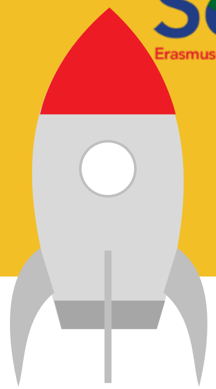
RABAT CONFERENCE ON COASTAL RISKS

(APRIL 23-24, 2019)



INTEGRATED MANAGEMENT OF A COASTAL LAGOON (RIA FORMOSA) USING A QUANTITATIVE DPSIR APPROACH

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Erasmus+ Programme
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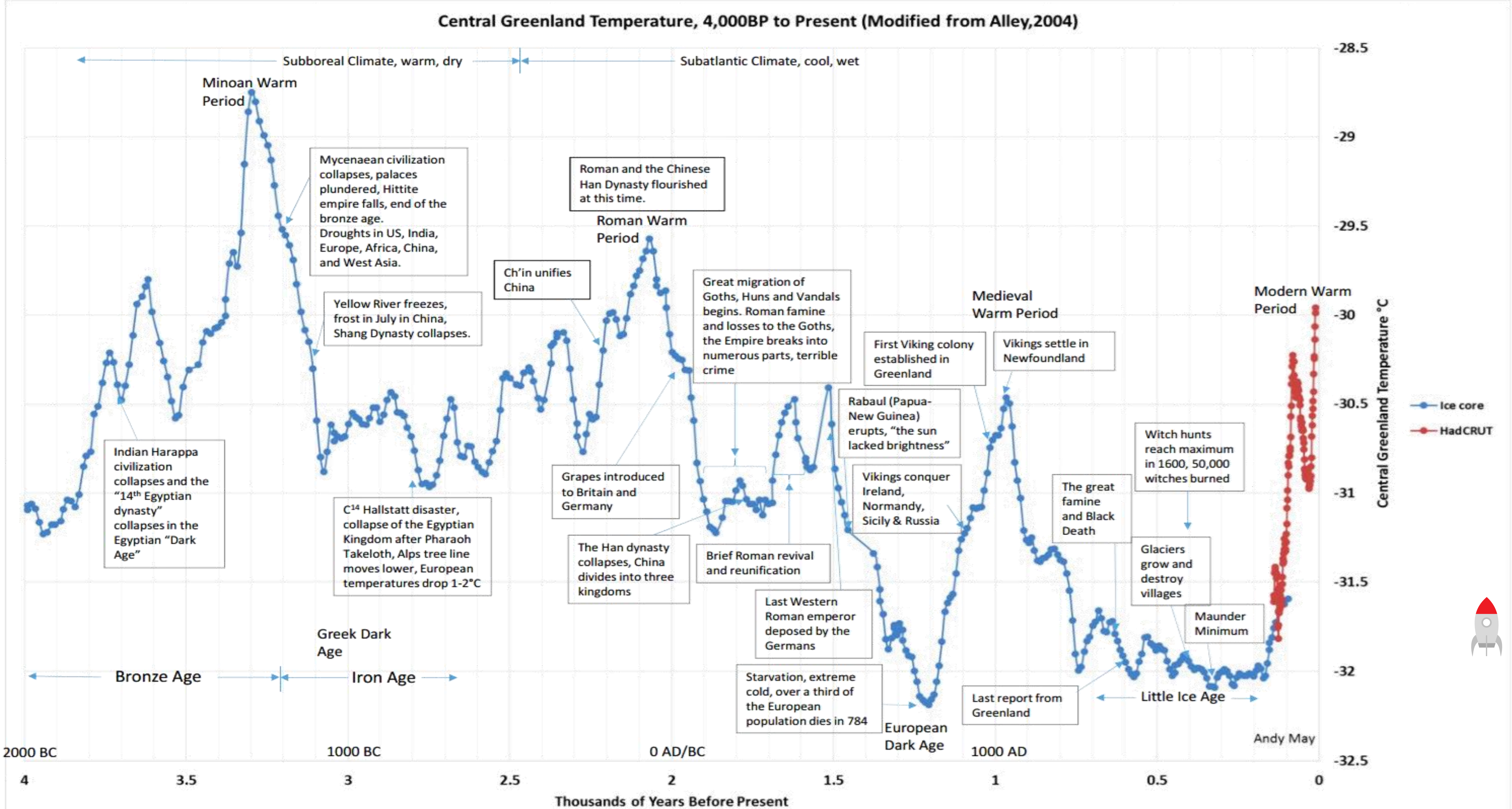
ScolaMAR
Erasmus+ Capacity building

DPSIR: what for?



DPSIR

Scientist and decision makers do not speak the same language…

Selection of sustainability indicators for planning: combining stakeholders participation and data reduction techniques

10.1016/j.jclepro.2015.01.005

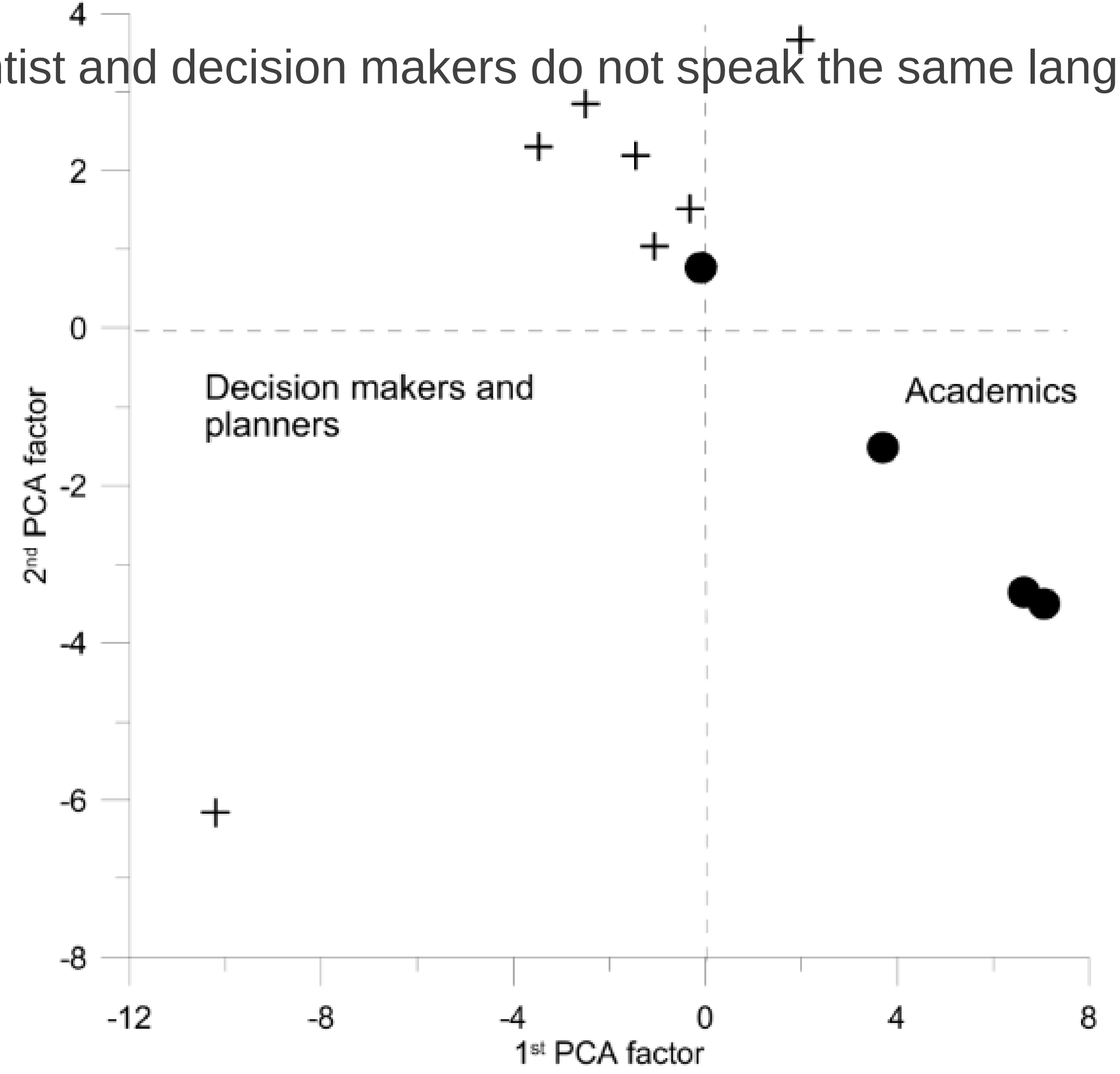


Figure 4 – Clusters resulting of stakeholders' scoring (crosses represent decision makers and planners, circles represent academics).

