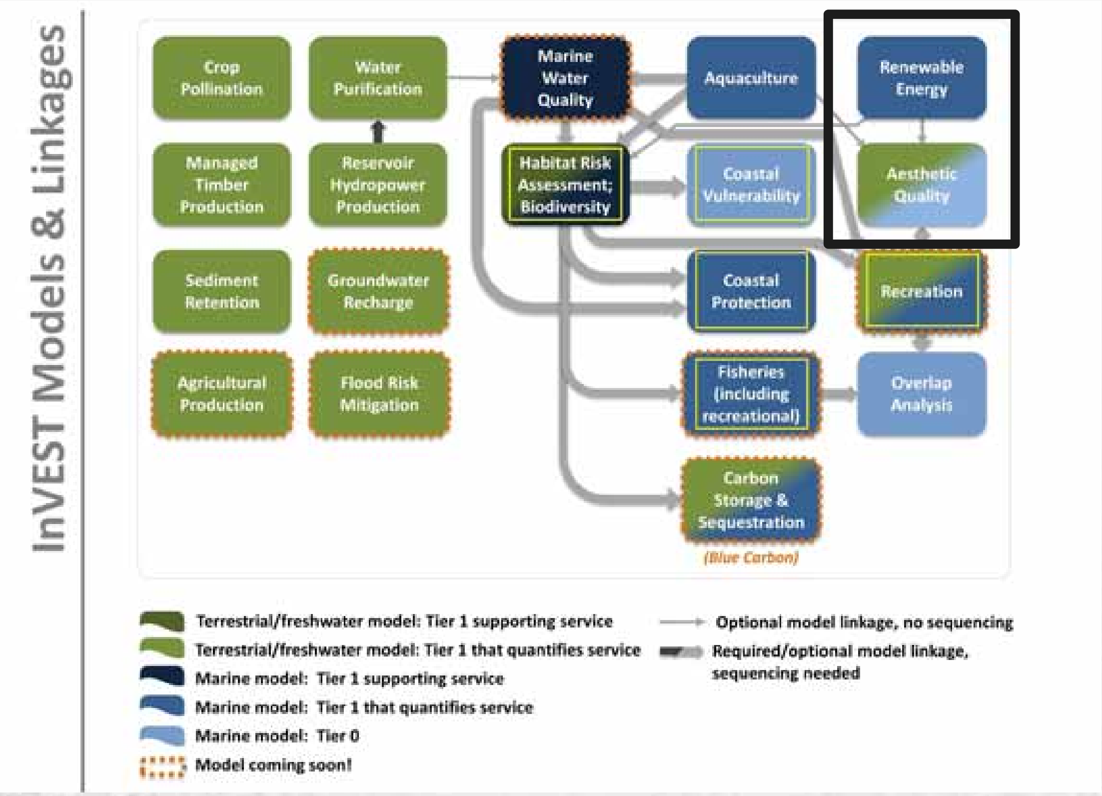
ECOSYSTEM SERVICE TRADE-OFFS

- 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

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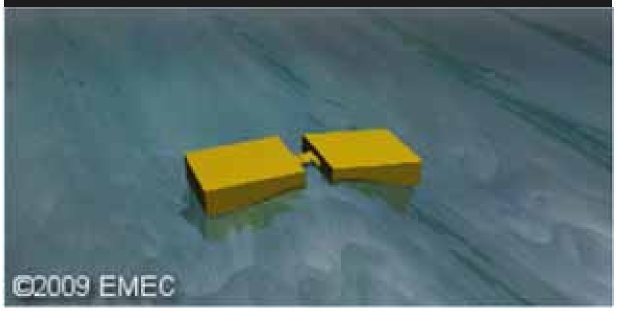
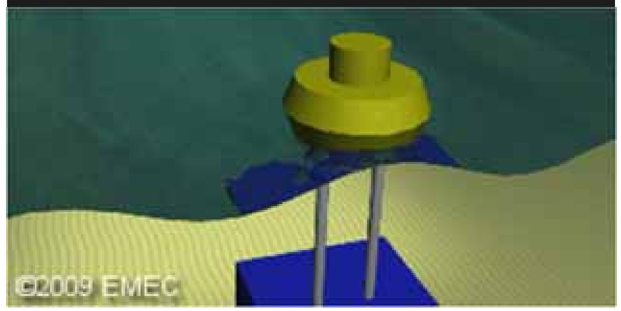
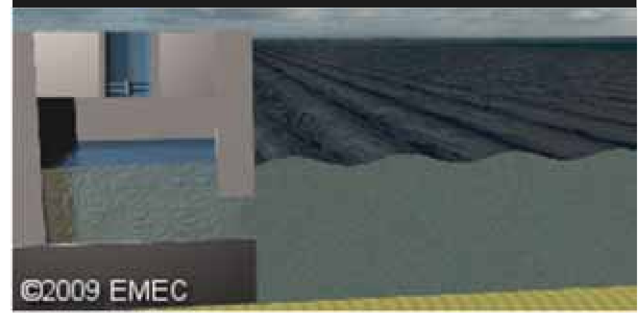
Attenuator



