A proposal of Typology for Mediterranean transitional waters

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Typology can be defined as the discrimination of surface waters into units "ecosystem types", to ensure that type-specific biological reference conditions can be reliably derived. It follows that typology has to focus on the identification of the major sources of variation of the biological quality element descriptors (mainly abundance, richness and diversity), in order to minimize their intra-type variation and to be functional to Classification of ecological status.

According to this definition and meaning of Typology, we promoted in the past month an electronic discussion within the scientific community in order to achieve a preliminary evaluation of Typology of Mediterranean transitional waters with a expert view approach.

During the week of on-line discussion some documents were produced, many expert views on factors relevance were introduced in this website and more than 140 contacts were received by the produced documents, led to a hierarchical definition of *a priory* Typology simple and reliable.

In fact, even though different views emphasized a major relevance of a few factors: tidal range, salinity (and range), depth (mean), surface, residence time and substrate conditions (organic fraction and granulometry), most views agreed on two first steps of Typology definition:

1. a subdivision into running (deltas or river mouths) and lentic transitional waters; and then,
2. a first subdivision of the lentic transitional waters according to tidal range into lagoons [tidal range $\geq$ 50 cm (micro tidal *sensu* WFD coastal waters)] and non tidal [tidal range $\leq$ 50 cm (not tidal);
3. a second subdivision of the lentic transitional waters into large (surface $\geq$ 3 km^2) and small (surface $\leq$ 3 km^2) lentic transitional waters.

The final document of the on-line discussion was submitted to the Coast WG, which accepted only the first subdivision, in agreement with the decision of some Member States (see Table 1).

Table 1. Typology of transitional waters by the Mediterranean Member States

		France	Greece	Italy
River mouth/delta		**X**	**X**	**X**
Coastal lagoons	**Microtidal lagoons**	**X**	**X**	**X**
	Non-tidal lagoons			**X**

Actually, Italy is going to agree completely with the first level subdivision into river delta, micro- and non-tidal lagoons, while France and Greece considered coastal lagoons as a single group. This differentiation is attributable to an high variation of tidal range among Italian lagoons than among both Greek and French lagoons. North Adriatic lagoons have a tidal range close to 1m, which is greater than the range occurring in the other parts of the Mediterranean pertaining to UE Member States.

To evaluate the *a priori* Typology scheme, a preliminary analysis based on bibliographic data structural descriptors of a biotic quality element (i.e. benthic macro-invertebrates) was performed on a sample of Italian lagoons. 36 Italian lentic transitional waters have been selected, according to biological data availability, and a presence/absence matrix including 1084 benthic macroinvertebrate taxa has been obtained in order to analyze

relationship between biotic descriptors and structural features of transitional waters. Some major generalizations, with implications on Mediterranean transitional ecosystems Typology, arose from the data-set analysis, despite a certain degree of variability in the data-set, due to different sampling effort and methodology, to taxonomic and functional spectra considered, to taxonomic resolution in published papers and to different number of contributions published on different lagoons:

1. *Taxonomic composition and species richness, which are two quality element descriptors proposed by WFD, are extremely heterogeneous among lagoons*. An analysis of similarity (Sorensen index) carried out on the data-set, considering two WFD suggested descriptors of quality elements (i.e taxonomical composition and richness), emphasized the extreme heterogeneity of taxonomic composition among the considered coastal Italian lagoons. Average similarity among biotopes was less than 15% and it was always low even if lagoons very close each other were compared. Moreover, less than 5% of the 1084 taxa were found in more than 15 out of the 36 biotopes while more than 50% of taxa were found in only one biotope.

2. *Physiographical and hydrological characteristics of lagoons explain an highly significant proportion of the quality element descriptor variability*. Multivariate analysis (e.g. multivariate regression, CANOCO, etc) relating the biological data-set with an abiotic data-set, including physiographical and hydrological parameters showed that a four level classification (Outlet width/Surface, minimum axis, maximum salinity, range of salinity) explains up to 75% of variation in the biotic data set (Table 2)

Table 2. Multivariate regression of taxonomic richness with physiographical and hydrological characteristics of the lagoons

