A methodology for defining homogeneous water bodies in transitional and coastal waters

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Problem definition and Context

Ecosystem division into waterbodies for monitoring and management of coastal systems:

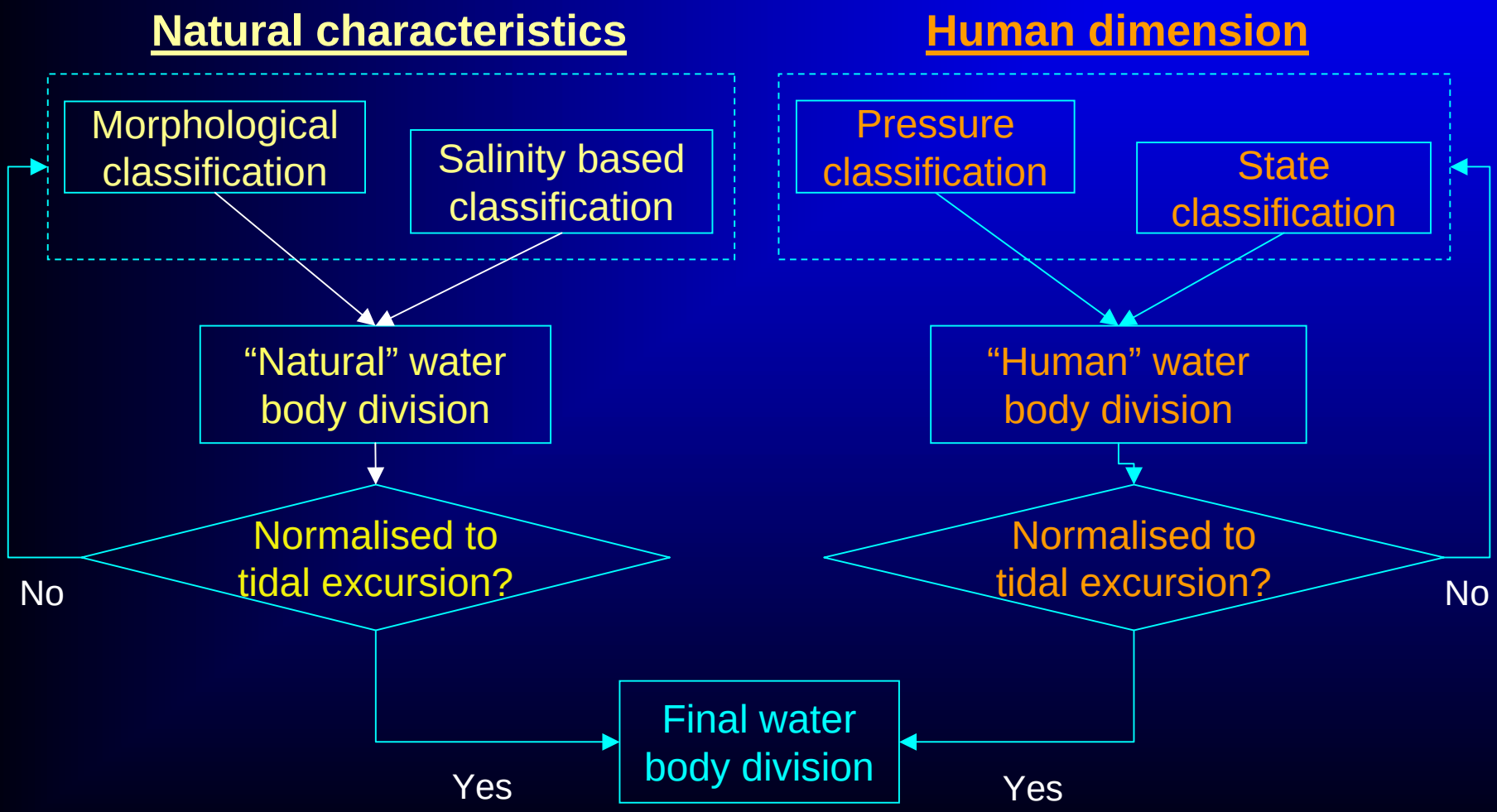
- ✓ **Required by Water Framework Directive and useful for fulfilment of other legislation such as US Clean Water Act**
- ✓ **Methodology should be based on sound scientific grounding and also meaningful for managers**
- ✓ **Must bring together both natural and human criteria**

Objectives: to develop and test a methodology for different types of estuarine and restricted coastal systems.

Ferreira, J. G., A. M. Nobre, T. C. Simas, M. C. Silva, A. Newton, S.B. Bricker, W. J. Wolff, P.E. Stacey, A. Sequeira. 2006. A methodology for defining homogeneous water bodies in estuaries – Application to the transitional systems of the EU Water Framework Directive. Estuarine Coastal and Shelf Science 66: 468-482.

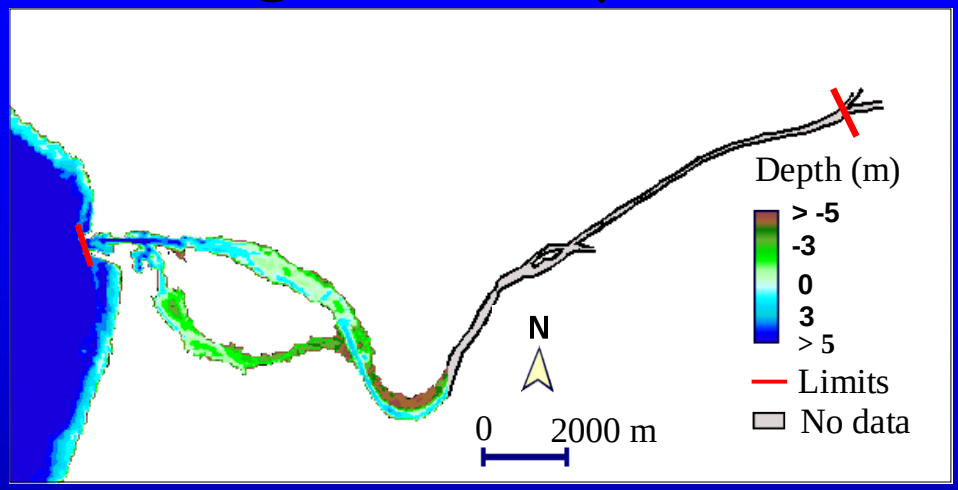
Methodology

Semi-quantitative methodology that divides estuaries and inshore coastal waters into a meaningful set of water bodies, bringing together the following criteria:

