ESTUARIES ON THE EDGE

CONVERGENCE OF OCEAN, LAND AND CULTURE

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Understanding and managing eutrophication in coastal lagoons

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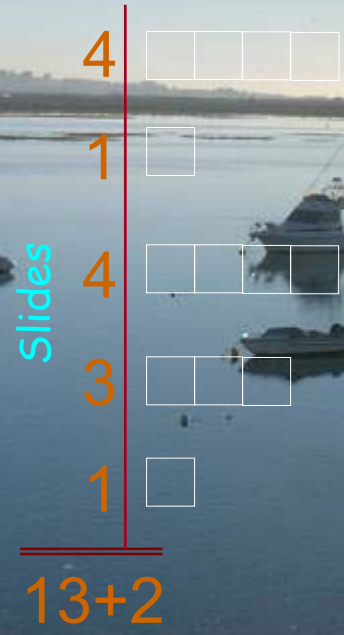
Topics

- ASSETS/NEEA (approaches)
- Systems (key descriptors)
- Results (ASSETS/NEEA scores)
- Research models and ASSETS
- Conclusions



Ria Formosa: Ancão

Key aspects of the ASSETS/NEEA approach

The NEEA approach may be divided into three parts:

- ✓ **Division of estuaries into homogeneous areas**
- ✓ **Evaluation of data completeness and reliability**
- ✓ **Application of indices**

- **Tidal freshwater (<0.5 psu)**
- **Mixing zone (0.5-25 psu)**
- **Seawater zone (>25 psu)**

Spatial and temporal quality of datasets (completeness)
Confidence in results (sampling and analytical reliability)

Overall Eutrophic Condition (OEC) index ---------- State
Overall Human Influence (OHI) index ---------- Pressure
Determination of Future Outlook (DFO) index ---------- Response

S.B. Bricker, J.G. Ferreira, T. Simas, 2003. An integrated methodology for assessment of estuarine trophic status. Ecological Modelling, In Press.

