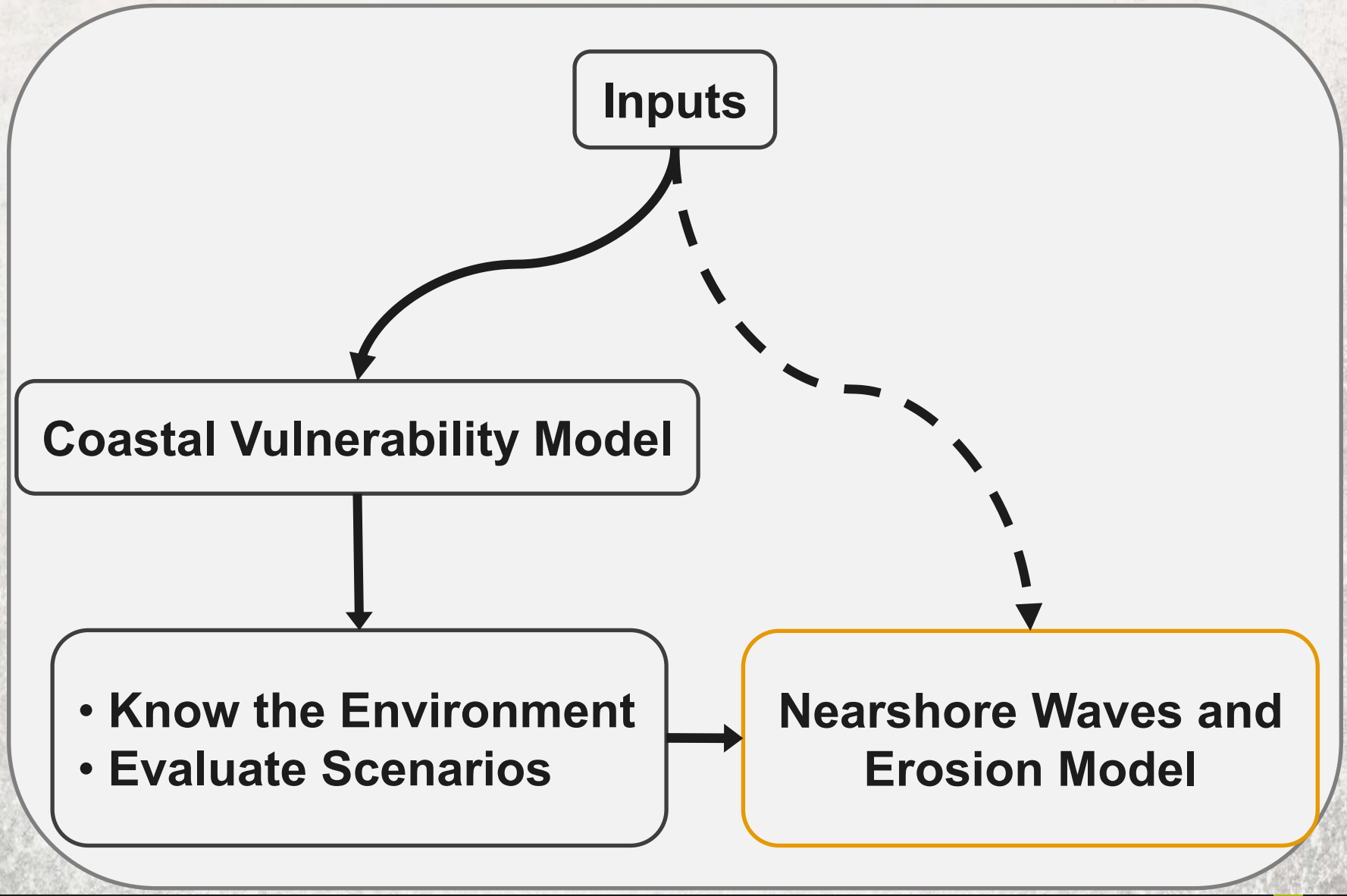




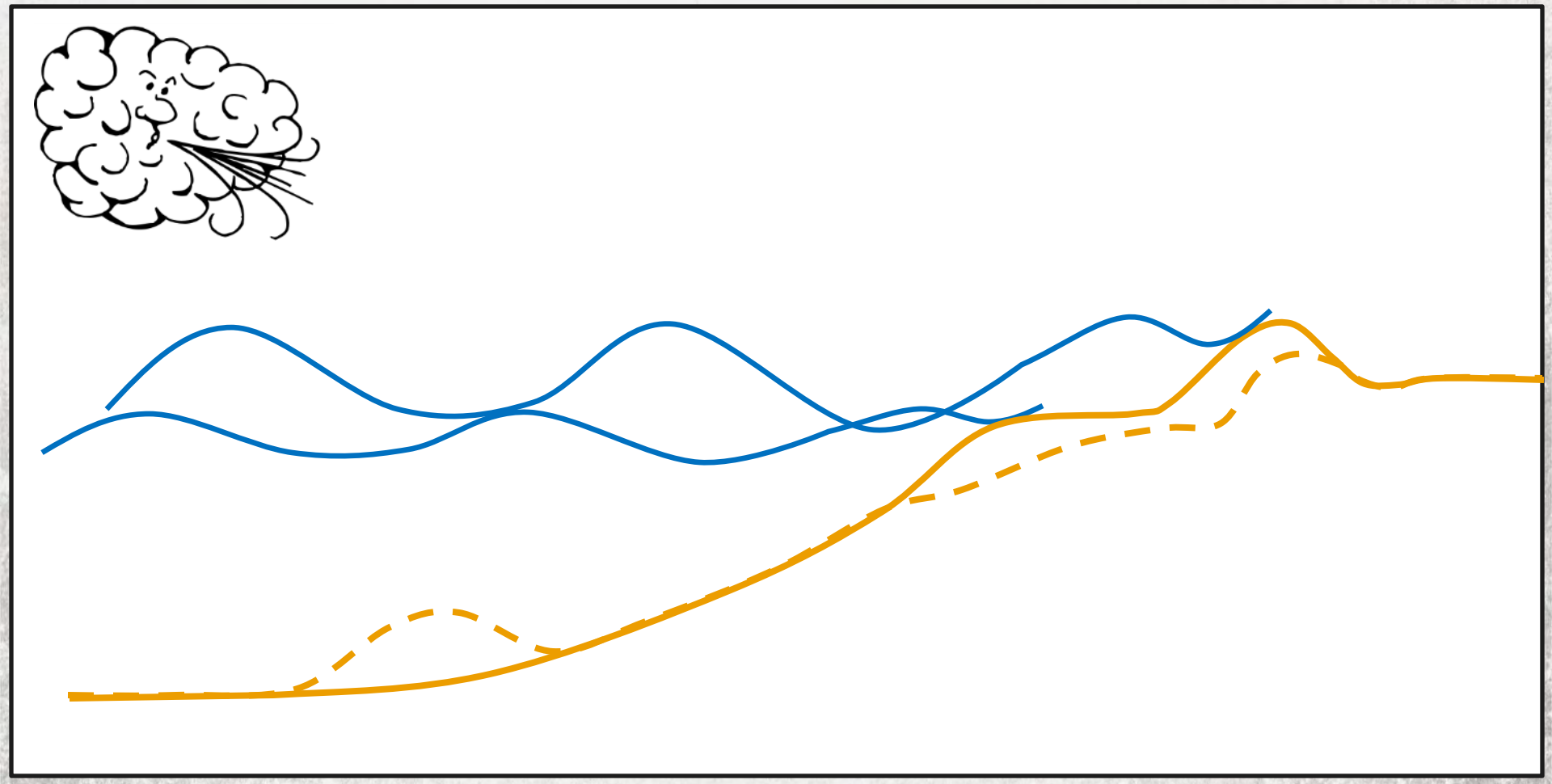
COASTAL VULNERABILITY



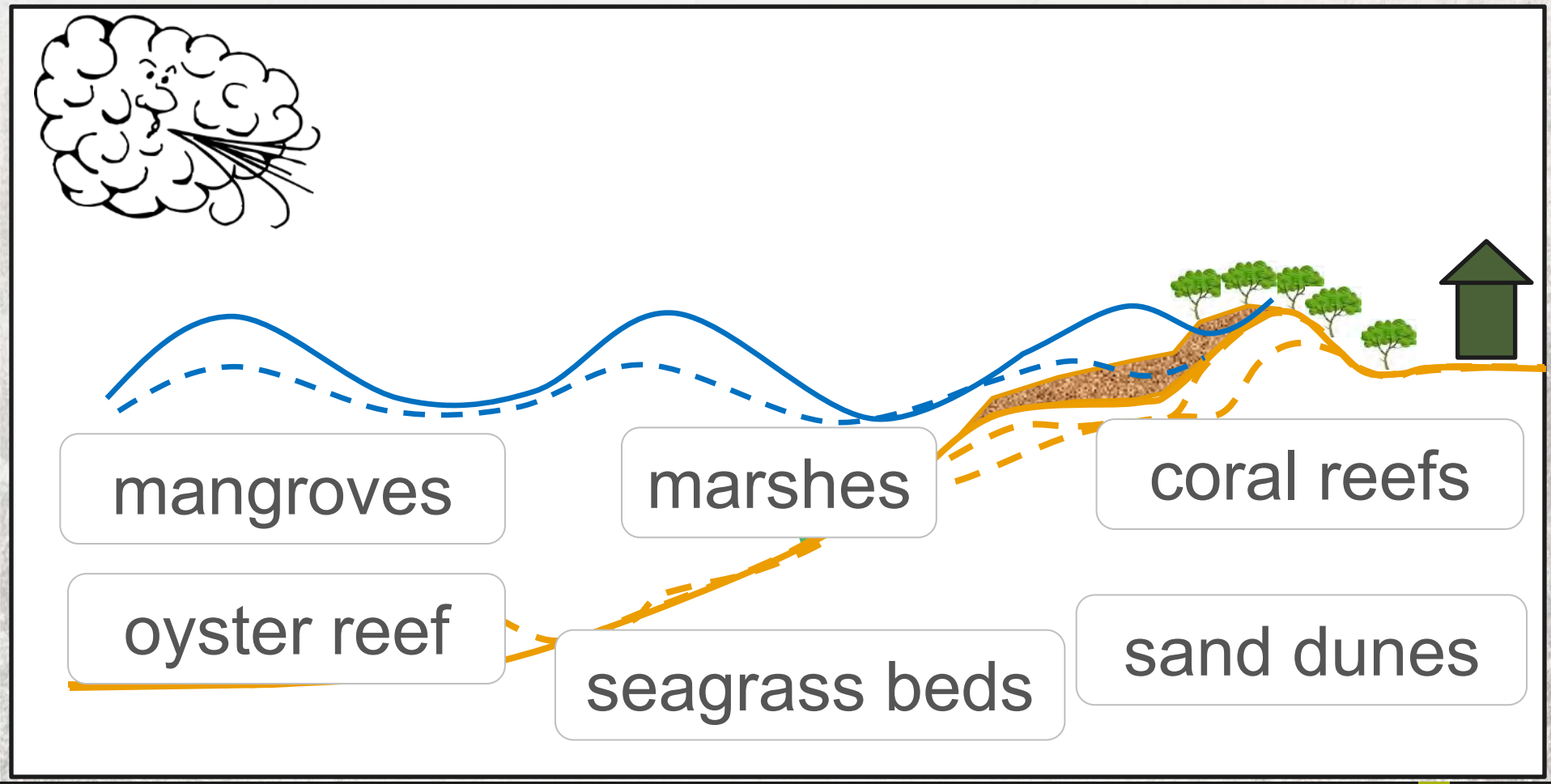
