## Investe

### Integrated Valuation of Environmental Services and Tradeoffs

AR 482844

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FARG

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## Topics

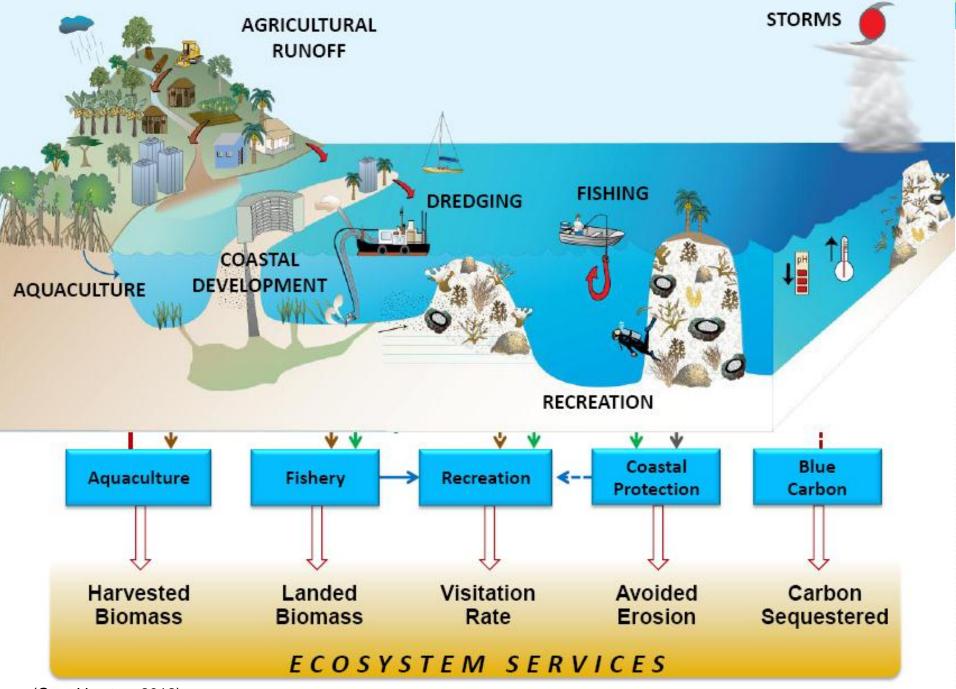
- 1. Ecosystem Services
- 2. What is InVEST?
- 3. Available models
- 4. Description of some models
  - Provisioning Cultural Supporting Regulating
- 5. Case study
- 6. Discussion



### **1. Ecosystem Services**







(Greg Verutes, 2012)

- InVEST is a framework of « open source » models for mapping and valuing ES
- Integrates multiple ES
- **Spatially** explicit (GIS)
- Decision support scenarios
- Economic and biophyisic valuation
- Developed by Natural Capital Project (<u>http://www.naturalcapitalproject.org</u>)



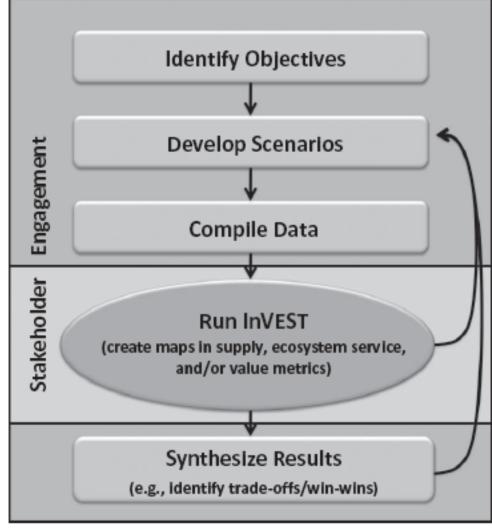






ENVIRONMENT

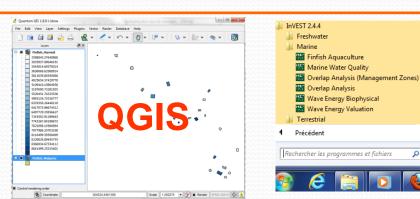
University of Minnesota Driven to Discover

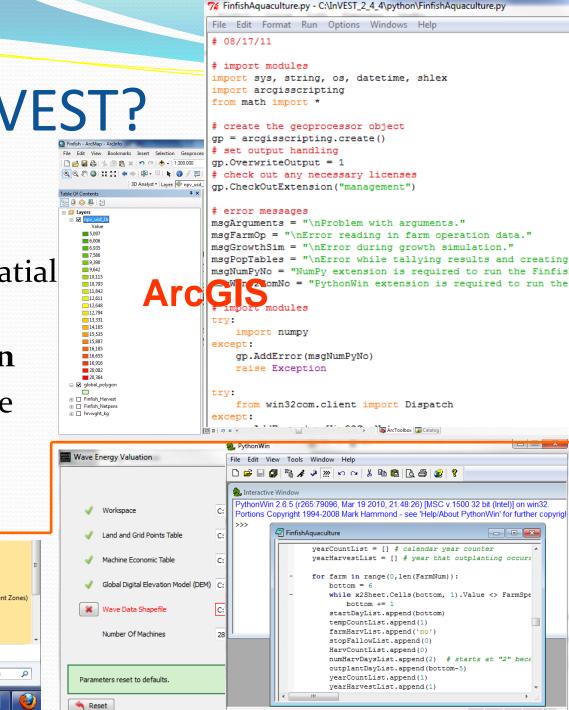




(Guerry et al 2012)

- Version 2.4.4
- Regular updates
- ArcGIS ArcView with Spatial Analyst
- Open source with Python
- Also works in stand-alone mode
- QGIS, gvSIG...





Ready

NUM

00001 001



### Software

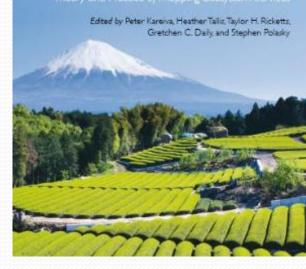
http://www.naturalcapitalproject.org/InVE ST.html

• Forum

http://invest.ecoinformatics.org/

Mailing list:

https://mailman.stanford.edu/mailman/list info/invest-users



NATURAL CAPITAL

### InVEST 2.4.4 User's Guide:

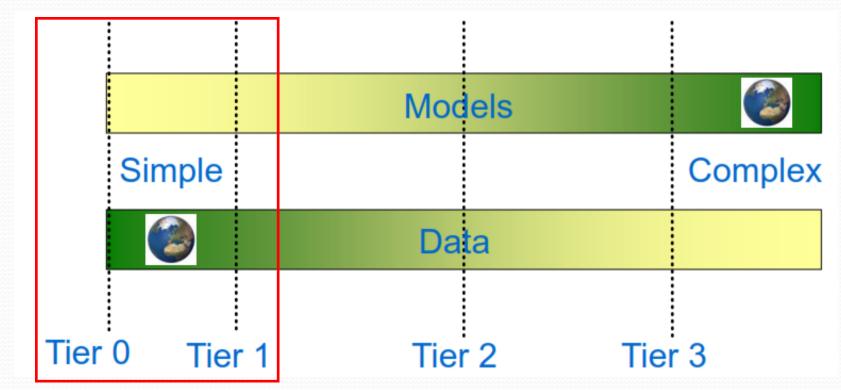
Integrated Valuation of Environmental Services and Tradeoffs

