The use of artificial intelligence algorithms to assess ecological patterns from marine landscapes. The RIOSAMP experience.

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WinMon.BE Conference 27-28 November 2013 - Royal Belgium Institute of Natural Sciences, Brussels

RIOSAMP Project

Coastal Resource Management Council (CRMC)- Fugate

SAMP Management Team
Fugate – McCann- Spaulding - Nixon – De Bow

Ocean Engineering

- Hydrodynamics and sediment transport [Grilli S. and Harris]
- Acoustic [Miller & Potty]
- Geotechnics [Baxter]
- Wind Resource Assessment [Grilli A. and Spaulding]
- Siting and Environmental Impact [Grilli A. and Spaulding]

Graduate School of Oceanography

- Oceanography [Codiga and Ullman]
- Mammals [Kinney]
- Geology and Habitat (King)
- Fisheries (Coolie)
- Primary productivity (Nixon&Oviate)
- Meteorology(Merril)

College of Environment and Science

- Birds [Paton]
- Fisheries [Smythe]
- GIS [Damon]

College of Art and Science

- Archeology[Mather]

Coastal Research Institute

- Outreach (McCann)

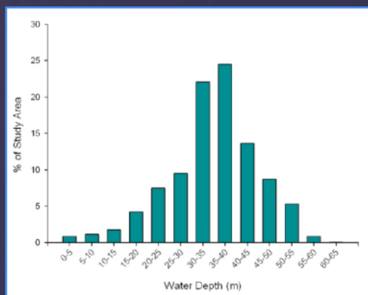
Full list contributors and complete flow chart: http://seagrant.gso.uri.edu/oceansamp/pdf/documents/about_org_chart.pdf

Objectives:

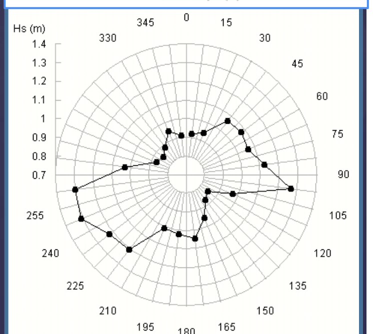
- Provide up to date scientific information to guide CRMC in its renewable energy permit policy
- Provide a zoning map of the SAMP area identifying optimal area for wind farm siting
-