COASTAL PROTECTION



NEARSHORE WAVES AND EROSION

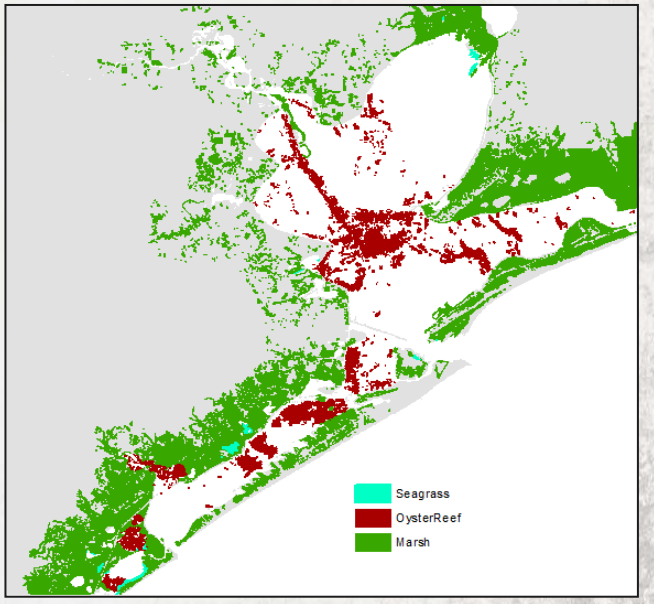


NEARSHORE WAVES AND EROSION