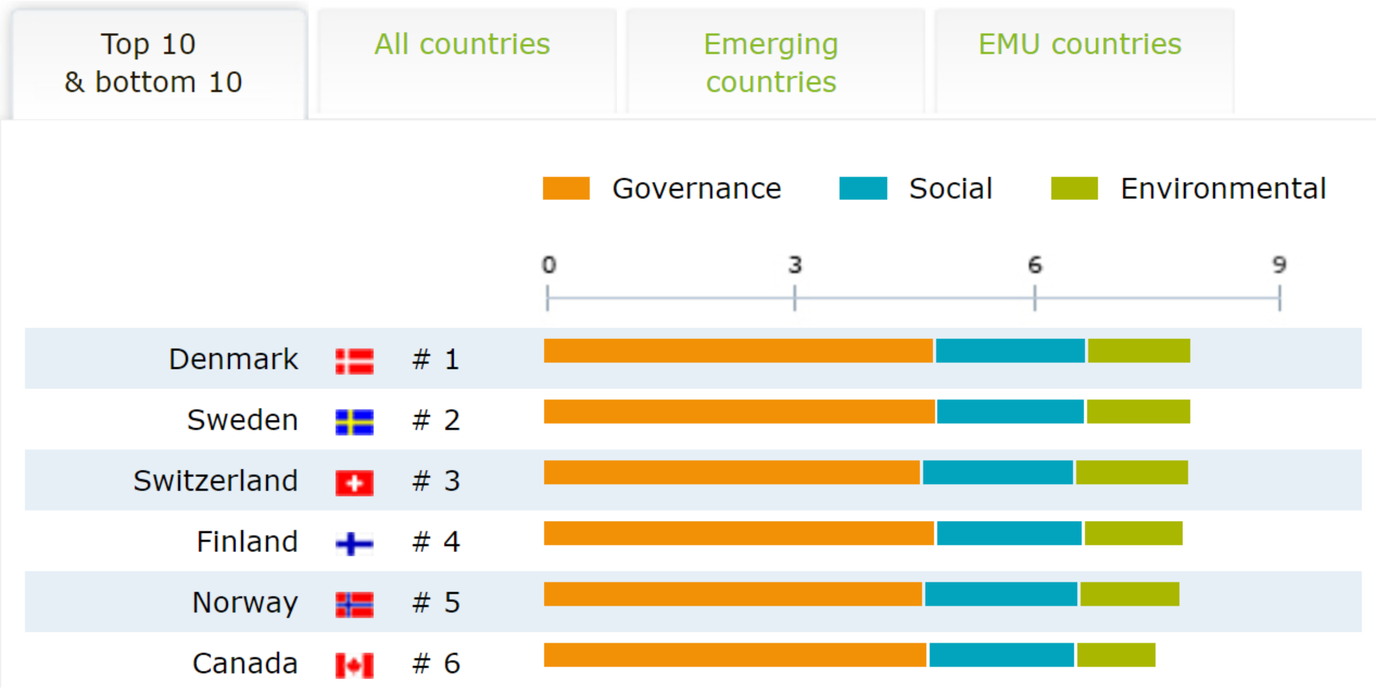
DPSIR

In the meanwhile the economic system is deciding for all…

ROBECOSAM
We are Sustainability Investing.

S&P

As of April 2018



The country sustainability score is based on 17 environmental, social and governance indicators, which receive a weight of 15%, 25% and 60% of the total score, respectively. The score ranges from 1 to 10 and should be interpreted as a grade, with the highest grade being 10 and the lowest 1. The purpose of the score is to compare countries on the basis of ESG indicators that we consider to be relevant for investors.

DPSIR

Causal framework for describing the interactions between society and the environment

The Driver-Pressure-State-Impact-Response (DPSIR) conceptual framework brings together natural sciences, social sciences and economics in one framework for adaptive management.

DPSIR

OBJECTIVES

01

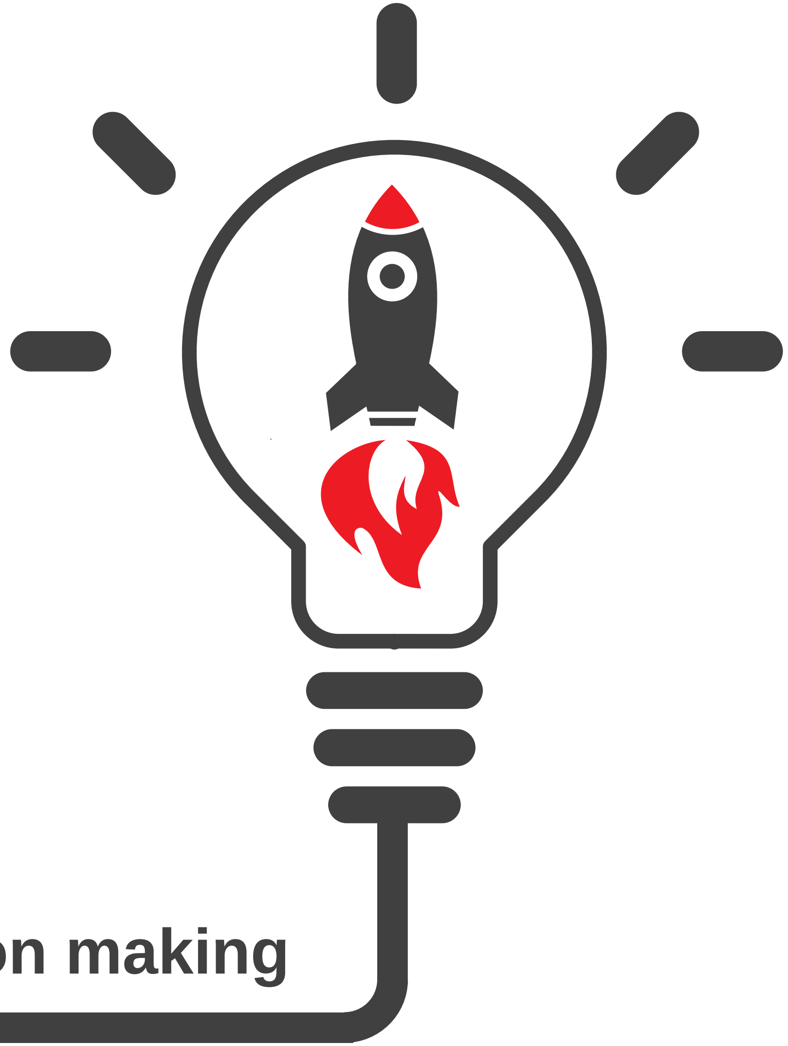
UNDERSTAND
The relationships between causes and effects (human activities – impacts)

