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

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http://www.noaa.gov

## **Problem definition and Context**

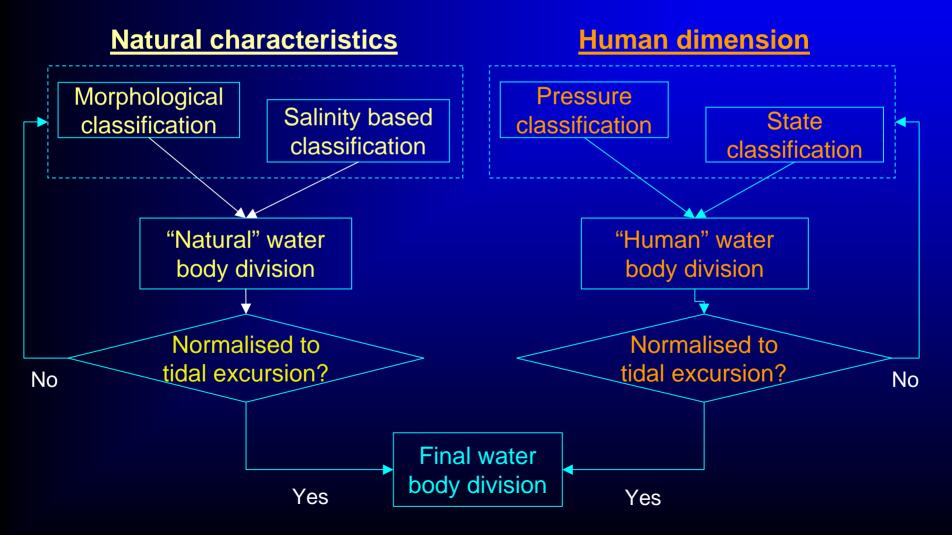
Ecosystem division into waterbodies for monitoring and management of coastal systems:

- 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.

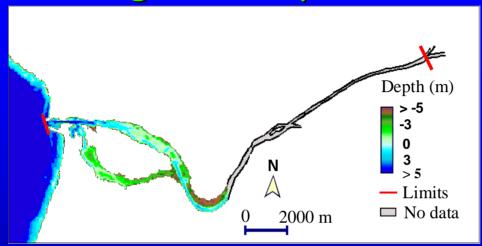
# Methodology

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

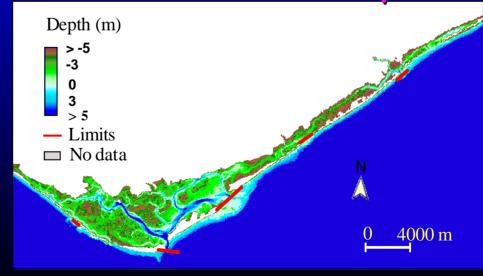


#### **Case studies**

Mondego Estuary - a tubular ecosystem

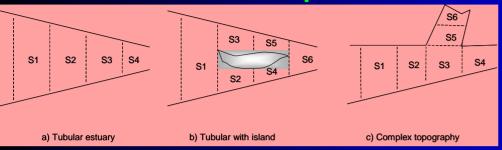


Ria Formosa - a dendritic ecosystem



# Methodology - morphological criteria -

1. Draw cross-sectional profile



2. Calculate the adimensional shape factor o for each section

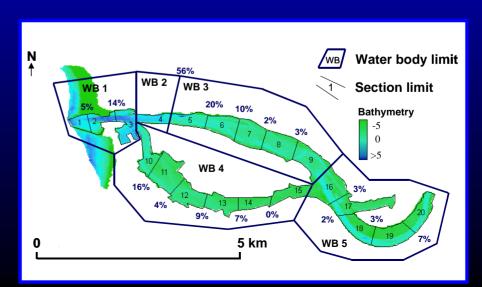
w.: Mean width of section i (m)

z<sub>i</sub>: Mean depth of section i (m)

