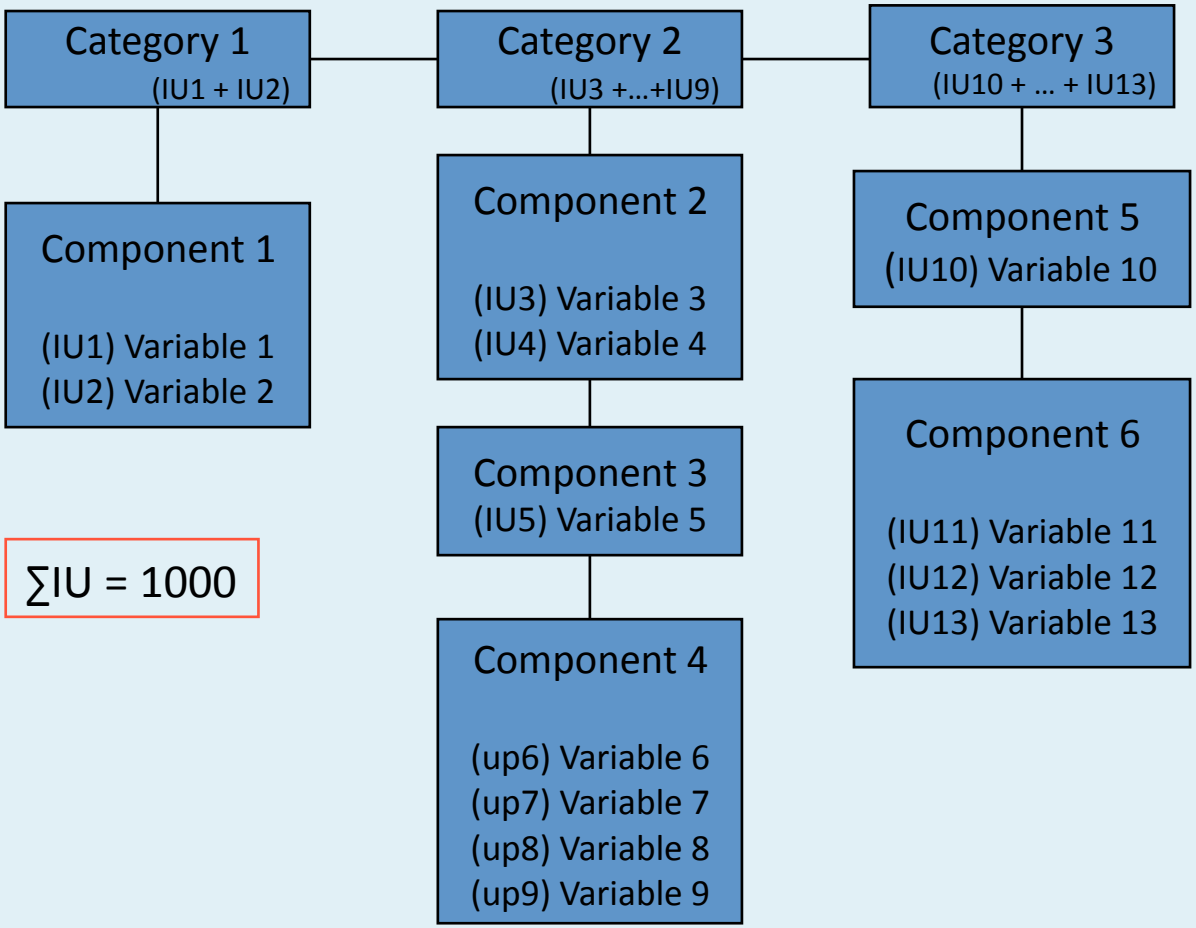
Application of the Battelle Environmental Evaluation System (EES) to assess the environmental quality of meadows of the seagrass *Zostera noltei* Hornem.

Ignacio Hernández, María del Mar Chaves, Patricia García-Marín, Juan José Vergara y Fernando G. Brun

Área de Ecología, Universidad de Cádiz, 11510 Puerto Real.

Miércoles 9 de octubre de 2013
II Jornadas Técnicas sobre Las praderas marinas en el litoral español: conservación, uso y gestión

THE BATTELLE ENVIRONMENTAL EVALUATION SYSTEM



	Compartment	Variables		Units	References
Physico-chemical variables	Water column	Temperature		°C	1
		Salinity		psu	1, 2
		pH			1
		Dissolved oxygen		%	1
		Suspended solids		mg L^{-1}	1
		Dissolved Inorganic Nutrients	NH_4^+	μM	1, 3, 4, 5
			$NO_2^- + NO_3^-$		
			PO_4^{3-}		
		$\delta^{15}N$ isotopic signal		%	6, 7, 8
	Sediment	Eh		mV	5, 9, 10, 11
		Organic matter		%	5, 9, 10
		Heavy metals content (Cd, Cr, Cu, Pb, Zn)		μg g dw^{-1}	12, 13, 14, 15, 16
		Nutrients	NH_4^+	μM	3, 5, 11,17
			$NO_2^- + NO_3^-$		
			PO_4^{3-}		
Biological variables	Plant	Percentage cover		%	18, 19, 20
		Shoot density		N° shoots m^{-2}	5, 10, 20, 21, 22, 23, 24, 25, 26, 27
		Biomass (aboveground and belowground)		g dw m^{-2}	10, 18, 19, 20, 21, 22, 23, 27
		Maximum leaf length		cm	5, 21, 22, 27, 28,
		Sucrose (leaves)		mg g dw^{-1}	23, 29, 30
		Tissue N		% dw	5, 31
		Tissue P		% dw	5, 31
		Heavy metals content (Cd, Cr, Cu, Pb, Zn)		μg g dw^{-1}	32, 33, 34 35.
		$\delta^{15}N$ isotopic signal		%	6, 7, 8, 20, 36