02

ASSESS
The effects of management strategies

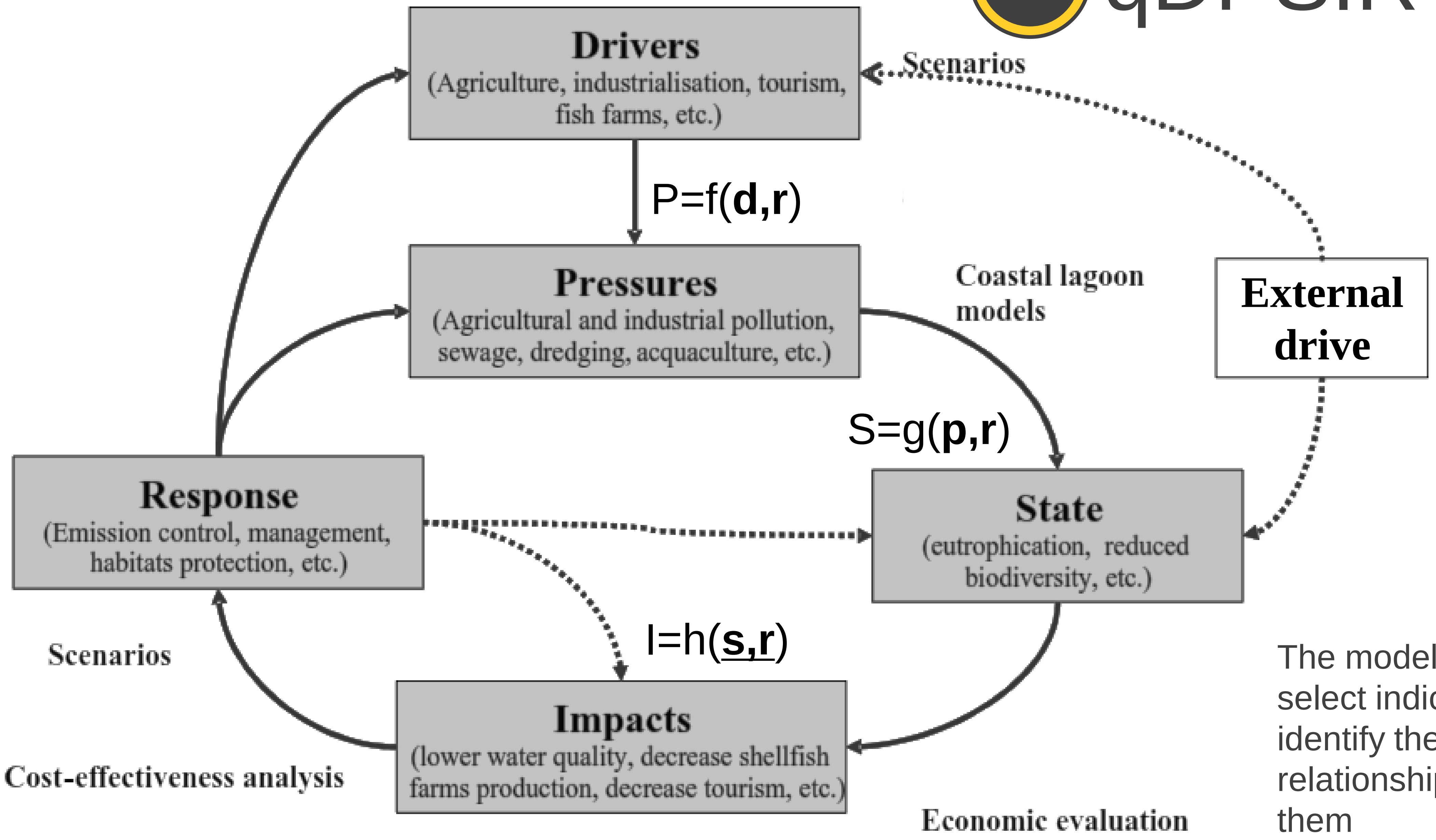
03

FORECAST
The impact of policies and strategies of development



Decision making

qDPSIR



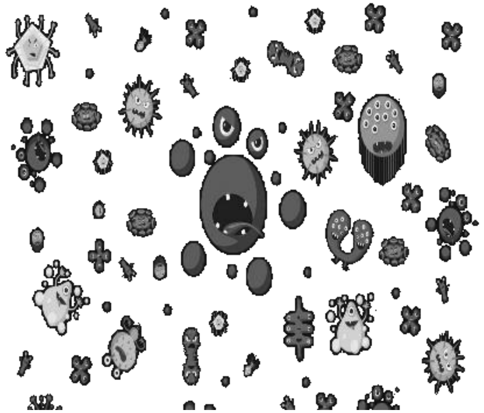
The modeler should select indicators and identify the causal relationship between them

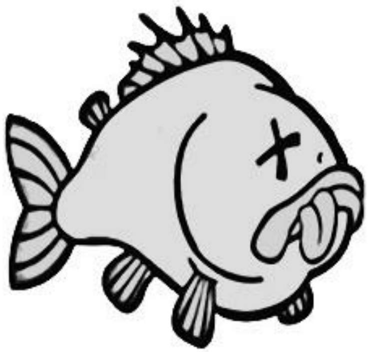
Qualitative

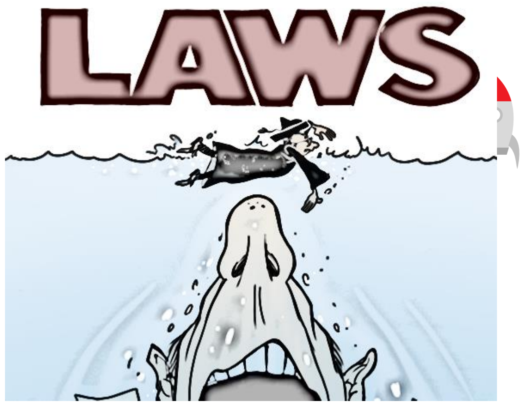
E.g.,

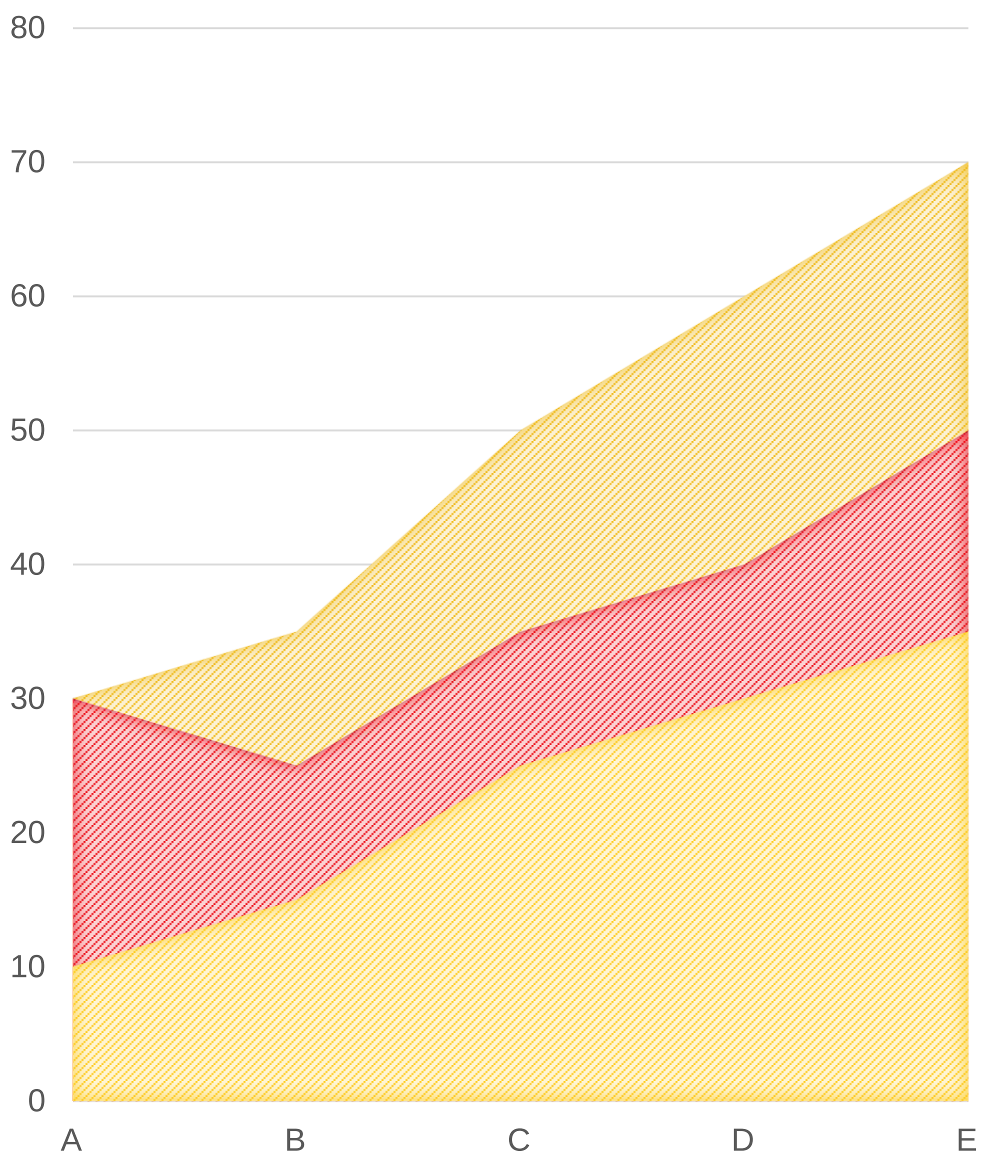
The modeler should select relevant and measurable indicators