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

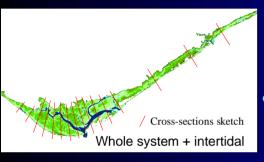
3. Aggregate longitudinally into water bodies  $\phi_{i,i+1} = \frac{\left|\Delta\sigma_{i,i+1}\right|}{\left(\sigma_i + \sigma_{i+1}\right)/2} \begin{cases} \text{using a times.} \\ \phi_{i,l+1} : \text{Aggregation factor (no units);} \\ \Delta\sigma : \text{Absolute difference between s}_i \text{ and s}_{i+1} \text{ (no units).} \end{cases}$ using a threshold value of  $\phi$ 

Mondego Estuary



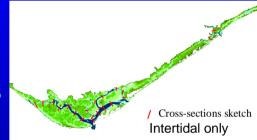
# Methodology - morphological criteria -

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



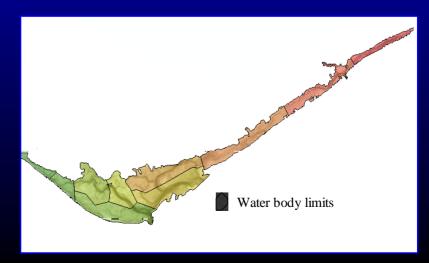
Two possibilities for drawing crosssections:

- 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)

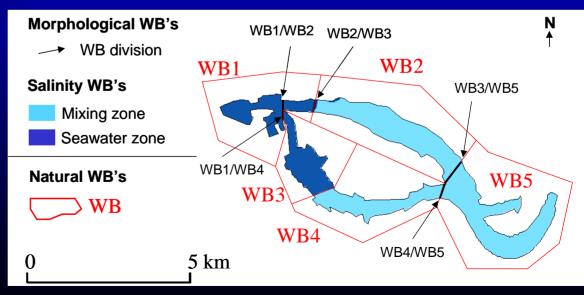
Salinity zones are interpolated using annual average values over the water column for each sampling station.

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

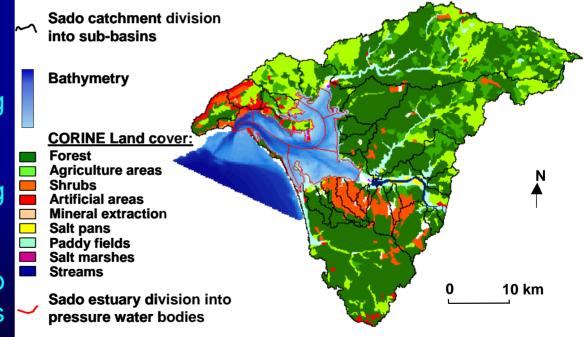
 In other cases potentially lead to more water bodies



# Methodology – human pressure criteria -

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

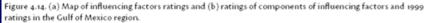
- Selection of the significant pressure (and representative variables)
- Assessment and partitioning of loads
- Normalization, analysis and aggregation:
- Extend section of each sub-basin to the estuary
- Normalise N and P loading for each sub-basin
- Determine the limiting nutrient (using Redfield ratio)
- Use of a similarity index to aggregate contiguous lengths of the shoreline with similar



pressure

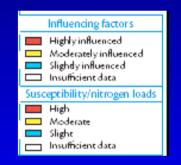
 $\tau_{i,l+1}$ : Aggregation factor (no units);  $\lambda_i$ : N load normalised per length of shoreline (kg Nutrient y<sup>-1</sup> m<sup>-1</sup>);  $\Delta\lambda$ : Absolute difference between  $\lambda_i$  and  $\lambda_{i+1}$  (kg Nutrient y<sup>-1</sup> m<sup>-1</sup>).

