# Definition of type-specific reference conditions in Mediterranean lagoons[1]

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**Abstract**: Defining 'reference conditions' (sensu Water Framework Directive) in Mediterranean lagoons is a challenging issue since the Mediterranean societies have used lagoons for centuries, lagoons are naturally enriched ecosystems, physically stressed and characterised by strong and unstable internal gradients and lagoons show an high taxonomic redundancy and a low taxonomic similarity. Here, accounting for these peculiarities, we have compared *a priori* and *a posteriori* approaches to identify the main sources of uncertainty in the ecological status of Mediterranean lagoons. Mixed model analysis showed that the *a posteriori* approach emphasises metric-specific ecosystem types and reduces the uncertainty of the ecological status classification when compared with the *a priori* approach based on fixed ecosystem Typology.

**Keywords**: macroinvertebrate, lagoon, reference conditions, typology, ecological status, mixed models, uncertainty.

## 1. Introduction

The Water Framework Directive (hereafter WFD) requires EU Member States to classify the ecological status of every water body in Europe larger than some minimum threshold defined in the Directive (WFD, 2000). Ecological status is an ecosystem property, which is a measure of ecosystem functioning and is assumed to be high in aquatic ecosystems totally or nearly totally undisturbed by human activities. Therefore, ecological status of ecosystems is conceptually independent of the natural variability of its structural components, which can be very large conditions on spatial and temporal scales both among and within aquatic ecosystems. Since ecological status of ecosystems is commonly assessed from the characteristics of their biotic components, the natural variability of plant and animal guild attributes, depending on the abiotic context (i.e.,

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the niche of the environment, Emlen, 1973; Zobel, 1997), represents a major source of uncertainty in the process of ecological status assessment.
The WFD addresses the uncertainty derived from natural variability with the classification of ecosystems into 'types', defined according to the main drivers of variation of the biotic components using a discrete scale. For example, Typology of lagoon ecosystems in the Mediterranean ecoregion was proposed to be based on a hierarchical organization of three drivers, tidal range, lagoon surface area and water salinity, producing globally 20 types (2 classes of tidal range x 2 classes of surface area x 5 classes of water salinity; Basset et al., 2006; Lucena-Moya et al., 2009). Recently, the degree of confinement was also proposed as a major driver of biotic component variation in Mediterranean lagoons. A classification of ecosystems into types, if the proper drivers are selected, actually reduces the natural variability within every type, but being generally based on the assumption of linear responses along the driver gradients it can incorporate both redundancy between types and uncertainty within a few types. Recently, the application of a mixed model approach was found very effective in optimizing the definition of 'ecosystem types' and assessment of ecological status in Mediterranean lagoons (Barbone et al., 2011), but this *a posteriori* approach may be biased by the data source used and less general than the *a priori* approach.
Here, we have compared the *a priori* and the *a posteriori* approach using a data-set on benthic macroinvertebrate guilds of Mediterranean and Black Sea lagoons and the *a priori* typological classification of Mediterranean and Black Sea lagoons available in the literature or on official documents of the Committee in charge of implementing the methodological procedures of aquatic ecosystem assessment in Europe according to the WFD.

## 2. Materials and Methods

Data analysis was performed of biotic and abiotic data available at the Transitional Water Platform (www.circlemednet.unisalento.it). Data were originally collected on fourteen Mediterranean and Black Sea lagoon ecosystems in the framework of the European project TWReferenceNet. The studied ecosystems or ecosystem areas were selected because of their high degree of naturality, when compared with the average conditions in the EcoRegional area; all studied ecosystem areas were exposed to low anthropogenic pressures (Table 1) and utilised as potential reference conditions in order to explore the influence of spatial and temporal sources of natural variability. The data used for this study are based on a nested sampling with habitat types (2/3), sites (2) and replicates (5) nested within lagoons (14) and times (2). Abiotic data include measures of pressures, ecosystem physiography and hydrology, at the ecosystem level, and measures of chemical-physical water parameters, at the level of sampling sites/times. Biotic data refer to the macroinvertebrate guilds of the studied lagoons/lagoon areas and include measurements of species composition, numerical abundance and individual traits at the replicate level; data were then aggregated for the analysis at the site level. As individual trait, individual body size was quantified on all sampled individuals as body length and ash free body mass; body mass was not determined in less than 5% for technical problems.
Simple metrics and multi-metric indices were computed from the original data; the former includes measures of species composition and richness, numerical abundance,

diversity, average individual mass and size spectra components, the latter include four main multi-metric indices, namely BAT (Benthic Assessment Tool), BITS (Benthic Index based on Taxonomic Sufficiency), ISS (Index of Size Spectra), M-AMBI (multivariate AMBI).
The amount of variation of both simple and multi-metric indices explained by standard lagoon typologies, based on water salinity, lagoon surface area, tidal range and confinement, or by a posteriori assessed typology with the use of mixed model approaches have been quantified and compared. The uncertainty of ecological status assessments at the level of sampling sites, or lagoons following the two different approaches and the different indices was also addressed.