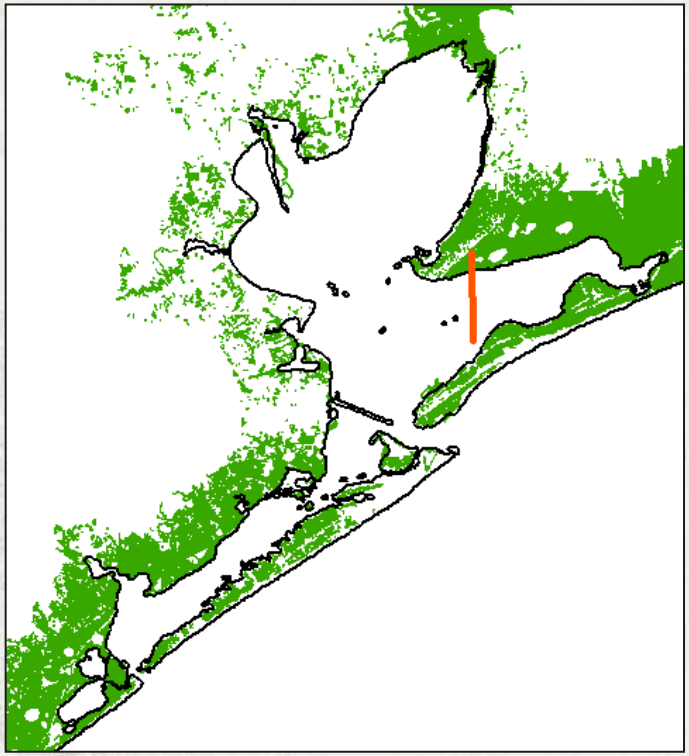
APPLICATION

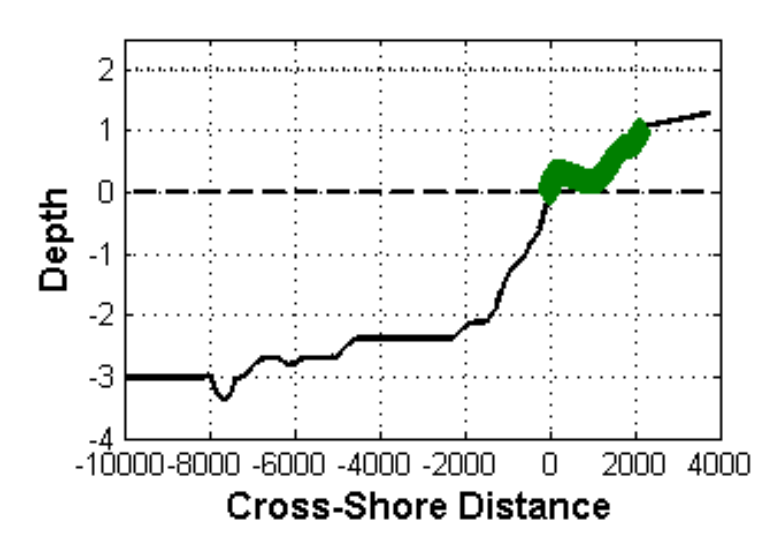
1. Cat. 2 Storm
2. 3.5 m surge
3. Hurricane wave heights