25 selected variables
(Large literature survey)

References: 1) Annex II of the Order 14/1997 of the regional government of Andalusia which classifies the littoral waters of the region and establish the objectives of quality in waters directly affected by discharges; 2) Borum et al. (2004); 3) Touchette and Burkholder (2000); 4) Brun et al. (2002), 5) Cabaço et al. (2008); 6) Machás et al. (2006); 7) Castro et al. 2007; 8) Morris et al. (2009); 9) Valle et al. (2011); 10) Cabaço et al. (2009); 11) Short (1987); 12) Morillo et al. 2004; 13) CEDEX (1994); 14) Usero (2004); 15) CCME (1999); 16) OSPAR (2009a); 18) OSPAR (2009b); 19) Guimaraes et al. (2012); 20) García-Marín et al. (2013); 21) Auby and Labourg (1996); 22) Plus et al. (2001); 23) Brun et al. (2003a); 24) Alexandre et al. (2005); 25) Cabaço et al. (2005); 26) Cabaço et al. (2011); 27) Pérez-Lloréns and Niell (1993); 28) Brun et al. (2003b) 29) Vermat and Verhagen (1996); 30) Brun et al. 2008; 31) Duarte (1990); 32) Lyngby and Brix (1982); 33) Llagostera et al. (2011); 34) Oliva et al. (2011); 35) Carral et al. (1995); 36) Schubert et al. (2013).