Wind Farm Siting Optimization

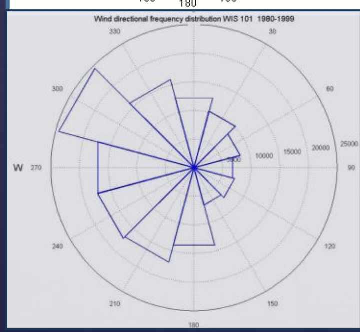
38 000 Km^2
Depth
15 - 60 m

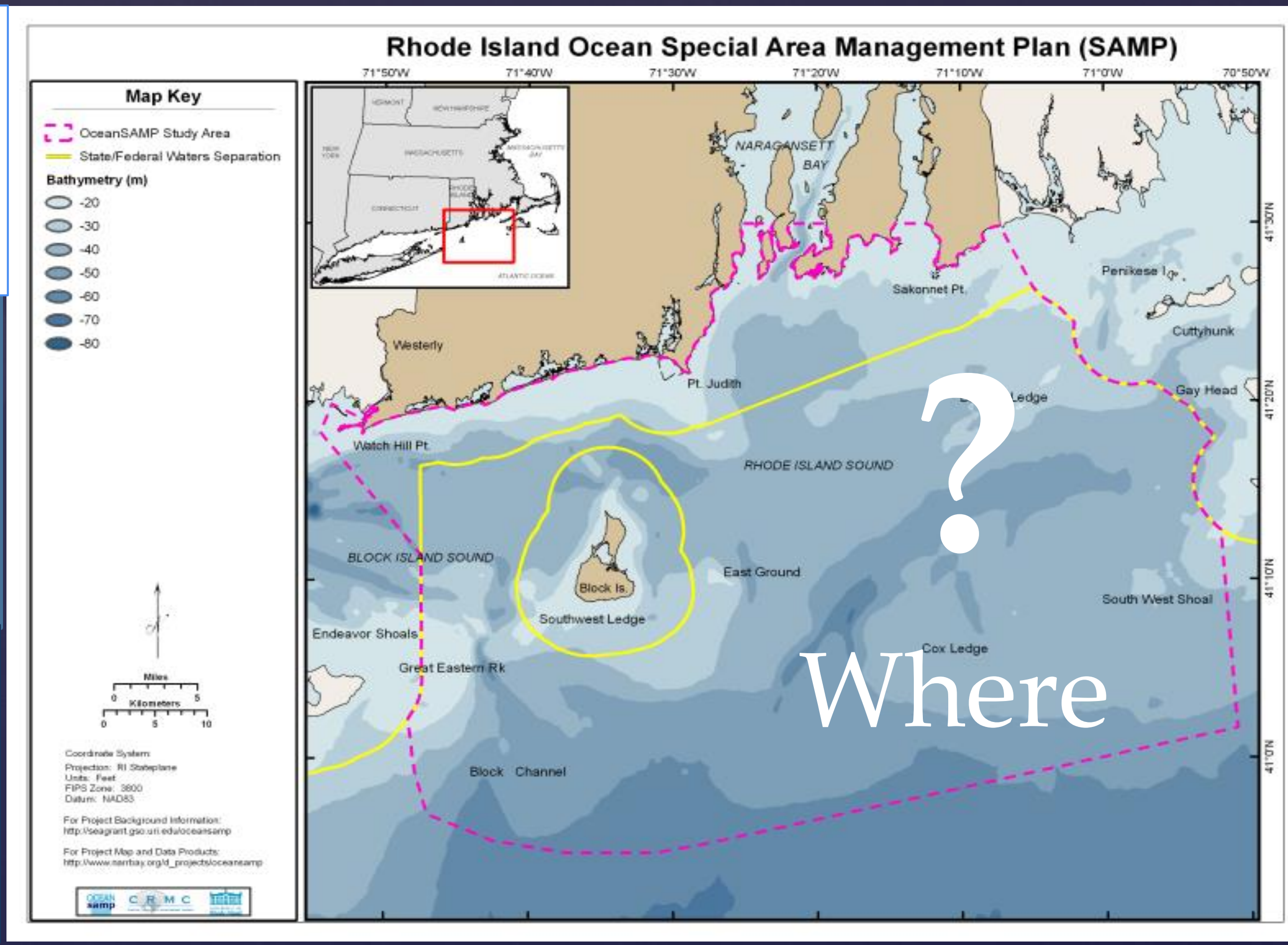


Wave
Climate

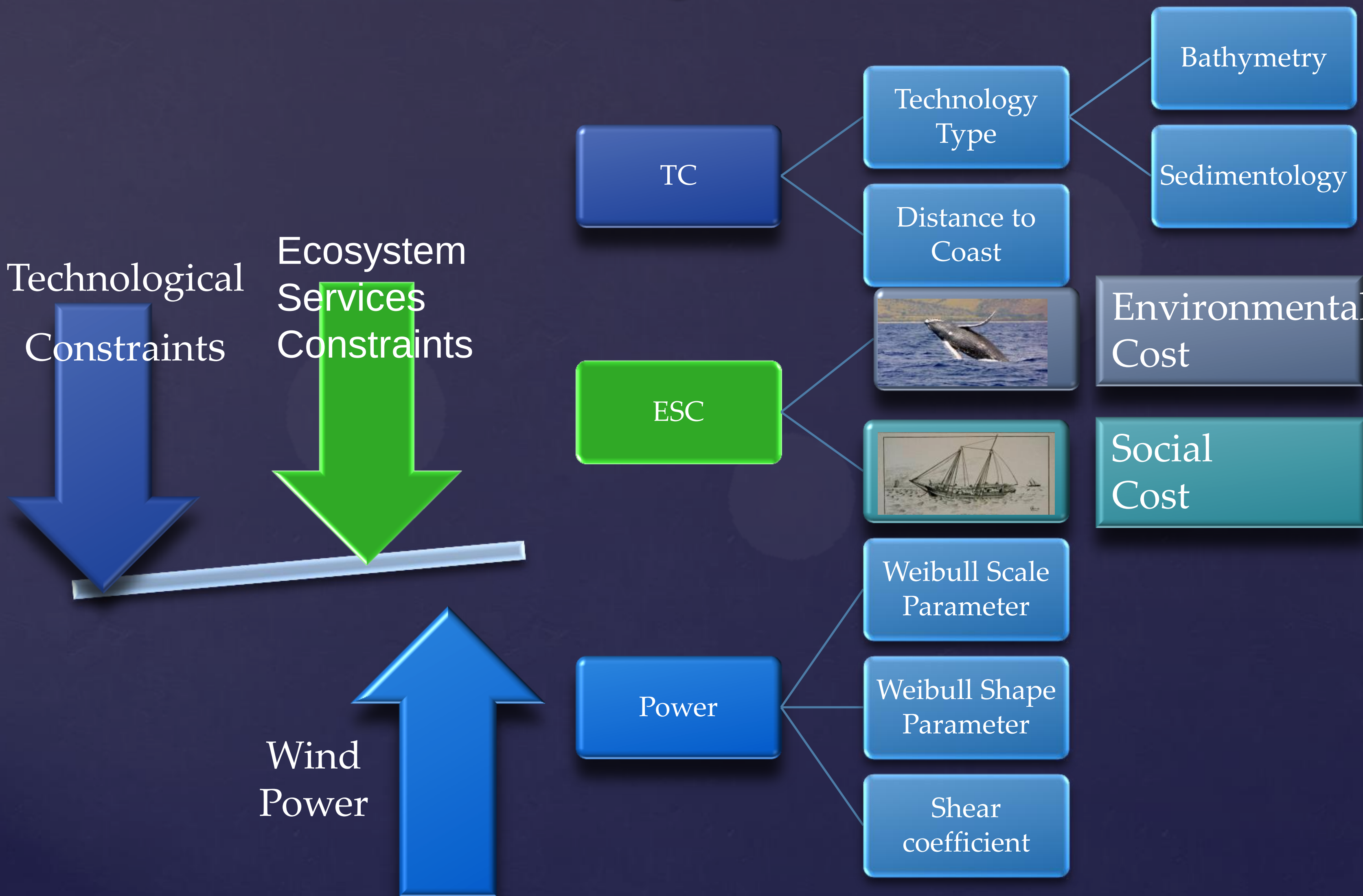


Wind
Climate





Wind Farm Siting Index (WiFSI)



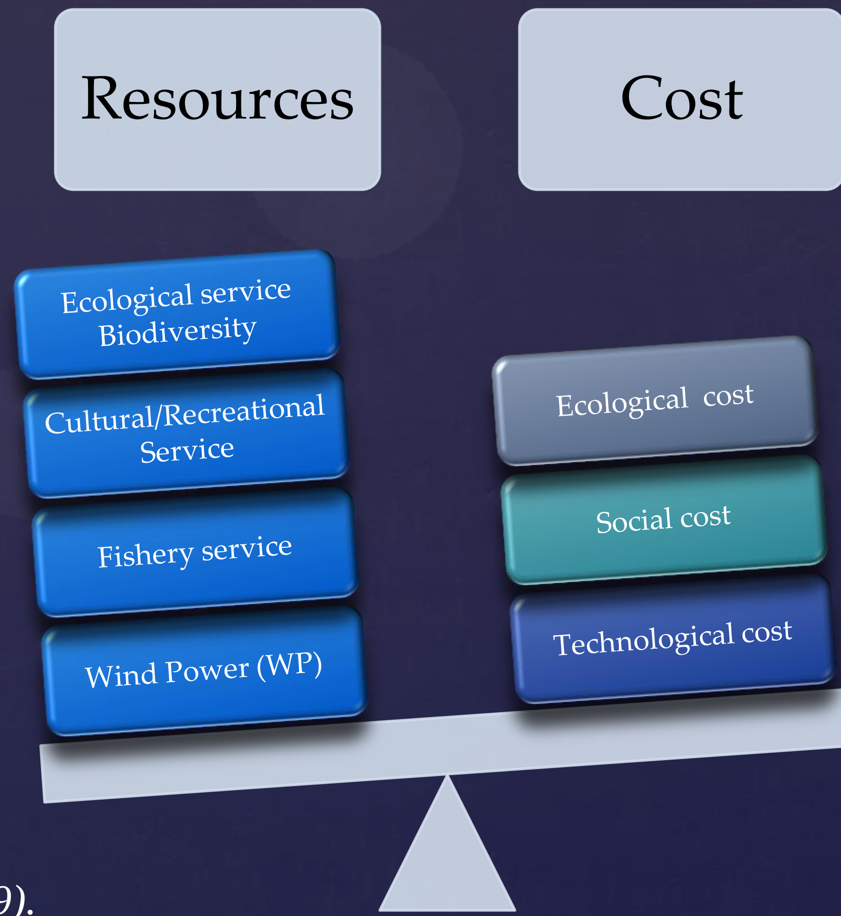
SAMP Ecosystem based Management (EBM) conceptual Framework

GOAL: *keep a healthy, productive and resilient ecosystem which provides to human the services they need (ecosystem services)*

Provisioning
- Food: Fishery (FS)
- Energy: Wind Power(WP)

Cultural
- Recreation: Recreational Fishing(RS)
- Sailing/Racing
- Archeological Diving
- Aesthetics

Regulating
- Biological Biodiversity (Ecological S)



Nomenclature of Karen McLeod and Heather Leslie (2009).

Modified according to Oumeraci, 2011

Ecosystem Services Valuation

ECOLOGICAL

SERVICE

Typology

- Ecosystem services sub-regions/ZONES
- Ecosystem services "assemblages"