A modeling suite developed by the Natural Capital Project to support environmental decision-making



## 3. Available models

#### **InVEST**





### 15 models: freshwater, marine and terrestrial

#### **AESTHETIC QUALITY**

### Maps the visibility of features on a seascape or landscape **BIODIVERSITY**

Characterizes habitat quality and quantifies relative habitat loss

#### CARBON

Quantifies and values carbon storage and sequestration in terrestrial ecosystems

#### **COASTAL PROTECTION**

Quantifies and values the benefits of nearshore habitats for coastal protection

#### **COASTAL VULNERABILITY**

#### Assesses the relative risk to coastal areas from storms

#### **CROP POLLINATION**

Quantifies and values the contribution of wild pollinators to agricultural production

#### HABITAT RISK ASSESSMENT

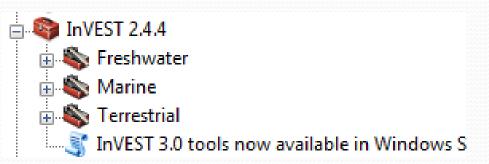
Evaluates the risk to marine or terrestrial habitats from anthropogenic factors

#### MANAGED TIMBER PRODUCTION

Values timber harvest

#### MARINE FISH AQUACULTURE

Estimates the harvest weight and value of farmed salmon



#### MARINE WATER QUALITY

Models concentration of pollutants at sea **OVERLAP ANALYSIS** 

Identifies areas of potential conflict between various human uses

#### **RESERVOIR HYDROPOWER PRODUCTION**

Quantifies the amount and value of hydropower produced by a reservoir

#### SEDIMENT RETENTION

Quantifies soil loss and retention and values the avoided cost of water treatment or dredging