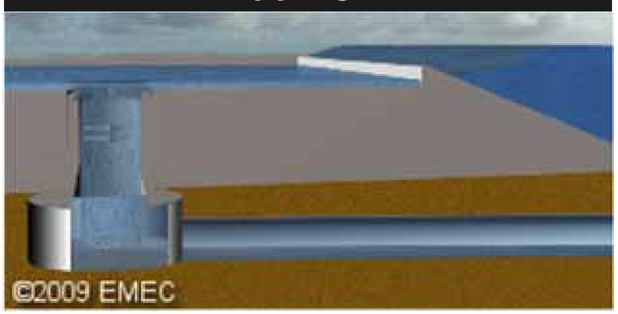
Point Absorber



Oscillating Water Column

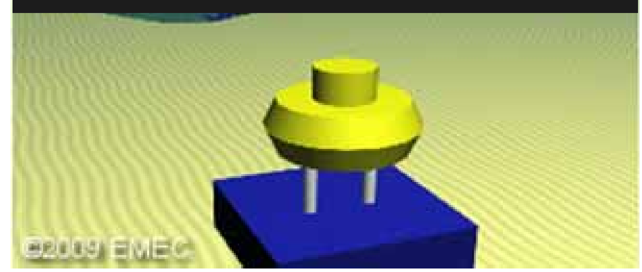


Overtopping Device

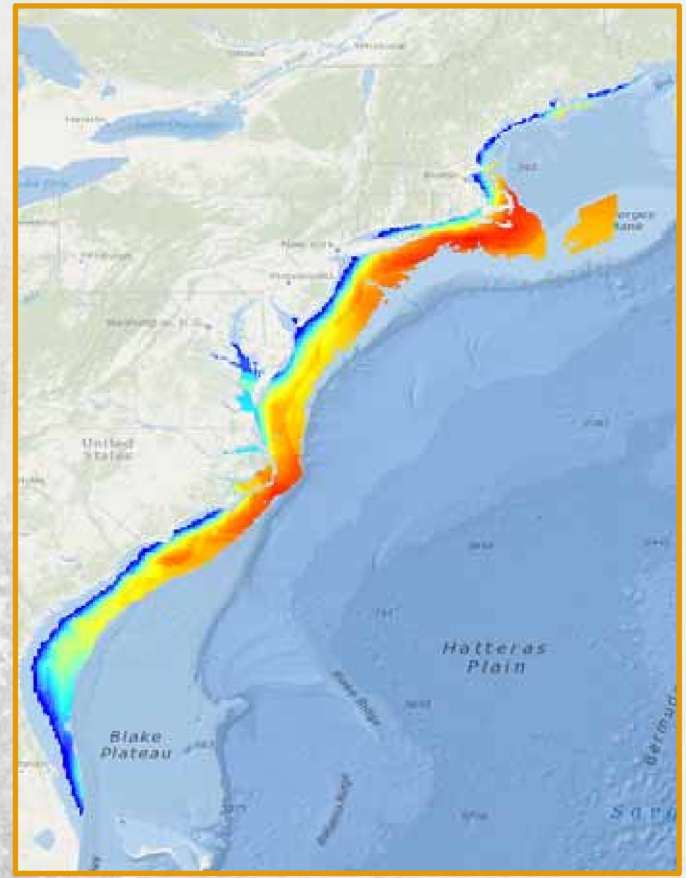


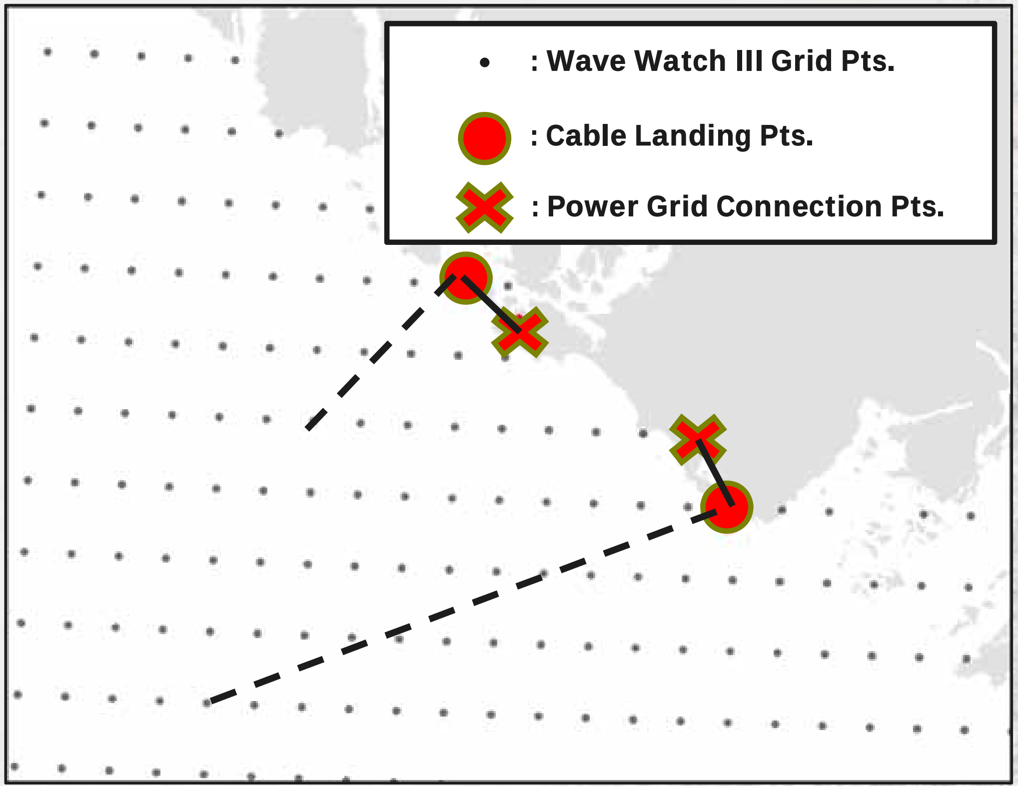
Oscillating Wave Surge Converter

Submerged Pressure Differential



RENEWABLE ENERGY MODELS
THE BASICS



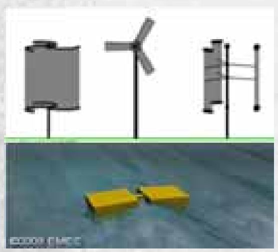


RENEWABLE ENERGY MODELS
INPUTS AND OUTPUTS

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)

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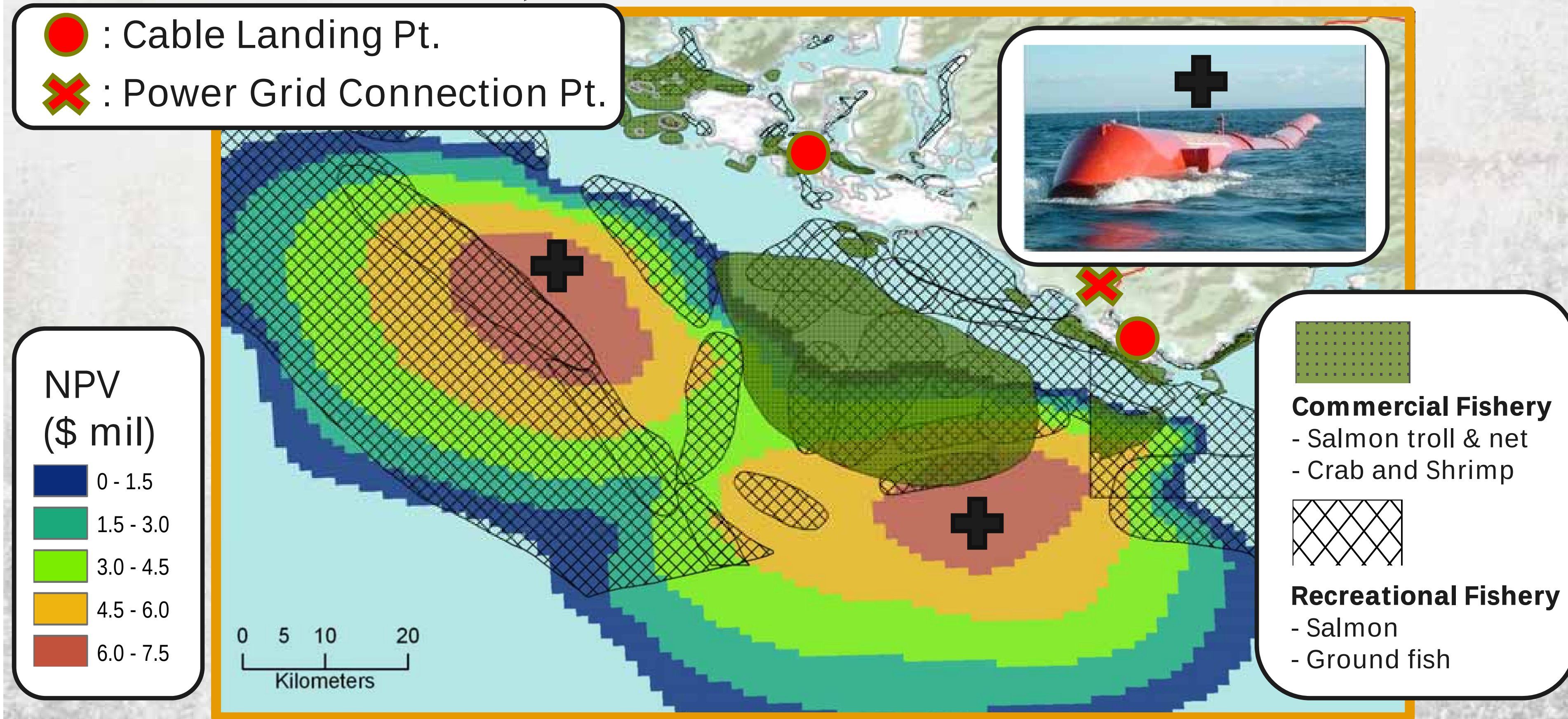
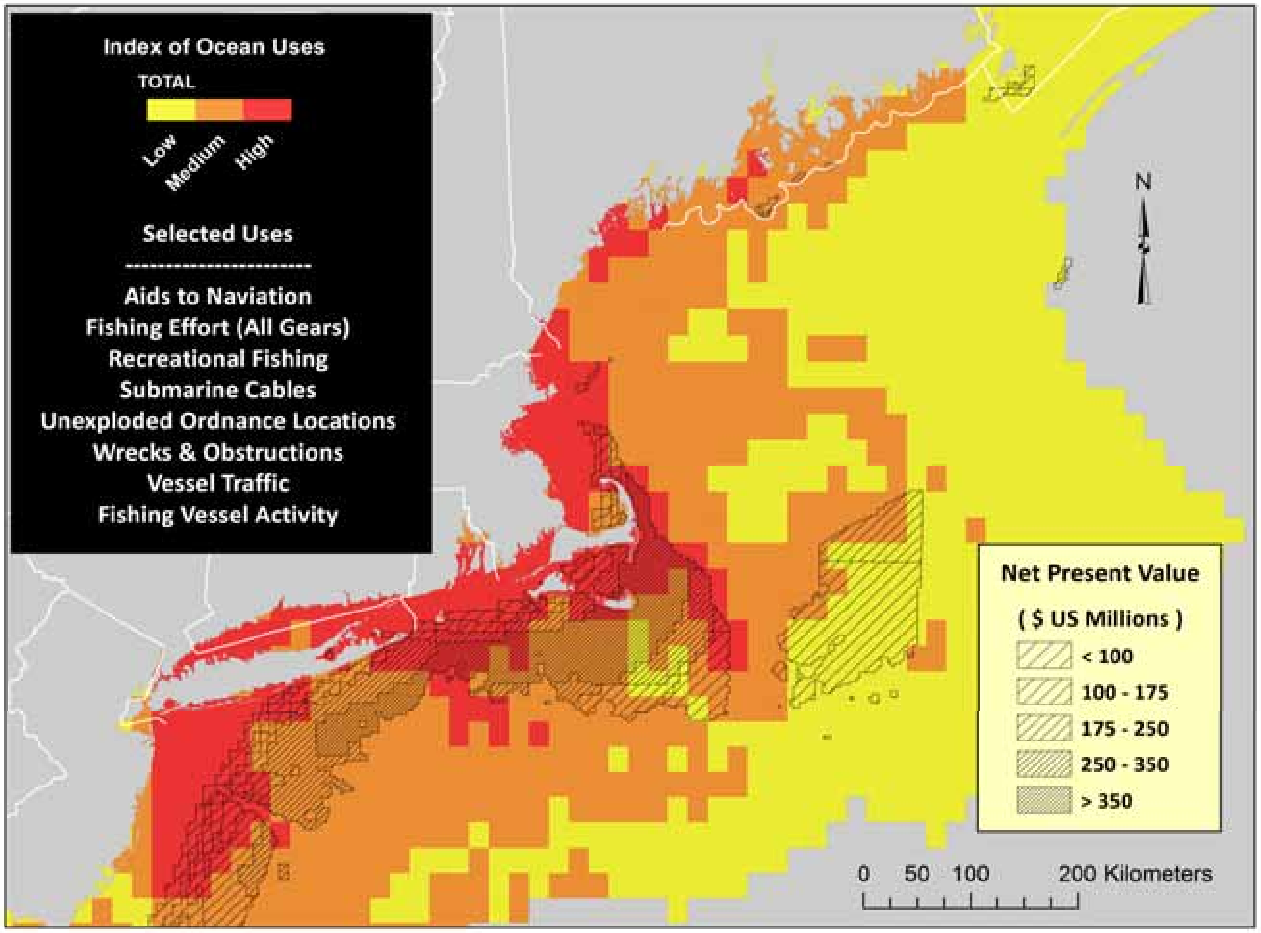