#### **Gulf of Mexico Region: Influencing Factors**



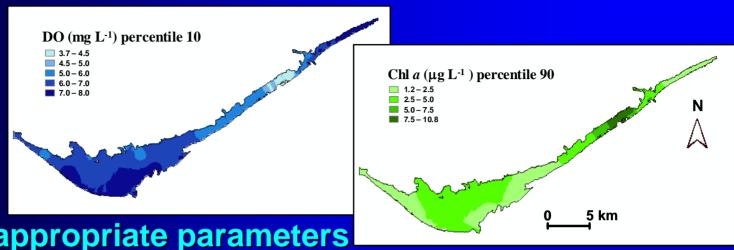






From: Bricker, S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks and J. Woerner. 2007. A Decade of Change: Effects of Nutrient Enrichment in the Nation's Estuaries early 1990s to 2000s - National Estuarine Eutrophication Assessment Update. NOAA Coastal Ocean Program Decision Analysis Series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

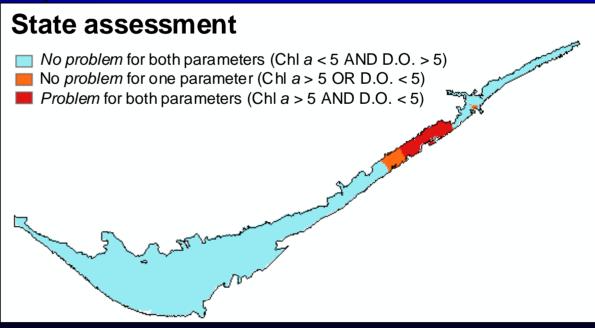
# Methodology - state criteria -



Selection of appropriate parameters

**Data analysis** 

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



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

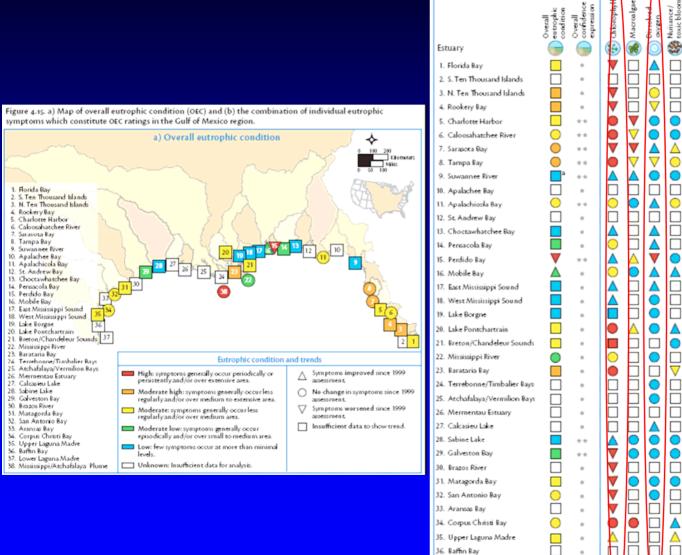
#### **Gulf of Mexico Region: Eutrophic Condition Symptoms**

37. Lower Laguna Madre

38. Mississippi/Atchafalaya Plume

For Suwannee River, variability in rainfall precludes determination of change

b) Overall eutrophic condition & Atrophi symptoms

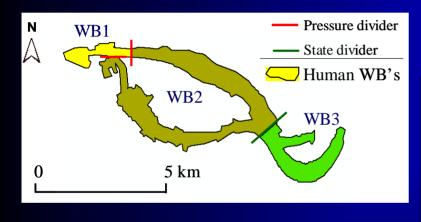


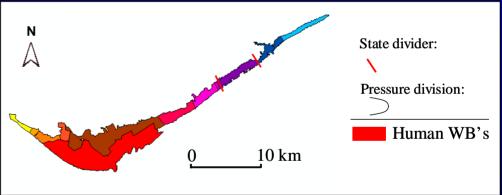
Eutrophic condition
in 2004
High
Moderate high
Moderate
Moderate low
Low
Insufficient data
Overall confidence
expression in 2004
* * * High
* * Moderate
* Low
Change in eutrophic
condition since 1999
assessment
△ Improved
O No change
∇ Worsened
Insufficient data