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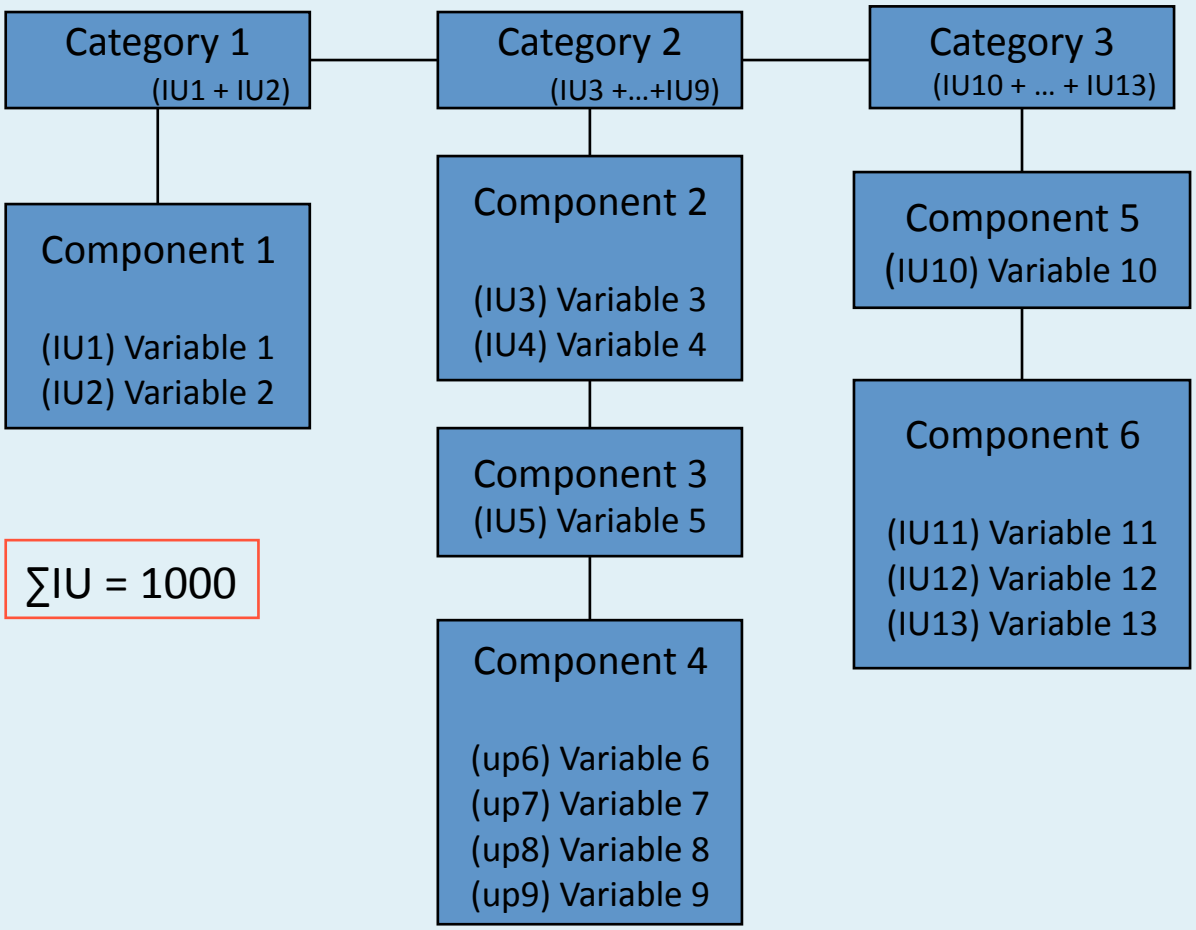
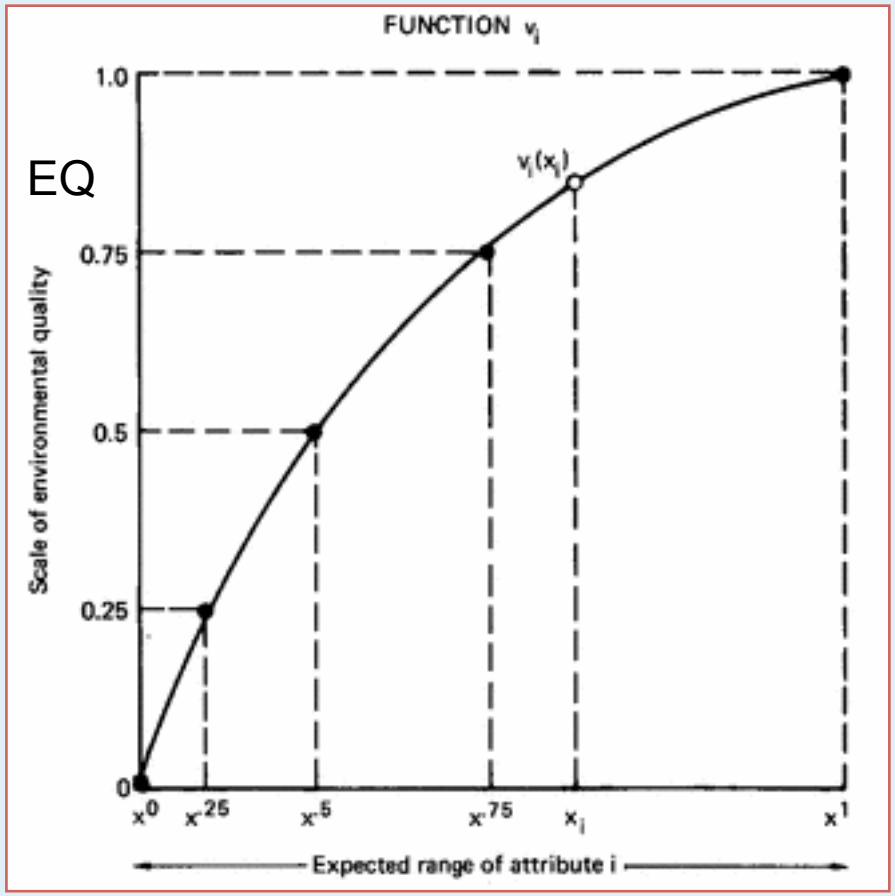
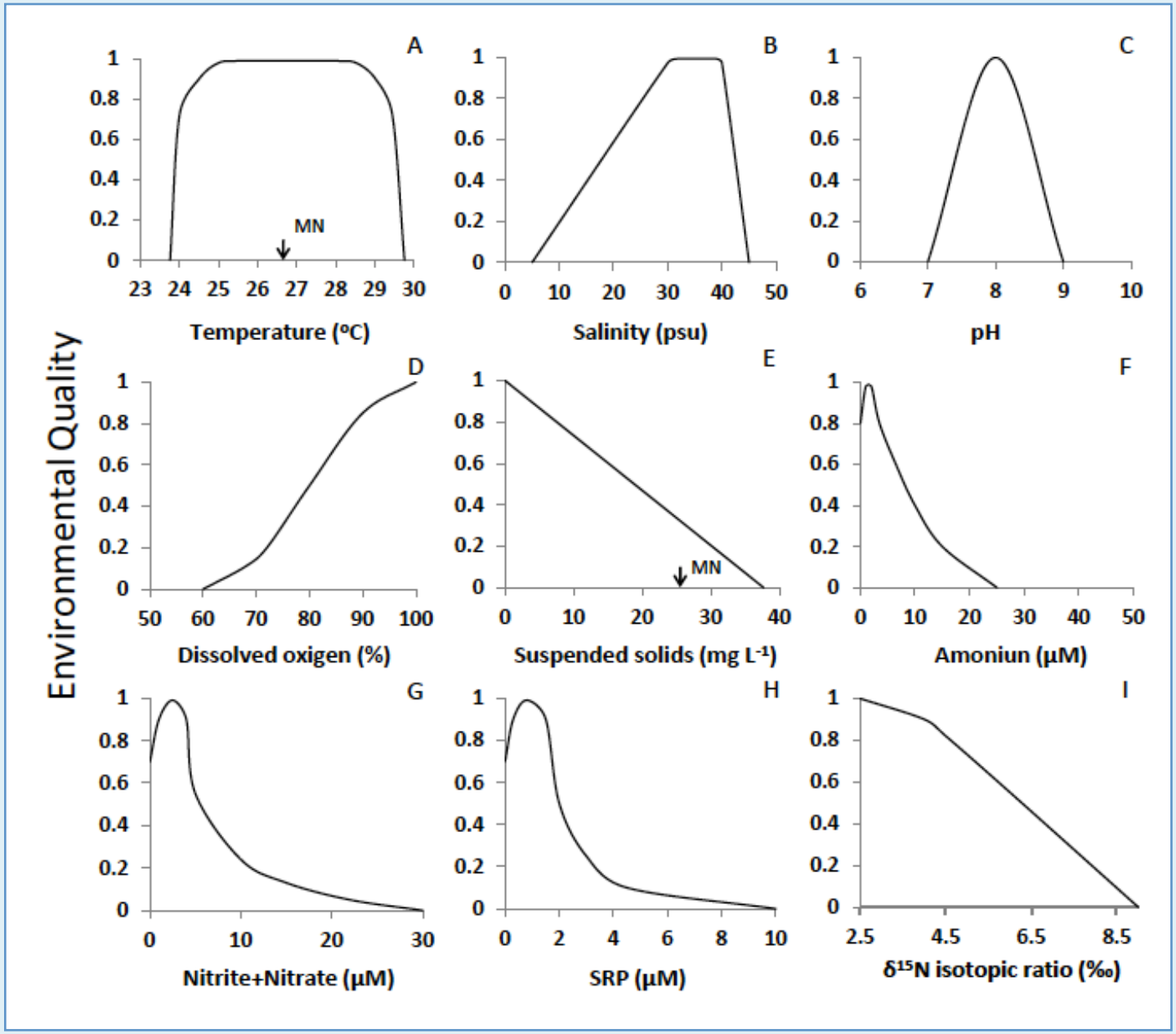