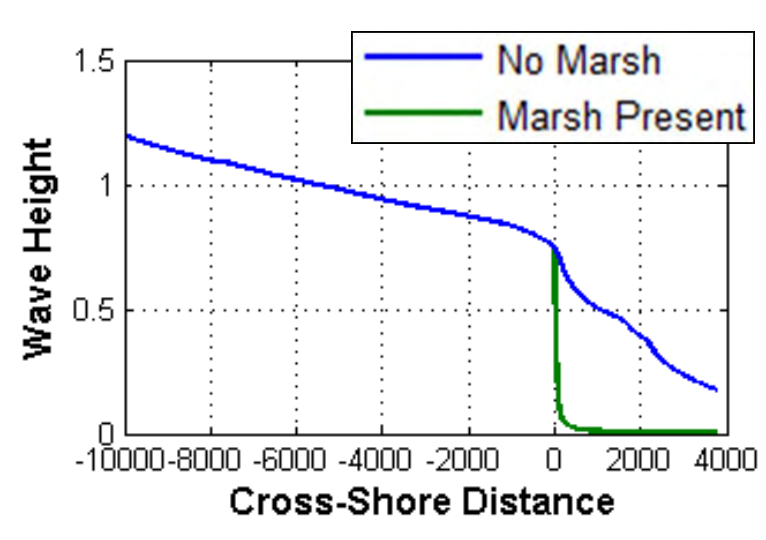


1. Surge height reduction ~7 cm/km
2. Standard vegetation characteristics

WETLANDS ATTENUATE WAVES

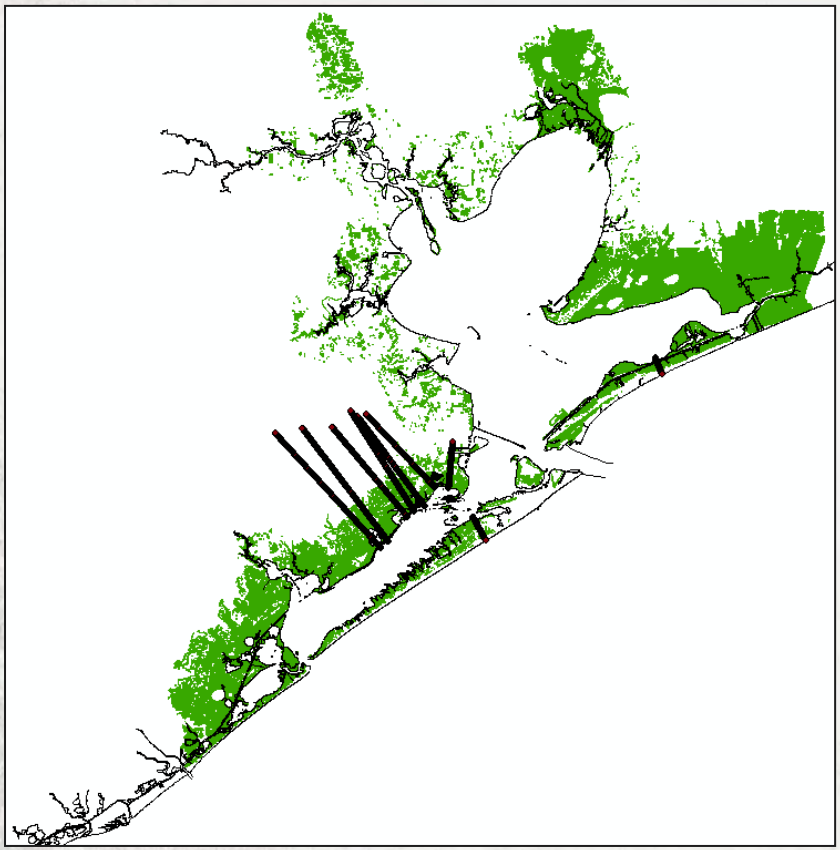


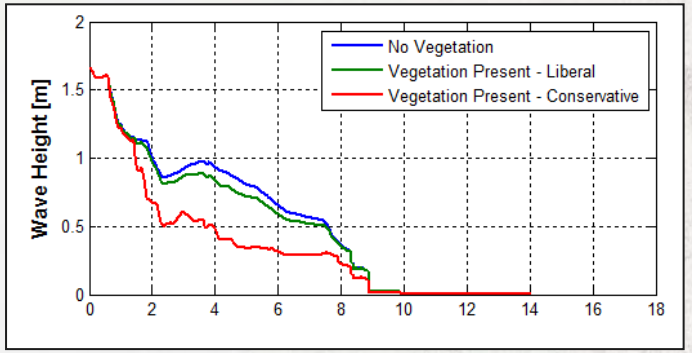


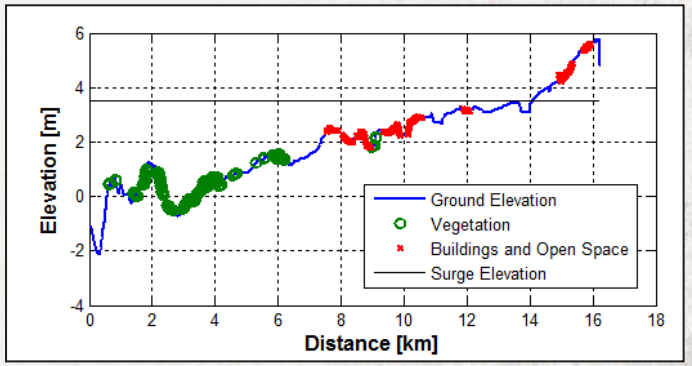