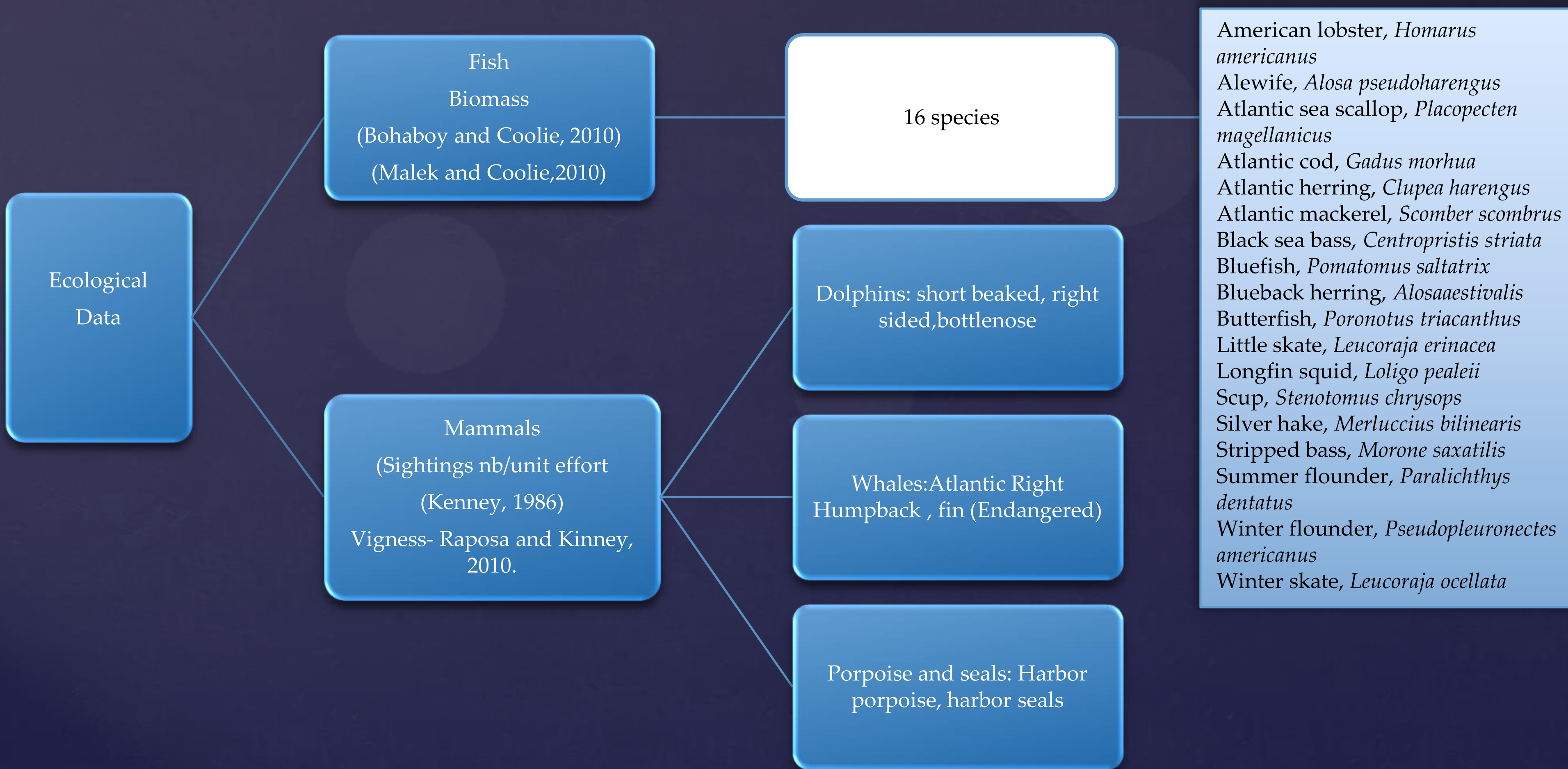
Value

- Rarity
- Fitness
- Aggregation

Sensitivity to wind farm impact

- Resilience/sensitivity to wind farm impact

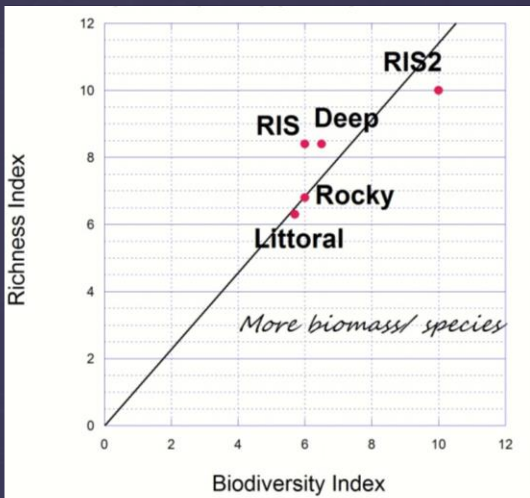
Ecological Service

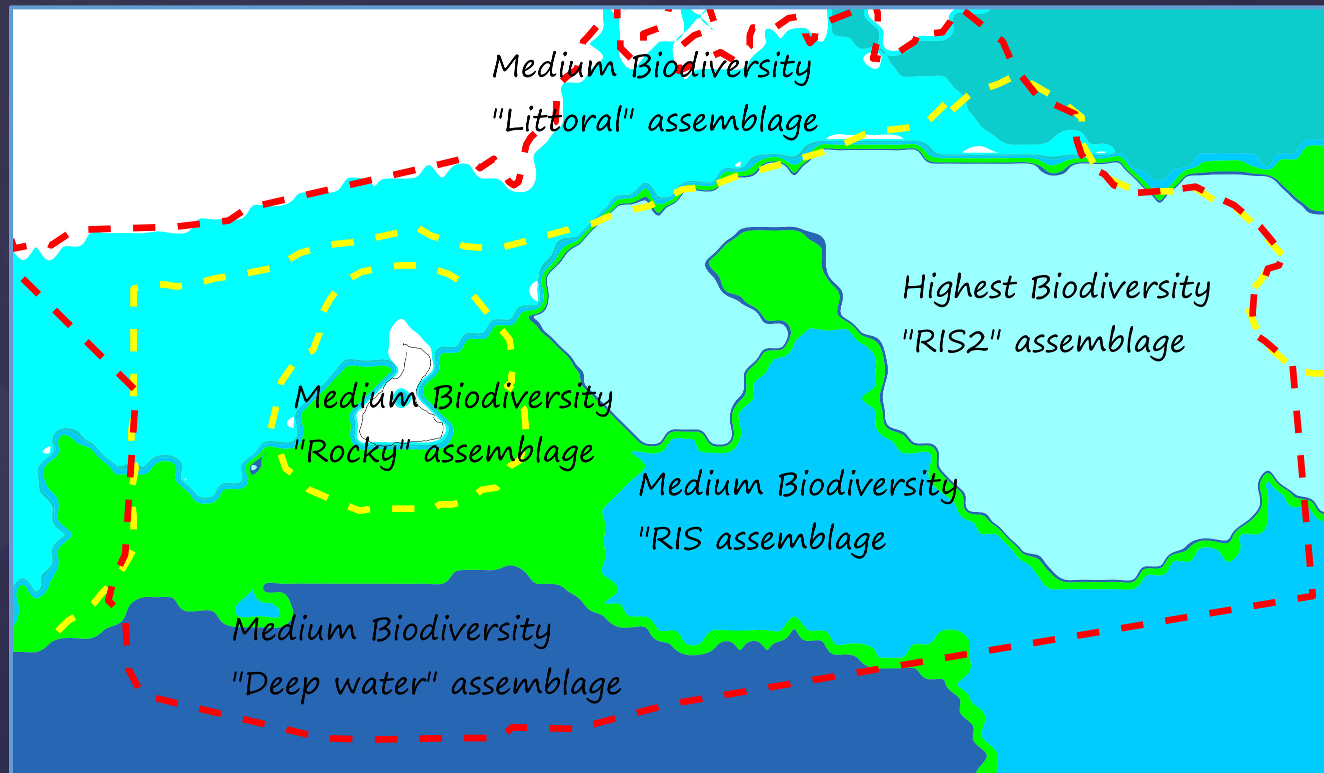


Ecological Data Analysis

STATISTICAL DISTRIBUTION	• LOG-NORMAL DISTRIBUTION • NORMALISATION
SPATIAL INTERPOLATION	• MINIMUM 30 POINTS • KRIGGING ON 250X 250 M GRID • STATISTICAL DISTRIBUTION CONSERVED
MULTIVARIATE SPATIAL ANALYSIS	• PRINCIPAL COMPONENTS • CLUSTER ANALYSYS (K-MEANS)

Ecological Typology Spring





Deep	•Mammals
Rocky	•Demersal
RIS	•Herring •Mammals
RIS2	•Demersal •Herring
Littoral	•Demersal •Lobster

Ecological Service Sensitivity To Wind Farm Impact

Species Sensitivity coefficient

Based on French McKay

Based on French McKay	
10	• Death
8	• Health Damage
6	• Habitat Modified
4	• Behavior Disturbance
2	• Non significant impact
0	• No impact
-2	• Attraction

Noise Sensitivity Coefficient c1

Reef Effect Sensitivity coefficient c2

Each Species

EMF Sensitivity Coefficient c3

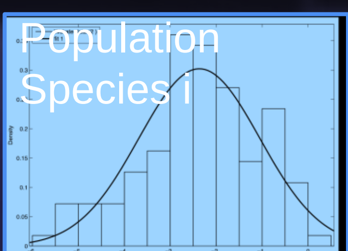
Turbidity Sensitivity Coefficient c4

For each cluster

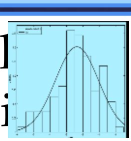
$$I_{c,o} = \sum_{n} \left(S_i^2 * c_{i(c,o)} \right)$$

$$ESI_{c,o} = sign(I_{c,o}) * \frac{\sqrt{\left| I_{c,o} \right|}}{N \sqrt{\max \left| \left(S_i^2 * c_{i(c,o)} \right) \right|}}$$