VALUE FUNCTIONS

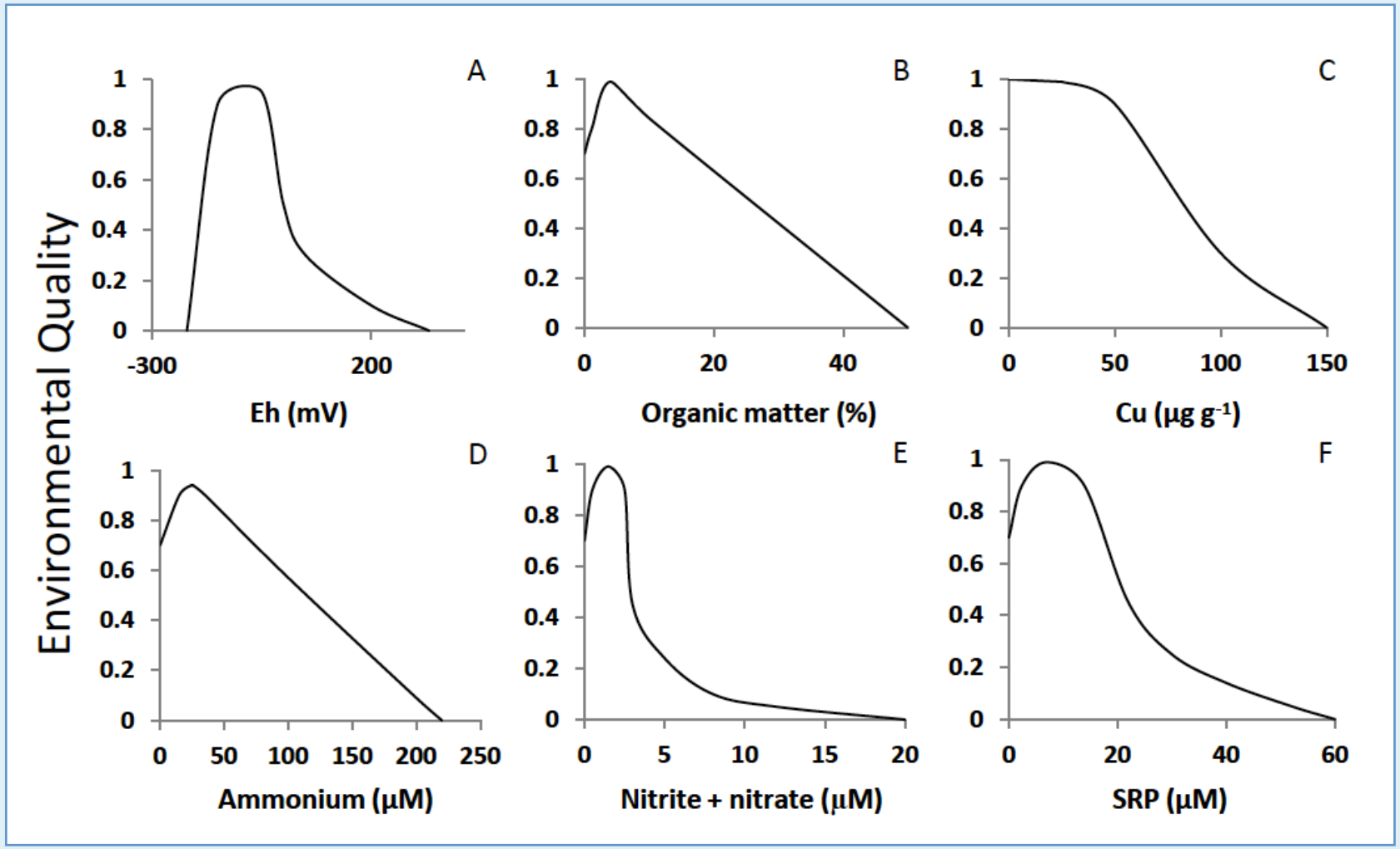


The selected variables must be converted into common commensurable units of EQ by a value function.
Sources: environmental legislation, published literature and our own experience (brainstorming)