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.651[a]	.424	.406	62.684	.424	23.547	1	32	.000
2	.795[b]	.633	.609	50.855	.209	17.619	1	31	.000
3	.832[c]	.692	.661	47.371	.059	5.728	1	30	.023
4	.857[d]	.735	.698	44.693	.043	4.702	1	29	.038

a. Predictors: (Constant), Surface

b. Predictors: (Constant), Surface, max salinity

c. Predictors: (Constant),Surface, max salinity, salinity range

d. Predictors: (Constant),Surface, max salinity, salinity range, min axis

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.670[a]	.449	.431	61.323	.449	26.040	1	32	.000
2	.780[b]	.608	.583	52.547	.159	12.581	1	31	.001
3	.830[c]	.689	.658	47.555	.081	7.851	1	30	.009
4	.870[d]	.757	.723	42.769	.068	8.090	1	29	.008

a. Predictors: (Constant), outlet width

b. Predictors: (Constant), outlet width, max salinity

c. Predictors: (Constant), outlet width, max salinity, min axis

d. Predictors: (Constant), outlet width, max salinity, min axis, salinity range

Outlet width of coastal lagoons and surface area, the latter as a measure of transitional biotope shape, were found to be the two major factors explaining biological data variation. Minimum axis, probably accounting for habitat heterogeneity inside transitional biotopes, and both maximum salinity and salinity range were the other factors significantly accounting for biological data variation.

Canonical Correspondence analysis, performed after a re-organization of all the abiotic parameters into three groups describing respectively sensitivity, heterogeneity and functional size of the transitional ecosystems, gave

a result similar to that shown by multivariate regression, explaining up to 43.3% of the variation of the macroinvertebrate taxa matrix.

It is relevant to observe that for the analysis we considered only abiotic characteristics of lentic transitional waters, which are relatively independent of anthropogenic pressures. These latter can affect taxonomic composition and richness, as well, and are likely to be responsible of the unexplained variation in the data set.

Therefore, a four level factorial classification of transitional waters into types would greatly reduce the variability of the considered descriptor of biological quality, reaching the goal of improving Typology for *Reference conditions* analysis and ecological status *Classification*. In order to minimize the number of ecosystem types and to optimize the accuracy of ecological status classification, we think that at this stage at least a two level factorial definition of Mediterranean lagoon Typology is required and that more detailed definition, with three or more levels, could be appropriate to more accurate definition of monitoring programs at local and regional scales.

3. *The inclusion of lagoon surface area in the proposed* a priori *Typology of Mediterranean lagoons is validated by the* a posteriori *analysis*. On the basis of this preliminary results we found that surface area of lentic transitional waters, as a measure of transitional water shape, which is one of System B descriptors (WFD, 2000), represented the physiographic feature with the strongest functional, rather than phenomenological, influence on benthic macro-invertebrates quality element descriptors. Surface area explained almost the same proportion of variation explained by outlet width but the former relationship has a stronger theoretical foundation; a significant species area power relationship was observed in the data set (Figure 1). Interestingly, a similar result was also found for phytoplankton quality element descriptors on different data set obtained on a sub-sample of sites (Figure 2).

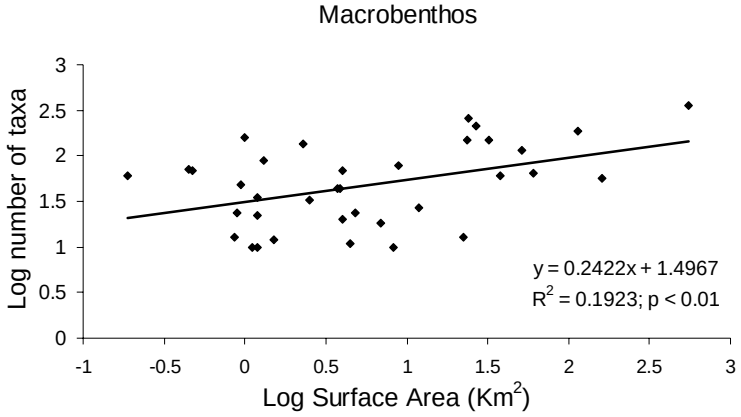

Figure 1 Relationship between surface area (km^2) and benthic macroinvertebrate taxa number recognized in each of the transitional ecosystem selected.