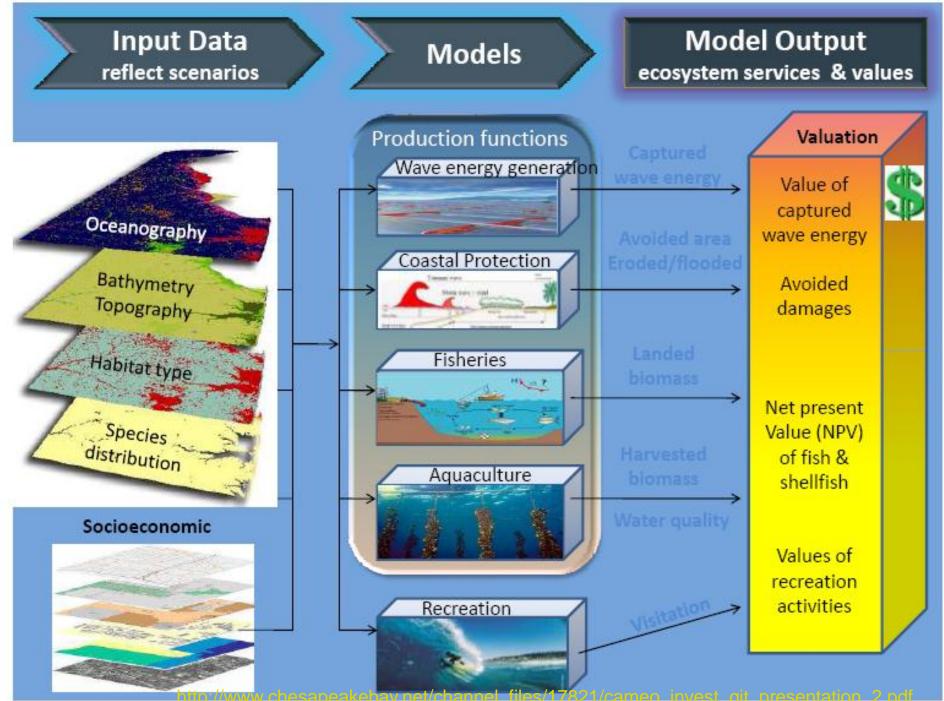
#### WATER PURIFICATION

Quantifies nutrient retention, and values the avoided cost of water treatment

#### WAVE ENERGY

Models and values harvested energy from wave power facilities





git\_precentation\_zipai

## 4.1 Marine Fish Acquaculture (Tier 1)

InVEST Version 2.4.4 | Model documentation | Send feed

	Step	Data requirements	Process	Output
Required	Service	farm operations (number of fish, feed target harvest weight, weight at outplanting, date of outplanting, fallowing practices) farm locations temperature	, estimates biomass of fish produced per farm	Biomass of fish produced per farm
onal	Value	operating costs market price revenues	Calculates present value of fish produced per farm	net present value of fish produced per farm
Couches		? 💕 📽 ଡ଼ି 💰 🛣 < 🗎 ☆ ☆ K 🤅 • 🔍 ष		» 🕼 » 🔌 » 산 »
Finfish_Netpens	ØX	•	•	» Ç <sup>a</sup> » ∖ <u>)</u> » <u>ili</u> e »
Finfish_Netpens	BIX     Ie - Finfish_Netpens = 1 / 22 fea	• T		j ti toj timi
Finfish_Netpens	(B) X Ie - Finfish_Netpens = 1 / 22 fee ∇ AREA_SQM AR	sture() selected	•	
Finfish_Netpens	(B) X Ie - Finfish_Netpens = 1 / 22 fee ∇ AREA_SQM AR	• T		j ti toj timi
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Finfish_Netpens	(d) (R) le - Finfish_Netpers = 1 / 22 fee AREA_SQM AR 19 225137 21 226554 18 895941	ature(s) selected Control Cont		0 0 0 0
Finfish_Netpens	(₫)8) ke - Finfish, Netpens :: 1 / 22 fee V AREA.SQM AR 19 265137 21 286964 18 895941 17 294663	sture()) selected		j ti toj timi
Finfish_Netpens	(e) (E	sture(s) selected  E&_HECT 33538e-05 0.000110355 353897e.05		
Finfish_Netpens	(6) X are - Finfish_Netgens = 1 / 22 fee AREA.50M AR 19 265137 21 286964 17 294663 20 460922 16 348399 15 279952	nture() selected   E&A HCT  3.4558-05  3.5584-05  3.5598-05 3.55988-05 3.55988-05 3.55988-05 3.55988-05 3.55988-05		0 0 0 0
Finfish_Netpens	(6) X are - Finfish_Netgens = 1 / 22 fee AREA.50M AR 19 265137 21 286964 17 294663 20 460922 16 348399 15 279952	nture(s) selected   EAL-HECT  3.3538-05  3.3538-05  3.2597-05  5.2084-05  4.2971-05		
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Finfish_Netpens	(d) (x) le - Finfish, Netgens = 1 / 22 fee AREA SCM AR 19 2255137 21 2265541 17 224663 20 440902 16 943939 15 279952 8 119457 7 212401 9 217197	ature() selected   EA_HECT 3358e-05 3359e-05 32597e-05 32598e-05 43971e-05 34558e-05 126271e-03 245971e-05 26219e-05		
Finfish_Netpens  Finfish_Netpens  Attribute tak  FarmID  G  FarmID  Far	(€) (E) (E) E = Finfish, Netpens : 1 / 22 fee V = AFEA.SQM = AF 19 = 265137 21 = 26664 18 = 855641 17 = 24665 20 = 480592 16 = 34339 15 = 219952 8 = 119457 7 = 212401 9 = 217197 9 = 217197 10 = 55558 10 = 55558	nture(i) selected   EA_HECT  3.35584-05  3.35349-05  5.03037-05  5.00037-05  5		
Finfah, Netpens           # Attribute tab           0           1           2           3           4           5           6           7           0           10           11           12           3           4           5           6           7           10           11	(d) (k) le - Finfub, Netgens = 1 / 22 fee X AREA_SCM AR 19 225137 21 2265547 17 224663 18 895941 17 224663 20 446092 16 348399 15 27955 8 113457 7 212401 9 217197 10 55558 9 14 114435	ature() selected   EA_HECT  JASSR=05		
Finfish, Nelpens           # Attribute tai	(d) (k) ie - Finfish, Netpens = 1 / 22 fee V AREA, SOM ARA 19 22 286664 18 895941 17 224663 20 480592 15 227952 2 15 27952 7 21601 9 217197 10 55558 14 116435 14 20009	nture(i) selected   EA_HECT 3.4558e-05 3.3549e-05 5.000011085 5.000011085 5.00001-05 5.00004-05 3.4558e-05 1.4748i-05 3.4558e-05 1.4748i-05 3.4558e-05 1.488i-05 1.488		
Findish, Netpens           # Attribute tab	(d) (k) le - Finfab, Neters = 1 / 22 fee V AREA.5QM AR 19 225137 21 226664 19 225137 22 226664 19 2265137 23 226664 19 2265137 24 225137 25 226664 19 227197 2 217197 9 217197 9 217197 10 55658 11 4116435 11 200099 22 302198	ature()) selected   E&A.HECT  3.3558e-05 3.334e-05 3.000110355 3.62997-05 3.26564-05 4.2977-05 3.26564-05 1.47481-05 2.63219-03 6.63612-05 1.47481-05 3.4558e-05 3.4598e-05 3.4588e-05 3.45		
Finfish, Nelpens           # Attribute tai	(d) (x) (d) (x) (d	nture(i) selected   EA_HECT 3.4558e-05 3.3549e-05 5.000011085 5.000011085 5.00001-05 5.00004-05 3.4558e-05 1.4748i-05 3.4558e-05 1.4748i-05 3.4558e-05 1.488i-05 1.488		

1	Workspace	C:\InVEST_2_4_4\Aquaculture	$\bigcirc$
1	Finfish Farm Location	C:\[nVEST_2_4_4\Aquaculture\]nput\Finfish_Netpens.shp	0
	Farm Identifier Name	(FarmID 🔹	0
	Fish Growth Parameter (a)	0.038	0
	Fish Growth Parameter (b)	0.6667	0
	Daily Water Temperature at Farm Table	C:\InVEST_2_4_4\Aquaculture\Input\Temp_Daily.csv	0
	Farm Operations Table	C:\InVEST_2_4_4\Aquaculture\Input\Farm_Operations.csv	0
	Outplant Date Buffer	3	0
	Run Valuation? (optional)		0
	Market Price per Kilogram of Processed Fish	2.25	0
	Fraction of Price that Accounts to Costs	0.3	0
	Daily Market Discount Rate	0.000192	0

#### Parameters reset to defaults

General Operations Parameters (applies t	o all farms)		Instructions:				
Fraction of fish remaing after processing Natural mortality rate on the farm (daily)	85% 0,000137		When necessary, modify values for farm operations and/or add new farms (beginning				
Duration of simulation (years)	5	l	with row "32"). Do not, however, modify the				
			location of cells	in this template			
	I						
<u> </u>	irm-Specific C	perations Param	neters				
	weight of	target weight			Length of		
	fish at start	of fish at	number of fish	start day for	Fallowing		
Farm #:	(kg)	harvest (kg)	in farm	growing	period		
1	0,06	5,40	600 000	60	0		
2	0,06	5,40	600 000	60	0		

		macrocoms.																		
		1. Ensure the	at the belo	wnumber	s in row 5 (	highlighte	d in yellow	) correspo	nd to integ	er values u	inderneat	h the user-	specified "	Farm Iden	tifier Name	e" in the Fi	nfish Farm	Location 0	GIS shapefi	le (model
	input #2). The below numbers must be unique, consecutive, positive integers, starting with a value of 1 in cell "C,5".																			
2. When necessary, modify daily temperature values for each farm and/or add new farms (beginning with column "Y"). Do not, however, modify the location of cells in this template.																				
											<u>Far</u>	<u>n#</u> :								
	Day#	Day/Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1	01-janv	8,447	8,447	8,947	8,649	9,082	9,014	8,311	8,311	8,311	8,379	8,514	8,514	8,514	8,514	8,379	8,379	8,379	8,447
	2	02-janv	8,406	8,406	8,906	8,600	9,035	8,970	8,276	8,276	8,276	8,341	8,470	8,470	8,470	8,470	8,341	8,341	8,341	8,406
	3	03-janv	8,366	8,366	8,866	8,551	8,989	8,927	8,242	8,242	8,242	8,304	8,427	8,427	8,427	8,427	8,304	8,304	8,304	8,366



## 4.1 Marine Fish Acquaculture (Tier 1)

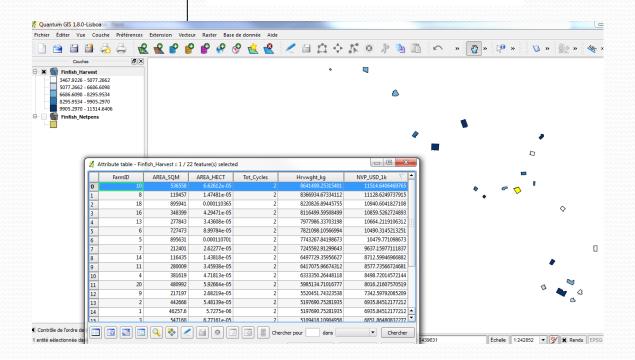
Weight  $W_t$  at time t (day), in year y, and on farm f is modeled as:

$$W_{t,y,f} = (aW_{t-1,y,f}^b \cdot T_{t,f}\tau) + W_{t-1,y,f}$$

The total weight of processed fish TPW on farm f in harvest cycle c:

$$TPW_{f,c} = W_{t_h,h,f} \cdot d \cdot n_f e^{-M \cdot (t_h - t_0)}$$

$$NPV_{f,c} = TPW_{f,c}[p(1 - C)] \cdot \frac{1}{(1 + r)^t}$$



Finfish Aquaculture Annuler
Exécution de Finfish Aquaculture...
Annuler
Conducting growth simulation for 5
years...