Population Species i



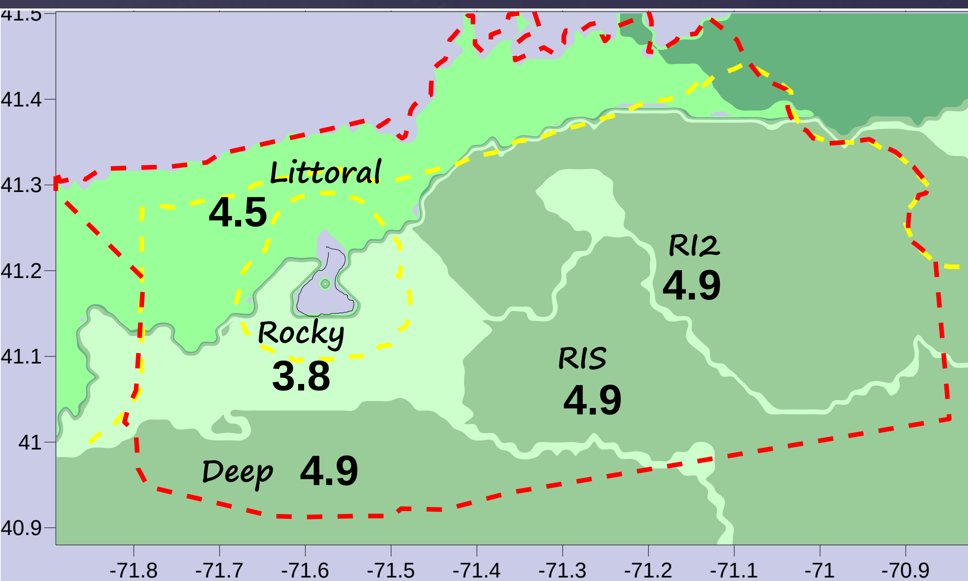
Cluster I Species i



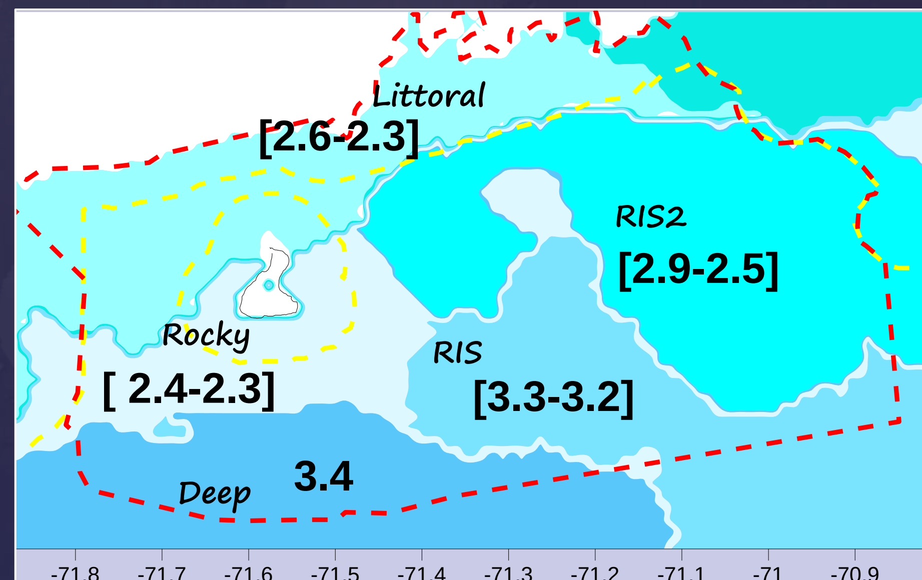
"S"

Each species in a cluster/zone obtains a score S based on the combination of its relative abundance probability distribution (PD) to the population PD. and to its local relative richness

Ecological Service Sensitivity Index To Wind Farm Impact



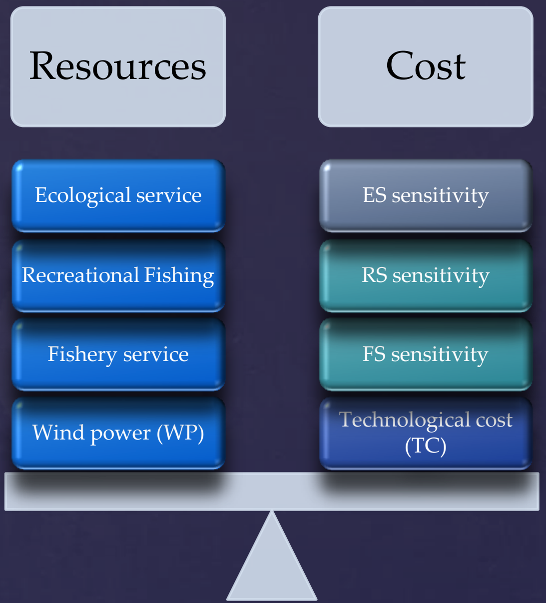
Construction phase (Spring)



Operation Phase (Spring)

Grilli, A.R., Lado, T., and M. Spaulding 2012. A protocol to include ecosystem services in a wind farm cost model. *J. Environmental Engineering* 139:2, 176-186, doi:10.1061/(ASCE)EE.1943-7870.0000599

Wind Farm Siting Index [WiFSI]

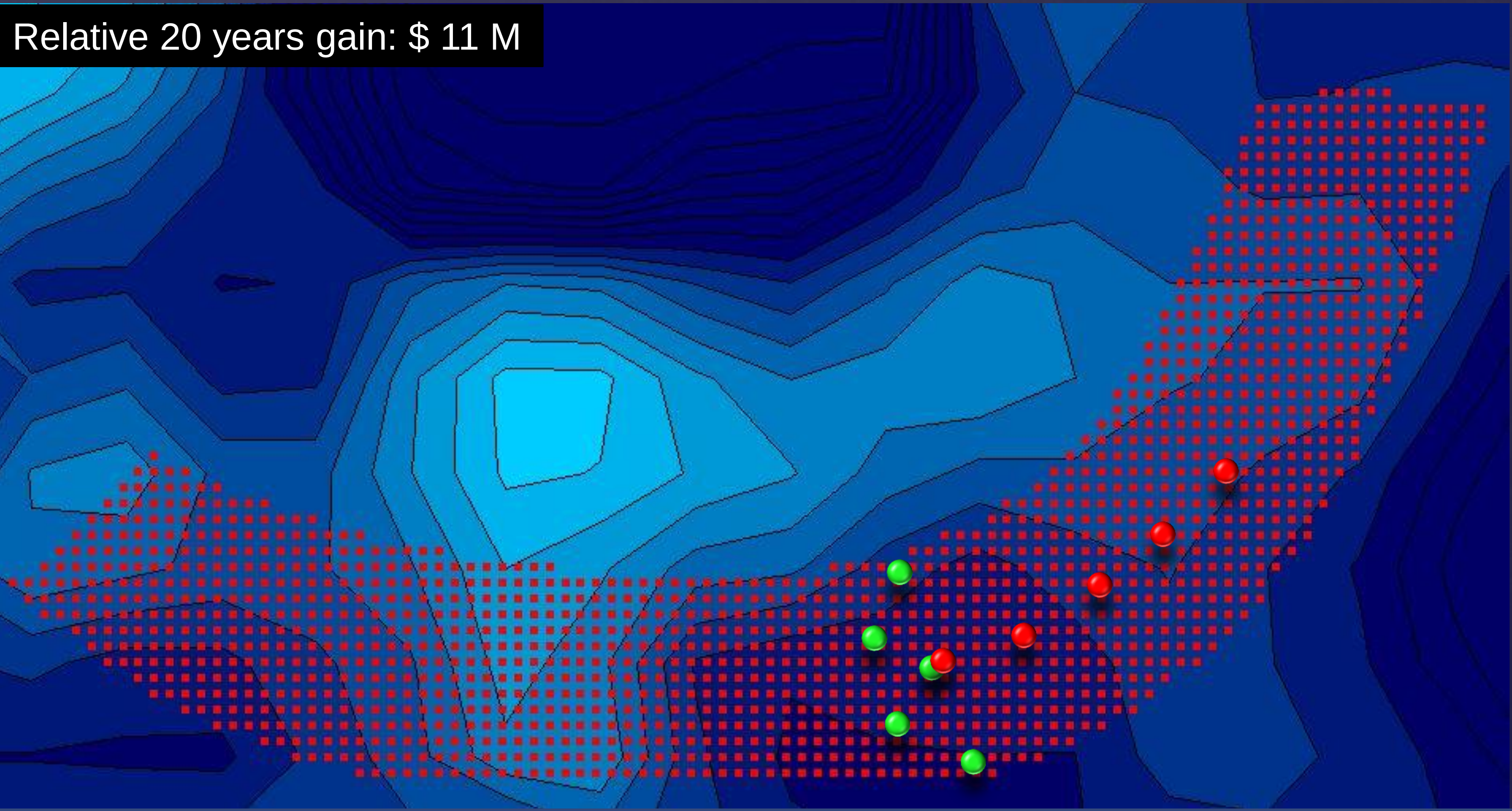


$$WiFSI = \frac{w_1 * TC + w_2 * ESI + w_3 * FSI}{WP}$$

Grilli, A.R., Lado, T., and M. Spaulding 2012. A protocol to include ecosystem services in a wind farm cost model. *J. Environmental Engineering* 139:2, 176-186, doi:10.1061/(ASCE)EE.1943-7870.0000599