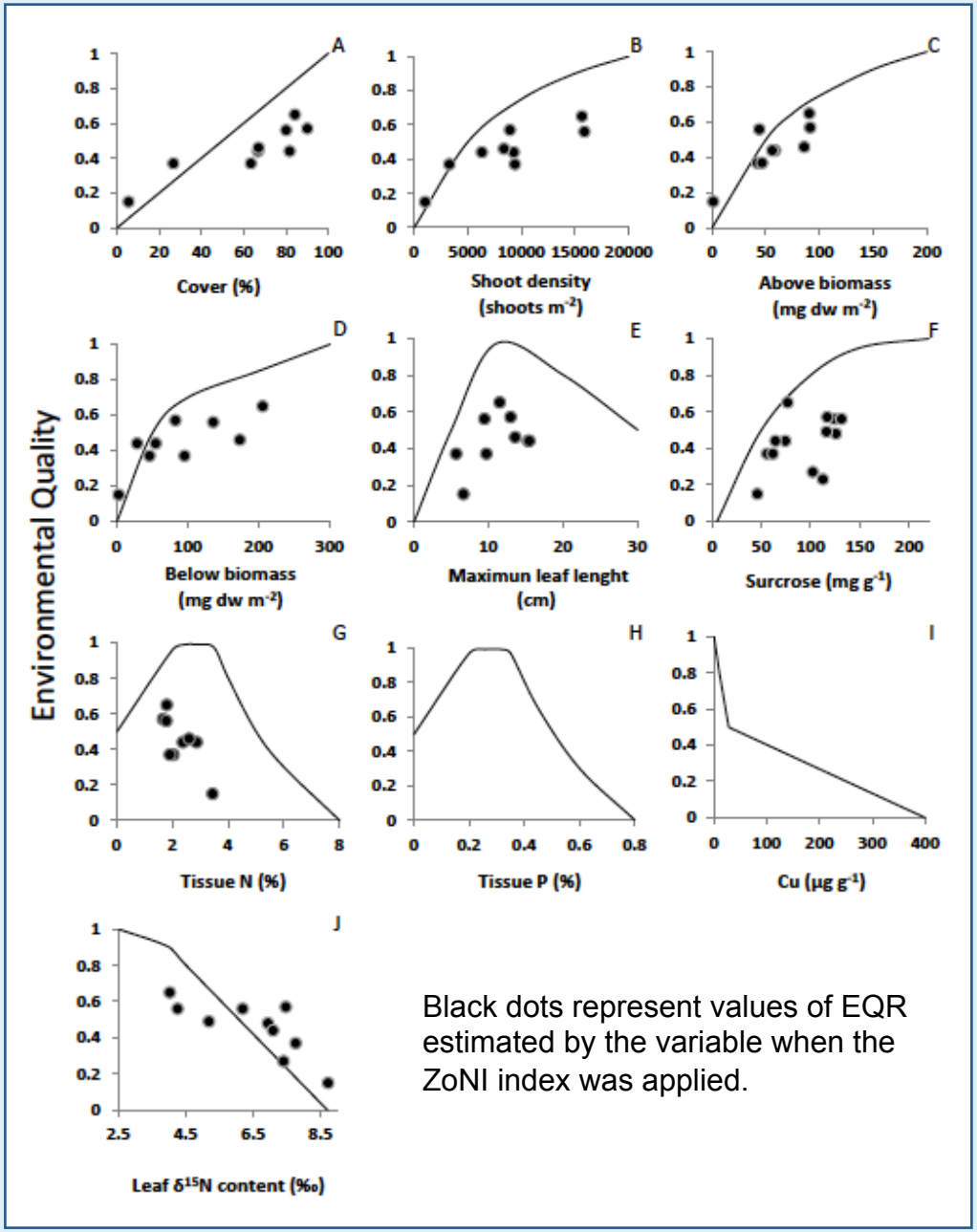
VALUE FUNCTIONS OF VARIABLES RELATED TO THE WATER COLUMN



VALUE FUNCTIONS OF VARIABLES RELATED TO THE SEDIMENT



VALUE FUNCTIONS OF VARIABLES RELATED TO PLANTS



Black dots represent values of EQR estimated by the variable when the ZoNI index was applied.