Table 1. Pressure evaluation on the list of the transitional water ecosystems considered: A = organic load; B = nutrient load; C = hazard substances; D[a] = fishing; E = alien species; F = navigation; G= physical modification; H= average pressure; I[a] = net pressure The intensity of every pressure type was evaluated using a scale of value ranging from 0 (absent) to 4 (4=high).

| Transitional waters | Pressures | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D* | E | F | G | **H** | **I*** |
| Agiasma | 2 | 2 | 1 | 3 | - | - | 2 | **2.0** | **1.7** |
| Logarou | 1 | 2 | 1 | 4 | - | - | 3 | **2.2** | **1.7** |
| Alimini | 1 | 1 | - | 3 | 1 | - | 1 | **1.4** | **1.0** |
| Grado Marano[b] | 2 | 2 | 3 | - | 2 | 3 | 2 | **2.3** | **2.3** |
| Grado Valle Cavanata | 1 | 1 | 1 | - | 1 | - | 1 | **1.0** | **1.0** |
| Grado Valli da Pesca[b] | 1 | 1 | - | 4 | 4 | - | 2 | **2.4** | **2.0** |
| Le Cesine | - | 1 | - | - | - | - | 2 | **1.5** | **1.5** |
| Margherita di Savoia[b] | 2 | 2 | - | 1 | - | - | 4 | **2.2** | **2.6** |
| Torre Guaceto | - | 1 | 1 | - | - | - | 1 | **1.0** | **1.0** |
| Karavasta | 1 | 1 | - | 4 | 1 | 1 | 3 | **1.8** | **1.4** |
| Narta[b] | 2 | 2 | - | 3 | - | - | 4 | **2.7** | **2.6** |
| Patok | - | - | - | 2 | 1 | - | 1 | **1.3** | **1.0** |
| Lehaova | 1 | 1 | - | 1 | 1 | - | 1 | **1.0** | **1.0** |
| Sinoe | 1 | 1 | - | 3 | | - | 3 | **2.0** | **1.6** |

[a] Fishing pressures are not considered so effective on benthic macro-invertebrates. Net Pressures exclude fishing [b]Pressures at less perturbed sites can be estimated 0.33 of Net pressures.

## 3. Results

The main results achieved from with the data analysis are listed below:

1. Simple metrics are sensitive to internal lagoon patchiness while multi-metric indices are not;
2. All multi-metric indices showed a significant variability among lagoon ecosystems;
3. Considering only the multi-metric indices, BITS has an higher intrinsic variability than the other three metrics;

4. Water salinity is the typological category accounting for most variability of M-AMBI, BAT and ISS, while confinement was an important source of BITS variability;
5. The *a posteriori* mixed model analysis showed clear metric-specific, type specific reference conditions;
6. Accounting for these reference conditions, the accuracy of both M-AMBI and ISS in the classification of ecological status of the studied lagoons was highly improved (Figure 1);
7. A priori, categorical, lagoon classification also explained part of the multi-metric variation, improving the ecological status classification of the studied lagoons.

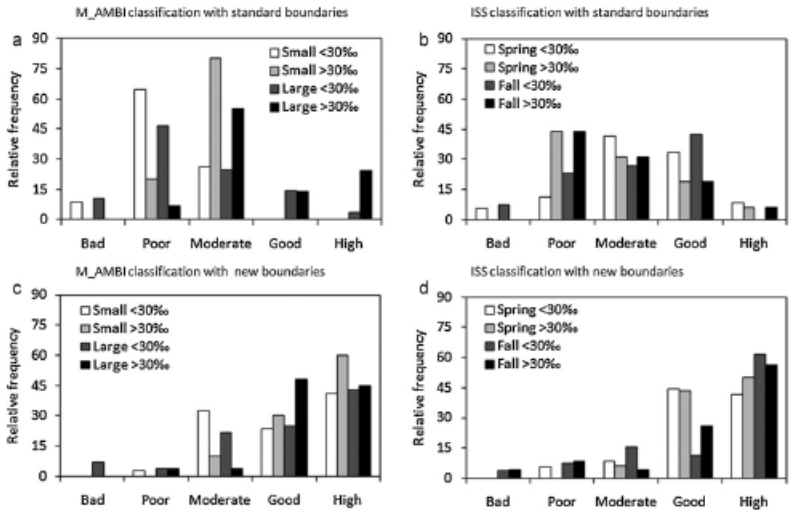


**Figure 1**: Ecological quality classification of the study sites among type specific categories (da Barbone et al., 2011).

## 4. Concluding remarks

The comparative analysis of the performance of a priori and a posteriori approaches to the definition of a typological classification of aquatic ecosystem has a major applied implication in the optimization of the regional and national monitoring programs .

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