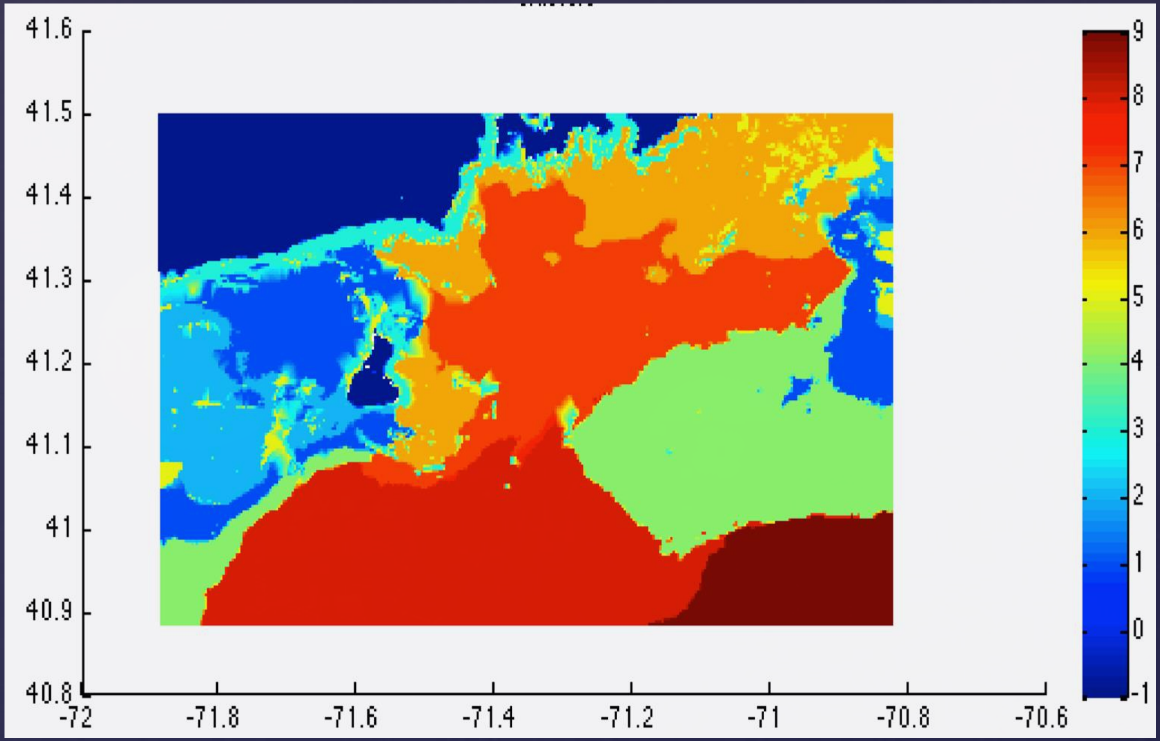
OPTIMIZATION RESULTS

Genetic Algorithm – Include WaSP Wake model in optimization function



O'Reilly C., Grilli A. and Potty G. 2013. Micrositing Optimization of the Block Island Wind Farm, RI, USA. Proceeding of the International Conference on Ocean, Offshore and Arctic Engineering (OMAE 2013), Nantes June 9-14, 2013

Marine Landscapes



Shumchenia E. and A.R. Grilli, 2012. Enhanced ocean landscape and ecological value characterization for the Rhode Island Ocean Special Area Management Plan study area using Habitat Typology and Habitat Template .lOSI) project, Technical Report.

Data

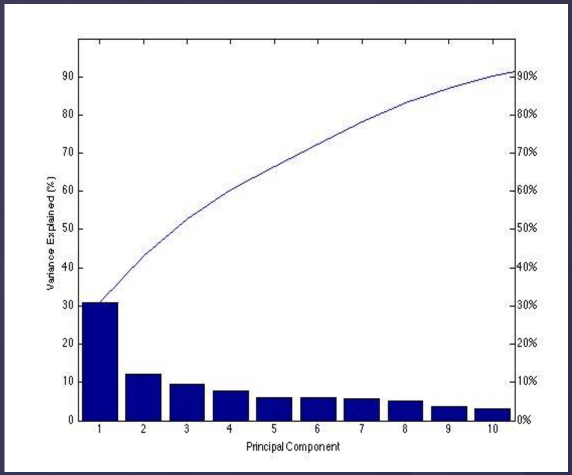
Variable name	Description	Unit	Source
Tidal velocity*	Maximum tidal velocity	m/s	ROMS modeling Grilli S. et al. 2010; Harris et al., 2012.
Significant wave height*	95 % Significant wave Height in a 50 year storm event	m	STWAVE modeling Grilli A. et al 2008
Depth*	Water Depth	m	NGDC Coastal Relief Model
Distance to shore	Distance from each grid cell to closest point to shore	km	Grilli A. et al, 2010
Slope	Maximum slope between 2 grid cells (200 m apart)	Deg.	NGDC Coastal Relief Model ; SURFER toolbox
Roughness	Slope Standard deviation in 1000 m radius		LaFrance et al. 2010
Phi median	Sediment median diameter (on a phi scale ; $\Phi = -\log_2 D_{mm}$)	Φ	SEABED: Atlantic coast offshore surficial sediment data. US Geological Survey Reid et al. 2005
Clay	Fraction of clay in sediment	%	SEABED: Atlantic coast offshore surficial sediment data. US Geological Survey Reid et al. 2005
SST Spring	Mean Seasonal Sea surface Temperature (Spring)	Degree Celsius	Satellite data NASA Terra and Aqua (MODIS sensors)Codiga et Ullman, 2010
Stratification Spring	Buoyancy frequency squared 0.25 to 2.5 km resolution	s^{-2}	FVCOM modeling. Codiga et Ullman, 2010 Chen et al (2006)
SST Fall	Mean Seasonal Sea Surface Temperature (Fall)	Degree Celsius	Satellite data NASA Terra and Aqua (MODIS sensors)Codiga et Ullman, 2010

17 variables
Similar variables to Degraer's Belgium environment typology (2012)

Stratification Fall	**Buoyancy frequency squared 0.25 to 2.5 km resolution**	s^{-2}	**FVCOM modeling Codiga et Ullman, 2010 Chen et al (2006)**
Aspect Ratio	Slope directionality	Degree [0-360]	NGDC Coastal Relief Model ; Satellite data NASA Terra and Aqua (MODIS sensors) SURFER toolbox
BPI fine scale	Bathymetric position index fine scale [negative values indicate a canyon; positive values indicate a ridge; around 0, flat or constant slope]		NGDC Coastal Relief Model and GIS
BPI large Scale	Bathymetric position index large scale[negative values indicate a through; positive values indicate a ridge; around 0, flat or constant slope]		NGDC Coastal Relief Model and GIS
North-ness	North -South component in slope sin(Aspect Ratio) positive value indicates North-ness		NGDC Coastal Relief Model and GIS
East-ness	West-East component in slope Cos(Aspect Ratio) positive value indicates East-ness		NGDC Coastal Relief Model and GIS

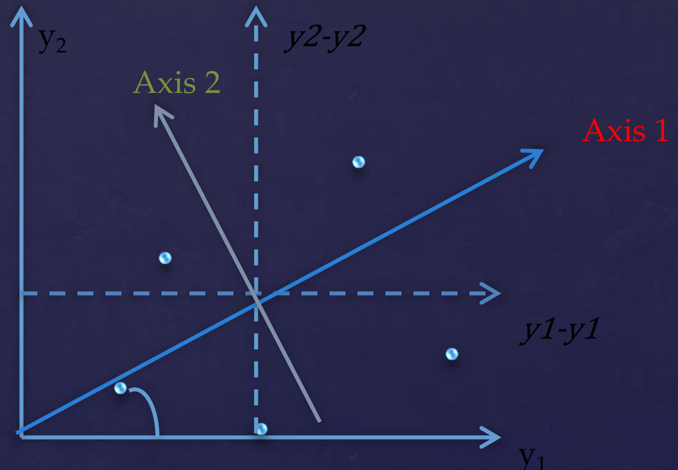
Shumchenia E. and A.R. Grilli, 2012. Enhanced ocean landscape and ecological value characterization for the Rhode Island Ocean Special Area Management Plan study area using Habitat Typology and Habitat Template .lOSI) project, Technical Report.