Overlap Analysis

- 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

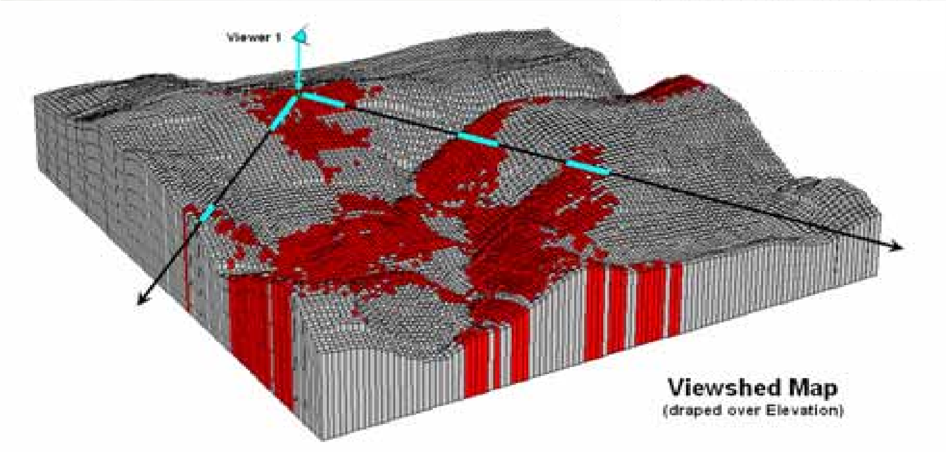
- Fishing / Vessel Activity
- Shipping
- Recreation
- Wrecks and Obstructions
- Aquaculture
- and **SCENIC QUALITY!**

SCENIC QUALITY

AESTHETICS (VIEWSHED ANALYSIS)

INVEST SCENIC QUALITY MODEL
THE BASICS

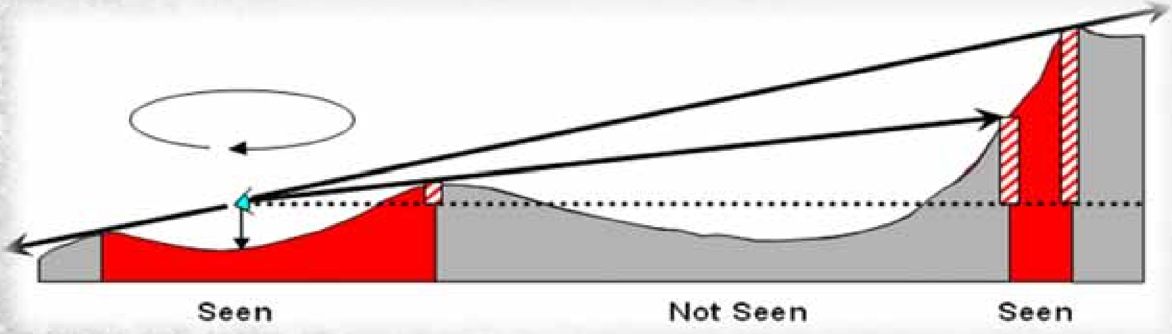
- A **viewshed** is an area that is visible from a specific location.
- This type of analysis is common functionality available within most GIS software.

