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Assessment of river quality within the context of the EU's Water Framework Directive (2000/60/EC): the RiverNet experiences

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Abstract

The purpose of the EU's Water Framework Directive (WFD) is the achievement of ecological good status for all its superficial water bodies and courses. However, the most controversial and difficult aspect is the choice of an appropriate method to define a "reference condition", the expected value upon which comparisons are to be made and quantitatively expressed as EQR metric (ecological quality ratio). A major burden is the adjustment of national standards to assess the quality of aquatic habitats according to the technical specifications explicitly stated in the WFD. This aspect is also one of the major objectives within the RiverNet project. We compared standard methods used in Italy (not compliant with WFD requirements) with those currently under study by the pan-European intercalibration panel. Data spanning one year (2002) from the Abruzzo monitoring program were used. Data from 229 samples (78 sites and 38 water courses) were reanalyzed using both Italian (LIM, IBE, SECA) and other metrics (family richness, BMWP, ASPT, EPT, EPT%). Resulting ecological status assessments were compared quantitatively and expressed as EQR. Indices based on benthic invertebrates were closely interrelated (R^2=0.71–0.88 for pairwise correlations), and performed better than the abiotic LIM index. The BMWP index seems better suited than the non-WFD-compliant IBE index to describe ecological status. Though the dataset was relatively limited, we were able to identify 13 class-1 (least impacted) sites that can be used as reference sites for Abruzzo. Additionally, EQR-based range and threshold values for each tested metric were quantified for the high, good and moderate quality classes. Utilization of historical data may be a cost- and time-effective approach potentially leading to a regional and nationwide establishment of reference conditions and range quality-class values for riverine systems.

Introduction

The Water Framework Directive (WFD) of the European Union (EU) is an innovative piece of legislation because of its holistic approach, treating aquatic habitats as indivisible ecological units. The WFD also defines environmental quality goals for several types of water bodies and courses.

The WFD principles and goals, despite their general clarity, may not be that easy to incorporate into national legislations by EU Members States (MSs) because of their technical complexity and sometimes flexible interpretation. In order to facilitate the implementation of the WFD, the EU has issued a Common Implementation Strategy (CIS) to harmonize methods across MSs. Panels of experts appointed by the EU's MSs, called Working Groups (WGs), have been created to develop guidelines, whose applicability to regional conditions are to be later verified by each MS (e.g., EC 2003 a, b, c).

A major burden on MSs is the adjustment of national standards to assess the quality of aquatic habitats according to the methods and technical specifications explicitly stated in the WFD [2000/60/EC: Annex V (EU 2000)].

For superficial water courses (rivers and streams), the WFD defines five classes of environmental quality, based on the Ecological Quality Ratio (EQR): the ecological status of a water course is to be related to a reference condition, i.e., the optimal status that it would have in the absence of human pressure or human-related disturbance (Fig. 1).

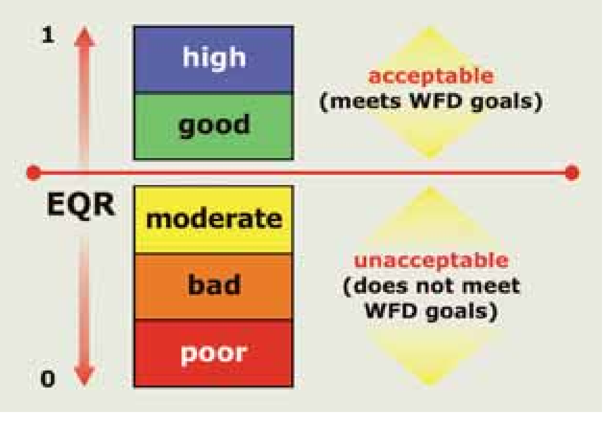

Figure 1- Classification of running waters based on the Ecological Quality Ratio (EQR) principle. See text for major details.

The parameters that define the biological, hydromorphological, and physicochemical aspects of the ecology of a water course have to be measurable and need to be expressed in a form relative to the reference condition. In such an assessment system, an EQR value of zero would express the highest degree of human-related alteration, while a value of 1 would express absent or negligible human-related alteration (Fig. 1).