Driver	Pressure	State	Impact	Policy response (*)
Urban and tourism development	Increase in resident and seasonal population: wastewater production freshwater consumption wetland reclamation soil impermeabilisation	Eutrophication Development of bacteria of sanitary concern Contamination by POP	Altered freshwater/saline water equilibrium Reduced water quality Eutrophication Anoxic crises	Increase treatment level for domestic wastewater Increase wastewater reuse Develop buffer zones









DPSIR

How to establish the causal relationships?

$$P = f(\mathbf{df})$$

$$S = g(\mathbf{p})$$

$$I = h(\underline{\mathbf{s}})$$

Qualitative
Identification of relationships without quantifying

Quantitative
Second step where quantitative relationships are established

Quantitative (Pressures)

P = f(**d**,**r**)   **Pressure indicators are converted to the same unit of measurement**

P = GHG (**d**,**r**); **d**: pressures due to consumption and generation; **r**: responses

$$GHG = f\left(g_w(C_w),\ g_{ww}(G_{ww}), g_s(G_s),\ g_p\left(C_p\right),\ g_g\left(C_g\right),\ g_{ws}(G_{ws}),\ g_t(G_t),\ g_o(C_o); EF_e, EF_g, EF_v\right)$$

C refers to consumption, **G** to generation, and **EF** to emission factor.

Subscript **w** refers to water supply, **ww** to wastewater, **e** to electricity, **g** to gas, **ws** to waste, **t** to transport and **o** to others.

Quantitative (Pressures)

$$GHG_w\left(\frac{kgCO_2\,eq}{year\times res}\right)=g_w(C_w)=EC_w\left(\frac{kWh}{m^3}\right)\times C_w\left(\frac{m^3}{year\times res}\right)\times EF_e\left(\frac{kgCO_2\,eq}{kWh}\right)$$

$$GHG_{ww}\left(\frac{kgCO_2\,eq}{year\times res}\right)=g_{ww}(G_{ww})=EC_{ww}\left(\frac{kWh}{m^3}\right)\times G_{ww}\left(\frac{m^3}{year\times res}\right)\times EF_e\left(\frac{kgCO_2\,eq}{kWh}\right)$$

$$GHG_e\left(\frac{kgCO_2\,eq}{year\times res}\right)=g_e(C_e)=C_e\left(\frac{kWh}{year\times res}\right)\times EF_e\left(\frac{kgCO_2\,eq}{kWh}\right)$$

$$GHG_g\left(\frac{kgCO_2\,eq}{year\times res}\right)=g_g(C_g)=C_g\left(\frac{kWh}{year\times res}\right)\times EF_g\left(\frac{kgCO_2\,eq}{kWh}\right)$$

$$GHG_{ws}\left(\frac{kgCO_2\,eq}{year\times res}\right)=g_{ws}(G_{ws})=G_{ws}\left(\frac{t}{year\times res}\right)\times EF_{ws}\left(\frac{kgCO_2\,eq}{t}\right)$$

$$GHG_t\left(\frac{kgCO_2\,eq}{year\times res}\right)=g_t(G_t)=G_t\left(\frac{km}{year\times res}\right)\times EF_v\left(\frac{kgCO_2\,eq}{km}\right)$$

ECw and ECww are the energetic costs of supplying water and managing wastewater, respectively;
Cw, Ce and Cg are the water, electricity and gas consumptions;
Gww and Gws are the wastewater and waste generation, and **Gt** is the accumulated length of journeys.
Efe , EFg, Efws and Efv represent the emission factors for electricity, gas, waste management and vehicles

Quantitative (Impacts)

Impacts

I = h(**s,r**)

1. Computed from GHG

$$\mathbf{I}\ (€) = \mathbf{GHG}\ (\text{ton } CO_{2e}/\text{res}) \cdot \mathbf{res} \cdot \mathbf{K_1}\ (€/\text{ton } CO_{2e}) \qquad (1)$$

2. Computed using “Willingness to pay” values

$$\mathbf{I}\ (€) = \mathbf{Var}\ (\text{unit}) \cdot \mathbf{K_2}\ (€/\text{unit}) \qquad (2)$$

$\mathbf{K_1}$= CO_2 European Emission Allowances (ref period 2016): 7.12 €/ ton CO_{2e}
$\mathbf{K_2}$= Value of ecosystem services, scenic values, perceived health risks

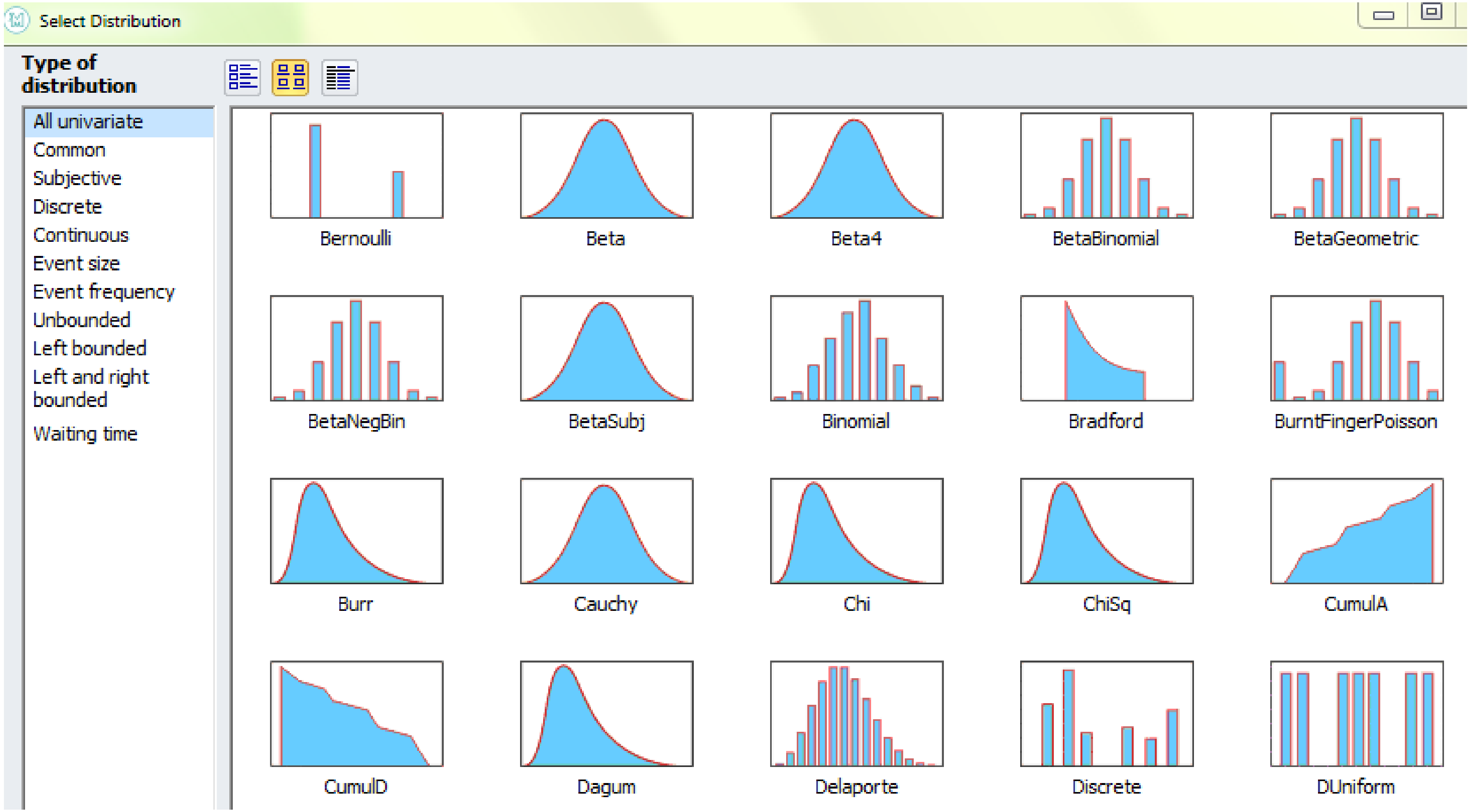
Quantitative (Impacts)