Dense, tall, thick marshes reduce height of waves

WETLANDS ATTENUATE WAVES

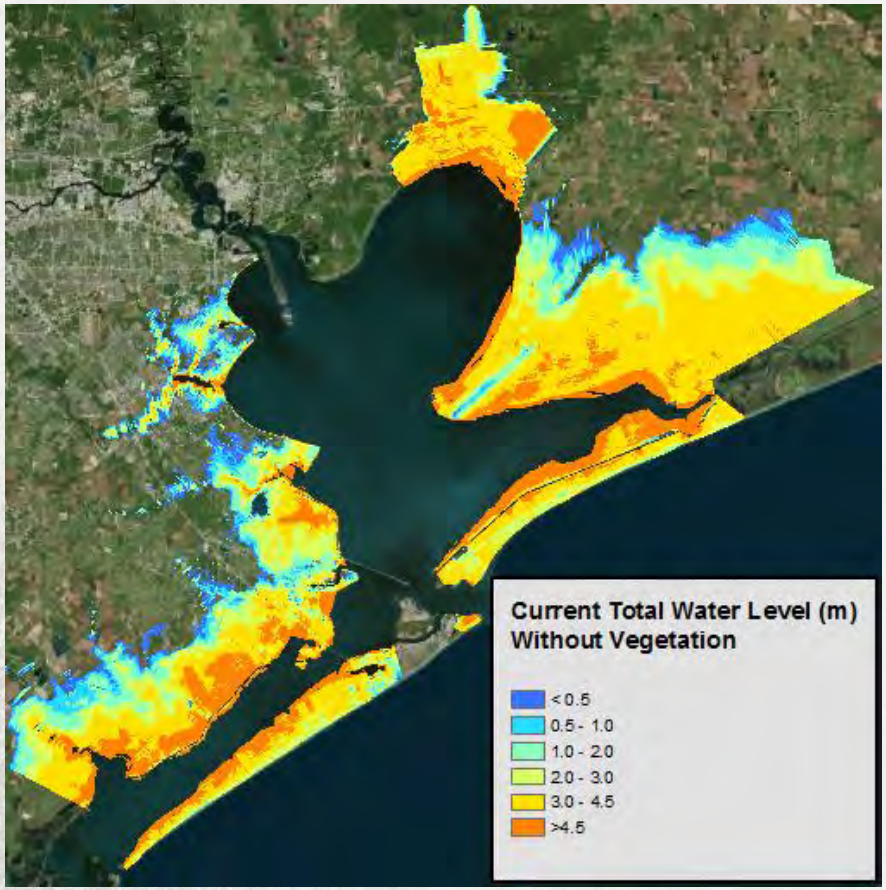




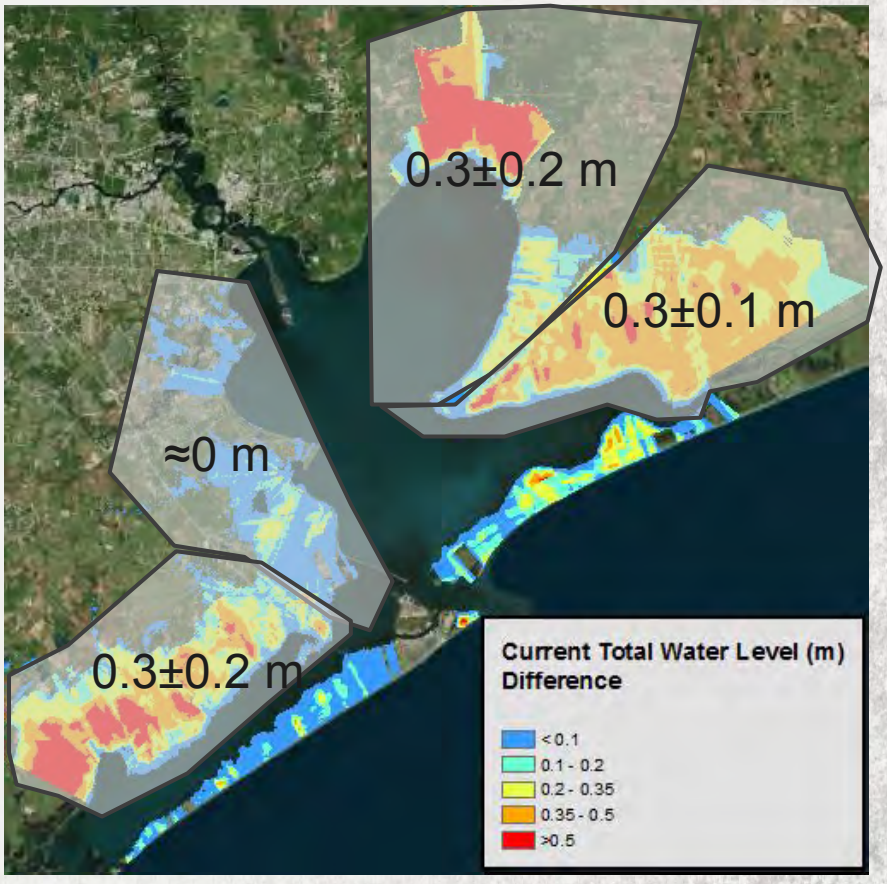


TOTAL WATER LEVEL RESULTS

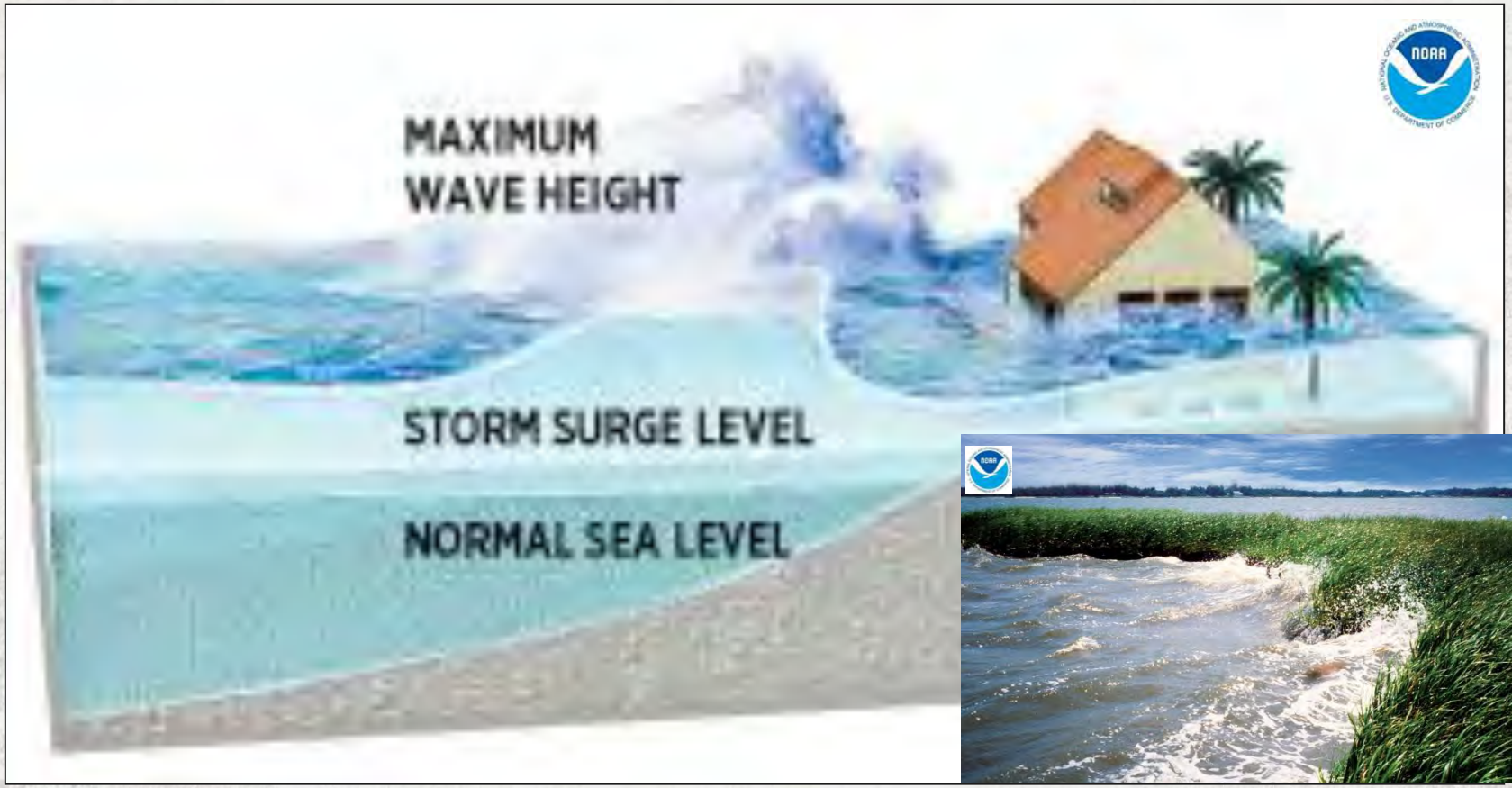
Bare



Marsh Present