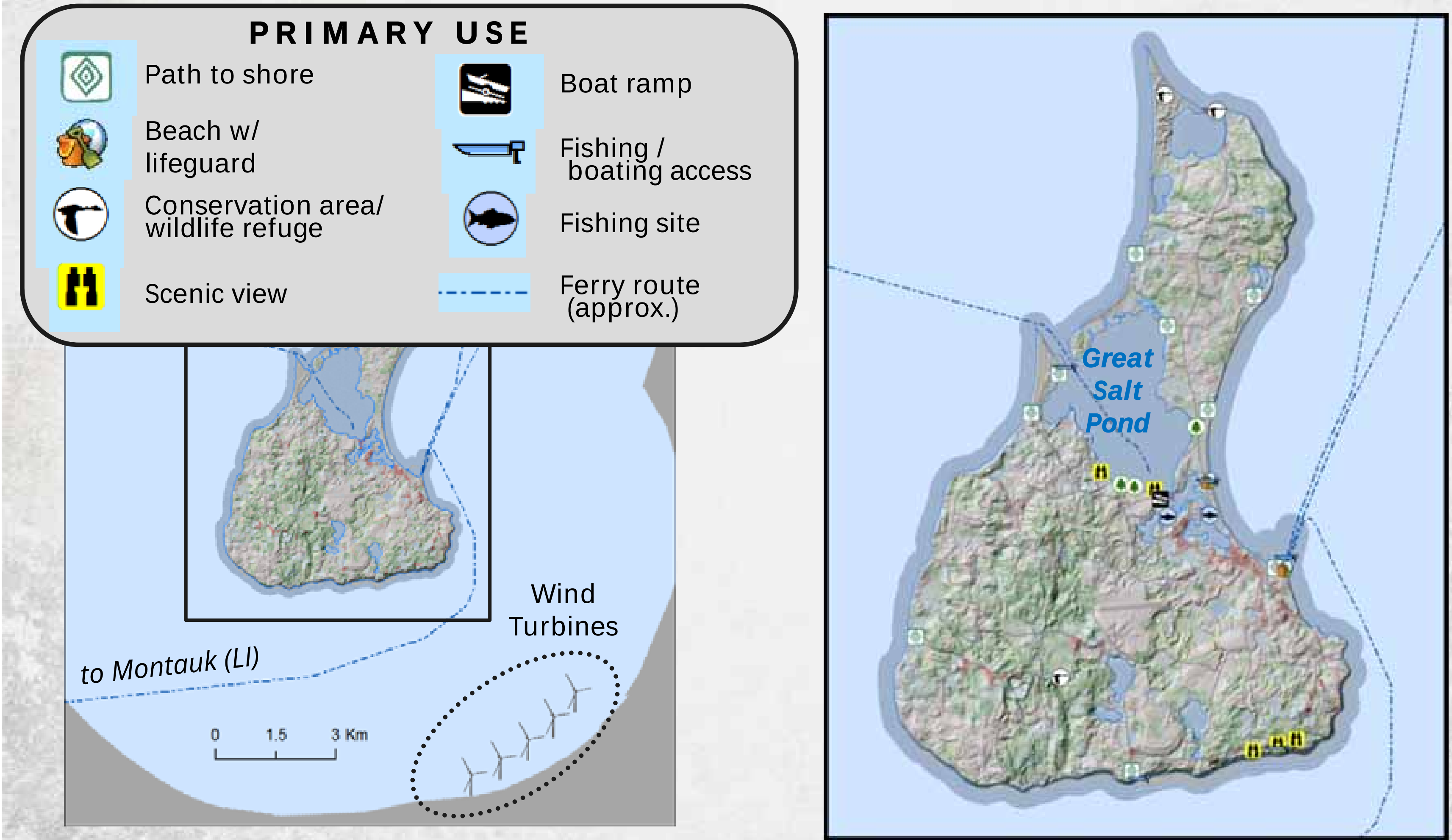


- Viewshed analysis uses the elevation value of each cell of a DEM to determine visibility to or from a particular cell.
- Application example: Locations on land where five new offshore wind turbines are visible

SCENIC QUALITY
HOW IT WORKS

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





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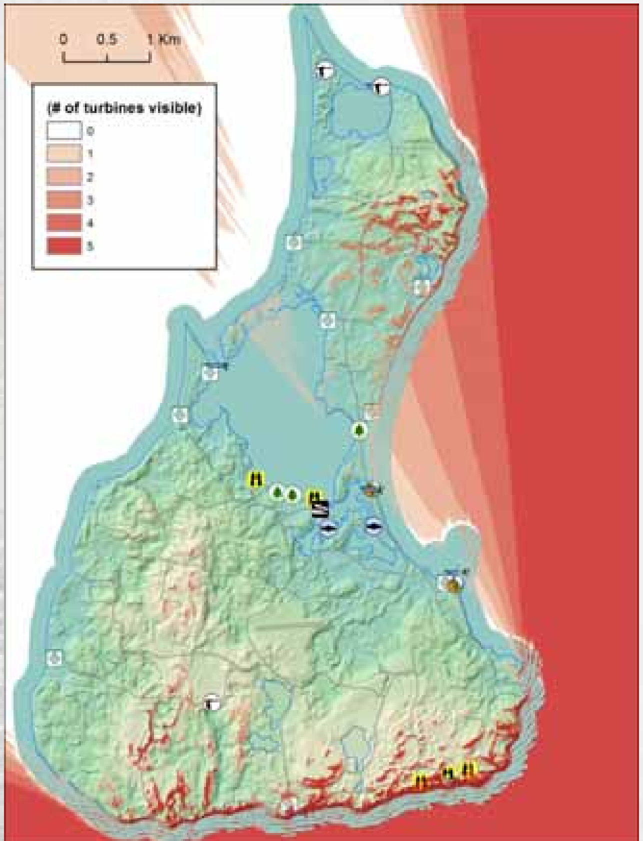
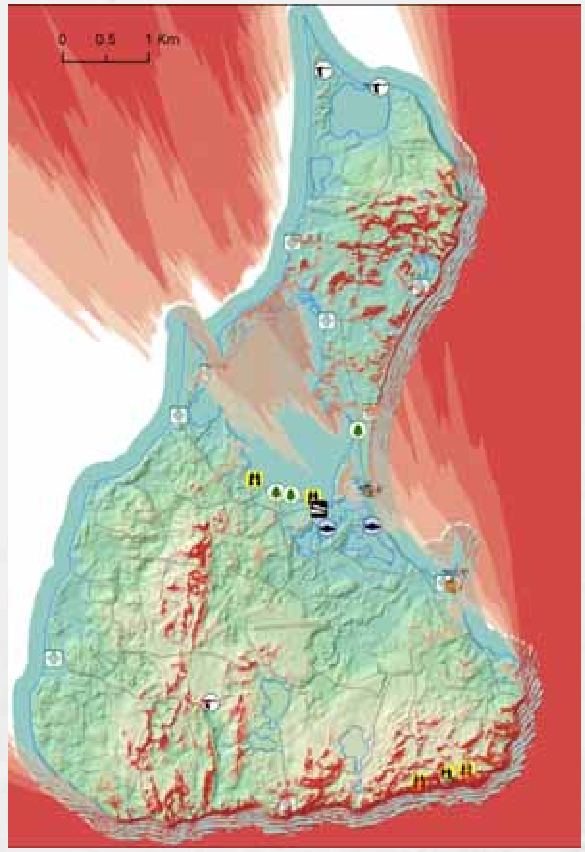
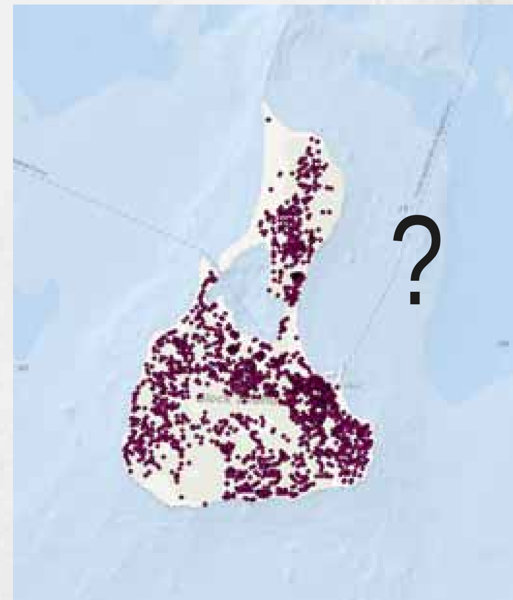
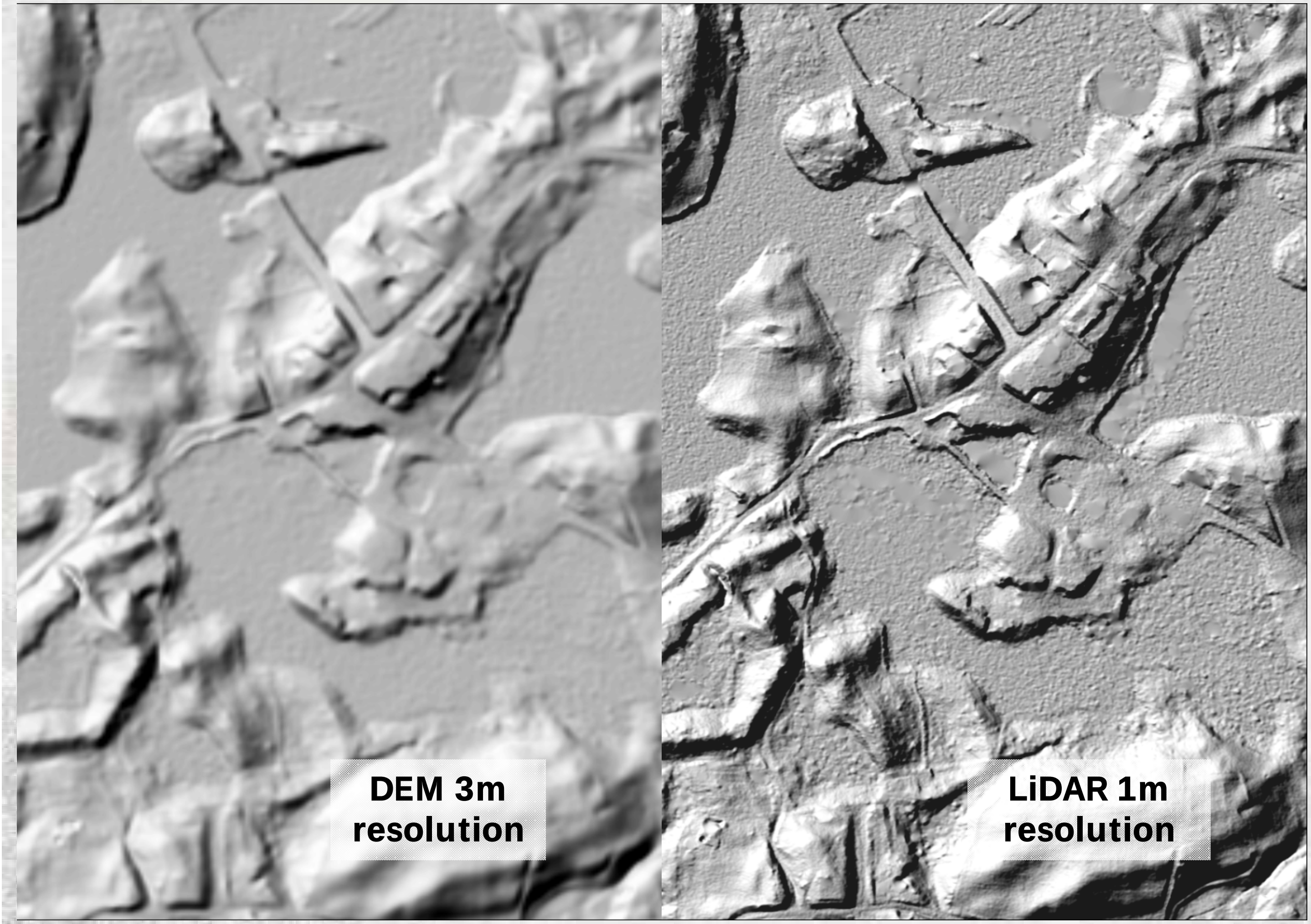
VIEWSHED RESULTS