Production and valuation functions:

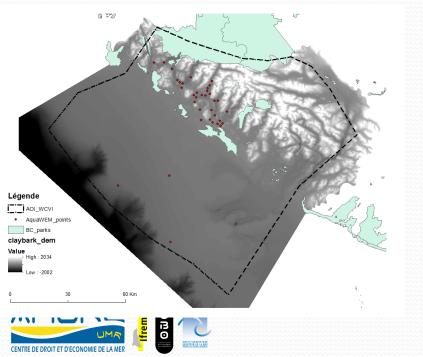


## 4. Description of models: cultural

Légende i----i

## 4.2 Aesthetic quality (Tie

	Step	Data requirements	Process	Output
	Supply	attributes of marine environment (location of natural desired features & development/infrastructure) attributes of shoreline environment (location of natural desired features & development/infrastructure) bathymetry topography	calculates points from which natral/desired or infrastructure can be observed	
	Service	access points location of public parks location of private property	calculates points from which infrastructure can be observed	number of natural (non-infrastructure or development) views pe location
Optional	Value	capital costs (e.g., device, cables, etc.) operating costs revenue	Calculates present value of electricity captured per array	net present value of electricity captured from waves per array



C:HDMEST_14_4 les leticQuality	
Are of Inter at (A I)	
Cell Size (meters) (facultatif) 500	
Point Features Impacting Aesthetic Quality	
AquaWEM_points 🗾 🖻	
Digital Elevation Model (DEM)	
claybark_dem 🗾 🖻	
Refractivity Coefficient	
0.13	
Global Population Raster (facultatif)	
C:\InVEST_2_4_4\Base_Data\Marine\Population\global_pop	
Polygon Features for Overlap Analysis (facultatif)	
BC_parks	
	-
OK Annuler Environnements Afficher l'aide :	>>

- O X



#### **Population Statistics**

Workspace

AOI_WCVI			
vshed_qual `; VIS_QUAL `	<u>`</u>	Number of Features Visible	Population (estimate)
High Visual Impact Low Visual Impact Medium-High Visual No Visual Impact	Impact	None visible (unaffected)	7121
Vp_overlap AreaV Shed No Overlap 1 - 25% Overlap	<b>*</b> *.	l or more visible	1359
26 - 50% Overlap 51 - 75% Overlap 76 - 100% Overlap 0 30	60 Km		ł

# 4.3 Overlap analysis (Tier 0)

Step	Data	requirements	Process	Output	
Required	Supply	location of natural desired features for recreation (e.g., whale sightings, mammal haul outs, kelp for SCUBA, beaches, etc.) location and quality of environmental conditions affecting recreation value	maps locations of recreation activities		
		(e.g., wave energy for beach enjoyment or wildlife viewing)			
		location of infrastructure in support of recreation activities (e.g., campgrounds, boat launches, etc.)			
Required	Service	distance between access points and activities	calculates index of recreation importance	index of recreation importance by activity and weighted overall	
	Scivice	visitation rates for each location, activity	increasion importance	index	

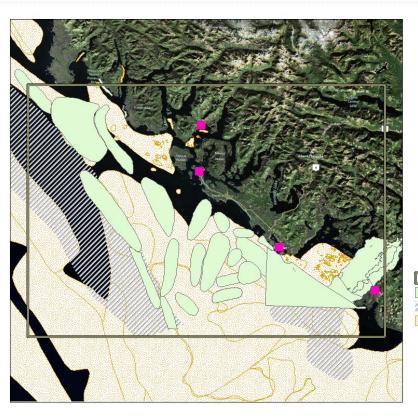
ace		
309		
309		
	C:\InVEST_2_4_4\OverlapAnalysis	
s Zones Layer	C:\[nVEST_2_4_4\OverlapAnalysis\]nput\ManagementZones_WCVI.shp	
Analysis Data Directory	$C:\label{eq:linvest_2_4_4} C:\label{eq:linvest_2_4_4} C:\label{eq:linvest_2_4} C:eq:li$	
ve been loaded from the i	most recent run of this model. <u>Reset to defaults</u>	
		s Zones Layer C:\[In\FEST_2_4_4\]OverlapAnalysis\[Input\]ManagementZones_WCVI.shp o Analysis Data Directory C:\[In\FEST_2_4_4\]OverlapAnalysis\[Input\]FisheriesLayers_RI ve been loaded from the most recent run of this model. <u>Reset to defaults </u>

Importance Score (IS)

$$IS_i = \sum_{i,j} U_{ij}I_j$$



# 4.3 Overlap analysis (Moder Fisher Contents)



-	Workspace	C:\InVEST_2_4_4\OverlapAnalysis		0					
-	Analysis Zones Layer	C:\InVEST_2_4_4\OverlapAnalysis\Input\AOI_WCVI.shp		0					
	Analysis Cell Size (meters)	1000		0					
	Overlap Analysis Data Directory	C:\InVEST_2_4_4\OverlapAnalysis\Input\FisheriesLayers_RI		0					
	V Intra-Activity Weighting?			0					
	Intra-Activity Attribute Name	RI		0					
	✓ Inter-Activity Weighting?			0					
	Inter-Activity Weight Table	C:\InVEST_2_4_4\OverlapAnalysis\Input\Fisheries_Inputs.csv		0					
	✓ Human Use Hubs?			0					
~	Points Layer of Human Use Hubs	C:\[InVEST_2_4_4\OverlapAnalysis\]Input\PopulatedPlaces_WCVI.shp		0					
	Distance Decay Rate	0.0001		0					
Parameters have been loaded from the most recent run of this model. <u>Reset to defaults</u>									
🔦 Re	eset	📣 Run		Quit					