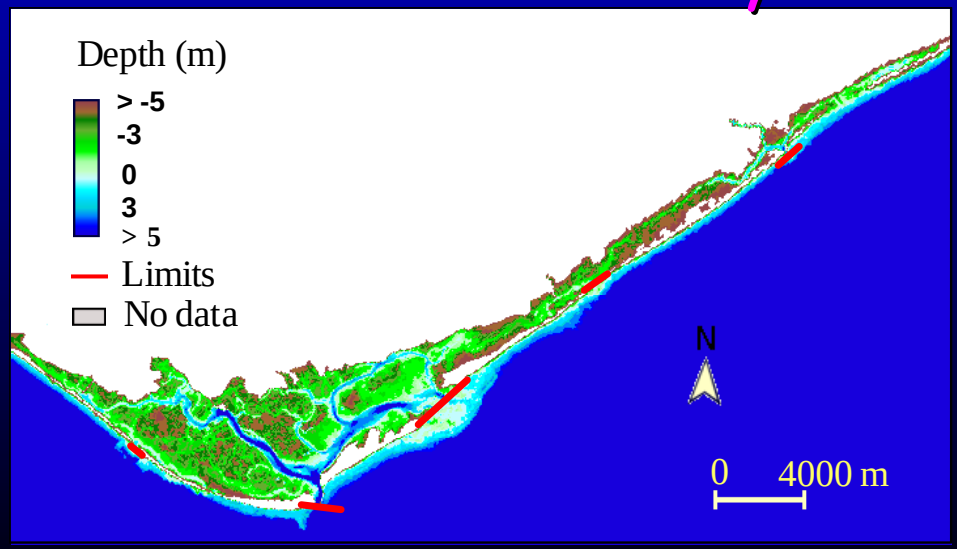


Case studies

Mondego Estuary - a tubular ecosystem

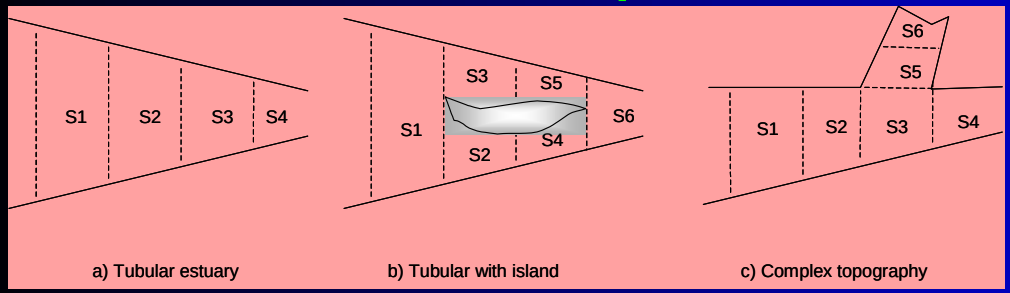


Ria Formosa - a dendritic ecosystem



Methodology - morphological criteria -

1. Draw cross-sectional profile



2. Calculate the adimensional shape factor σ for each section

$$\sigma_i = \log\left(\frac{w_i}{|\bar{z}_i|}\right)$$

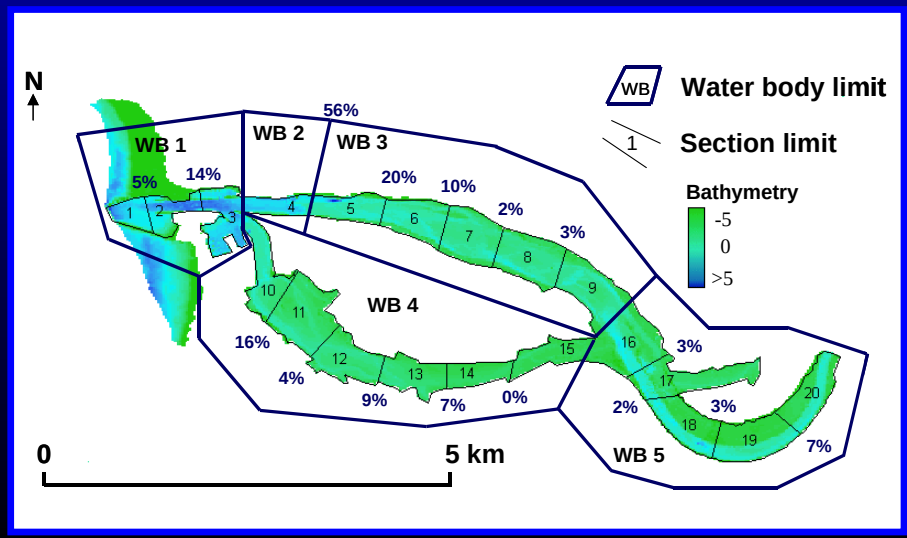
w_i: Mean width of section i (m)
z_i: Mean depth of section i (m)

3. Aggregate longitudinally into water bodies using a threshold value of ϕ

$$\phi_{i,i+1} = \frac{|\Delta\sigma_{i,i+1}|}{(\sigma_i + \sigma_{i+1})/2}$$

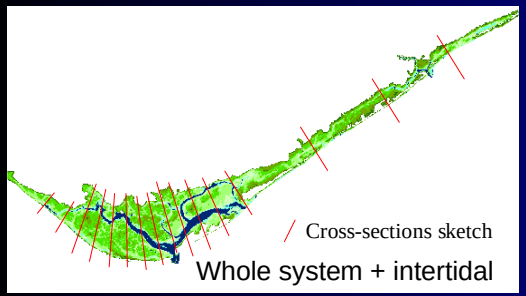
$\phi_{i,i+1}$: Aggregation factor (no units);
$\Delta\sigma$: Absolute difference between s_i and s_{i+1}(no units).