?



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TRADE-OFFS
REPRISE

Competing Uses

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

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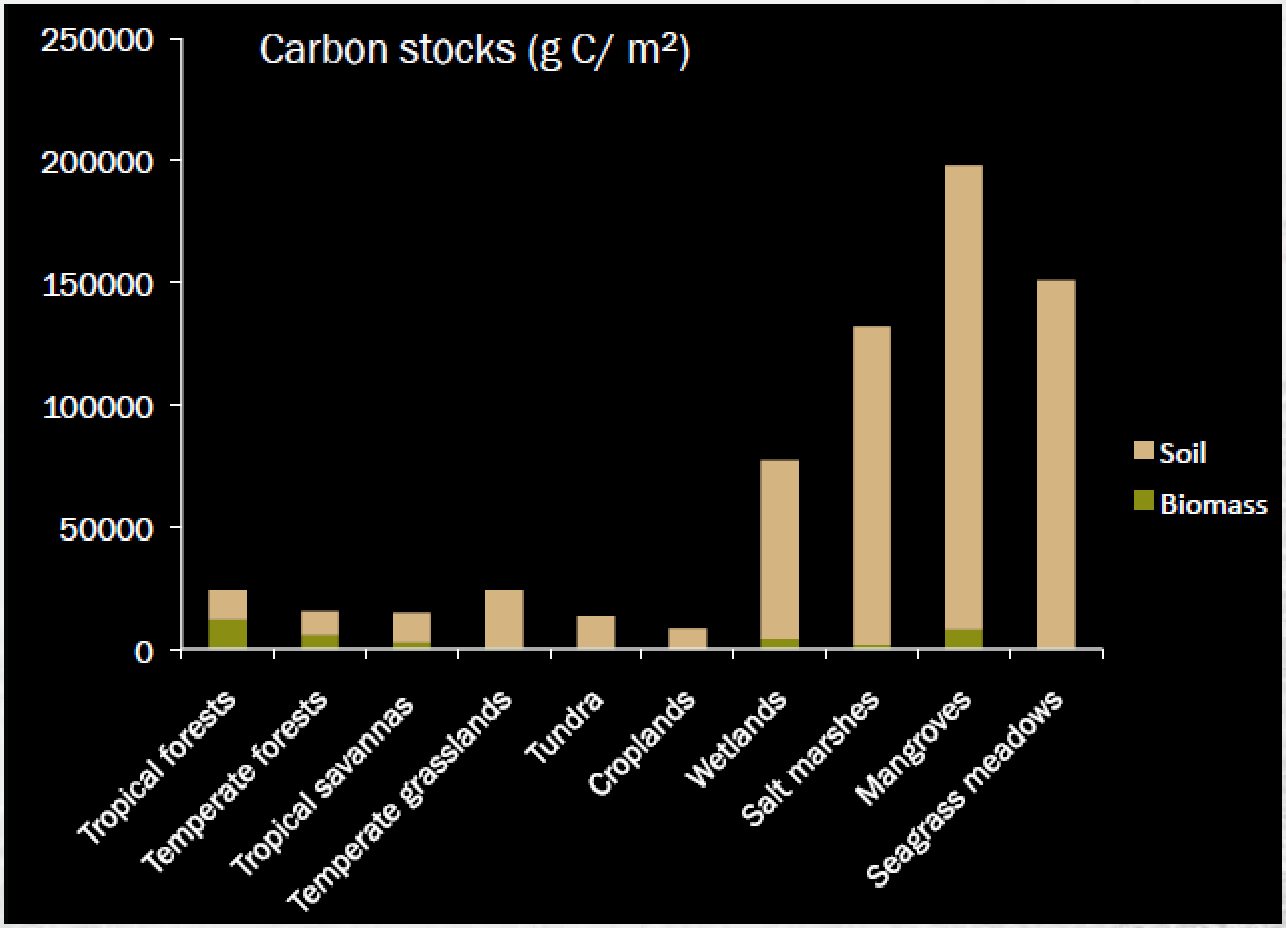
BLUE CARBON

Application in Galveston, Texas

The Nature Conservancy

Gregg Verutes, Joey Bernhardt, Martin Lacayo

BLUE CARBON
FUN FACTS



THE BASICS
INVEST BLUE CARBON MODEL

- "Blue Carbon " term is used to define carbon that is stored and sequestered in coastal vegetation and wetland habitats.
- These habitats are capable of storing, or "sinking", significant quantities of carbon in their plant matter and soils.
- CO_2 can become sequestered away as elemental carbon, effectively removing it from the atmosphere.
- Co-benefits:
  These habitats provide a multitude of other ecosystem services that benefit the people including nursery habitat, recreation opportunities, and shoreline protection.