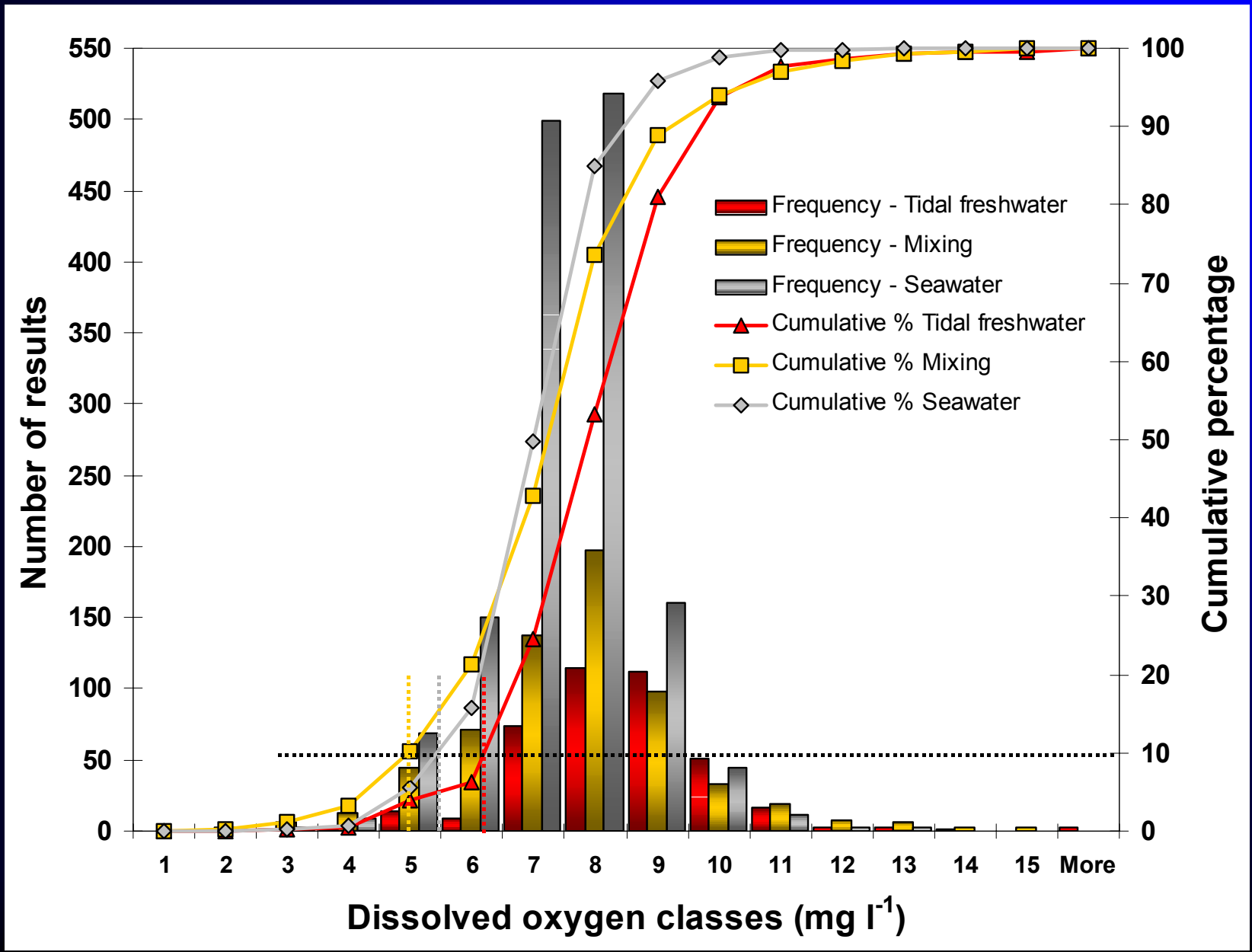
ASSETS extensions to the NEEA approach

- Use of relational databases to assimilate dispersed data into an easily searchable data mining framework;
- Use of simple models to determine pressure;
- Use of GIS techniques to improve spatial weighting, and additional zonation if required;
- Use of statistical criteria for some of the descriptors of state, such as chlorophyll *a* and dissolved oxygen;
- Synthesis of results using a PSR approach

Complementing datasets using research models (tested for the Ria Formosa)

- Use of seaweed biogeochemical and population models;
- Use of "local" models for O_2 in intertidal areas;

ASSETS calculation of secondary symptom dissolved oxygen scores



ASSETS scoring system for PSR

Grade	5	4	3	2	1
Pressure (OHI)	Low	Moderate low	Moderate	Moderate high	High
State (OEC)	Low	Moderate low	Moderate	Moderate high	High
Response (DFO)	Improve high	Improve low	No change	Worsen low	Worsen high

Metric	Combination matrix	Class
P	5 5 5 4 4 4	High (5%)
S	5 5 5 5 5 5	
R	5 4 3 5 4 3	
P	5 5 5 5 5 5 5 4 4 4 4 4 3 3 3 3 3 3	Good (19%)
S	5 5 4 4 4 4 4 5 5 4 4 4 5 5 5 4 4 4	
R	2 1 5 4 3 2 1 2 1 5 4 3 5 4 3 5 4 3	
P	5 5 5 5 5 4 4 4 4 4 4 4 3 3 3 3 3 3 3 2 2 2 2 2 2 2 2 1 1	Moderate (32%)
S	3 3 3 3 3 4 4 3 3 3 3 3 5 5 4 4 3 3 3 4 4 4 4 4 3 3 3 2 3 3	
R	2 1 5 4 3 2 1 5 4 3 2 1 2 1 2 1 5 4 3 5 4 3 2 1 5 4 3 5 5 4	
P	4 4 4 4 4 3 3 3 3 3 3 3 2 2 2 2 2 2 1 1 1 1 1	Poor (24%)
S	2 2 2 2 2 3 3 2 2 2 2 2 3 3 2 2 2 2 3 3 3 2 2	
R	5 4 3 2 1 2 1 5 4 3 2 1 2 1 4 3 2 1 3 2 1 5 4	
P	3 3 3 3 3 2 2 2 2 2 1 1 1 1 1 1 1 1	Bad (19%)
S	1 1 1 1 1 1 1 1 1 1 2 2 2 1 1 1 1 1	
R	5 4 3 2 1 5 4 3 2 1 3 2 1 5 4 3 2 1	