PopulatedPlaces\_WCVI
AOI\_WCVI
CommSalmonTroll\_Fish
CommGF Fish
CommGF Fish

# 4.Description of models: cultural4.3 Overlap analysis (Tier 0)

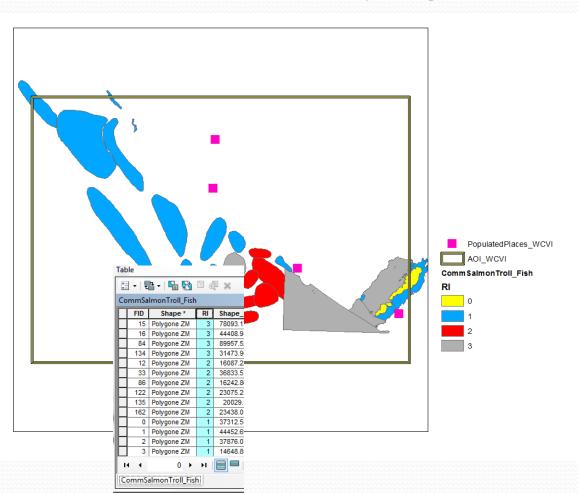
*Importance Score* (IS) with intra and inter activity weight:

$$IS_i = \frac{1}{n} \sum_{i,j} U_{ij} I_j$$

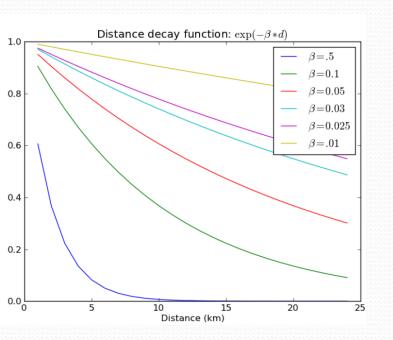
		Inter-activity	weight
		A	В
	1	LIST OF HUMAN USES	OPTIONAL:
	2	CommGF_Fish	2
	3	CommSalmonTroll_Fish	1.5
663	4	CommShrimp Fish	1.5



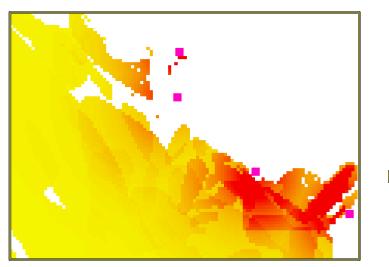
### Salmon Troll Intra-activity weight



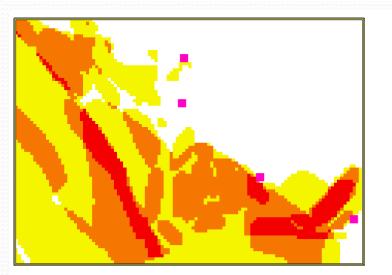
# 4.Description of models: cultural4.3 Overlap analysis (Tier 0)





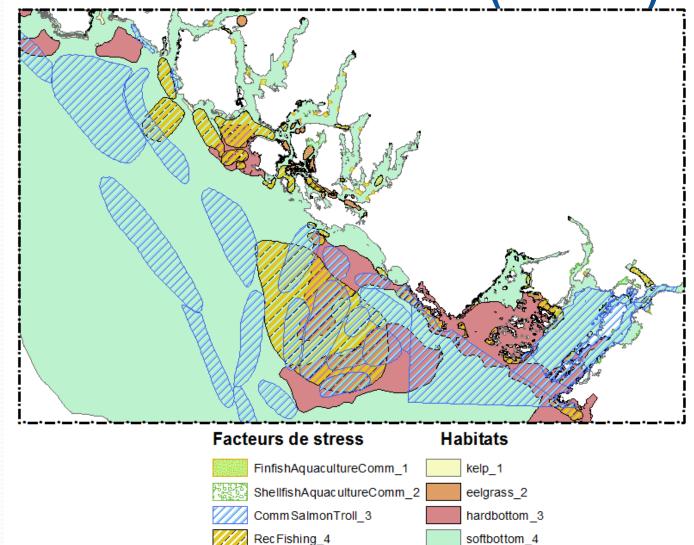


PopulatedPlaces\_WCVI
 AOI\_WCVI
 hu\_impscore.tif
 Valeur
 Elevée : 0.439273
 Faible : 9.90971e-005



PopulatedPlaces\_WCVI AOI\_WCVI hu\_freq.tif Valeur Elevée : 3 Faible : 1

# 4.4 Habitat Risk Assessment (Tier 0)





# 4.Description of models: supporting4.4 Habitat Risk Assessment (Tier 0)

**Step 1.** Likelihood of exposure of the habitat to the stressor and the consequence of this exposure

**Step 2.** Risk value for each stressorhabitat combination

$$R_i = \sum_{j=1}^J R_{ij}$$

Step 3. Cumulative risk of all stressors on the habitats

$$R_{ij} = \sqrt{(E-1)^2 + (C-1)^2}$$

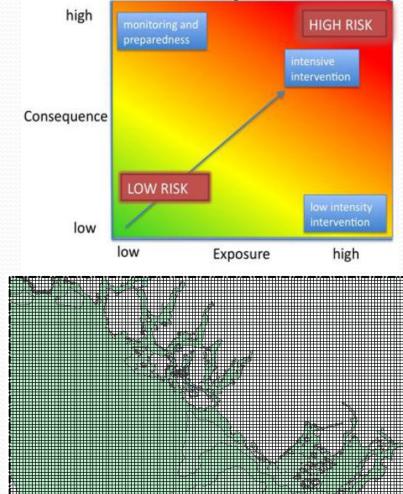
 $E = \frac{\sum_{i=1}^{N} \frac{e_i}{d_i \cdot w_i}}{\sum_{i=1}^{N} \frac{1}{d_i \cdot w_i}}$ 

 $C = \frac{\sum_{i=1}^{N} \frac{d_i}{d_i \cdot w_i}}{\sum_{i=1}^{N} \frac{1}{d_i}}$ 



# 4.4 Habitat Risk Assessment (Tier 0)

5	3 Habitat Risk Assessment			
	Workspace			*
	C:\InVEST_2_4_4\HabitatRiskAssess		2	
	Gridded Seascape (GS) Output Layer		_	
	gs_1000	-	<b>2</b>	
	Habitat Data Directory			
	C:\InVEST_2_4_4\HabitatRiskAssess\Input\HabitatLayers		<b>2</b>	
	Stressor Data Directory			
	C:\InVEST_2_4_4\HabitatRiskAssess\Input\StressorLayers		<b>2</b>	
	Habitat-Stressor Ratings CSV Table			
	C:\InVEST_2_4_4\HabitatRiskAssess\Input\CompletedSurvey_WCVI.csv		<b>2</b>	
	<ul> <li>✓ Create HTML Output with Risk Plots? (requires Matplotlib 1.0 extension) (facu</li> <li>✓ Generate Habitat Maps of Risk Hotspots? (facultatif)</li> </ul>	ltatif)		
				Ŧ
	OK Annuler Environnements	Afficher	l'aide >:	>