BLUE CARBON
DEVELOPMENT TEAM

Model advances the science because it is:
1) spatial and 2) incorporates disturbance information

GREGG VERUTES
Geographer

JOEY BERNHARDT
Marine Ecologist

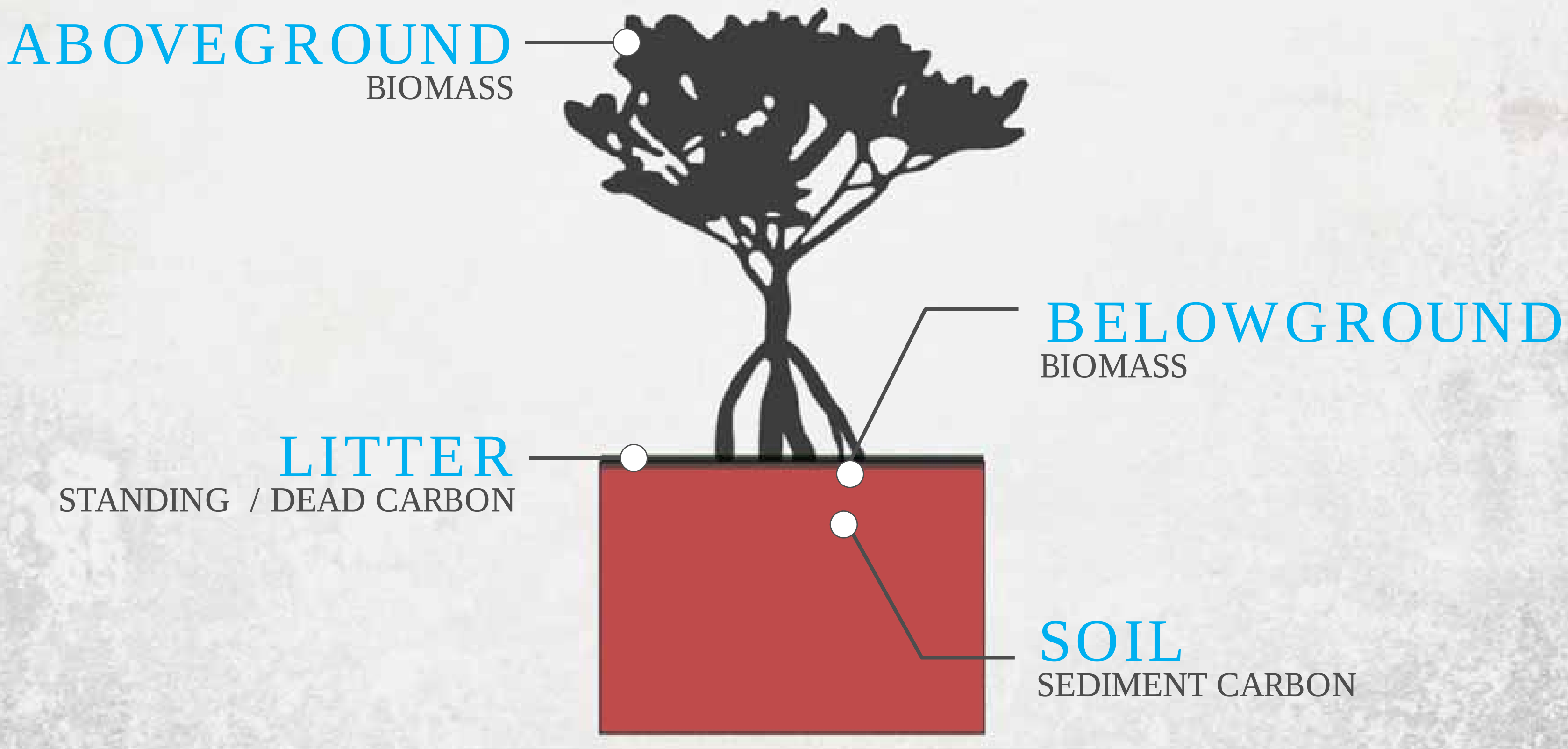
MARTIN LACAYO
Software Engineer

ROB GRIFFIN
Economist

Thanks to: Greg Guannel, Katie Arkema, Anne Guerry, Amy Rosenthal, Jess Silver, Mike Thompson

FOUR CARBON POOLS

MANGROVE EXAMPLE



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MODEL STEPS
BLUE CARBON

- Quantify carbon stored and sequestered under status quo
- Quantify changes under alternative management
- Value the avoided emissions (social or market)

MANGROVE

MARSH

SEAGRASS

OTHER

?

BLUE CARBON MODEL
FRAMEWORK

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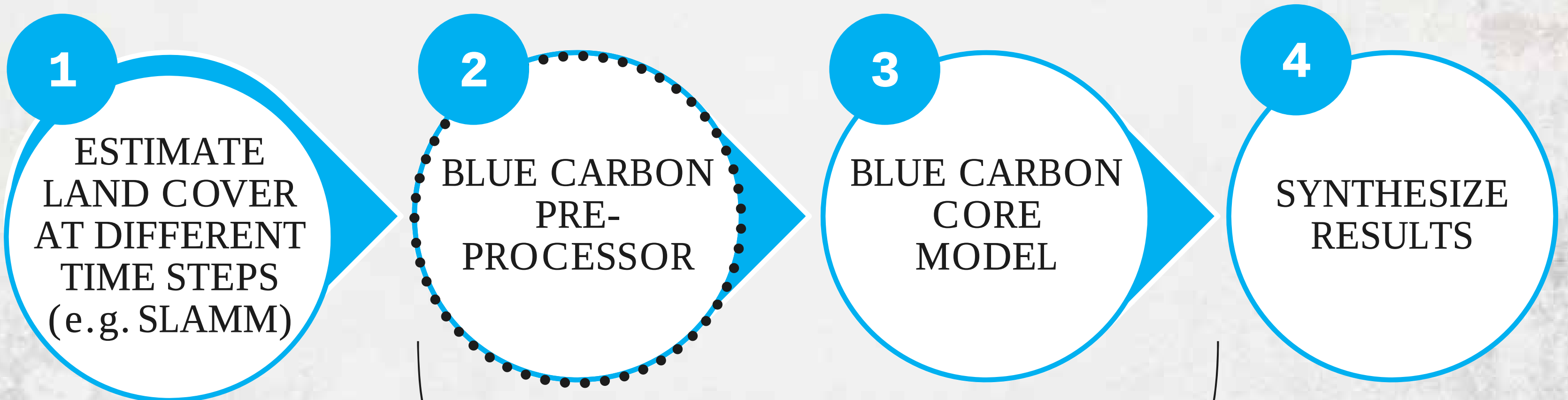

InVEST
integrated valuation of environmental services and tradeoffs

HOW IT WORKS
PRE-PROCESSOR

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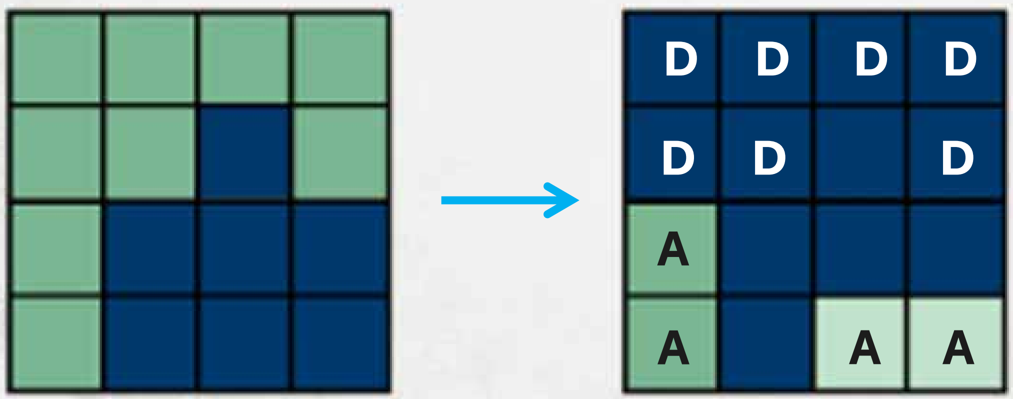