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 - human harmonization

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

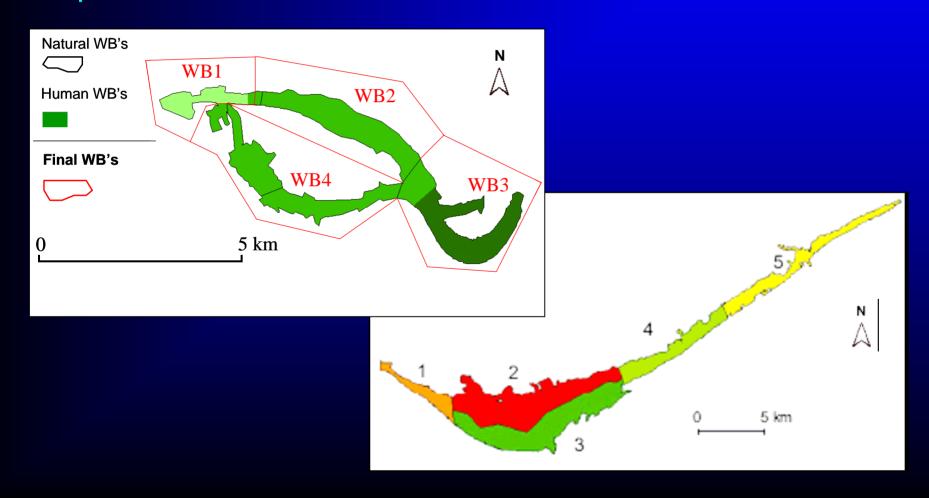




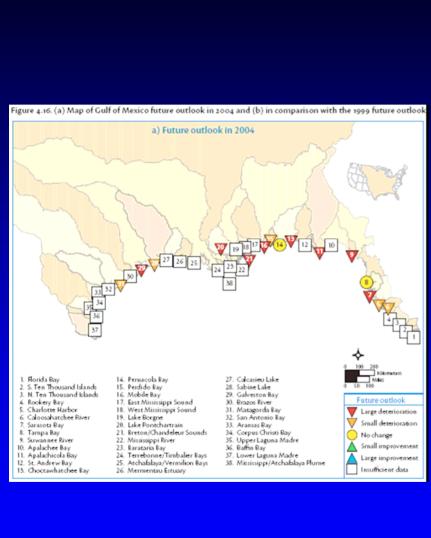
In each the straight forward combination of both criteria correspond to the human dimension water bodies

## 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**



b) Future outloo	ok com	parisons	
	Future outlook in 2004	condition	Future outlook in 1999
Estuary	8		8
1. Florida Bay 2. S. Ten Thousand Islands 3. N. Ten Thousand Islands 4. Rookery Bay 5. Charkotte Harbor 6. Caloosahatchee River 7. Sarasota Bay 8. Tampa Bay 9. Suwannee River 10. Apalachee Bay 11. Apalachicola Bay 12. St. Andrew Bay 13. Choctawhatchee Bay 14. Pensacola Bay 15. Perdido Bay 16. Mobile Bay 17. East Mississippi Sound 18. West Mississippi Sound 19. Lake Borgne 20. Lake Pontchartrain 21. Breton/Chandeleur Sounds 22. Mississippi River 23. Barataria Bay 24. Terrebonne/Timbalier Bays 25. Atchafalaya/Vermition Bays 26. Mermentau Estuary 27. Cakasieu Lake 28. Sabine Lake		Condition (1999 - 2004)   Condition (1999	
29. Galveston Bay 30. Brazos River 31. Matagorda Bay 32. San Antonio Bay 33. Aransas Bay 34. Corpus Christi Bay 35. Upper Laguna Madre	<b>▼</b> □ □ □ □ □		<b>∨</b>
36. Baffin Bay  37. Lower Laguna Madre			<b>V</b>

38. Mississippi/Atchafalaya Plume

b) Future outlook comparisons

Future outlook				
Large deterioration				
Small deterioration				
No change				
A Small improvement				
A Large improvement				
Insufficient data				
Change in eutrophic				
condition since 1999 assessment				
○ No change				
Insufficient data				

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.

#### **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

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