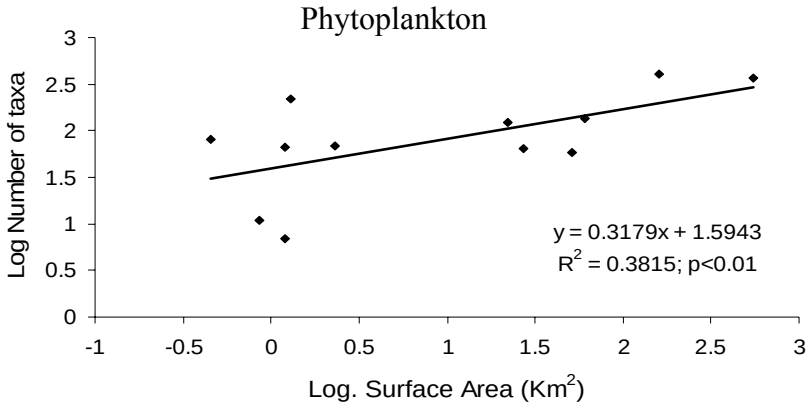

Figure 2 Relationship between surface area (km^2) and phytoplankton taxa number recognized in each of the transitional ecosystem of the sub-sample of sites selected.

Accounting for species/area relationship would greatly reduce the intra-Type variability of a quality element descriptors such as species composition/richness. It means that an *a posteriori* definition of Typology supported the second subdivision into small and large lagoons; i.e., the relevance of surface area has to be taken into account to the aim of a consistent definition of transitional water Typology.

An *a posteriori* evaluation of the threshold between small and large lagoons was performed on an inventory of the Italian lagoons, including 175 biotopes, 139 of which with a surface area lower than 10sqm (Table 3). Maximum differentiation among groups of small and large lagoons was observed with a threshold of 2.5km^2 (ANCOVA test, P≤0.001). Large and small lagoons, divided according to the above defined threshold, had significantly different number of taxa (t-Student test, P ≤ 0,02).

Table 3 – Distribution of Italian lagoons smaller than 10 km^2 into classes of surface area

Surface Class	*N° of Lagoons*
0.5	57
1.0	28
1.5	11
2.0	8
2.5	4
3.0	3
3.5	4
4.0	4
4.5	4
5.0	1
5.5	2
6.0	1
6.5	0
7.0	5
7.5	0
8.0	0
8.5	4
9.0	1
9.5	1
10.0	1

Therefore, the final proposal, arisen by *a priori* evaluation and validated by an *a posteriori* definition of Mediterranean lagoons Typology, can be summarized as follows:

1. **running transitional waters**
   1.1. deltas
   1.2. river mouths
2. **lentic transitional waters**
   2.1. micro tidal lagoons [tidal range ≥ 50 cm (micro tidal *sensu* WFD coastal waters)]
      2.1.1. large (surface ≥ 2.5 km^2)
      2.1.2. small (surface ≤ 2.5 km^2)
   2.2. non tidal lagoons [tidal range ≤ 50 cm]
      2.2.1. large (surface ≥ 2.5 km^2)
      2.2.2. small (surface ≤ 2.5 km^2)

Since the questionnaire already produced by the Coast WG for the inter-calibration purposes takes into account for only the first level of lentic transitional waters discrimination, between micro- and non-tidal lagoons, we suggest here, as minimum requirement, that the selection of sites for inter-calibration could take into account also the surface area of lagoons, providing small and large both reference and polluted sites at each Member State. It would allow to make an additional test of the relevance of surface area in the subdivision of transitional waters into types.

Other factors have certainly a relevant role on the biological quality element descriptors, as the preliminary analysis on the Italian lagoon data-base showed; among these factors, hydrodynamics [e.g., retention time (τ) and water flushing], sediment features (e.g., granulometry, organic matter content, geological origin), climatic/meteorological constraints and water salinity, seem to have a major role, which relative importance and which effective independence/autocorrelation would have to be directly tested within a research project finalised to define typology of Mediterranean transitional waters.

There is a final point we want to emphasise in this document regarding the intercalibration. Most of the attention in this first stage of the WFD implementation was on Typology and Reference Conditions but Intercalibration will be performed utilising descriptors. The selection of proper descriptors of ecological status of transitional waters is by far the most important and difficult challenge of the WFD. There is clearly a need to make things simple, but also to collect useful information. Some criteria for comparison and evaluation of descriptors, in terms of scientific basis, standardisation, variability, cost and simplicity have already been proposed and we attached to this document two tabular models, which are suggested for the comparative evaluation.

This paper results from the contributions of the participants to the Naples *LaguNet* Forum on *Major challenges to bridge basic ecology to applications* (Naples, June 17-19,2004), which are listed below. We want to thank all of them for their enthusiasm and effort brought on the discussion of these topics. We also want to thank Anna Fauci and the staff of the Ecology group of Naples Federico II University for their invaluable contribution to the organisation of the Forum and the Presidency of the Campania Region for the grant, which made possible the Forum.