Key descriptors for the four lagoon systems

	MD inland bays	Chincoteague bay	Ria de Aveiro	Ria Formosa
Pressure				
Population (X 10^3)	19-171	12-108	250-300	124-211
Nutrient loading (tN y^{-1})	550	913	2760	1028
State				
Volume (X 10^6 m^3)	56	267	84	92
Mean depth (m)	1.1	1.2	1.4	1.9
Mean tidal range (m)	0.7	0.5	2	2
Water temperature (°C)	2.0-32	-1-33	10.5-24.5*1	14.0-23.8*1
Salinity	28	29	0.7-35.5*1	34.9-37.0*1
Water residence time (days)	253	183	4	0.5-2
Impact				
Main impact Factors	Chlorophyll *a* HABs Macroalgae	HABs Macroalgae	SAV loss Red tides	Macroalgae Intertidal O_2 Bivalve mortality

*1 : 5th – 95th percentile

MD Inland Bays – NEEA/ASSETS Application

ASSETS: BAD

Indices	Methods	Parameters	Value	Level of expression	Index
Overall Human Influence (OHI)	Susceptibility	Dilution potential	Low	High susceptibility	MODERATE HIGH
ASSETS: 2		Flushing potential	Low		
	Nutrient inputs	Moderate nutrient input			
Overall Eutrophic Condition (OEC)	PSM*1	Chlorophyll *a*	1.0	High	HIGH
		Epiphytes	No Data		
		Macroalgae	1.0	High	
ASSETS: 1	SSM*2	Dissolved Oxygen	0.50	Moderate	
		Submerged Aquatic Vegetation	(SAV has increased)		
		Nuisance and Toxic Blooms	1.0	High	
Determination of Future Outlook (DFO)	Future nutrient pressures	Future nutrient pressures decrease			IMPROVE LOW
ASSETS: 4					

*1 – Primary symptoms method

*2 – Secondary symptoms method

$$\sum_{i=1}^{n}\left(\frac{A_z}{A_t}\right)\left(\begin{array}{c}Expression\\ value\end{array}\right) = \text{Symptom level of expression value for estuary}$$

n – Total number of zones
Az – Area of zone
At – Total estuary area

Chincoteague Bay – NEEA/ASSETS Application

ASSETS: BAD

Indices	Methods	Parameters	Value	Level of expression	Index
Overall Human Influence (OHI)	Susceptibility	Dilution potential	Moderate	High susceptibility	MODERATE
ASSETS: 3		Flushing potential	Low		
	Nutrient inputs	Low nutrient input			
Overall Eutrophic Condition (OEC)	PSM*1	Chlorophyll *a*	1.0	High	HIGH
		Epiphytes	No Data		
		Macroalgae	1.0	High	
ASSETS: 1	SSM*2	Dissolved Oxygen	0	No problem	
		Submerged Aquatic Vegetation	(SAV has increased)		
		Nuisance and Toxic Blooms	1.0	High	
Determination of Future Outlook (DFO)	Future nutrient pressures	Future nutrient pressures decrease			IMPROVE LOW
ASSETS: 4					

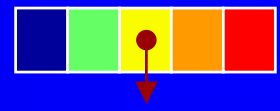
*1 – Primary symptoms method

*2 – Secondary symptoms method

$$\sum_{i=1}^{n}\left(\frac{A_z}{A_t}\right)\left(\begin{array}{c}Expression\\ value\end{array}\right) = \text{Symptom level of expression value for estuary}$$

n – Total number of zones
Az – Area of zone
At – Total estuary area

Ria de Aveiro – NEEA/ASSETS Application



ASSETS: MOD

Indices	Methods	Parameters	Value	Level of expression	Index
Overall Human Influence (OHI)	Susceptibility	Dilution potential	High	Low susceptibility	MODERATE LOW
ASSETS: 4		Flushing potential	Moderate		
	Nutrient inputs	High nutrient input			
Overall Eutrophic Condition (OEC)	PSM*1	Chlorophyll *a*	1	0.33 Moderate	MODERATE
		Epiphytes	0		
ASSETS: 3		Macroalgae	0		
	SSM*2	Dissolved Oxygen	0	0.5 Moderate	
		Submerged Aquatic Vegetation	0.5		
		Nuisance and Toxic Blooms	0		
Determination of Future Outlook (DFO)	Future nutrient pressures	Future nutrient pressures decrease			NO CHANGE
ASSETS: 3					