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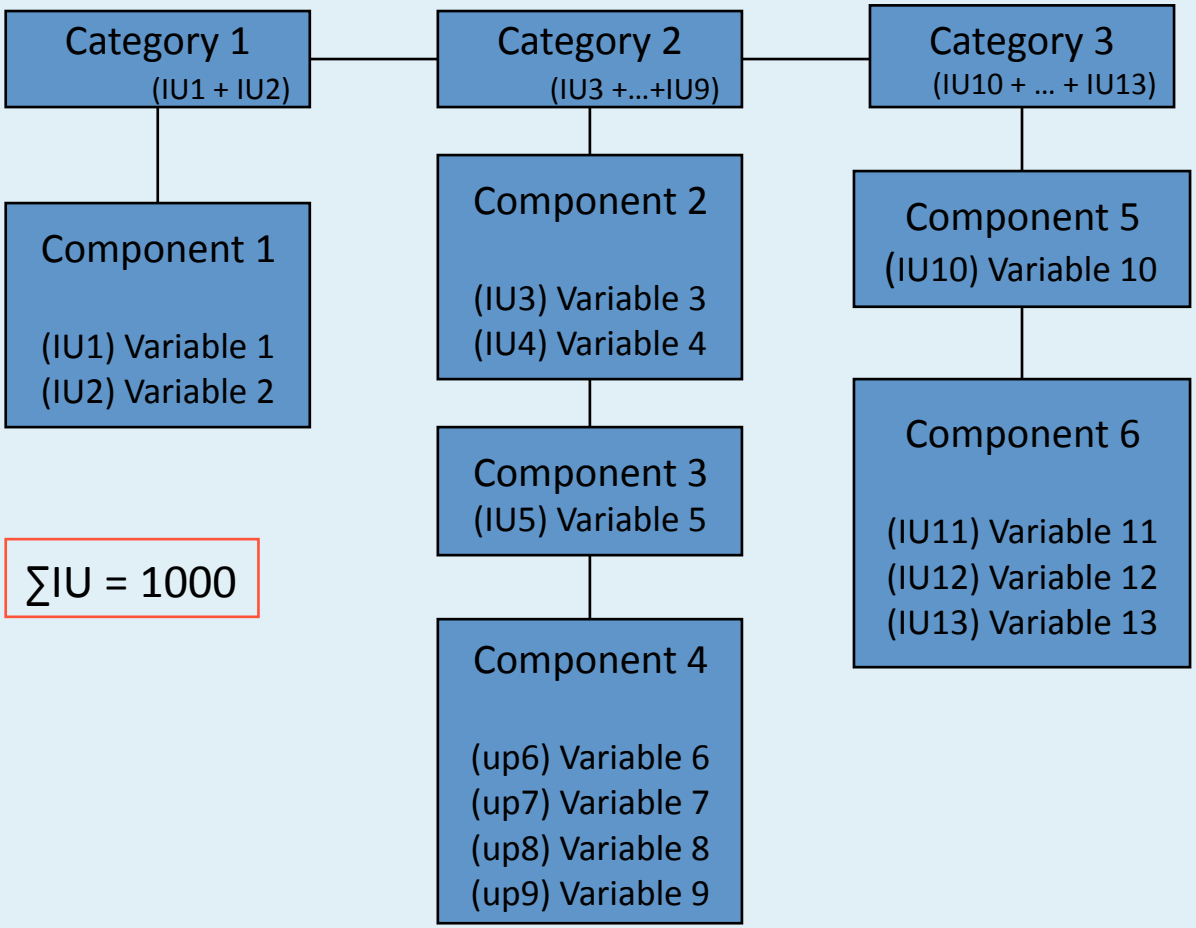

WEIGHTING OF SELECTED VARIABLES (UNITS OF IMPORTANCE; UI)

15 experts in the ecology of *Zostera noltei* (9 UCA, 1 UB, 4 Ualg, 1 UCo) were independently questiones how they would distribute the UI among the 25 variables

Compartment and variables (UI)		
Water column (302)	Sediment (227)	Plants (471)
Temperature (37)	Eh (44)	Percentage cover (68)
Salinity (21)	Organic matter (47)	Shoot density (89)
pH (14)	Heavy metals concentration (29)	Biomass (67)
Dissolved oxygen (25)	NH_4^+ in pore water (57)	Maximum leaf length (28)
Suspended solids (53)	$NO_2^- + NO_3^-$ in pore water (24)	Sucrose content (47)
DIN (NH_4^+) (64)	PO_4^{3+} in pore water (26)	Tissue N (48)
($NO_2^- + NO_3^-$) (29)		Tissue P (32)
SRP (PO_4^{3+}) (39)		Heavy metals concentration (41)
POC $\delta^{15}N$ isotopic ratio (20)		$\delta^{15}N$ isotopic ratio in leaves (51)