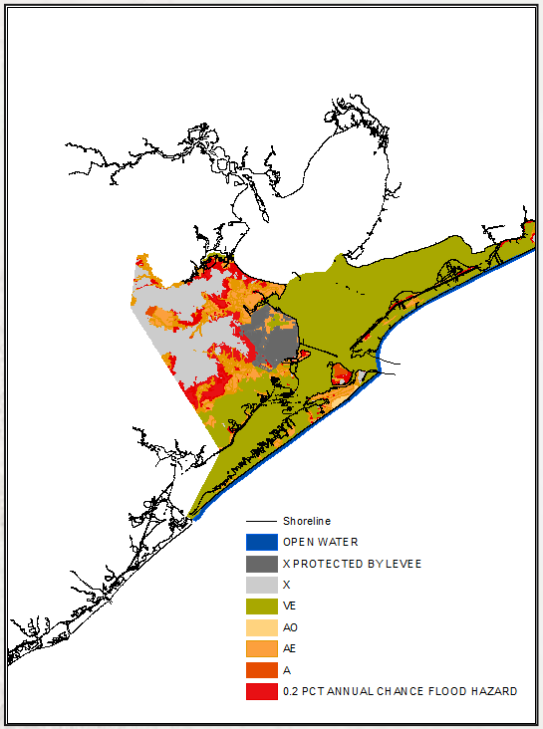


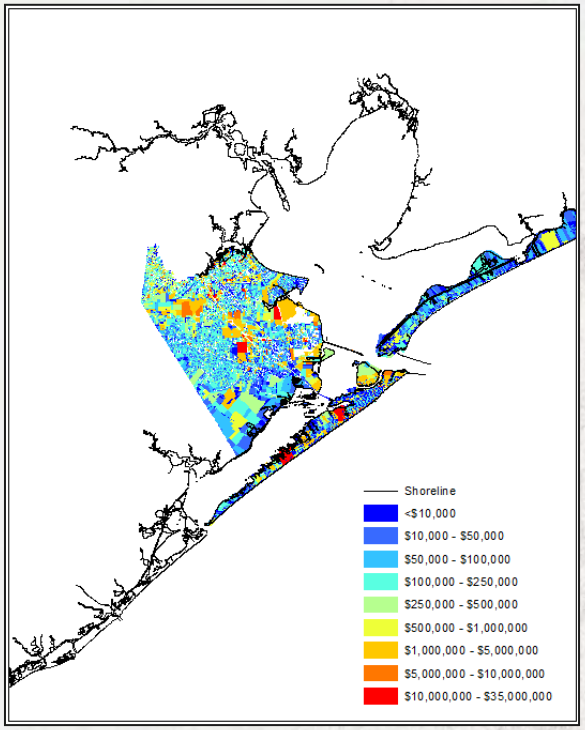
DAMAGES ASSESSMENT

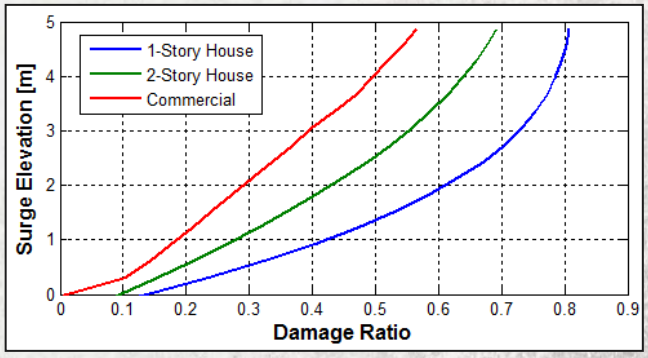


Damages = $f(water\ level, property\ value)$

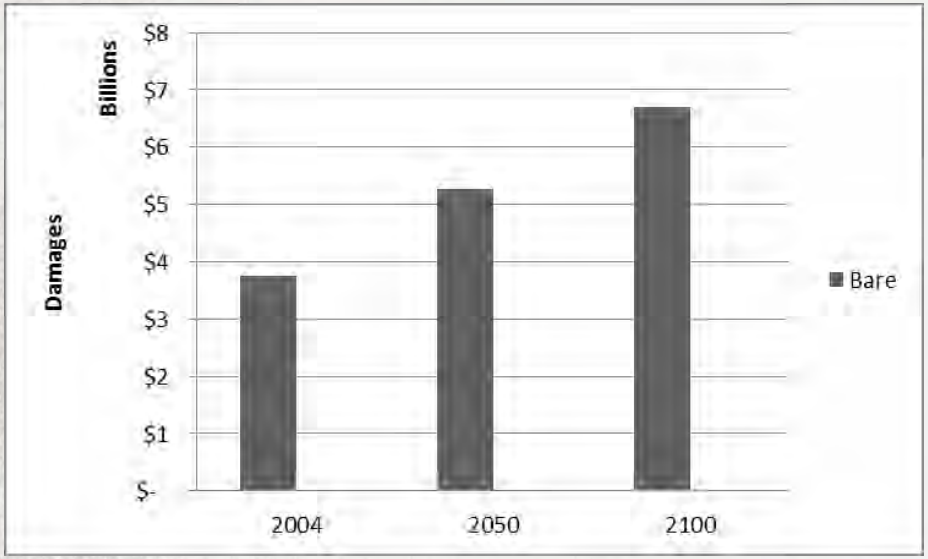
VALUATION OF MARSHES