Mondego Estuary



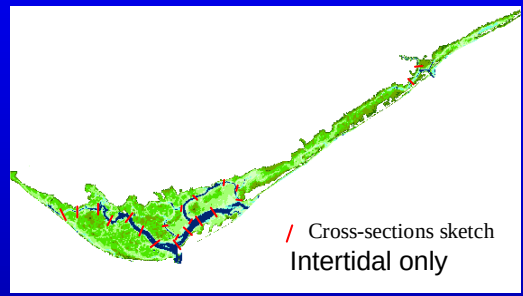
Methodology - morphological criteria -

In shallow systems with branched channels and large intertidal areas it is biased to define cross-sections:



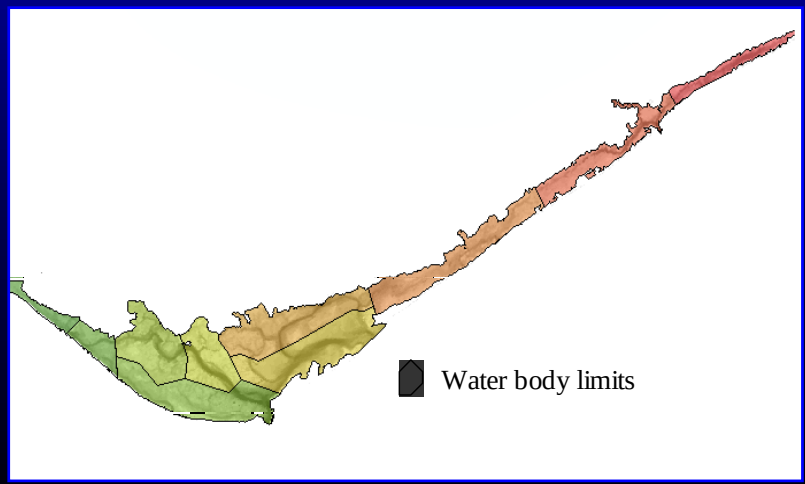
Two possibilities for drawing cross-sections:

- meaningless division of intertidal areas
- large set of small water bodies



Instead it is proposed that the division of dendritic systems is made using a heuristic criterion, e.g. drainage patterns evidenced by the bathymetry:

Ria Formosa



Methodology
- salinity criteria and *natural* harmonization-

Salinity zonation based on the NOAA National Estuarine Inventory:

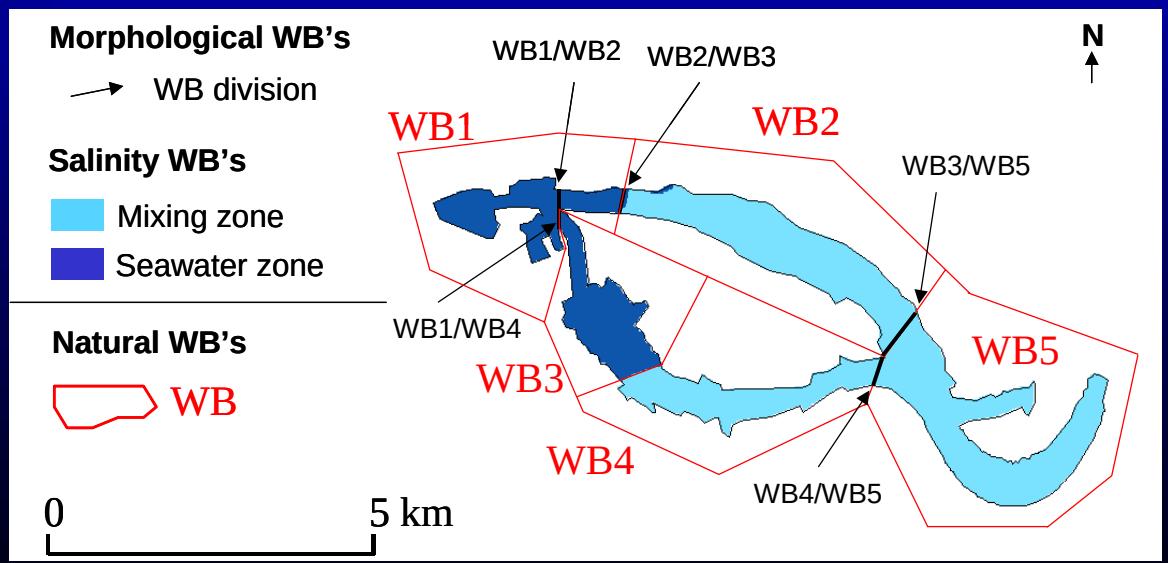
- **Tidal fresh zone (0 – 0.5)**
- **Mixing zone (0.5 – 25)**
- **Seawater zone (> 25)**

Salinity zones are interpolated using annual average values over the water column for each sampling station.

Combination of the morphology and salinity dividers into a set of 'natural' water bodies:

- In cases where both limits are close together a centerline is defined between

- In other cases potentially lead to more water bodies

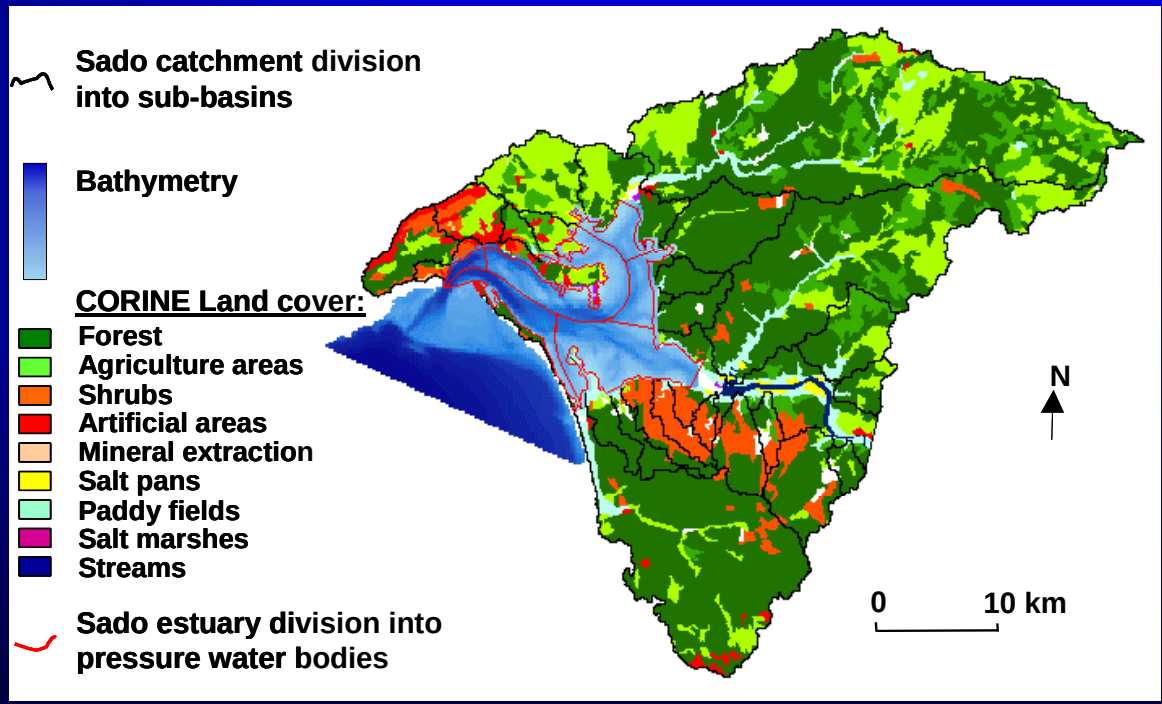


Methodology – human pressure criteria -

Steps for the definition of water bodies according with pressure criteria:

- Selection of the significant pressure (and representative variables)
- Assessment and partitioning of loads
- Normalization, analysis and aggregation:

- Extend section of each sub-basin to the estuary
- Normalise N and P loading for each sub-basin
- Determine the limiting nutrient (using Redfield ratio)
- Use of a similarity index to aggregate contiguous lengths of the shoreline with similar pressure

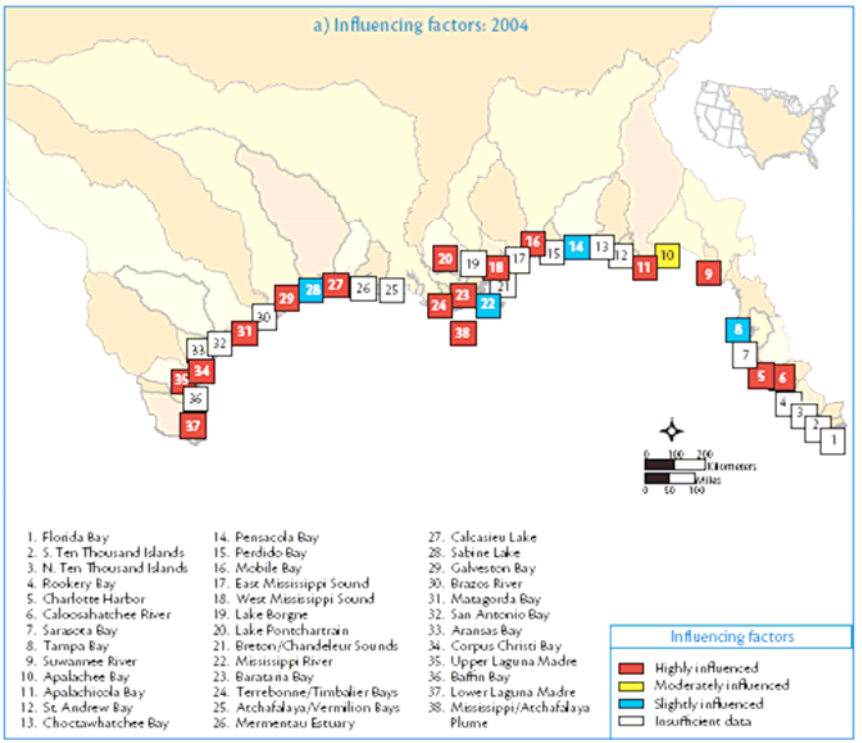


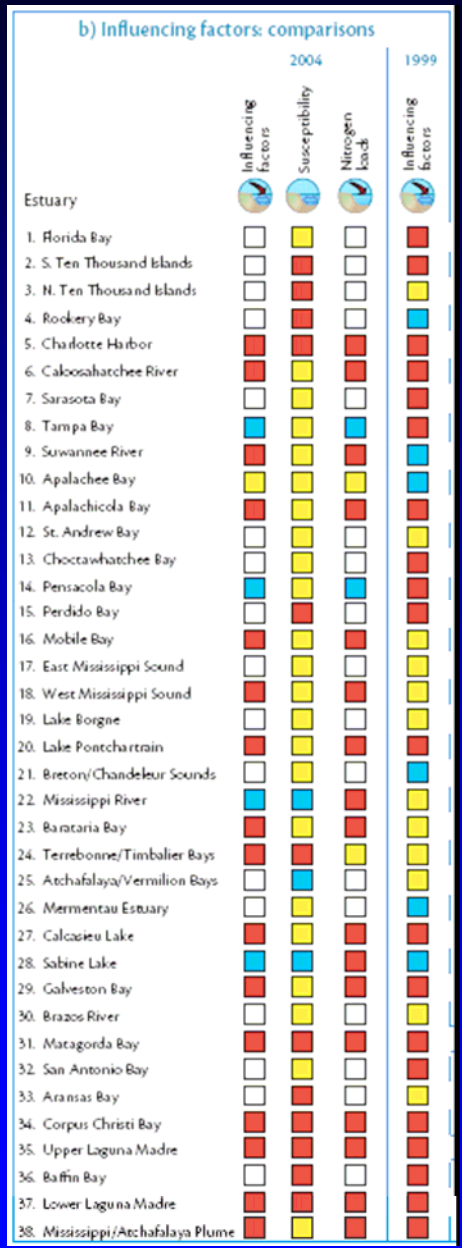
$$\tau_{i,i+1} = \frac{|\Delta\lambda_{i,i+1}|}{(\lambda_i + \lambda_{i+1})/2}$$