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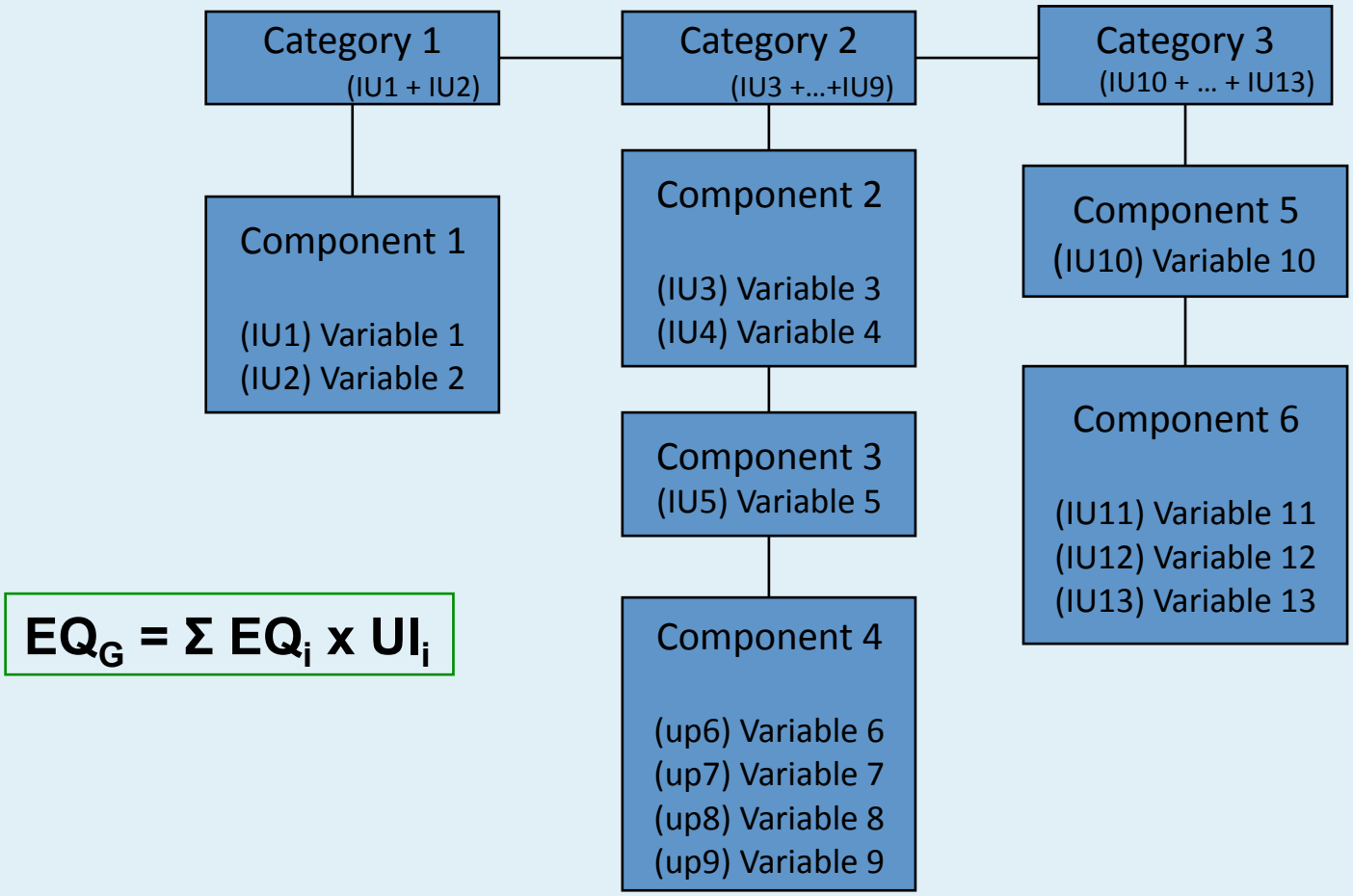
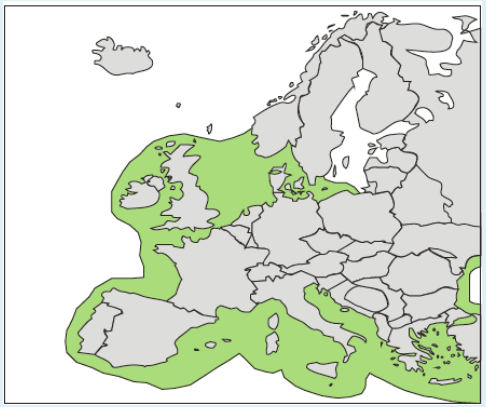
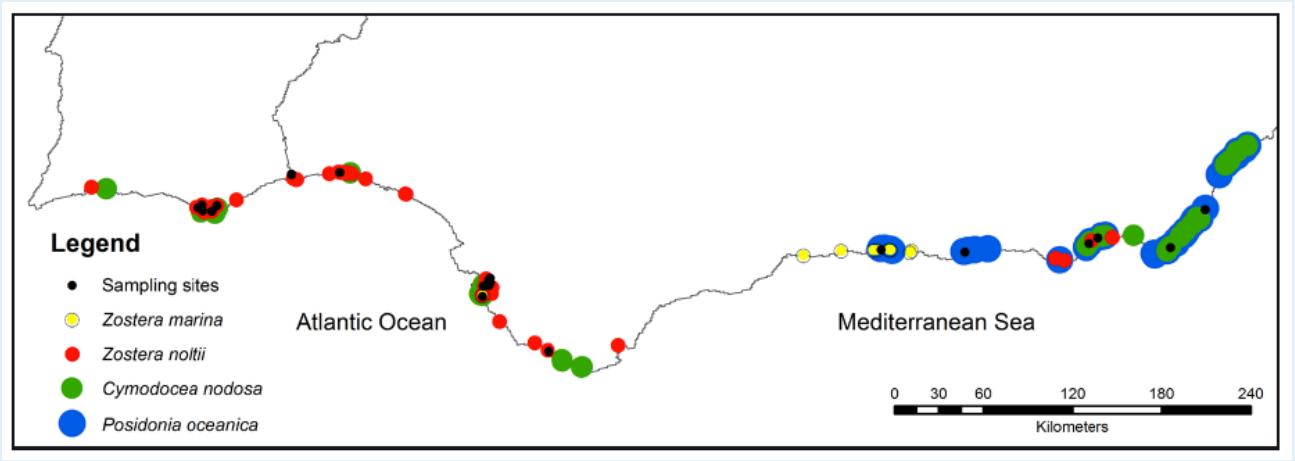
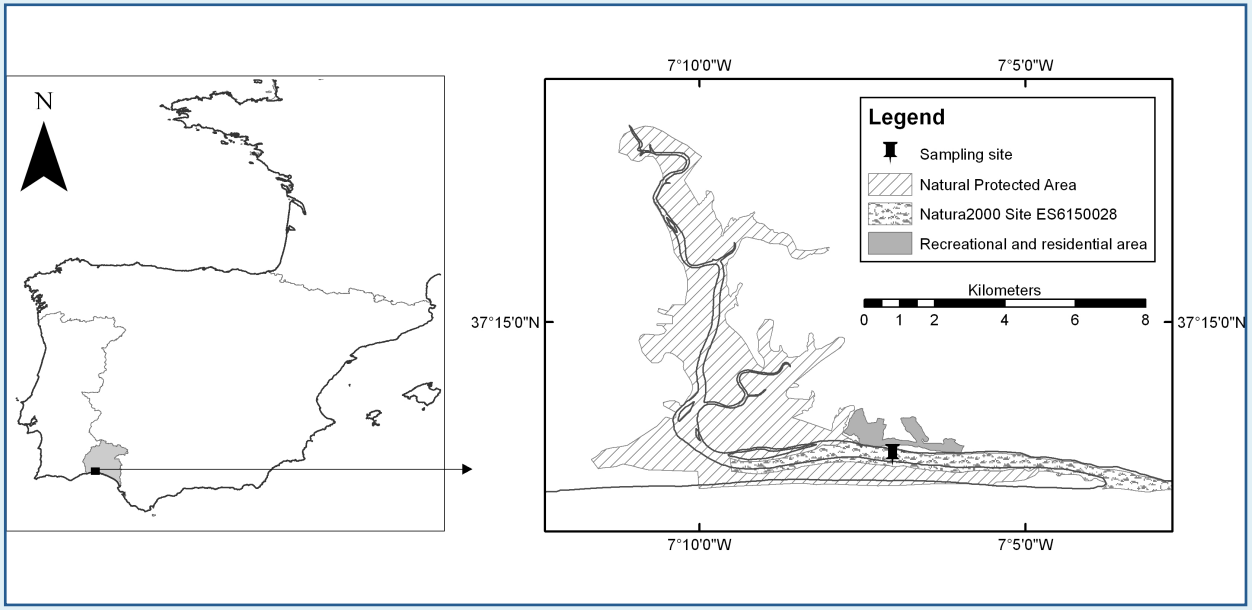