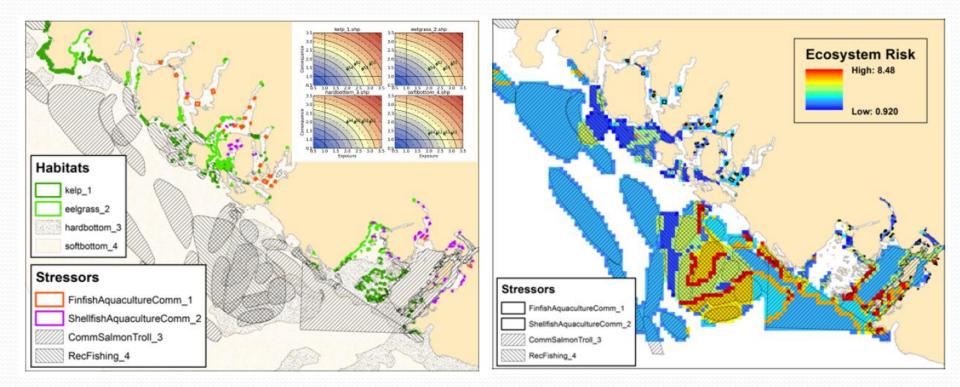




## 4.Description of models: supporting4.4 Habitat Risk Assessment (Tier 0)

Habitat ID	Habitat Name	Habitat DO	Mortality	Mortality DO	Recruitment	Docruitment I	Connectivity	Connectivity	Degeneration	Degeneration	DO	17. 17.
					Necruitment	A	Connectivity	Connectivity	r Regeneration	regeneration		X
	) kelp	1	1	0	2	0	2	0	1	0		
	eelgrass	1	1	0	1	0	1	0	1	0		
	hard bottom	2	0	0	0	0	0	0	3	0		
	soft bottom	2	0	0	0	0	0	0	1	0		
4	•											
Stressor ID	Stressor Nam			Intensity DQ	Management	Managment [						
	Finfish Aquad		3	0	3	0	300					
	Shellfish Aqu		2	0	2	0	250					
	Comm Salmo	2	3	0	3	0	150					
	Rec Fishing	2	2	0	2	0	100					<u></u>
16	6											i i i i i i i i i i i i i i i i i i i
Habitat ID	Habitat Name	Stressor ID	Stressor Nam	Area Change	Area Change	Structure Cha	Structure Cha	Disturbance	Disturbance	Temporal Ove	Temporal Ove	rlap DQ
(	) kelp	0	Finfish Aquad	2	1	2	1	2	1	3	1	
(	kelp	1	Shellfish Aqu		1	2	1	2	1	3	1	
(	kelp	2	Comm Salmo		1	1	1	2	1	2	1	
	) kelp	3	Rec Fishing	1	1	1	1	2	1	2	1	
	eelgrass		Finfish Aquad	3	1	3	1	2	1	3	1	
	eelgrass		Shellfish Aqu		1	3	1	2		3	1	
	eelgrass		Comm Salmo		1	2	1	2		2	1	
	eelgrass		Rec Fishing	2	1	2	1	2		2	1	
	hard bottom		Finfish Aquad	0	0	1	0	2		3	1	
	hard bottom		Shellfish Aqu		0	1	0	2		3	1	
	hard bottom		Comm Salmo		0	1	0	2		2	. 1	
	2 hard bottom		Rec Fishing	0	0	1	0	2		2	1	
	soft bottom		Finfish Aquad	0	0	1	0	2		2	1	
	soft bottom	1	Shellfish Aqu		0	1	0	2		3	1	
	soft bottom	2	Comm Salmo		0	1	0	2		3	1	
				0	0	1	0			2	1	
	soft bottom	3	Rec Fishing	0	0	1	0	2	. <b>U</b>	2	1	

# 4.Description of models: supporting4.4 Habitat Risk Assessment (Tier 0)





# 4.Description of models: supporting4.5 Water quality (Tier 0)

- Considers the physical transport and biogeochemical processes for simulating water state variables (e.g., contaminants, pollutants) in response to various management decisions under consideration by users.
- Advection-diffusion model

$$E^T \left( \frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2} \right) - \left( U \frac{\partial C}{\partial x} + V \frac{\partial C}{\partial y} \right) + S = 0$$

Where

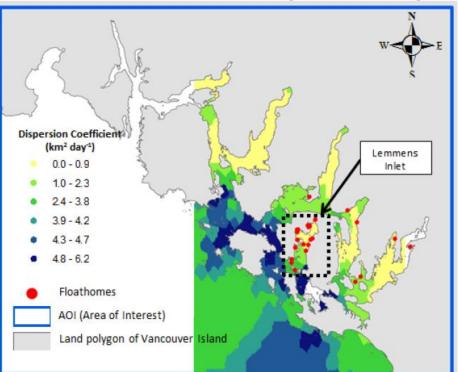
- x and y east and north coordinates, respectively
- · C tidal averaged concentration of a water quality state variable
- U and V advective velocities (i.e., Eulerian residual current) in x and y directions, respectively
- +  $E^T$  tidal dispersion coefficient
- · S term to account for sources and sinks of pollutant

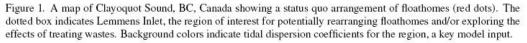


# 4.5 Water quality (Tier 0)

Marine	Water Quality Biophysical			53
		InVEST Version 2.4.4   Model documentation	<u>1   Send</u>	feedback
	Workspace	C:\InVEST_2_4_4\MarineWaterQuality		0
- 1	Area of Interest (AOI)	!_4_4\MarineWaterQuality\input\AOI_clay_soundwideWQ.shp		0
- 1	Land Polygon	$\label{eq:relation} \ensuremath{I_2_4_4}\ensuremath{WarineWaterQuality}\ensuremath{Viput}\ensuremath{S005_{VI}}\ensuremath{Viput}\ensuremath{Polygon.shp}\ensuremath{S005_{VI}}\ensuremath{Viput}\ensuremath{S005_{VI}}\ensuremath{Viput}\ensuremath{S005_{VI}}\ensuremath{Viput}\ensuremath{S005_{VI}}\ensuremath{S005_{VI}}\ensuremath{S005_{VI}}\ensuremath{S005_{VI}}\ensuremath{S005_{VI}}\ensuremath{S005_{VI}}\ensuremath{Viput}\ensuremath{S005_{VI}\ensuremath{S005_{VI}}\ensuremath{S005_{VI}\ensuremath{S005_{VI}}\ensuremath{S005_{VI}S005_{VI$		0
- 1	Output pixel Size in meters	100		0
- 1	Grid Cell Depth	1.0		0
- 1	Source Point Centroids	$T_2_4_4\MarineWaterQuality\input\floathomes\_centroids.shx$		0
- 1	Source Point Loading Table	C:\InVEST_2_4_4\MarineWaterQuality\input\WQM_PAR.csv		0
- 1	Decay Coefficient (Kb)	0.001		0
- 1	Tidal Diffusion Constants (E)	4_4\MarineWaterQuality\input\TideE_WGS1984_BCAlbers.shp		0
- 1	(Optional) Advection Vectors (UV as point data)	_4\MarineWaterQuality\input\ADVuv_WGS1984_BCAlbers.shp		0
Paran	neters reset to defaults.			
🔦 Re	eset	🥠 Run		Quit