Stochastic model

Crisp values are replaced by statistical distributions

Include Uncertainty

Study uncertainty propagation



Quantitative (Impacts)

Finaly:

$$\textbf{qDPSIR} = \Sigma \textbf{ Positive impacts} - \Sigma \textbf{ Negative impacts} \qquad (3)$$

Positive impacts include economic revenues and preservation values.

Negative impacts include all externalities.

COASTAL LAGOON (RIA FORMOSA)

SOUTH PORTUGAL

System of barrier islands that communicates with the sea through six inlets.

Case-study

Ria Formosa lagoon

Area: 14 500 ha

Extension: 55 km

Average depth: 3 m

Salinity: 35.5 – 36.9%o

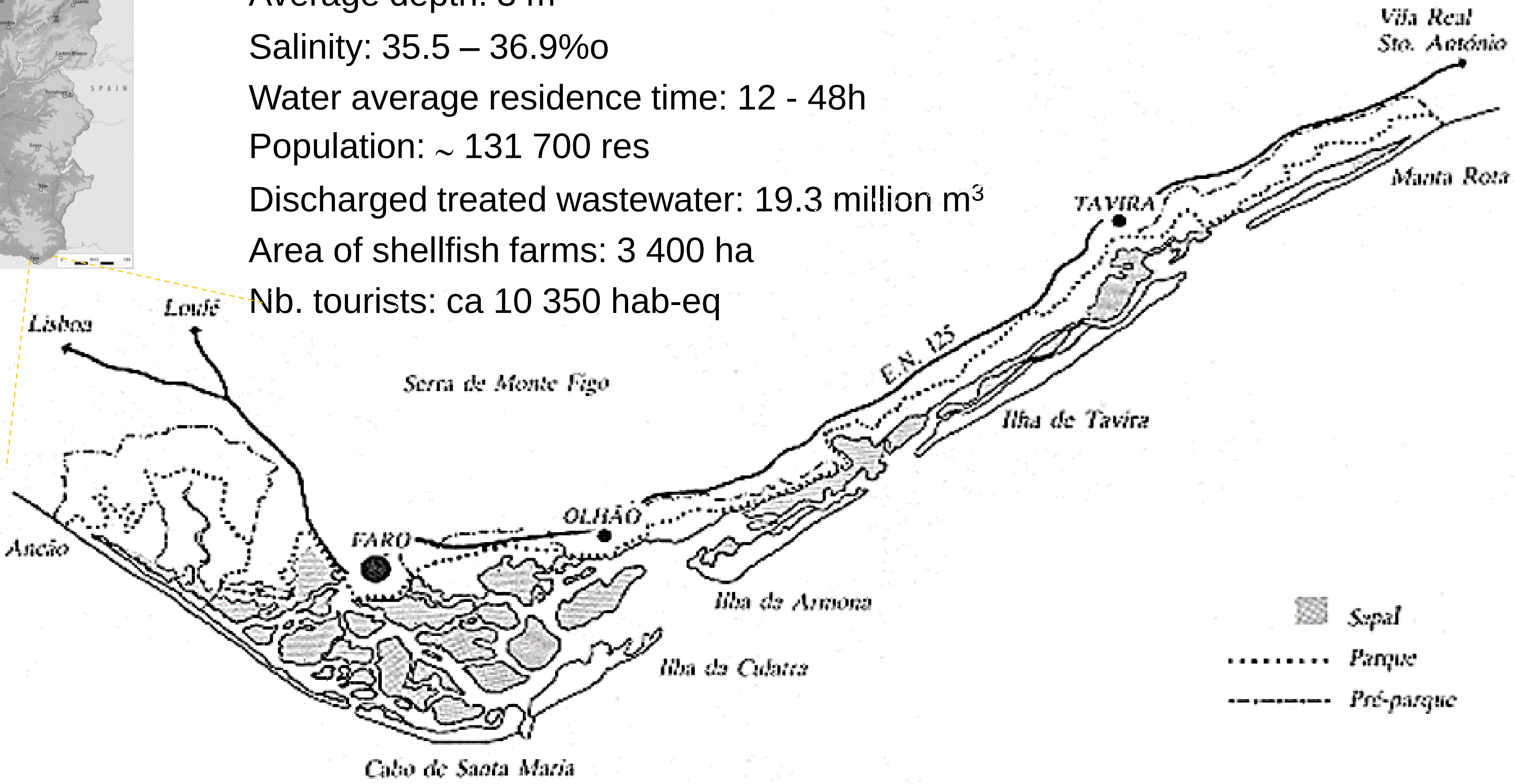
Water average residence time: 12 - 48h

Population: ~ 131 700 res

Discharged treated wastewater: 19.3 million m^3

Area of shellfish farms: 3 400 ha

Nb. tourists: ca 10 350 hab-eq



qDPSIR - COASTAL LAGOON

Main indicators: **PRESSURES**

Urban area

- Population (res)
- Urban area (ha)
- Ww prod (m^3/res)
- Waste prod (m^3/res)
- Water cons (m^3/res)
- Electricity cons (kWh/res)
- Nb vehicles (u/res)
- Railway users (res)
- Food cons (ton/res)
- Prod BaP WWTP (g/y/res)

Tourism

- Nb tourists (res)
- Area nature park (ha)
- % hotel occup
- Ww prod
- Waste prod
- Water cons
- Electricity cons
- Nb. vehicles
- Nb touristic boats
- Nb service hours public boat fleet
- Food cons

Aquaculture

- Land use (ha)
- Production (ton)
- Present economic revenue (€)
- % of forbidden days
- Potential economic revenue (€)