$$EQ_G = \Sigma\, EQ_i \times UI_i$$

CASE STUDY IN THE RIVER PIEDRAS (HUELVA)







RESULTS

	Variable		Estimated value	EQ	UI	EQxUI	Σ EQ
Water colum	*Temperature (°C)*		28.3	1	37	37	193.1
	Salinity (‰)		40	1	21	21	
	pH (P.S.U.)		7.88	0.73	14	10.22	
	Dissolved oxigen (%)		101	0.85	25	21.25	
	Suspended solids (mg L^{-1})		98.5	0	53	0	
	Nutrient content (µM)	NH_4^+	u. d. l.	0.7	64	44.8	
		$NO_2^- + NO_3^-$	1.57	0.95	29	27.55	
		PO_4^{-2}	u. d. l.	0.7	39	27.30	
	$\delta^{15}N$ isotopic signal (‰)		7.6	0.2	20	4	
Sediment	*Eh (mV)*		-27.065	0.6	44	26.40	165.5
	Organic matter(%)		5.08	0.7	47	32.90	
	Heavy metal content (µg g dw^{-1})	Cd	0.193	1	5.8	5.80	
		Cr	57.51	0.95	5.8	5.51	
		Cu	84.40	0.49	5.8	2.84	
		Pb	45.71	0.82	5.8	4.76	
		Zn	205.05	0.98	5.8	5.68	
	Nutrient content (µM)	NH_4^+	0.06	0.7	57	39.90	
		$NO_2^- + NO_3^-$	1.72	0.98	24	23.52	
		PO_4^{3-}	0.009	0.7	26	18.20	
Plants	*Percentage cover (%)*		66.93	0.67	68	45.56	311.5
	Shoot density (shoot m^{-2})		8380	0.7	89	62.30	
	Biomass (g dw m^{-2})	Aboveground	85.72	0.7	33.5	23.45	
		Belowground	87.59	0.66	33.5	22.11	
	Maximun leaf lenght (cm)		13.59	1	28	28	
	Surcrose in leaves (mg g dw^{-1})		57.32	0.53	47	24.91	
	Tissue N content (% dw)		2.6	1	48	48	
	Tissue P content (% dw)		0.52	0.5	32	16	
	Heavy metal content (µg g dw^{-1})	Cd	0.28	1	8.2	8.20	
		Cr	11.46	1	8.2	8.20	
		Cu	64.62	0.72	8.2	5.90	
		Pb	11.61	1	8.2	8.20	
		Zn	149.40	0.987	8.2	8.09	
	$\delta^{15}N$ isotopic signal (%)		8.6	0.05	51	2.55	
						Total EQ_G	670.1

The estimated EQ_G suggested a good ecological status.

The value was higher than that estimated independently by the ZoNI index (García-Marín et al. 2013) in the estuary (0.46, moderate)

EQ_G	Valor
High	1 - 0.775
Good	0.774 - 0.550
Moderate	0.549 - 0.325
Poor	0.324 - 0.1
Bad	0.1 - 0

CONCLUSIONS

1. It is possible the assessment of the environmental quality of stands of *Zostera noltei* by the adaptation of the Battelle EES.

2. The method has a great potential for ecosystem management. It enables the assessment of environmental impacts and mitigation measures in the estuary by further estimations of the environmental quality in the stands of *Z. noltei*

3. The method suggest a good ecological status of the seagrass meadow in the estuary.

4. The estimation of quality by the Battelle EES was higher than the ecological status of the water mass, estimated independently by the ZoNI index.


Gracias a todos, especialmente a aquellos que contestaron el cuestionario…
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Seagrass feedbacks and trade-offs: the cost of living in aquatic ecosystems