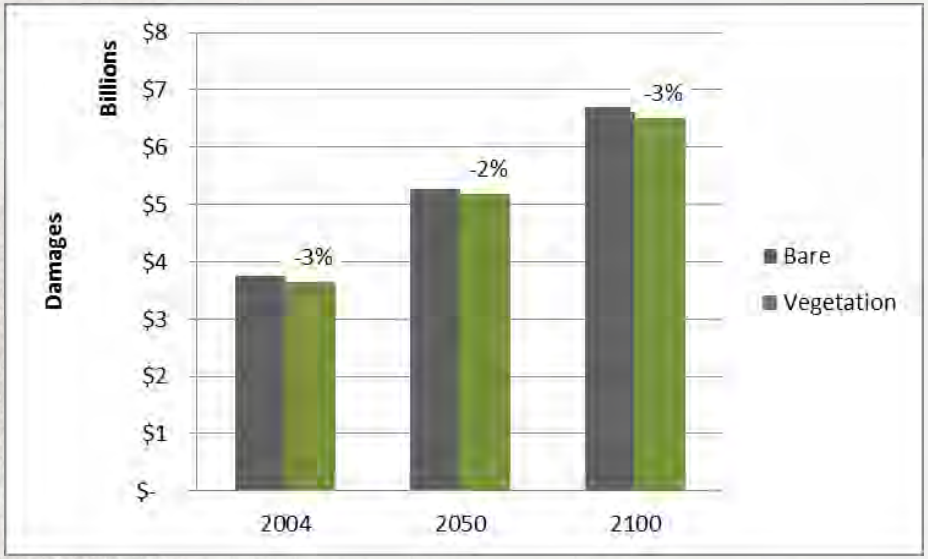




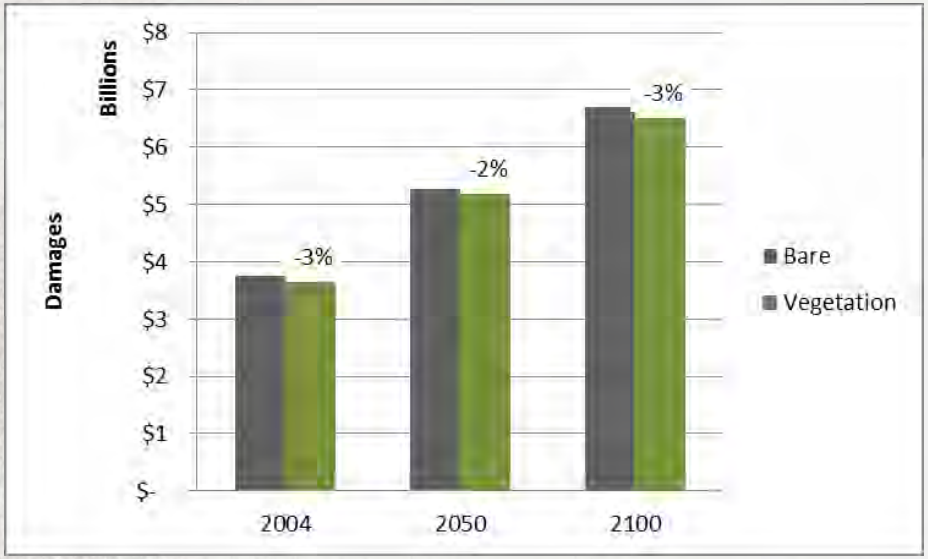
VALUATION OF MARSHES

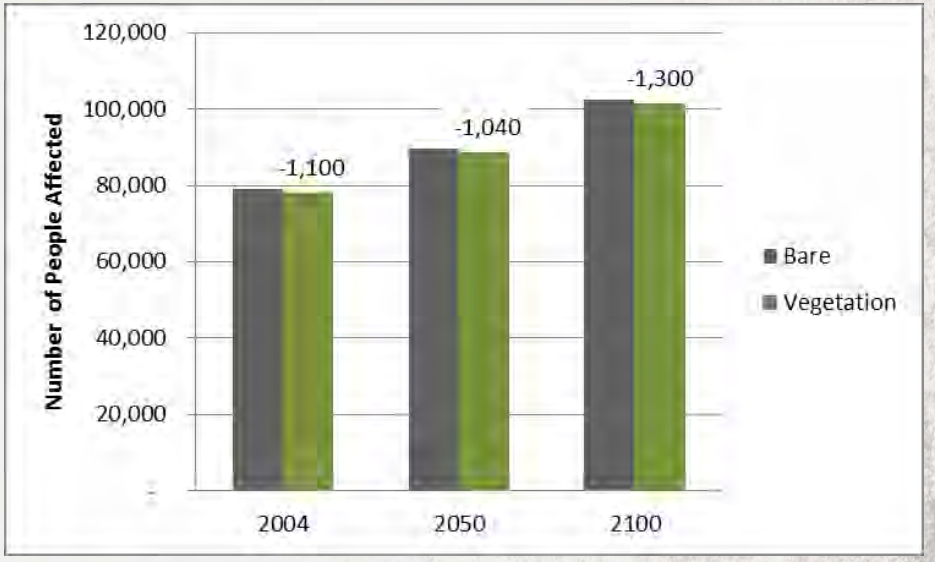


VALUATION OF MARSHES



VALUATION OF MARSHES





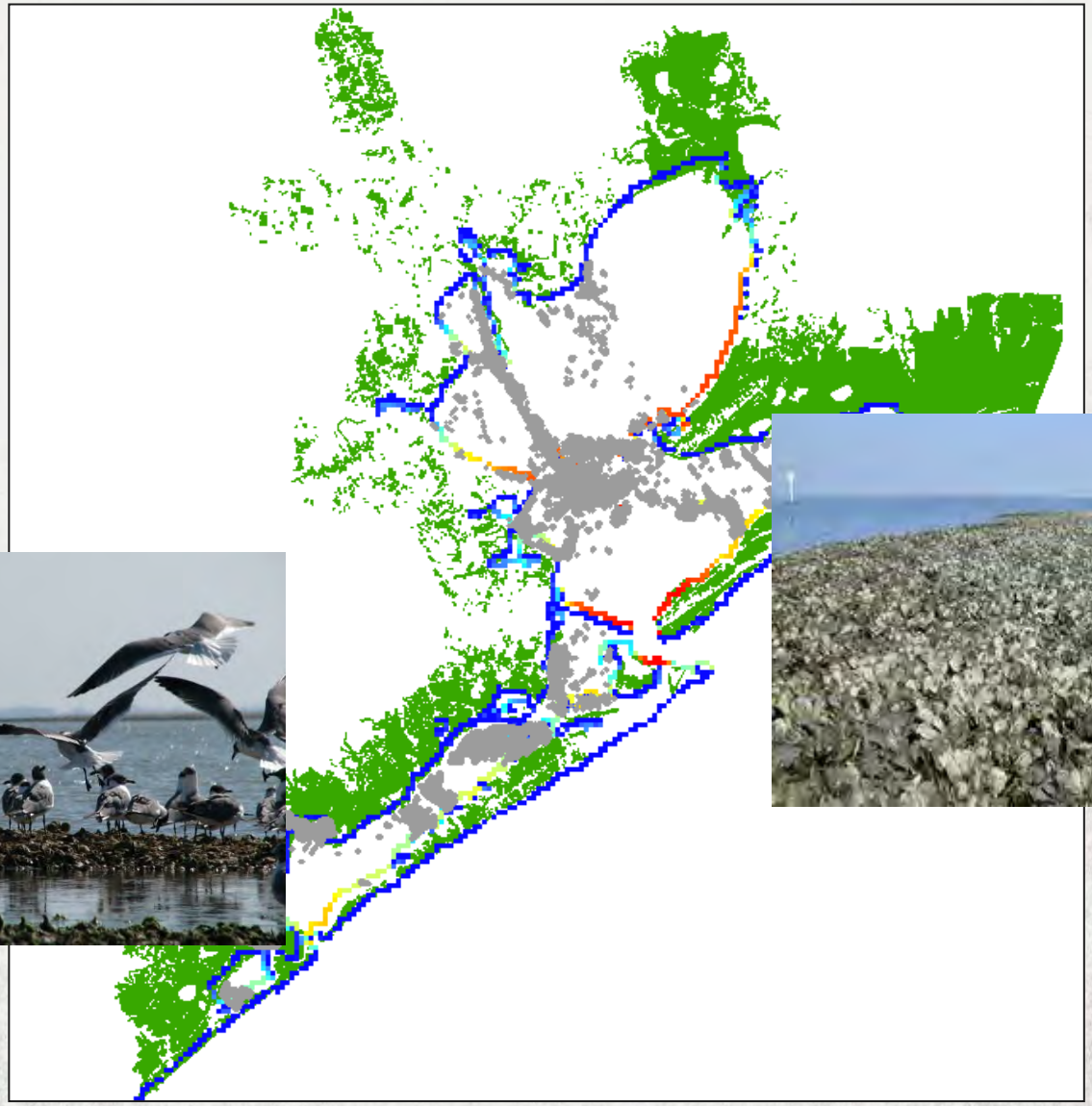
- **Damages will increase as sea level rises**