Airport & Port

- Nb passengers

- Nb Ship opperat.
- Ship type
- Hotelling time (d)

qDPSIR - COASTAL LAGOON

Main indicators: **STATE**

Urban area	Tourism	Aquaculture	Airport & Port
Estimated Lifetime Risk (ELTR) for BaP (1: million)	**W**illingness to pay for preservation (€/res/d): 1.71€/res/visit **E**cosystem services (€/ha): 29 000 €/ha/year	None	None

qDPSIR - COASTAL LAGOON

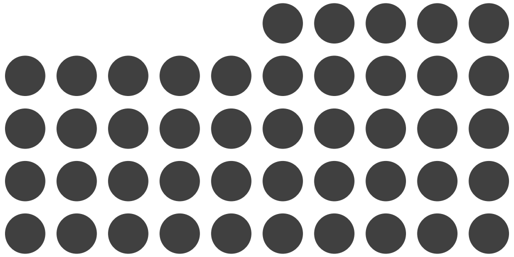
Main indicators: **IMPACTS**

Urban area	Tourism	Aquaculture	Airport/port
M€254	**M€678**	**(M€30)**	**M€30**
I(+): 258,000 k€	**I(+):** 678,000 k€	**I(+):** 30,700 k€	**I(+):** 32,400 k€
I(-): (4,000) k€	**I(-):** (415) k€	**I(-):** (61,500) k€	**I(-):** (4,600) k€

qDPSIR - COASTAL LAGOON

Study of management scenario for the future

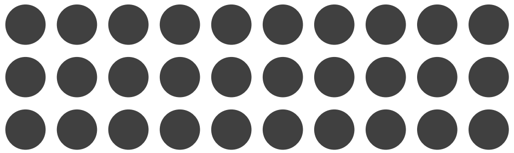
+30%



Tourism

Expected increase of 30% in the Nb of tourists

+20%

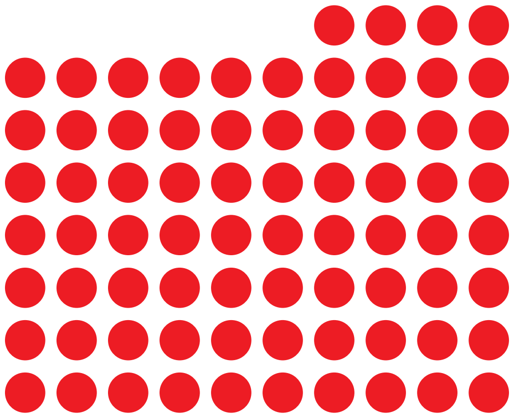


Resident population

Expected increase of 20% in the Nb of residents

Pressures

-50%



Response

50% of treated wastewater will be diverted for irrigation.

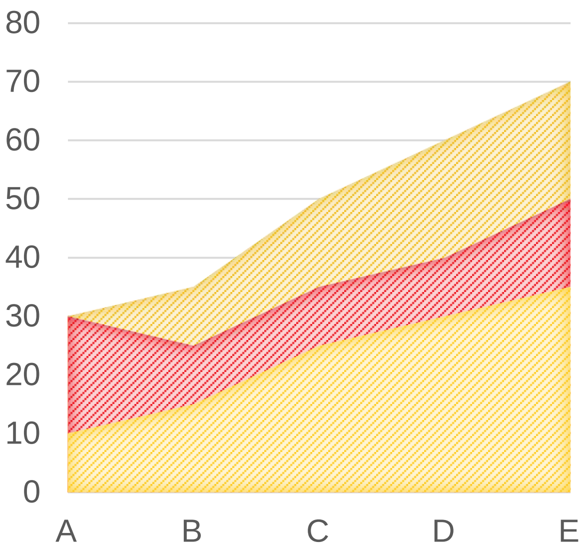
Response

qDPSIR - COASTAL LAGOON

Management Scenario

$$\Delta\ \mathbf{qDPSIR} = \mathbf{qDPSIR}_{Scn} - \mathbf{qDPSIR}_{base}$$

Δ DPSIR
~M€120
I(+): 121,300 k€ **I(-):** (1,300) k€



DPSIR

How far could tourism be increased?

Blind modelling…

Max **(Σ Positive impacts – Σ Negative impacts)**

Subjet to some restrictions

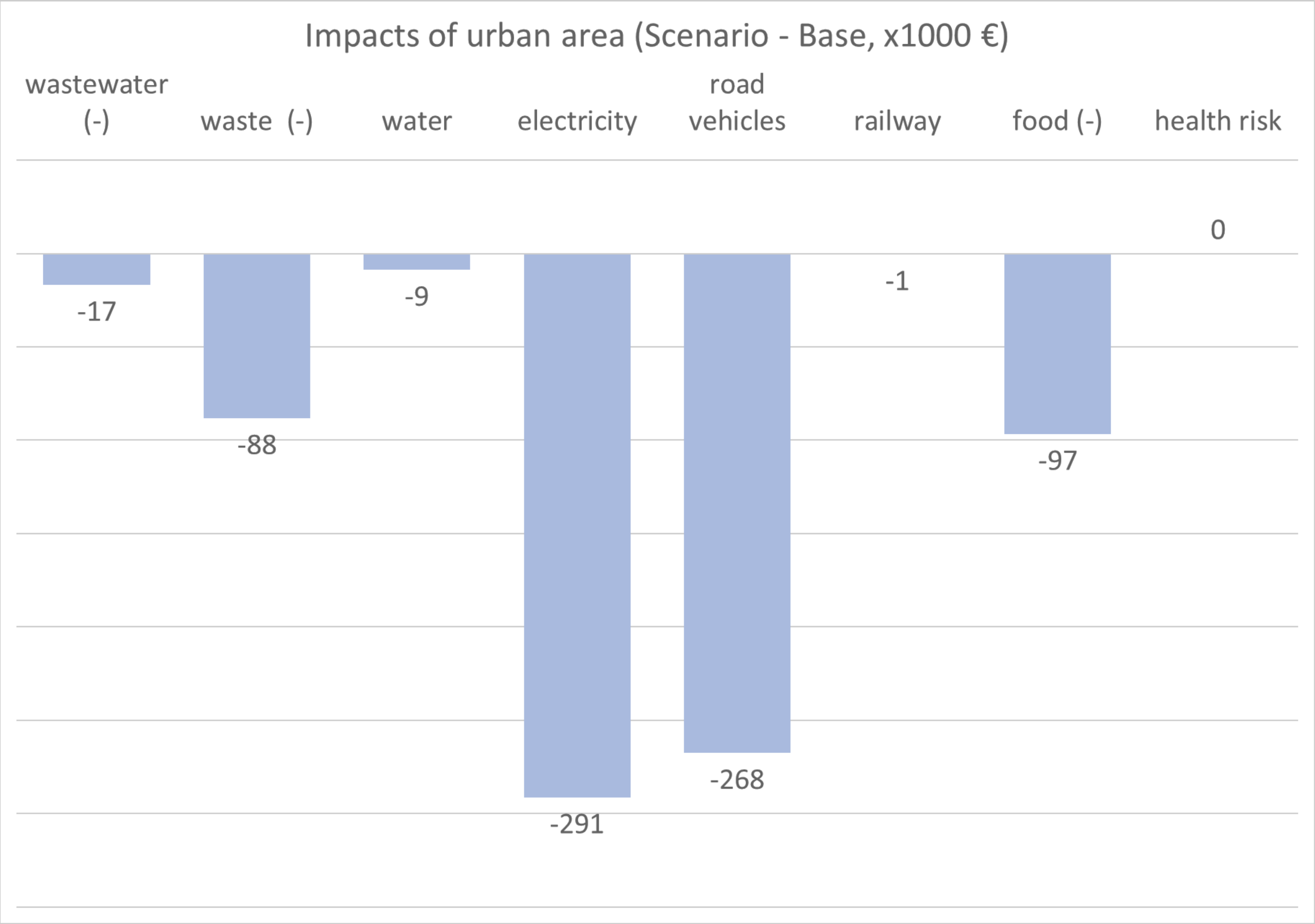
1. Decrease Ww volume	**100%**
2. Increase Nb tourists	**17 times**
3. Increase resident population	**8 times**
4. Increase urban area to	**12 617 ha** (hope we never get this far..)