# 4.5 Water quality (Tier O)





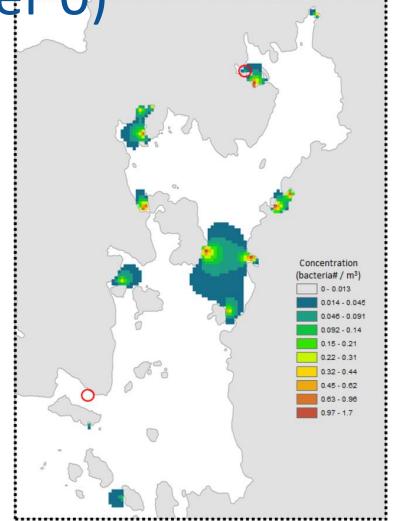




Figure 3. Map of modeled concentration of fecal coliform bacteria in Lemmens Inlet. Red circles indicate treated wastes. The results are for demonstration purposes only.

4. Description of models: regulating 4.6 Coastal vulnerability (Tier 0)  $P = \frac{1}{2}H^2T$  $VI = \sqrt{\frac{R_{Geomorphology}R_{Relief}R_{Habitats}R_{SLR}R_{WindExposure}R_{WaveExposure}R_{Surge}}{Count_{Var}}}$  $EI = \sqrt{\frac{R_{Geomorphology}R_{Habitats}R_{WaveExposure}}{3}}$  $\begin{cases} H = \widetilde{H}_{\infty} \left[ \tanh\left(0.343\widetilde{d}^{1.14}\right) \tanh\left(\frac{2.14 \cdot 10^{-4} \widetilde{F}^{0.79}}{\tanh(0.343\widetilde{d}^{1.14})}\right) \right]^{0.572} \\ T = \widetilde{T}_{\infty} \left[ \tanh\left(0.1\widetilde{d}^{2.01}\right) \tanh\left(\frac{2.77 \cdot 10^{-7} \widetilde{F}^{1.45}}{\tanh(0.1\widetilde{d}^{2.01})}\right) \right]^{0.187} \\ E_{w}^{l} = \sum_{k=1}^{16} P_{k}^{l} O_{k}^{l} \end{cases}$  $R_{Hab} = 4.8 - 0.5 \sqrt{1.5(\max_{k=1}^{N}(5-R_k))^2 + (\sum_{k=1}^{N}(5-R_k)^2 - (\max_{k=1}^{N}(5-R_k))^2)} REI = \sum_{k=1}^{10} U_n P_n F_n$  $E_w = \max(E_w^o, E_w^l) \qquad E_w^o = \sum_{k=1}^{16} H[F_k] P_k^o \quad H[F_k] = \begin{cases} 0 & \text{if } F_k < 50km \\ 1 & \text{if } F_k \ge 50km \end{cases}$ 

Rank	Very Low	Low	Moderate	High	Very High
Vari-	1	2	3	4	5
able					
Geo-	Rocky; high	Medium cliff;	Low cliff; glacial drift;	Cobble	Barrier beach;
mor-	cliffs; fjord;	indented coast,	alluvial plain,	beach;	sand beach;
phol-	fiard, seawalls	bulkheads and small	revetments, rip-rap	estuary;	mud flat; delta
ogy		seawalls	walls	lagoon; bluff	
Relief	<=20th	<=40th Percentile	<=60th Percentile	<=80th	>80th
	Percentile			Percentile	Percentile
Natu-	Coral reef;	High dune; marsh	Low dune	Seagrass;	No habitat
ral	mangrove;			kelp	
Habi-	coastal forest				
tats					
Sea	Net decrease		-1 to +1		Net rise
Level					
Change					
Wind	<=20th	<=40th Percentile	<=60th Percentile	<=80th	>80th
Expo-	Percentile			Percentile	Percentile
sure					
Wave	<=20th	<=40th Percentile	<=60th Percentile	<=80th	>80th
Expo-	Percentile			Percentile	Percentile
sure					
Surge	<=20th	<=40th Percentile	<=60th Percentile	<=80th	>80th
Poten-	Percentile			Percentile	Percentile
tial					

Table 4.1: List of Bio-Geophysical Variables and Ranking System for Coastal Exposure.



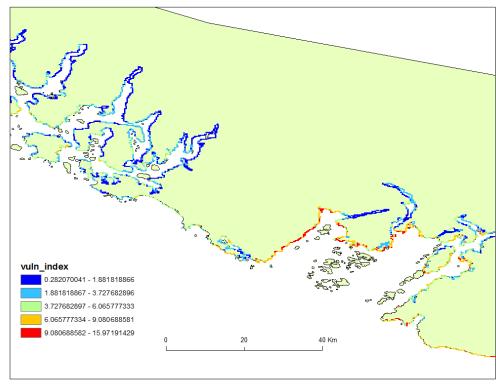
## 4.0 Coastal vulnerability (Tier 0)

1 Fetch Calculator		
Workspace		^
C:\InVEST_2_4_4\CoastalProtection		
Land Polygon		
C:\InVEST_2_4_4\Base_Data\Marine\Land\global_polygon.shp	- 🖻	
Land Polyline		
C:\InVEST_2_4_4\Base_Data\Marine\Land\global_polyline.shp	<b>2</b>	
Land Area Filter (kilometers squared) (facultatif)		
	5	
Area of Interest (AOI)		
AOI_BarkClay	I 🖻	
Cell Size (meters)	250	
Fetch Distance Threshold (meters)	2.50	
	12500	
		-
OK Annuler Environnements	Afficher l'aide >>	>
	/	

	1 Fetch Calculator	×
	Terminé	Fermer
		<< Détails
	Fermer cette boîte de dialogue lorsque l'exécution est terminée	
	Exécution de : FetchCalculator C:\InVEST_2_4_4\CoastalProtection \InVEST_2_4_4\Base_Data\Marine\Land\global_polygon.shp C:\InVEST \Base_Data\Marine\Land\global_polyline.shp 5 AOI_BarkClay 250 12 Heure de début : Mon Nov 26 15:35:49 2012 Exécution du script FetchCalculator	244 00
	Checking inputs and preparing data	
	Calculating fetch distances	
	Combining fetch results and determining coastal exposure Completed script FetchCalculator	
	Lander ~	
.égende		æ
etch_cmb		Part
aleur Elevée:4387		Front.
- Faible : 1		E. 2.
global_polygon		
0	20 40 Km	
	,	