TIME 1

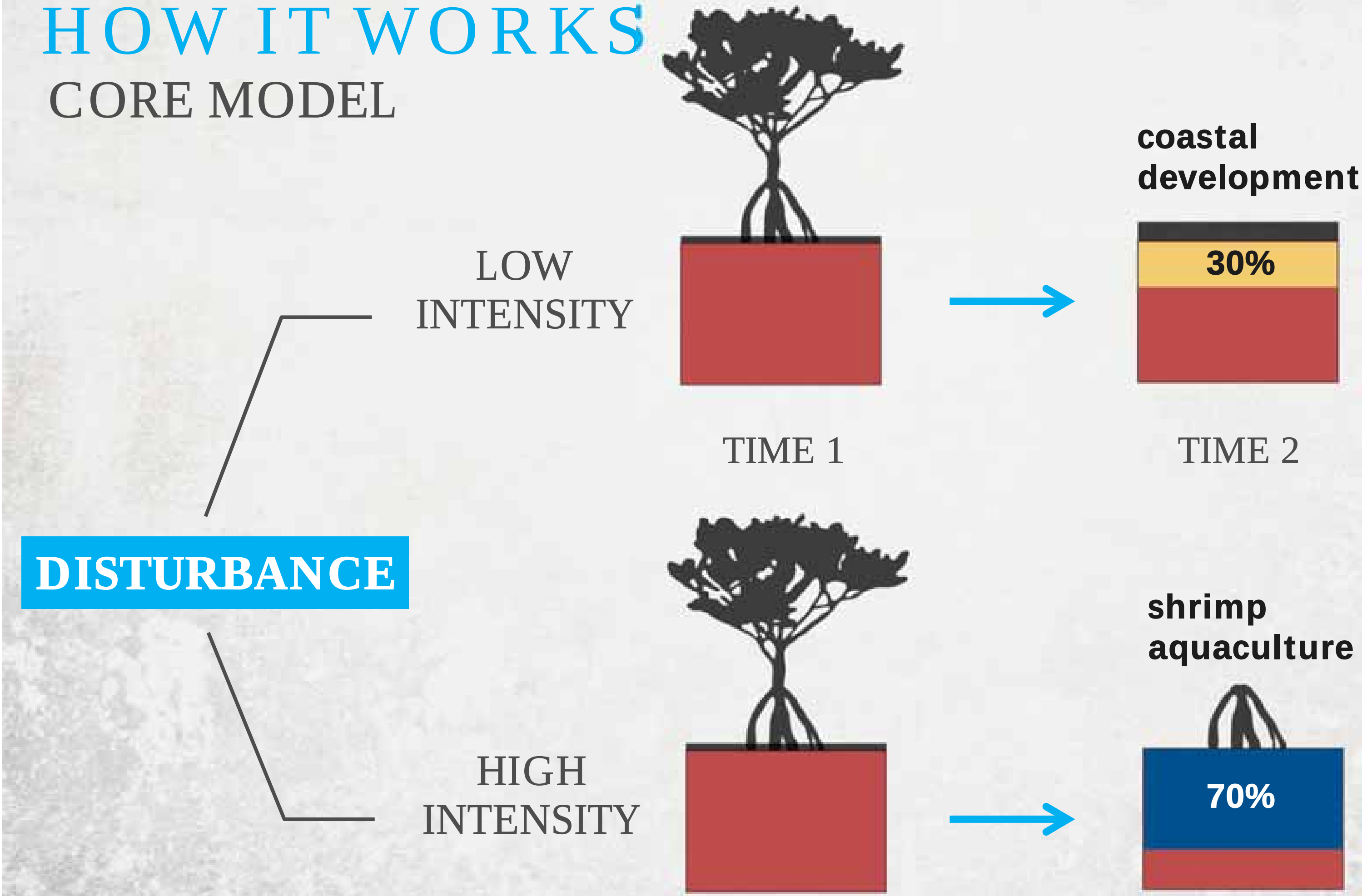
TIME 2

D = Disturbance
- **Low**
- **Medium**
- **High**

A = Accumulation
(vegetation/age-specific rate)

HOW IT WORKS

CORE MODEL



Half Life = 7.5 yrs
Every 7.5 years, half of carbon stored in the top 30% or 70% is lost to emissions

BLUE CARBON
GLOBAL DATABASE

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Location	General Location	Latitude	Longitude	Tonnes CO2e/ha/yr	Study	Year	Citation	Original Article if Cited in Review
Tijuana Slough, Calif.	California	32.50	-117.10	12.58	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld,	Cahoon et al 1996
Tijuana Slough, Calif.	California	32.60	-117.10	1.58	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld,	Cahoon unpublished data 1993
Alviso, San Francisco Bay, Calif.	California	37.50	-122.00	14.12	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld,	Patrick and DeLaune 1990
Bird Island, San Francisco Bay, Calif.	California	37.60	-122.20	1.98	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld,	Patrick and DeLaune 1990

Location	General	Lattitude	Longitude	Tonnes CO2e/ha/yr	Study	Year	Citation	Original Citation
South Africa	South Africa	-32.38	17.84	13.39	Cebrian	2002	Cebrian, J. (2002).	Baird and Ulanowicz 1993
Alfacs Bay Spain	Spain	40.60	0.63	1.74	Cebrian	2002	Cebrian, J. (2002).	Cebrian et al. 2000
Beafort NC	NC	14.32	94.55	0.39	Cebrian	2002	Cebrian, J. (2002).	Kenworthy and Thayer 1984
Florida Bay	FL Keys	25.00	85.58	0.84	Cebrian	2002	Cebrian, J. (2002).	Kenworthy and Thayer 1984
Florida Bay	FL Keys	3.63	103.52	0.87	Cebrian	2002	Cebrian, J. (2002).	Kenworthy and Thayer 1984
Beafort NC	NC	-7.05	112.48	0.92	Cebrian	2002	Cebrian, J. (2002).	Kenworthy and Thayer 1984

SPEC_LOC	GEN_LOC	LAT	LONG	TCO2eHaYr	STUDY	YEAR	CITATION
SW Florida	FL Keyes	25.80	-81.54	0.13	Cebrian	2002	Cebrian, J. (2002). "Variability and control of carbon con
Victoria Australia	Australia	-38.50	144.66	0.19	Cebrian	2002	Cebrian, J. (2002). "Variability and control of carbon con
Rookery Bay, Fla.	FL Keyes	26.00	-81.70	0.73	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld, et al. (2003). "Global carbo
Core 576, Herbert River region, Australia	Australia	-18.50	146.32	0.95	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld, et al. (2003). "Global carbo
SW Florida	FL Keyes	25.80	-81.54	0.99	Cebrian	2002	Cebrian, J. (2002). "Variability and control of carbon con
SW Florida	FL Keyes	25.80	-81.54	1.11	Cebrian	2002	Cebrian, J. (2002). "Variability and control of carbon con
Rookery Bay, Fla.	FL Keyes	26.00	-81.70	1.43	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld, et al. (2003). "Global carbo
Puerto Rico	Puerto Rico	18.54	-66.53	1.61	Cebrian	2002	Cebrian, J. (2002). "Variability and control of carbon con
HMF 3, Hinchinbrook Channel, Australia	Australia	-18.36	146.16	1.76	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld, et al. (2003). "Global carbo
Pohnpei Island, Micronesia	Micronesia	6.52	158.20	1.94	Fujimoto et al.	1999	Fujimoto, K., A. Imaya, et al. (1999). "Belowground carb
HM 2, Hinchinbrook Channel, Australia	Australia	-18.36	146.16	2.46	Chmura et al.	2003	Chmura, G. L., S. C. Anisfeld, et al. (2003). "Global carbo

APPLICATION FOCUS

WHAT IS THE AMOUNT OF CARBON STORED AND SEQUESTERED BY COASTAL MARSHES FOR 1-METER SEA LEVEL RISE SCENARIO?