Principal Components Analysis

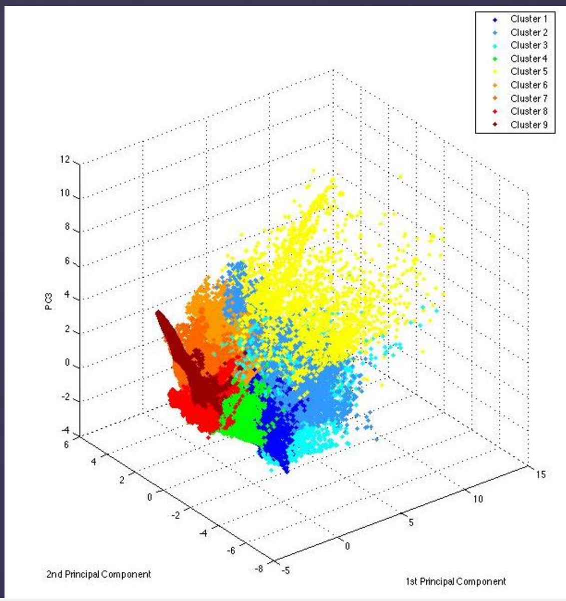


PC1: *Offshore-ness/coastal-ness*
PC2: *Sedimentology*
PC3: *Fresh Water input*
PC4: *Large scale geomorphology*
PC5: *Fine scale geomorphology*
PC6: *Upwelling*

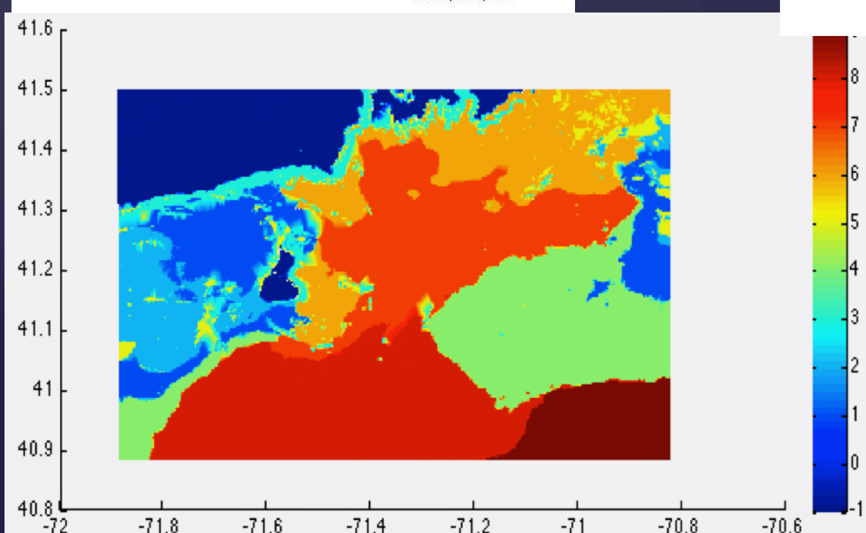
- PC analysis is a rotation of the original axes in the directions which explains the maximum variance.
- The new rotated axis or PC are independent. Few explains most of the variance.



Typology: Cluster Analysis



Cluster	PC 1 Offshoreness	PC 2 Sedimentology	PC 3 Fresh Water *[cold currents]*	PC 4 Large Scale Geomorphology	PC 5 Small Scale Geomorphology	PC 6 Upwelling stratfication
1	Intermediate	Medium sand	X	Relatively smooth		
2	Intermediate	Fine Sand/clay	XX	Relatively rough		
3	Coastal shallow water					
4	Offshore shallow water	Medium sand		Smooth	Smooth	
5		Fine sand/clay	XX	High roughness	High roughness	
6	Coastal	Fine sand/clay	-- warm			
7	Intermediate		--warm			X
8	Offshore deep water	Medium sand				X
9	Offshore deep water	Fine sand/clay				

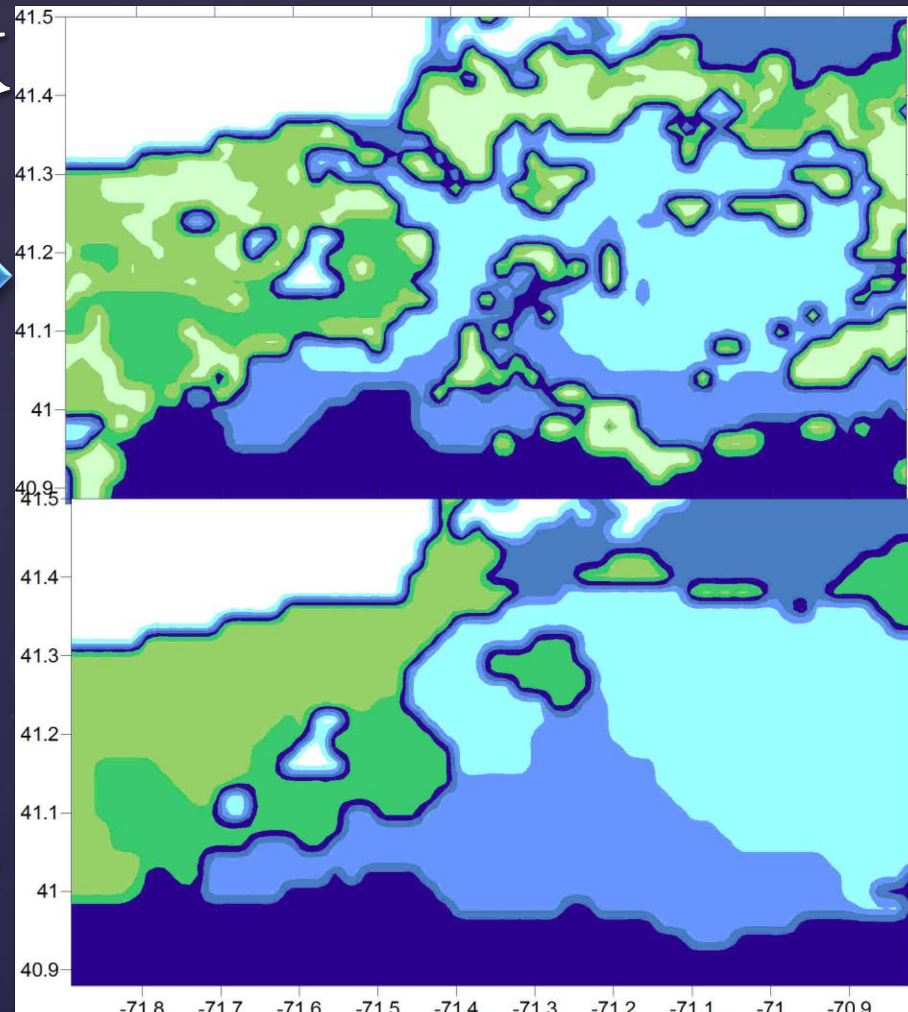


Pattern Recognition(AI) Neural Network

Automatic recognition from 5 Abiotic variables:

- Depth
- Temperature
- Stratification
- Roughness
- Phi median

Target ecological regions



Support Vector Machine(SVM)

Vapnick, 1995

Non Linear generalisation of the Generalized Portrait [Vapnick and Chervonenkis, 1964]

Support vector machines = dual to maximum margin classifiers (MMC)
Dual obtained by applying Lagrangian optimization theory to MMC optimization problem

SVM Non Linear Regression

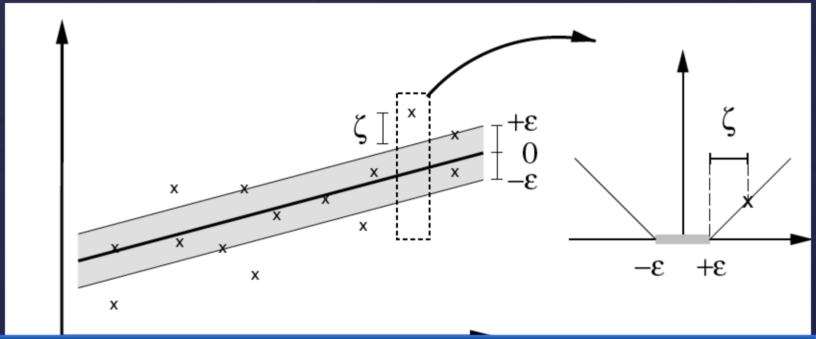
- A data universe X
- A sample set $S \subset X$
- Some target function $f: X \rightarrow R^n$
- A training data set D