*1 – Primary symptoms method

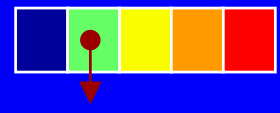
*2 – Secondary symptoms method

$$\sum_{i=1}^{n}\left(\frac{A_z}{A_t}\right)\left(\begin{matrix}Expression\\ value\end{matrix}\right)=$$

Symptom level of expression value for estuary

n – Total number of zones
Az – Area of zone
At – Total estuary area

Ria Formosa – NEEA/ASSETS Application



ASSETS: GOOD

Indices	Methods	Parameters	Value	Level of expression	Index
Overall Human Influence (OHI)	Susceptibility	Dilution potential	High	Moderate susceptibility	MODERATE
		Flushing potential	Low		
ASSETS: 3	Nutrient inputs	Moderate nutrient input			
Overall Eutrophic Condition (OEC)	PSM*1	Chlorophyll *a*	0.25	0.57 Moderate	MODERATE LOW
		Epiphytes	0.50		
		Macroalgae	0.96		
ASSETS: 4	SSM*2	Dissolved Oxygen	0	0.25 Low	
		Submerged Aquatic Vegetation	0.25		
		Nuisance and Toxic Blooms	0		
Determination of Future Outlook (DFO)	Future nutrient pressures	Future nutrient pressures decrease			IMPROVE LOW
ASSETS: 4					

*1 – Primary symptoms method

*2 – Secondary symptoms method

$$\sum_{i=1}^{n}\left(\frac{A_z}{A_t}\right)\left(\begin{matrix}Expression\\ value\end{matrix}\right)=$$

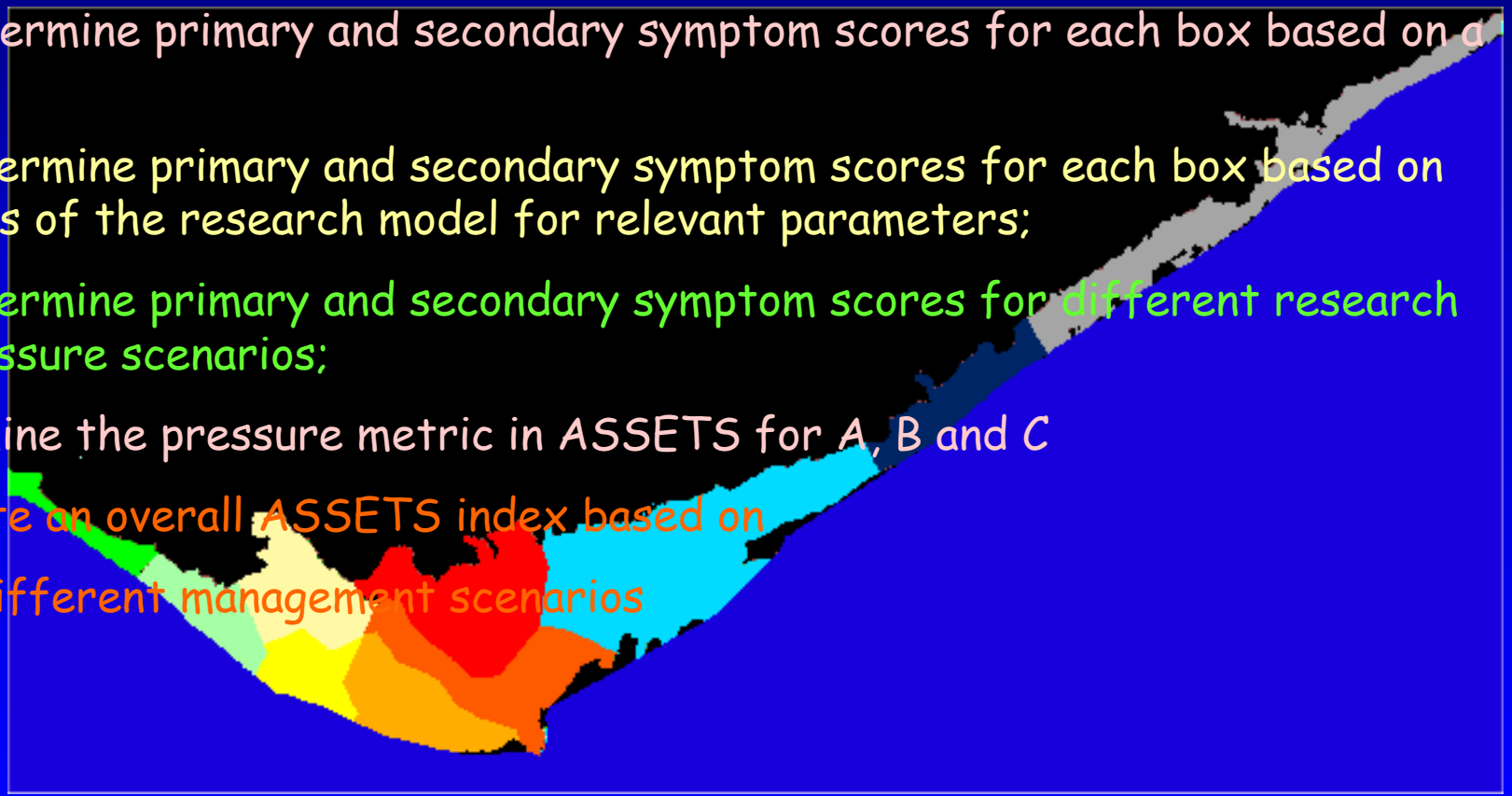
Symptom level of expression value for estuary