Galveston, TX
USA

InVEST integrated valuation of environmental services and tradeoffs

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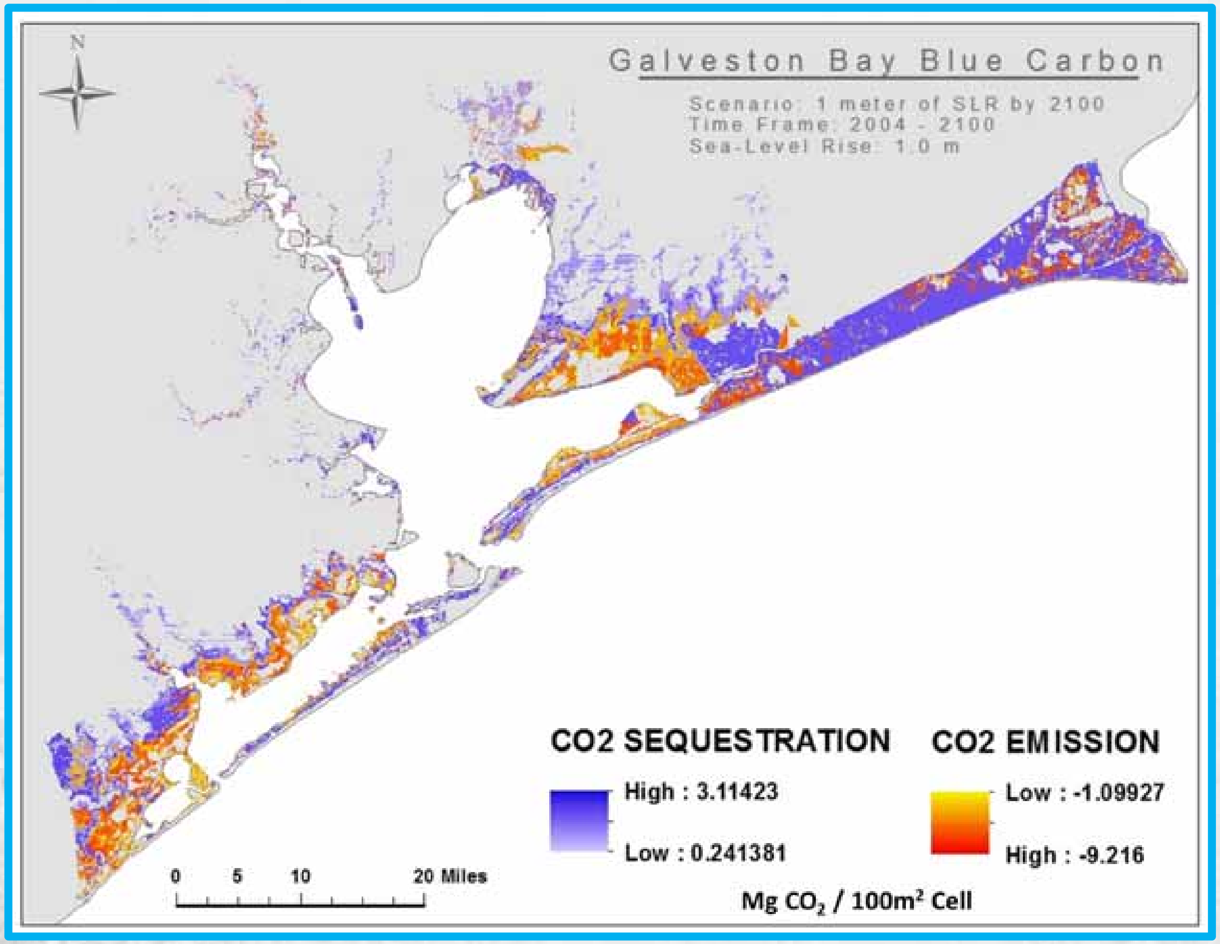
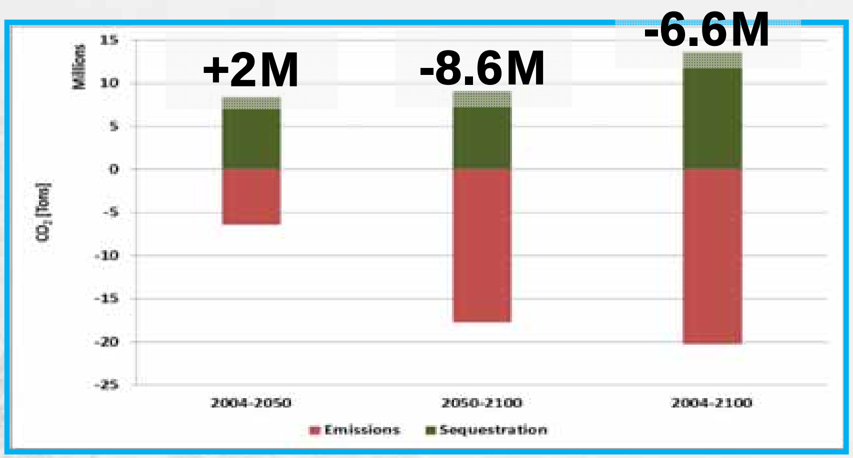
The Nature Conservancy

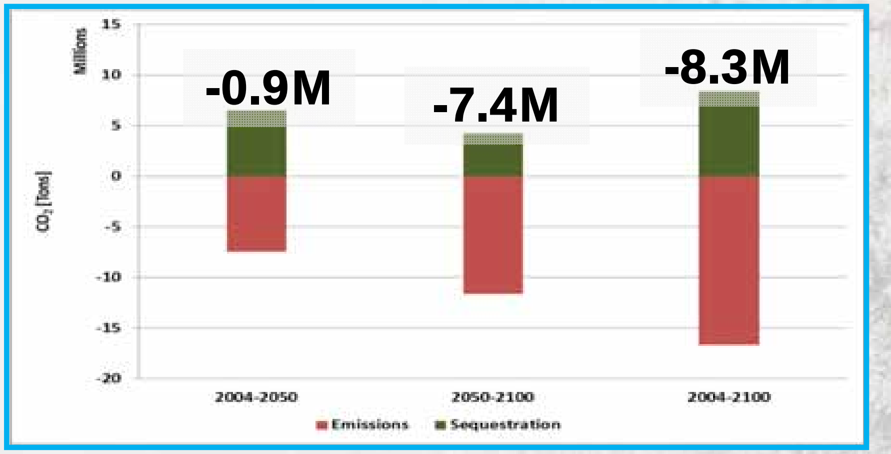

N
Galveston Bay Blue Carbon
Scenario: 1 meter of SLR by 2100
Time Frame: 2004 - 2100
Sea-Level Rise: 1.0 m
CO2 SEQUESTRATION
High : 3.11423
Low : 0.241381
CO2 EMISSION
Low : -1.09927
High : -9.216
0 5 10 20 Miles
Mg CO2 / 100m2 Cell

SEQUESTRATION AND EMISSION
SUMMARY

MIGRATION ALLOWED



NO MIGRATION



- Galveston Bay **emits carbon** under 1 meter sea level rise
- Emissions increases if marsh does not migrate
- Uncertainty analysis: mostly driven by the wide variation in accumulation rates

BETA TESTING
TWO NEW SITES

BETA TESTING
NEXT STEPS

	VIETNAM CA MAU PROVINCE	NEW ZEALAND NELSON HAVEN
VEGETATION	MANGROVES	MARSHES AND SEAGRASSES
QUESTIONS/ PROJECT GOALS	Where and how much carbon is emitted due to mangrove disturbance? • shrimp ponds • charcoal harvest	Quantify land use change impact on carbon: • infilling/draining • coastal development • hardening of intertidal margins • opening of new entrance channel
CHALLENGES	• Collecting information from stakeholders • Developing future mangrove maps (e.g. scenario generator)	• Inconsistent vegetation surveys from 1800s – present • Preparing disturbance information