  $D = \{(x,y) \mid x \in S \text{ and } y = f(x)\}$
- Compute a model

$\hat{f}: X \rightarrow \mathbb{R}$ $\quad$ *using D such that* $\hat{f}(x) \cong f(x)$ *for all* $x \in X$

$$f(x) = \langle w, x \rangle + b \qquad w \in X, b \in \mathbb{R}$$

$$\text{minimize } \frac{1}{2}\|w\|^2 \qquad \text{subject to } \begin{cases} y_i - \langle w, x_i \rangle - b \leq \varepsilon \\ \langle w, x_i \rangle + b - y_i \leq \varepsilon \end{cases}$$



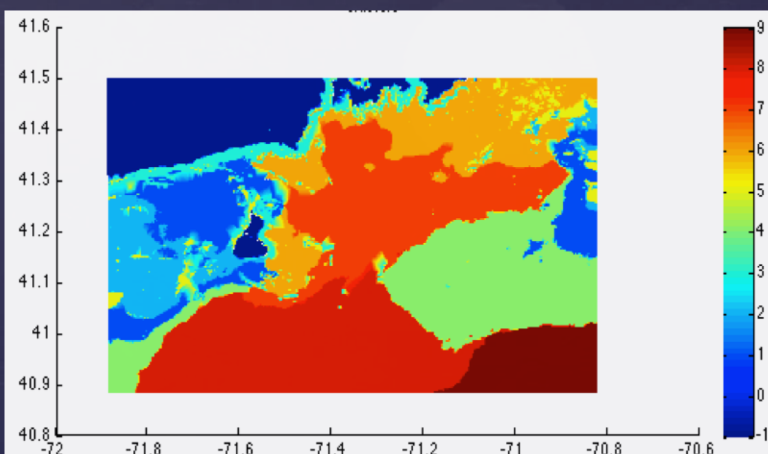
Objectives
1. Automatic Pattern recognition
2. “Novelty” detection (outliers)

Pattern Recognition

Support Vector Machine (AI)

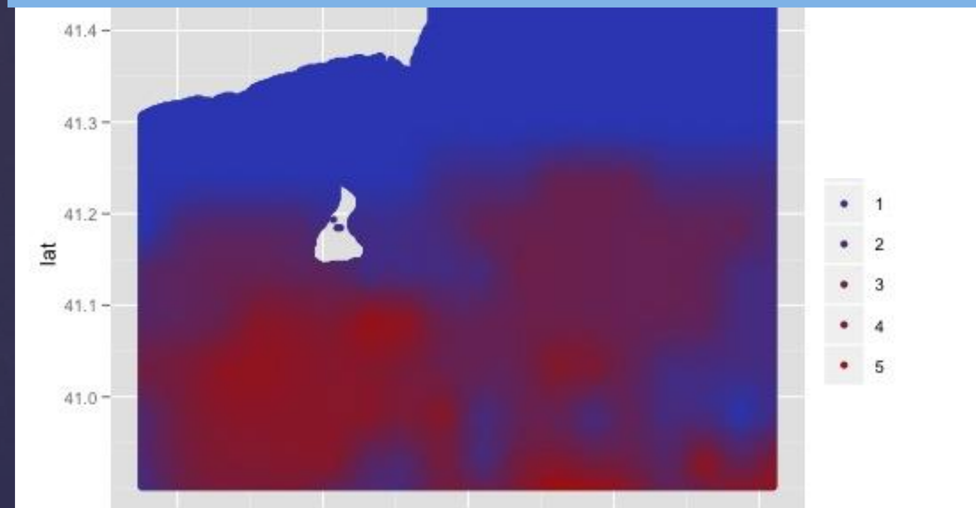
Use of non-linear regression to predict mammals distribution from abiotic variables

R^2 = 88% 5-fold

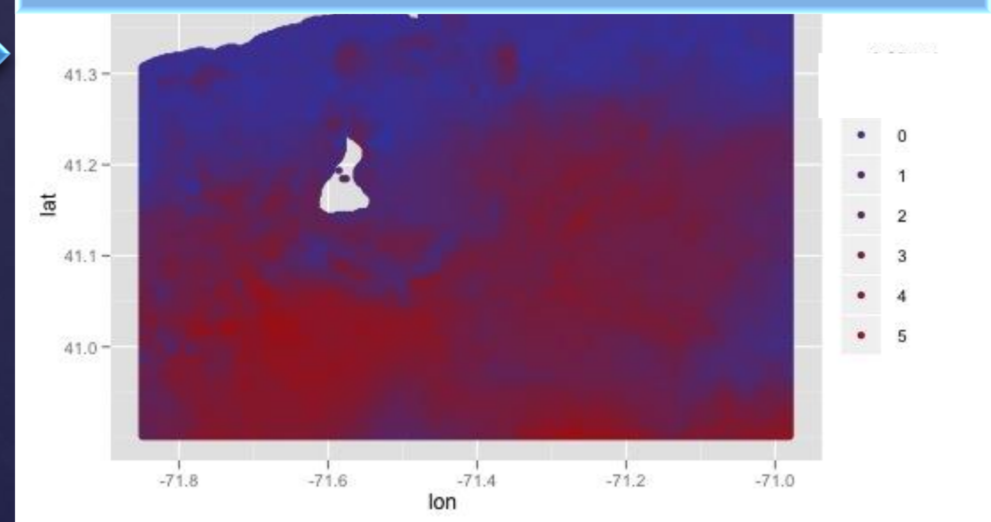


Abiotic Variables: depth, surface temperature, stratification, bottom Roughness, % clay, phimedian