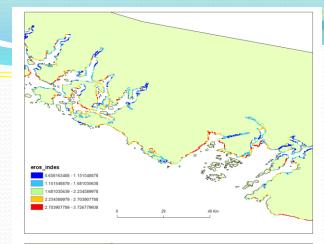


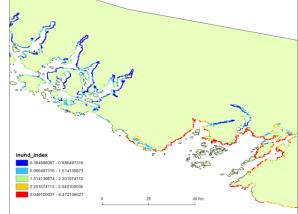
Workspace	
C:\InVEST_2_4_4\CoastalProtection\CV	<b>2</b>
Fetch Calculator Tool Run Workspace	
C:\InVEST_2_4_4\CoastalProtection	<b>2</b>
Population Raster (facultatif)	
C:\InVEST_2_4_4\Base_Data\Marine\Population\global_pop	I ≥
1a) WIND-WAVE EXPOSURE: Wave Watch III Model Data	
WaveWatchIII	- 2
1b) WAVE EXPOSURE: Average Depth (meters) within AOI (Note: Depth should be < 500 if it is shallow)	
	500
2) RELIEF: Digital Elevation Model (DEM)	

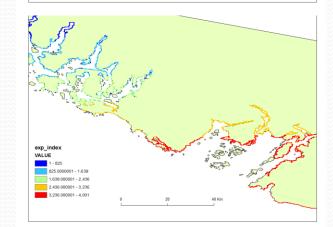


AM

CENTRE DE DROIT ET D'ECONOMIE DE LA MER







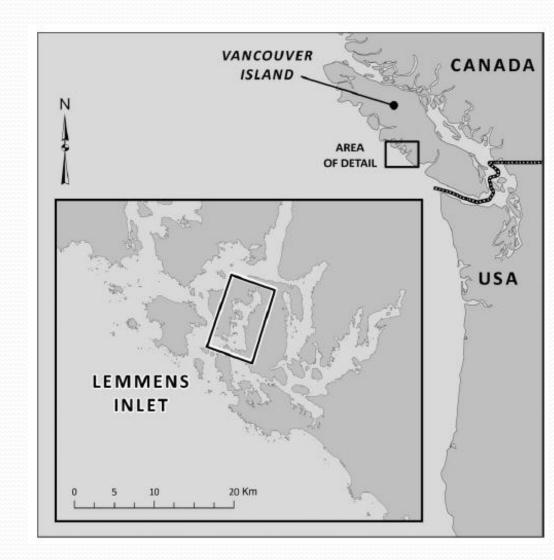
Application of marine InVEST to WCVI (Guerry et al, 2012)

### Problem

Creation of a MSP

### **Ecosystem services**

 Food, water quality, habitat and recreation





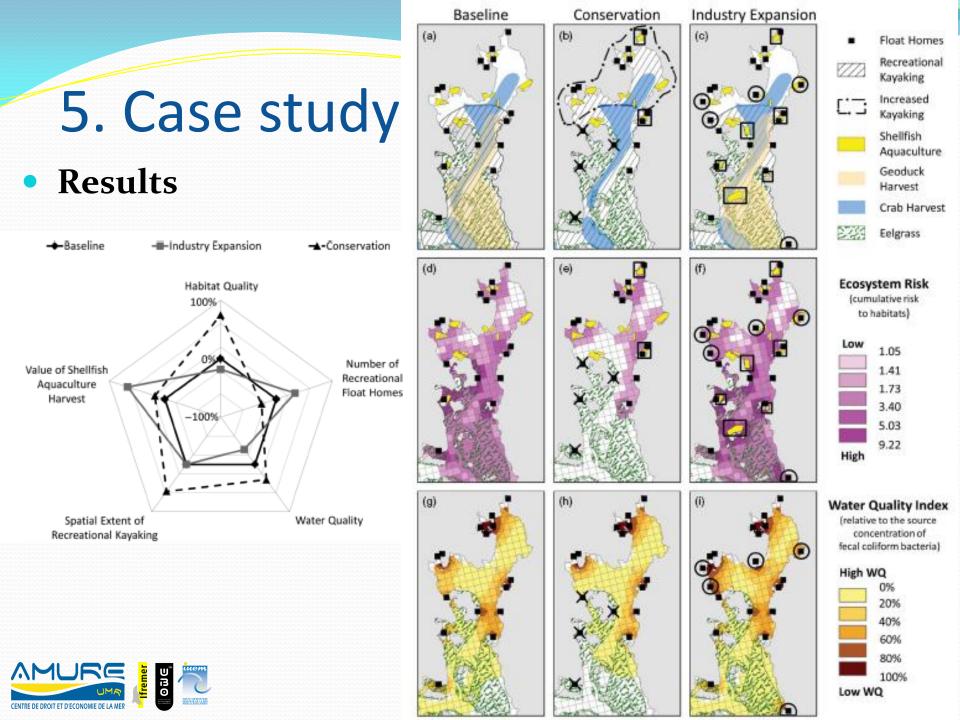
### Methods

- Interviews with stakeholders
- 3 management scénarios:
  - i) Industrial expansion (more shellfish acquaculture, more floating homes)
  - ii) Conservation (more usage restrictions)
  - iii) Baseline



- Methods
- Production:
  - Shellfish acquaculture
- Cultural:
  - Recreation (kayak and floating homes)
- Supporting services
  - HRA
  - Water quality





### Results

Conservation scenario

- Kayak route increase extension (57%)
- 98.998 USD (+18%) shellfish acquaculture
- Decrease in the number of floating homes (-4)
- Improovement of HRA (-75%)
- Increase of water quality (32%)

Expansion scenario

- Shellfish farms (+5). Increase of 367.726 USD (67%)
- Location of shellfish farms have low impact in WQ
- More floating homes (+5) decrease WQ
- Increase in HRA (18%)
- No impact in kayak activity



## 5. Discussion

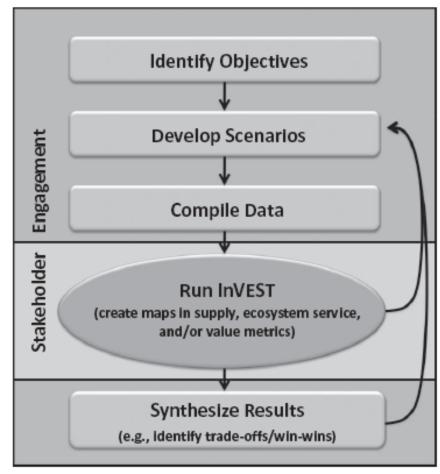
### InVEST is useful for MSP

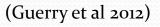
- Clarifies objectives
- Makes the tradeoffs explicit
- Provides metrics for comparing alternatives
- Facilitates an interactive and iterative engagement
- New models are planned
- Scenario generator



## 5. Discussion IMPORTANT QUESTIONS

- 1. What are the relevant SE?
- 2. Which level of complexity is necessary for modelling?
- 3. Data?
- 4. Which scenarios?







 « InVEST ins't a crystal ball that is going to tell us what to do...but it will help us to compare the options» (Anne Guerry, 2012)

### Thanks!