n – Total number of zones
Az – Area of zone
At – Total estuary area

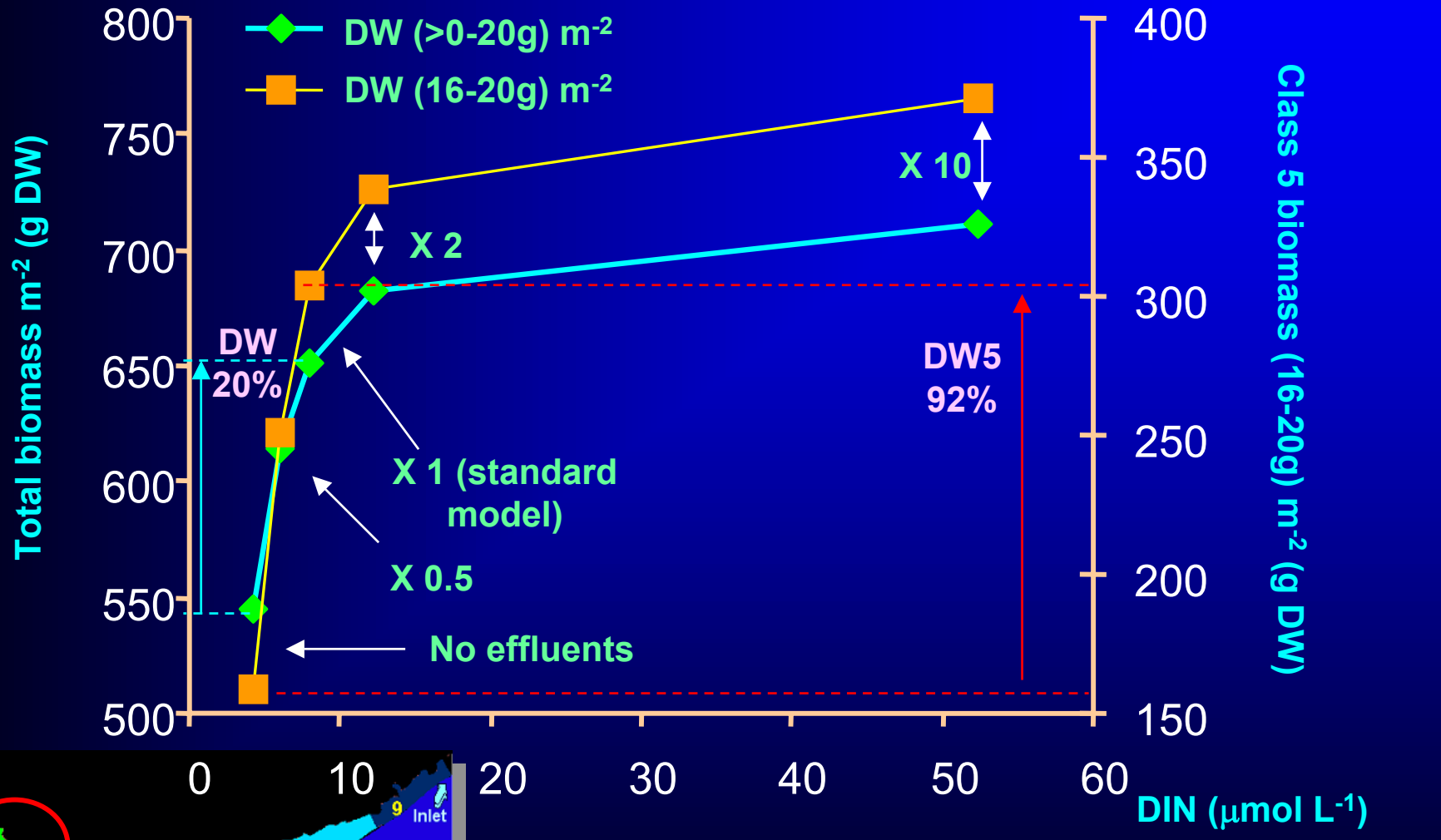
Application of research models to the ASSETS approach