qDPSIR - COASTAL LAGOON

Management Scenario

$DPSIR_{Scn}$ - $DPSIR_{base}$

Urban area
(M€0.77)
Δ DPSIR < 0



DPSIR - COASTAL LAGOON

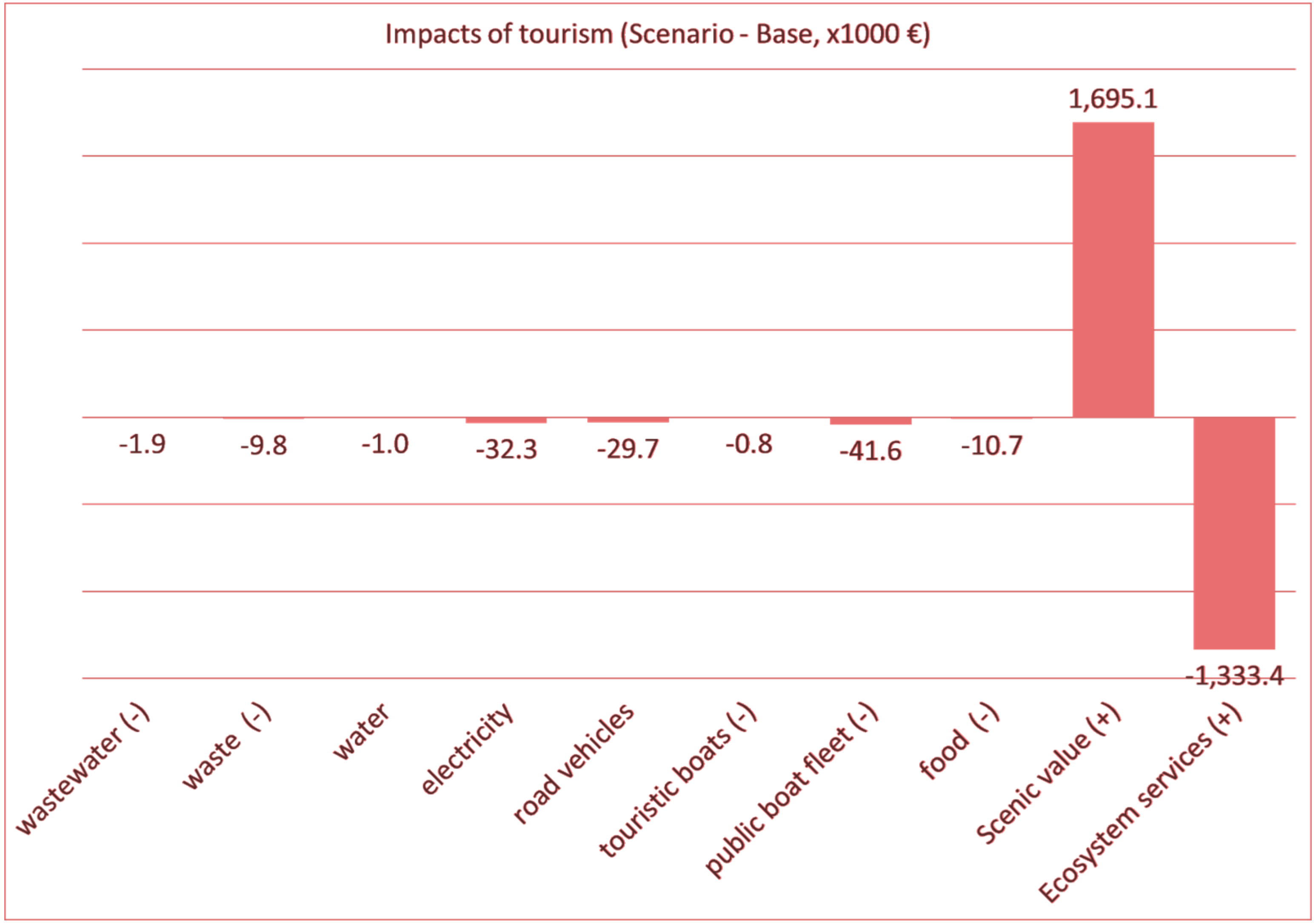
Management Scenario

$DPSIR_{Scn}$ - $DPSIR_{base}$

Tourism

M€81.3

Δ DPSIR > 0

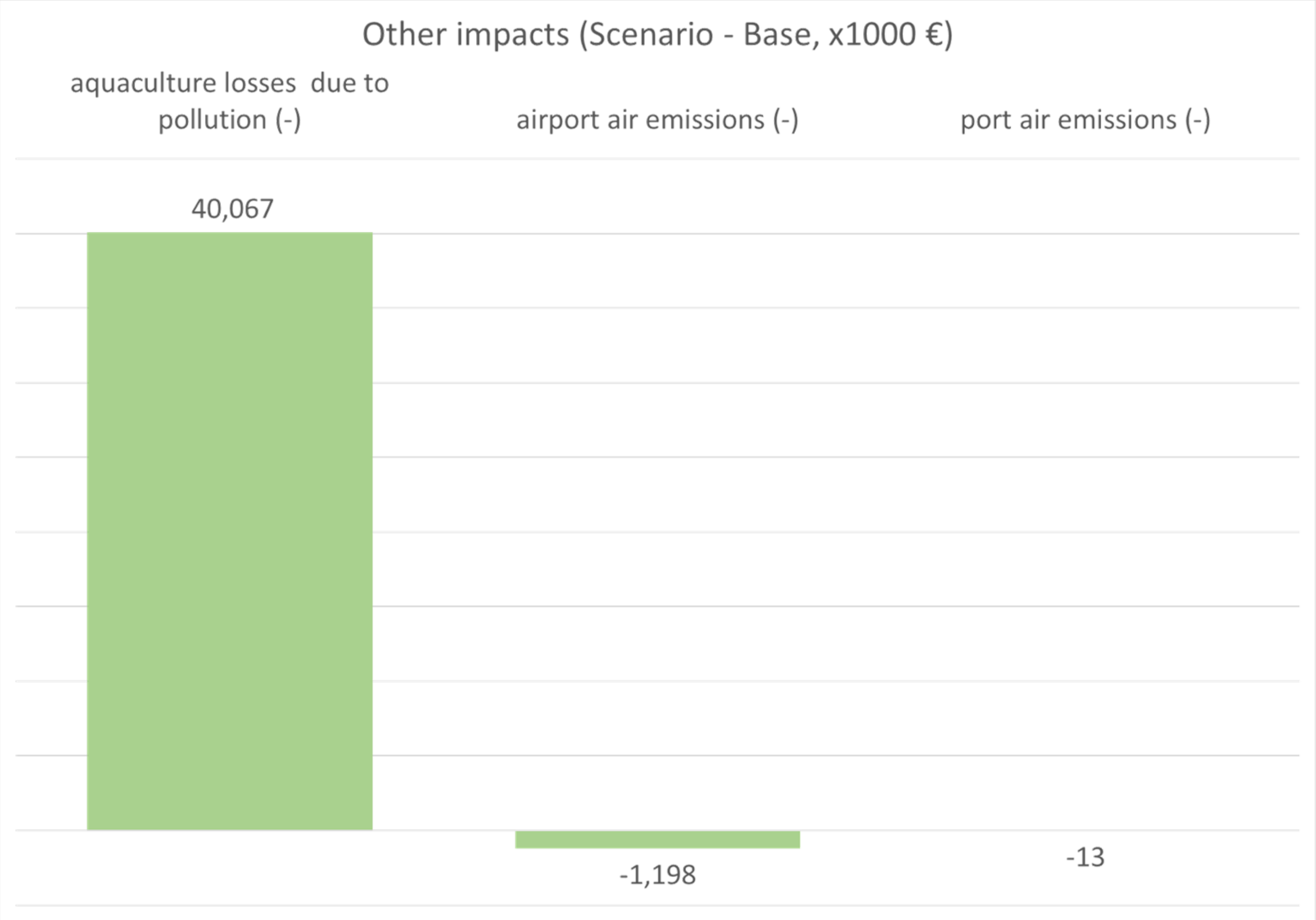


DPSIR - COASTAL LAGOON

Management Scenario

$DPSIR_{Scn}$ - $DPSIR_{base}$

Aquaculture
M€40
Δ DPSIR > 0

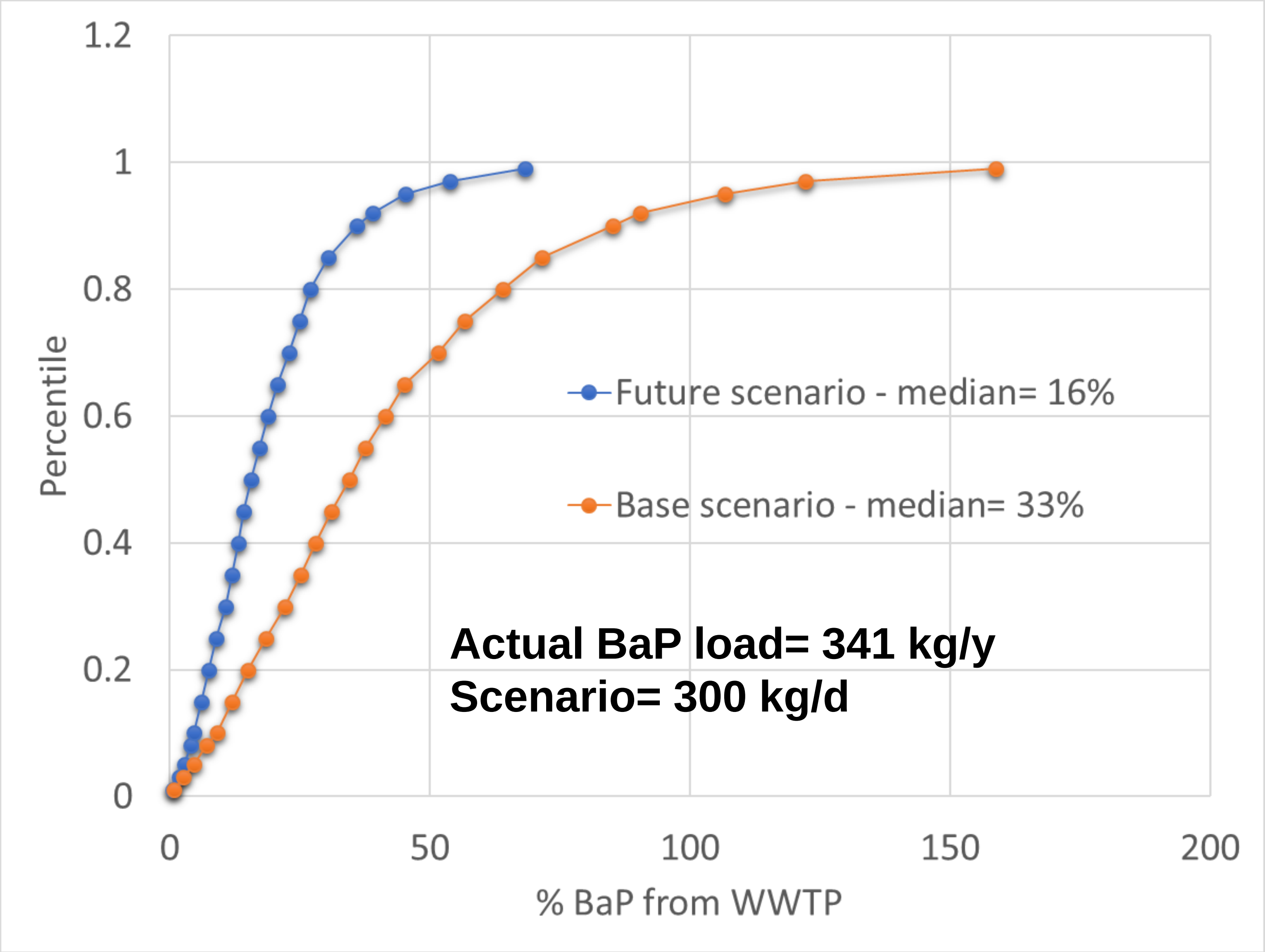


DPSIR - COASTAL LAGOON