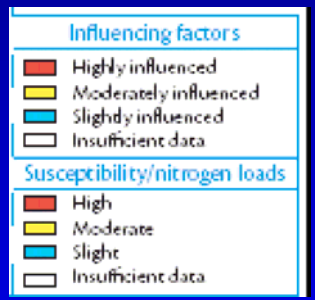
$\tau_{i,I+1}$: Aggregation factor (no units);
λ_i: N load normalised per length of shoreline (kg Nutrient y^{-1} m^{-1});
$\Delta\lambda$: Absolute difference between λ_i and λ_{i+1}(kg Nutrient y^{-1} m^{-1}).

Gulf of Mexico Region: Influencing Factors

Figure 4.14. (a) Map of influencing factors ratings and (b) ratings of components of influencing factors and 1999 ratings in the Gulf of Mexico region.

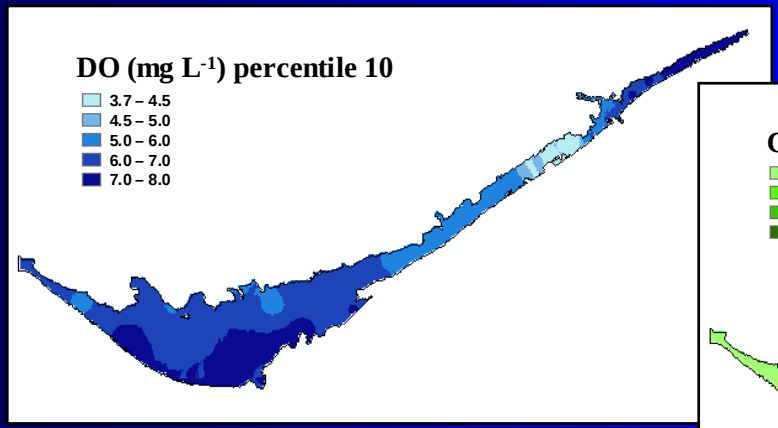


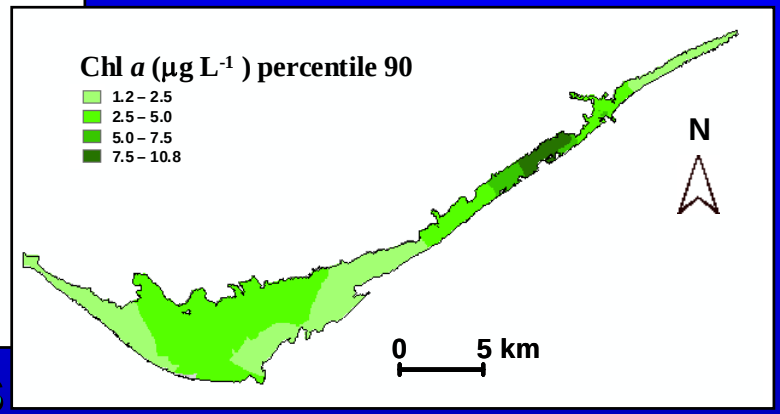




From: Bricker, S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks and J. Woerner. 2007. A Decade of Change: Effects of Nutrient Enrichment in the Nation's Estuaries early 1990s to 2000s - National Estuarine Eutrophication Assessment Update. NOAA Coastal Ocean Program Decision Analysis Series No. 26. National Centers for Coastal Ocean Science, Silver Spring, MD.