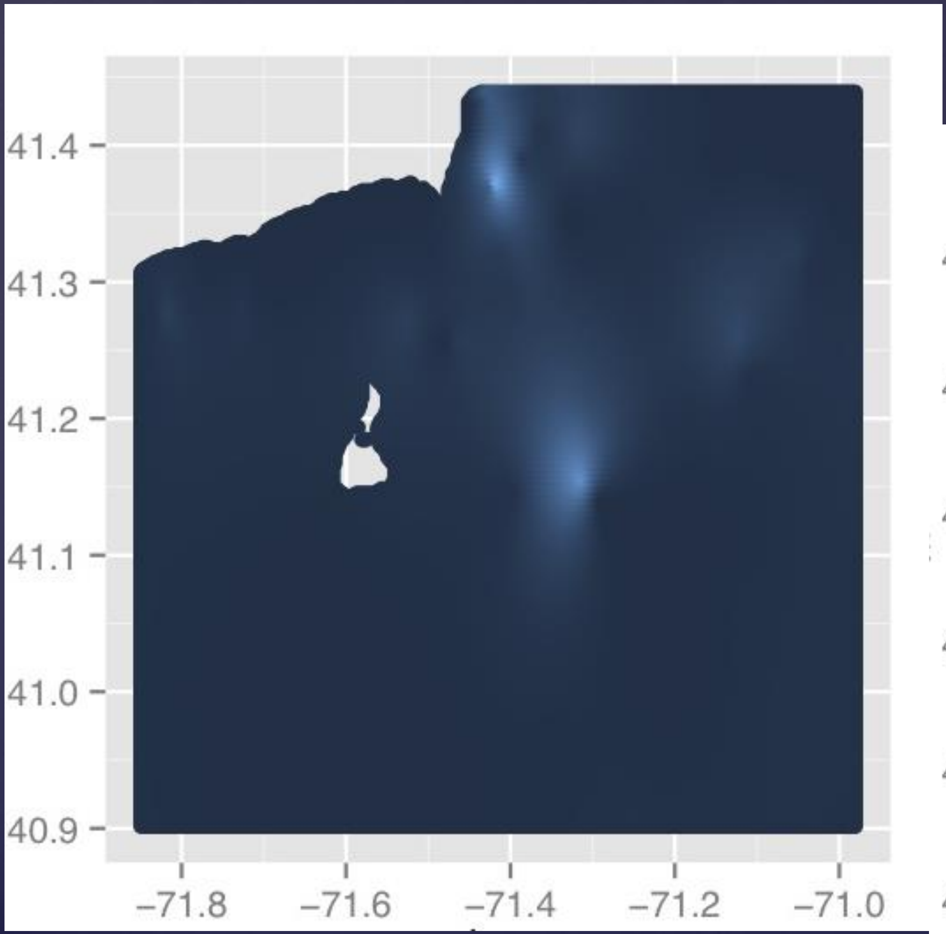
Mammals Abundance Spring Observations



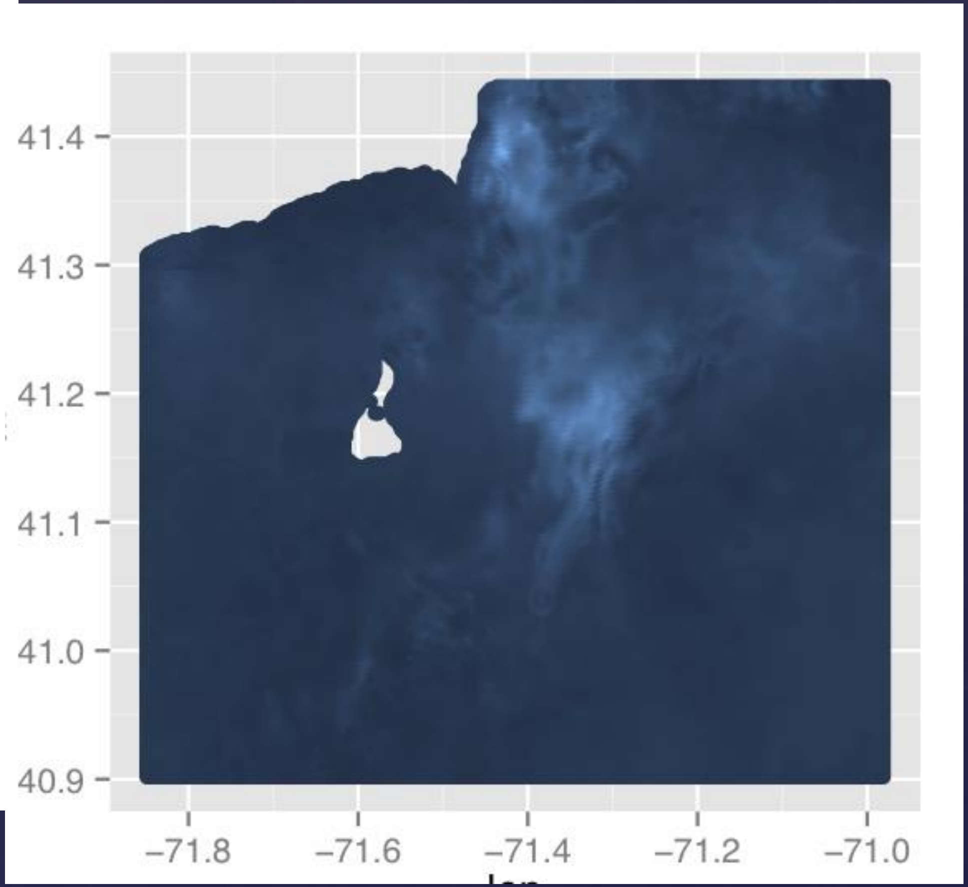
Mammals Abundance Spring Predictions



Homarus Americanus Spring

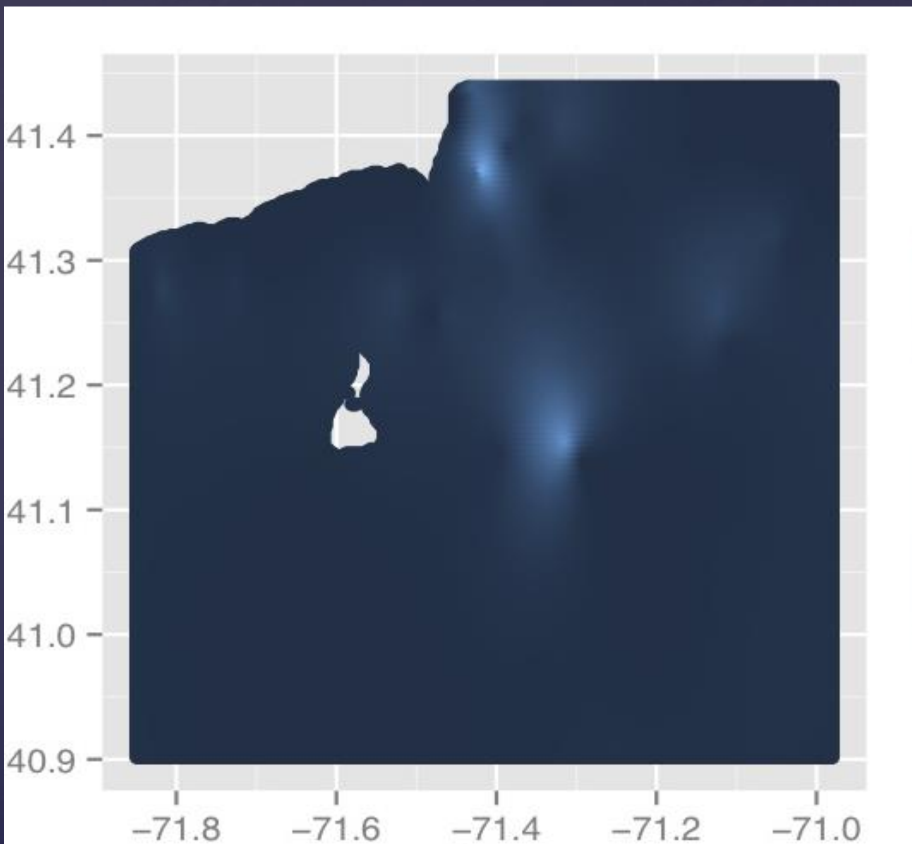


Observations

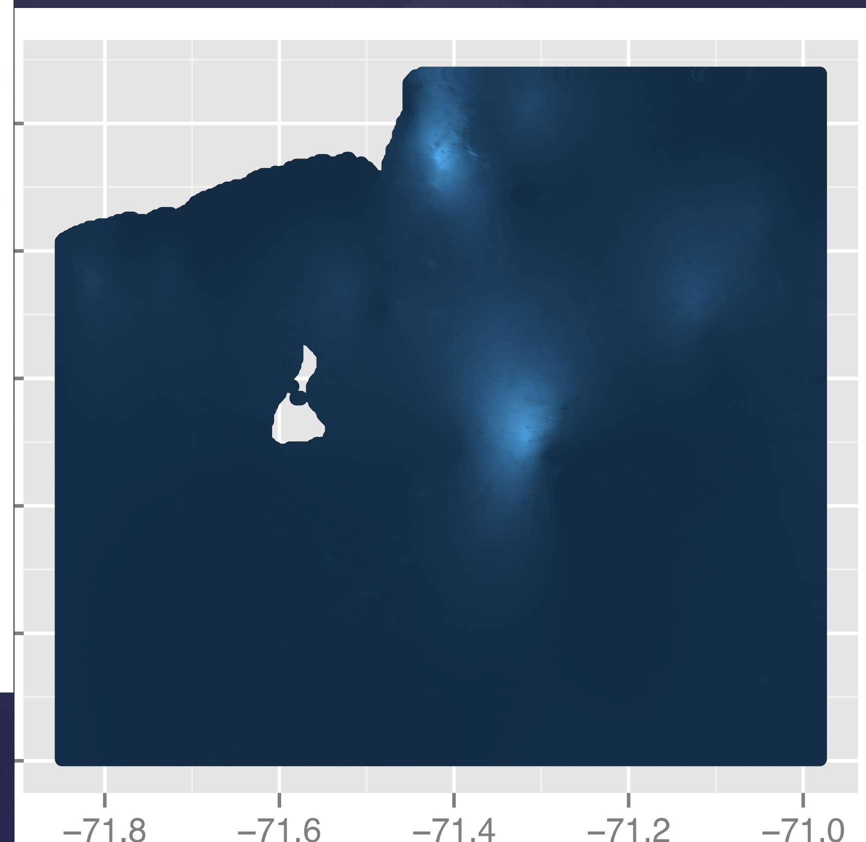


Predictions SVM 3-Fold

Homarus Americanus Spring



Observations



Predictions Random Forest

Photograph by Andrew Wong, 2008 International Photography Contest