- **Wetlands reduce damages by ~3%**
- **Wetlands protect ~1,000 people**

I WANT MY MARSHES!!

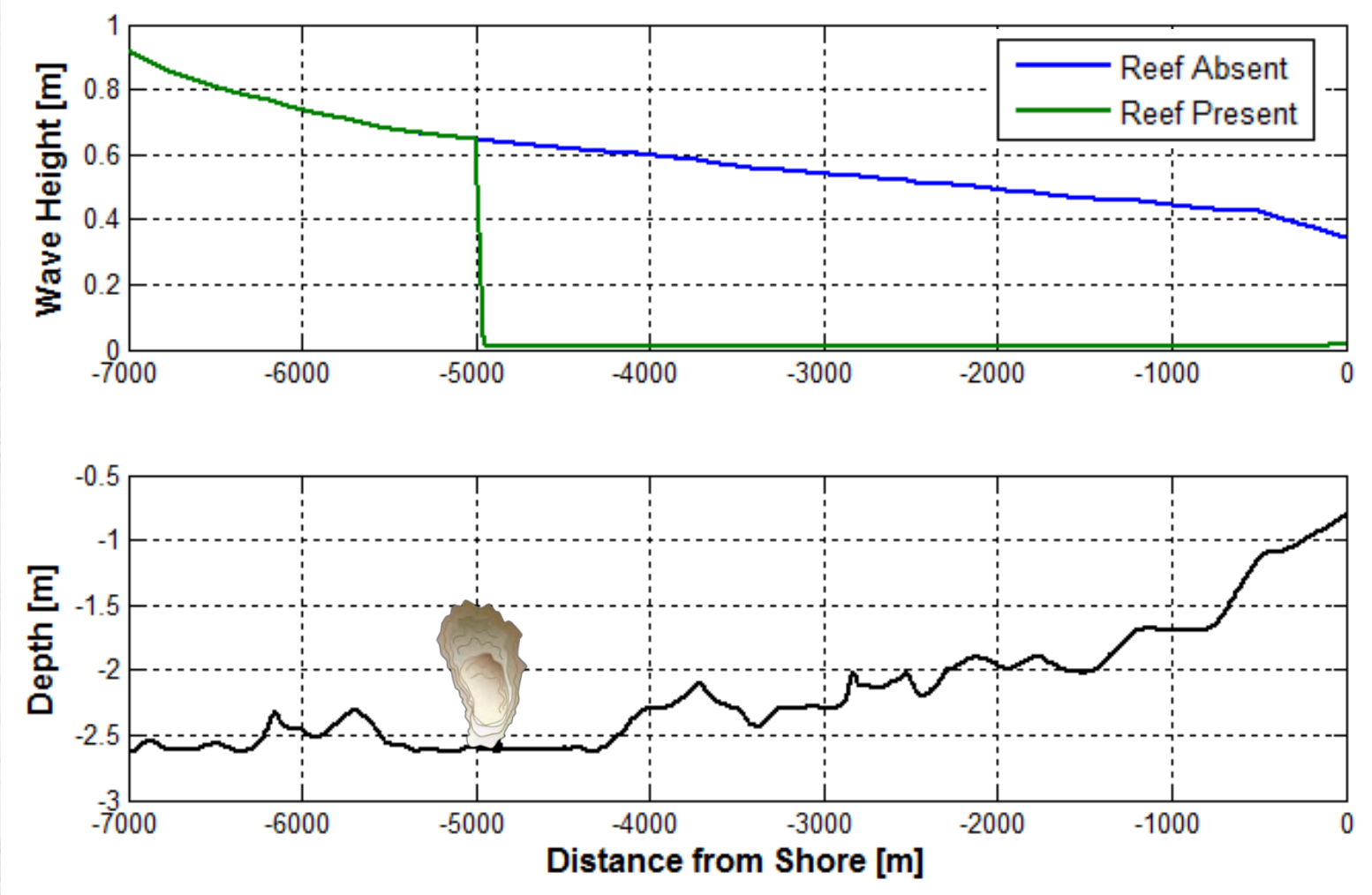
Coastal Vulnerability Model

Nearshore Waves and Erosion Model

I WANT MY MARSHES!!



OYSTERS TO THE RESCUE



THANKS