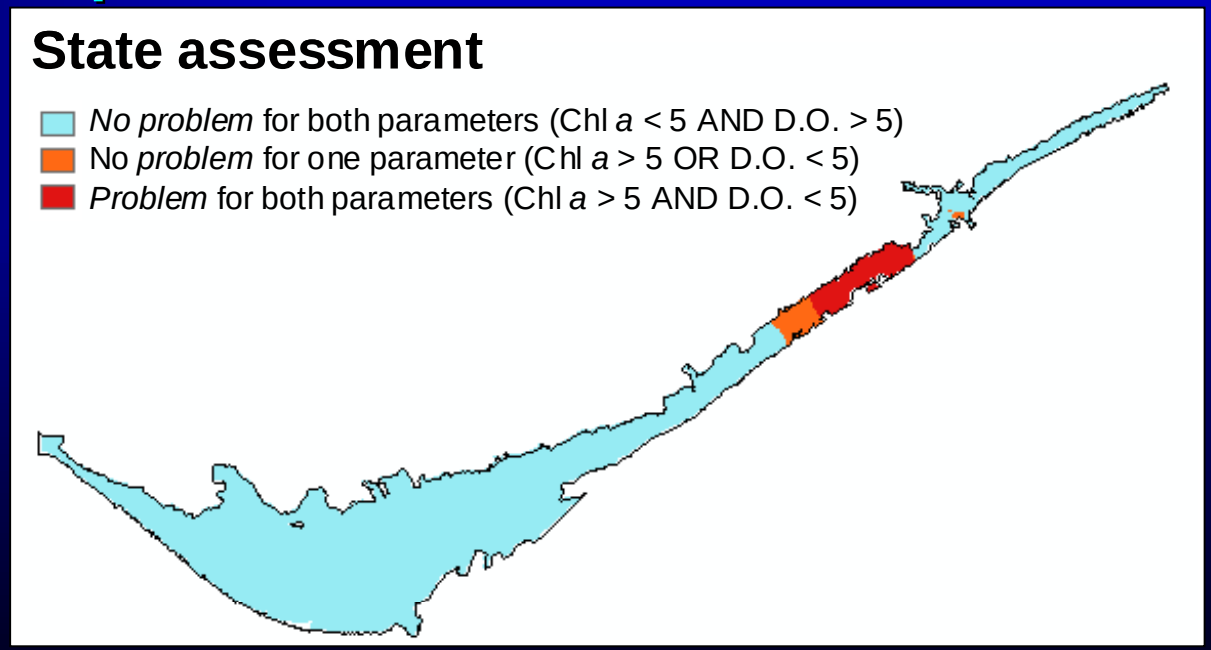
Methodology – state criteria -





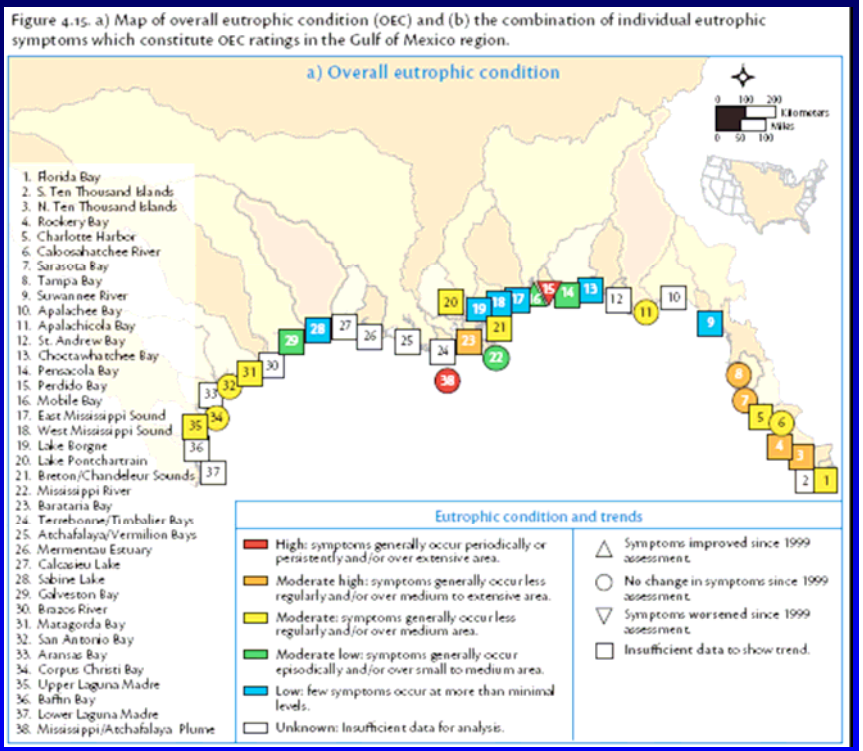
- **Selection of appropriate parameters**
- **Data analysis**

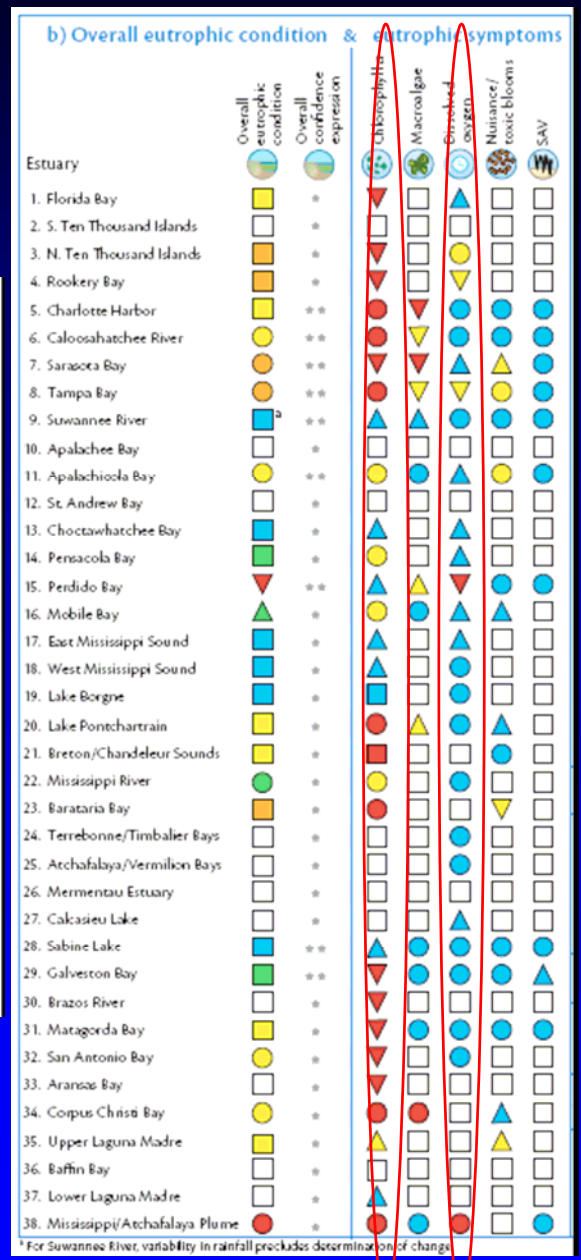
The 90th and 10th percentile cut-off points for chl *a* and D.O. were used as indicators of typically elevated (chl *a*) and low (D.O.) values *

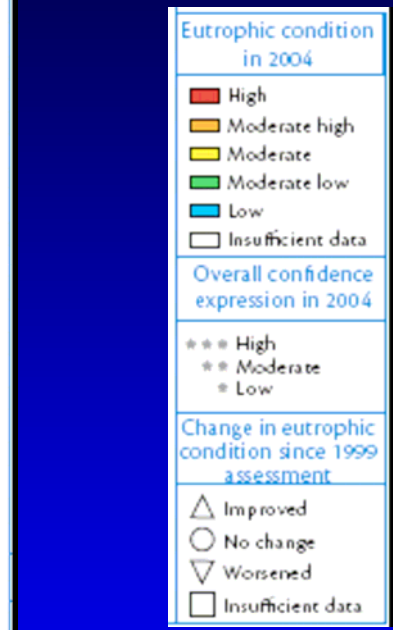


* Bricker, S.B., Ferreira, J.G. & Simas, T. 2003. An Integrated Methodology for Assessment of Estuarine Trophic Status. Ecological Modelling, 169: 39-60.