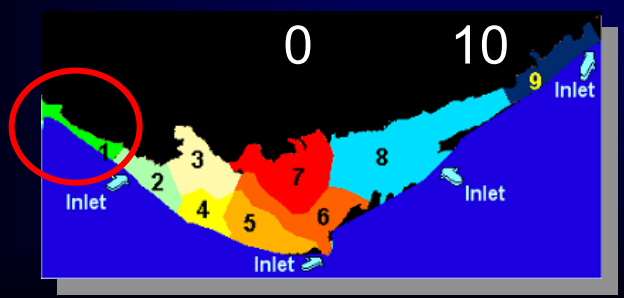
- Divide the system into the zones defined by the research ecological model boxes
- Use of statistical criteria for some of the descriptors of state, such as chlorophyll *a* and dissolved oxygen
- A - Determine primary and secondary symptom scores for each box based on a database;
- B - Determine primary and secondary symptom scores for each box based on the results of the research model for relevant parameters;
- C – Determine primary and secondary symptom scores for different research model pressure scenarios;
- Determine the pressure metric in ASSETS for A, B and C
- Calculate an overall ASSETS index based on

PSR for different management scenarios



Growth of Ulva sp. in the Ria Formosa
Percentile 90 values for different DIN loads





Results from EcoWin2000
Box 1 – Ancão area (Western Ria Formosa)

Ria Formosa –ASSETS validation & model scenarios

Index	Methods	Parameters	Value	Level of expression	Index
Overall Eutrophic Condition (OEC)	PSM	Chlorophyll *a*	0.25		MODERATE LOW
	Field data	Epiphytes	0.50	0.57	
ASSETS OEC: 4		Macroalgae	0.96	Moderate	
	SSM	Dissolved Oxygen	0		
		Submerged Aquatic Vegetation	0.25	0.25 Low	
		Nuisance and Toxic Blooms	0		
Overall Eutrophic Condition (OEC)	PSM	Chlorophyll *a*	0.25		MODERATE LOW
	Research model	*Epiphytes*	*0.50*	0.58	
ASSETS OEC: 4		Macroalgae	1.00	Moderate	
	SSM	Dissolved Oxygen	0		
		Submerged Aquatic Vegetation	0.25	0.25 Low	
		Nuisance and Toxic Blooms	0	28% lower	
Overall Eutrophic Condition (OEC)	PSM	Chlorophyll *a*	0.25		MODERATE LOW
	Model green scenario	*Epiphytes*	*0.50*	0.42	
ASSETS OEC: 4(5)		Macroalgae	0.50	Moderate	
	SSM	Dissolved Oxygen	0		
		Submerged Aquatic Vegetation	0.25	0.25 Low	
		Nuisance and Toxic Blooms	0		

Final comments

- ASSETS develops the NEEA approach into a PSR framework, and allows an overall combined score to be calculated
- Detailed ecological models may be used to provide complementary data, or to fill data gaps
- Four shallow water systems were classified using this methodology. The results differ significantly, depending on pressures, susceptibility or other factors.
- Research models may assist in highlighting particular effects of eutrophication (e.g. nocturnal anoxia in intertidal areas, under specific tidal conditions)
- Research models used to explore changes in state (impacts) due to various pressure scenarios provide detailed outputs appropriate for scientific analysis.
- These outputs may be synthesized using screening models such as ASSETS, which are much more tractable to environmental managers.