Uncertainty propagation: contribution of WWTP

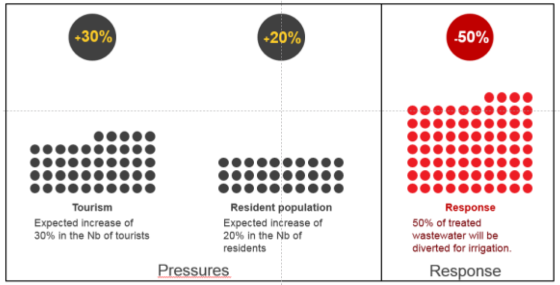
$DPSIR_{Scn}$ - $DPSIR_{base}$

Aquaculture
⚓
<BaP
< Health risk **> Economic revenue**



DPSIR

Return to scenario building to continue improving the (participated) decision



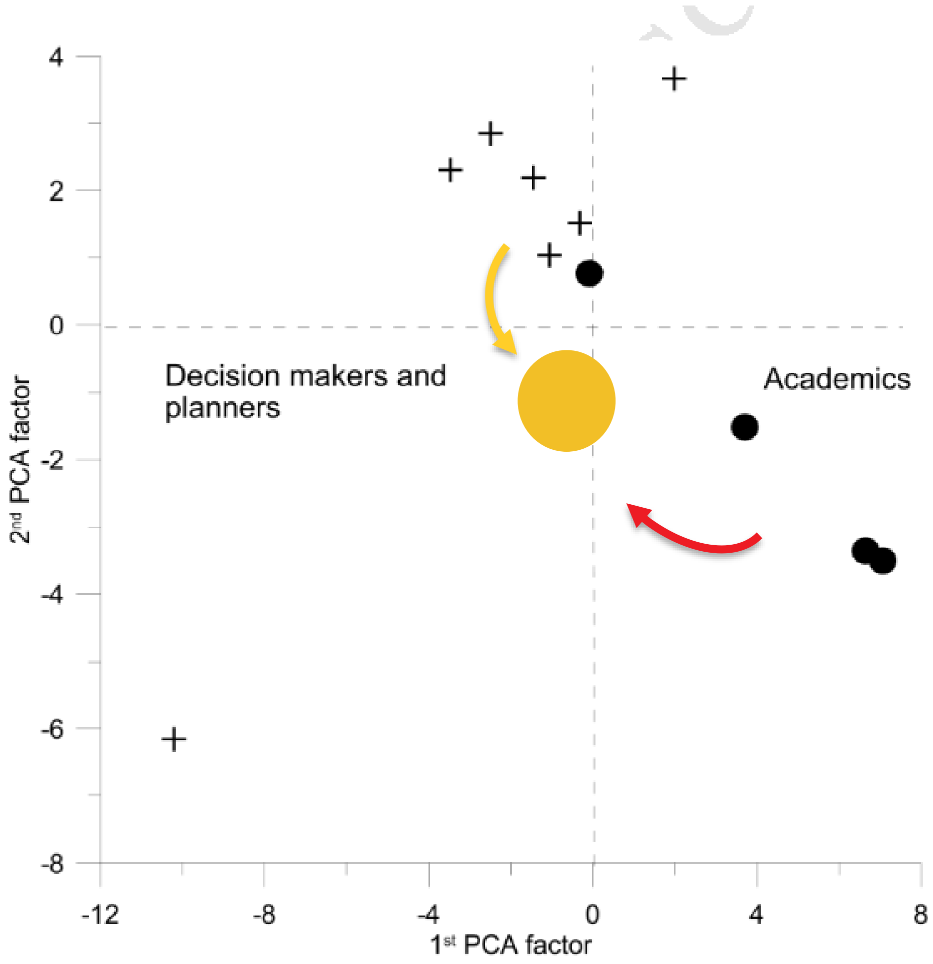
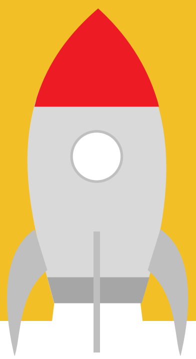


Figure 4 – Clusters resulting of stakeholders' scoring (crosses represent decision makers and planners, circles represent academics).



Thank you!!