Gulf of Mexico Region: Eutrophic Condition Symptoms







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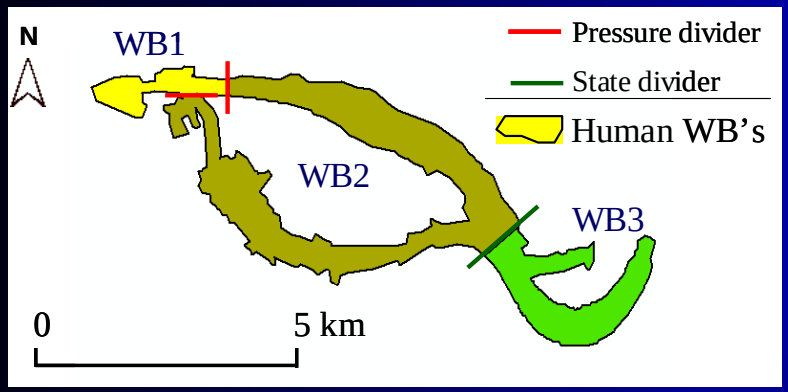
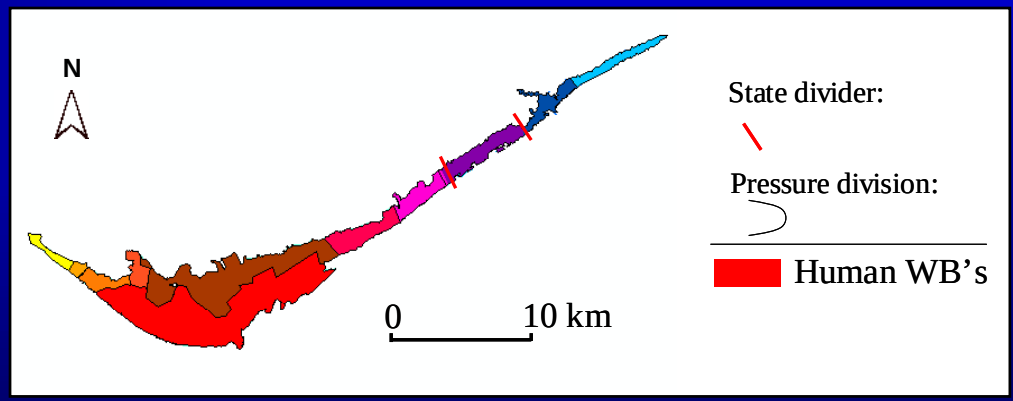
Methodology – *human* harmonization

Combination of the pressure and state dividers into a set of 'human' water bodies:

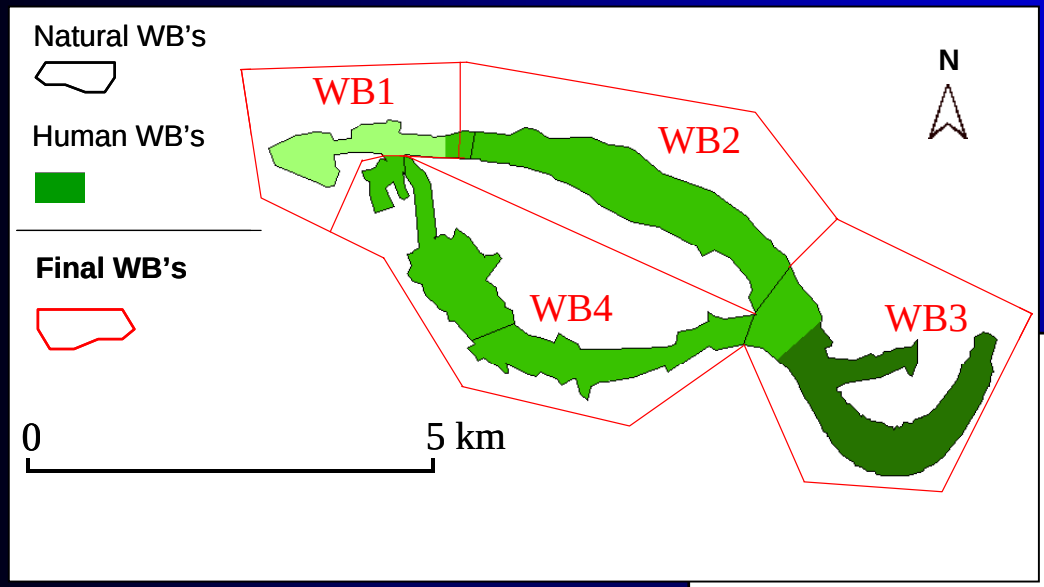


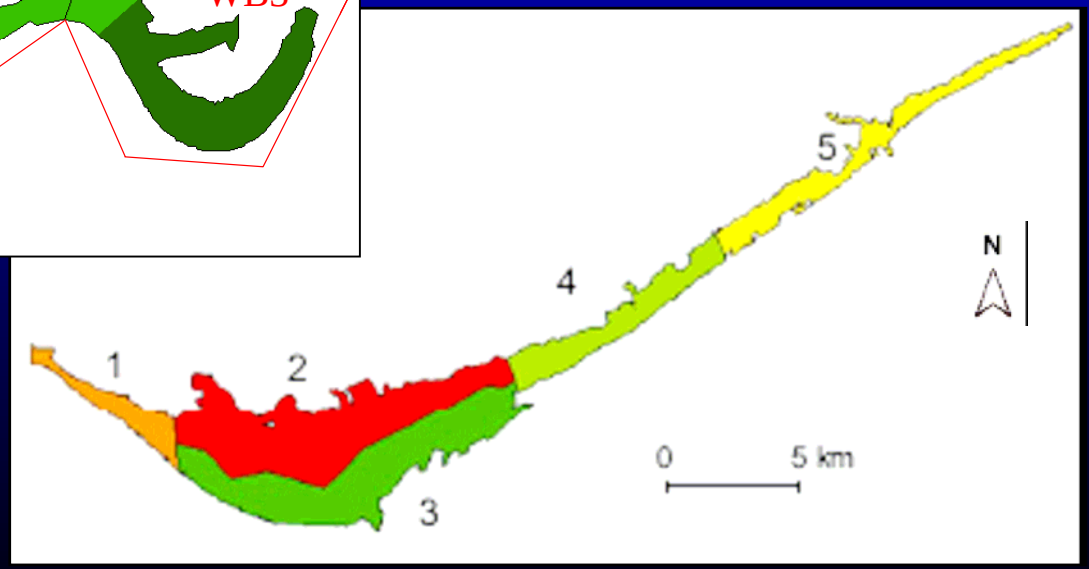


In each the straight forward combination of both criteria correspond to the human dimension water bodies

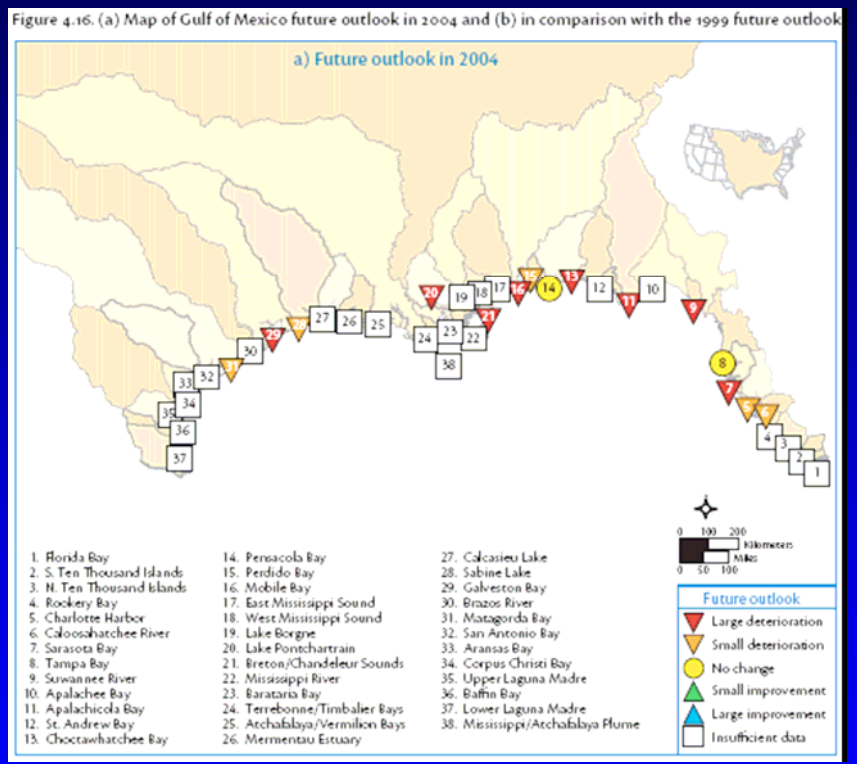
Methodology – final definition of water bodies -

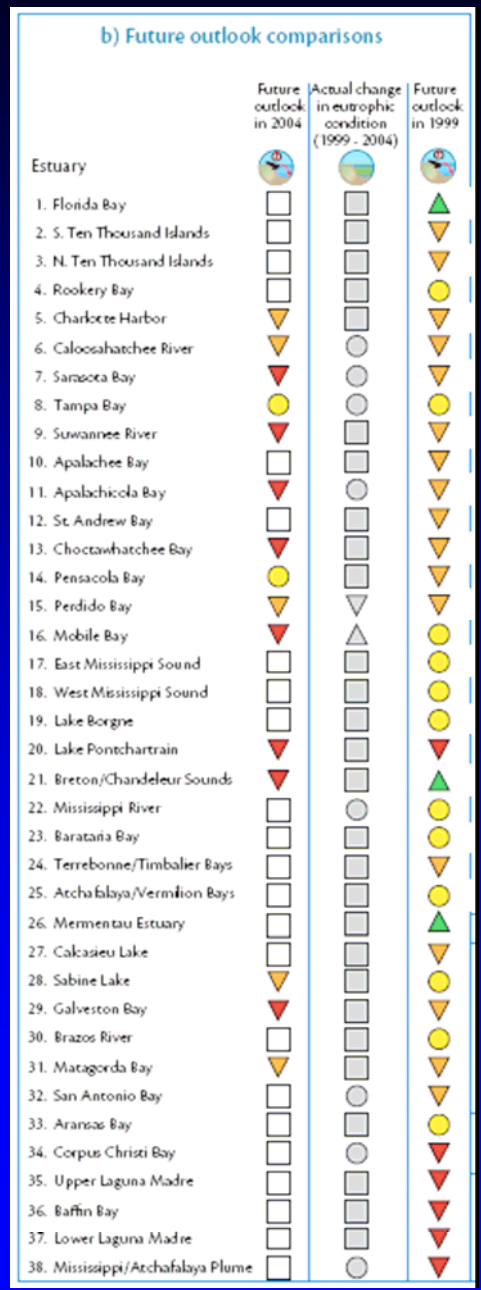
The final definition of water bodies for an estuary is obtained by combining and harmonizing the natural and human components:





Gulf of Mexico Region: Future Outlook





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Final comments

- Method divides coastal systems into meaningful set of water bodies integrating natural characteristics and management criteria
- Final definition will usually be a policy decision, this approach scientifically informs the decision-making process
- Significant challenges in the definition of water bodies to be used as “operational” units of the WFD, e.g. “natural” pressures such as harmful algal blooms. Science must play a key role in informing decision-makers on what may be identified as human influence responsive to management measures.
- Appropriate time for scientific discussion of issues i.e. technical definition, guidance and harmonisation in both EU and US
- Provides contribution to and promotes increased flow of scientific information to support coastal management