The Italian Scenario

A fundamental aspect of the WFD implementation at national scale is the choice and subsequent use of the parameters that define the ecological status of a water course. Current Italian standards in this regard – especially those concerning the biological part of the assessment – are drastically different from WFD requirements. River and stream classification in Italy follows the directives of the national law D.Lgs 152/99 and subsequent amendments.

The physicochemical (LIM), macroinvertebrate-based (IBE), and comprehensive ecological indices (SECA, SACA) (Fig. 2) do not comply with WFD criteria. The few preliminary intercalibration efforts have pointed out the inherent difficulty in the choice of appropriate metrics to establish reference conditions (Buffagni *et al.* 2004).

The RiverNet Experience

The ecological status and "health" of River Aterno have been investigated in detail within the inter-catchment

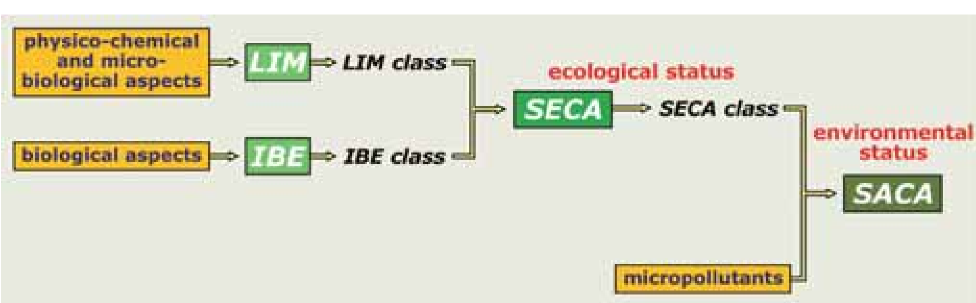

Figure 2- Classification scheme of Italian running waters based on current legislation (D.Lgs. 152/99 and subsequent amendments).

Table 1- Biological assessment of River Aterno (RiverNet project sites). Top: sites listed in ascending order of IBE scores. Bottom: sites listed in ascending order of BMWP scores. QC = IBE-based quality class; fam = Family richness; uWTP= upstream of water treatment plant; dWTP= downstream of water treatment plant. Colors follow quality classes as in Fig.1.

	fam	BMWP	ASPT	IBE	QC
Fossa	12	38	3.17	3	5
Piedicolle dWTP	17	63	3.71	6	3
Fontecchio dWTP	14	47	3.36	8	2
Tione dWTP	14	67	4.79	8	2
Acciano dWTP	14	73	5.21	8	2
Fontecchio uWTP	22	106	4.82	9	2
Tione uWTP	24	111	4.63	9	2
Piedicolle uWTP	26	140	5.38	9	2
Acciano uWTP	23	102	4.43	10	1
Casale	25	109	4.36	10	1
Molina	26	163	6.27	10	1
Cagnano	31	166	5.35	11	1

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project RiverNet. In particular, the investigation allowed to compare the assessment indices currently used in Italy (IBE, LIM, IFF: D.Lgs 152/99) with some of the indices used in the ongoing pan-European WFD-related intercalibration (Sandin and Hering, 2004)

The River Aterno investigation showed that site classification based on either the IBE or the BMWP index may be quite different (Tab. 1). For example, the station located just downstream the Fontecchio water treatment plant exhibited the lowest BMWP value, but was classified as in "good ecological status" (class 2) by the IBE index. Similar discrepancies are evident also for other IBE-based class-2 and class-1 stations, as well as between the IBE and ASPT indices. Such small-scale (few sampling stations along an individual water course) inconsistencies in assessment methods led us to attempt a larger-scale evaluation of the reliability of Italian standard indices (LIM, IBE, SECA) relative to other indices.

We have recalculated the IBE, LIM, and SECA indices using the data of the 2002 monitoring year for the Administrative Region of Abruzzo (Turin *et al.* 2003). The dataset includes 229 samples collected at 78 stations, encompassing 38 distinct water courses. After an appropriate transformation of the original dataset we also applied other indices currently under study in the intercalibration WGs, namely: BMWP, ASPT, EPT, EPT% and Family richness (for a detailed description of the indices see Barbour *et al.* (1999); Armitage *et al.* (1983); Alba-Tercedor and Sanchez-Ortega (1988).

The physicochemical index LIM yielded a verdict of "good ecological status" for most samples (Fig. 3). However, the LIM results were not comparable with those from the biology-based index IBE. LIM-based class-2 samples were

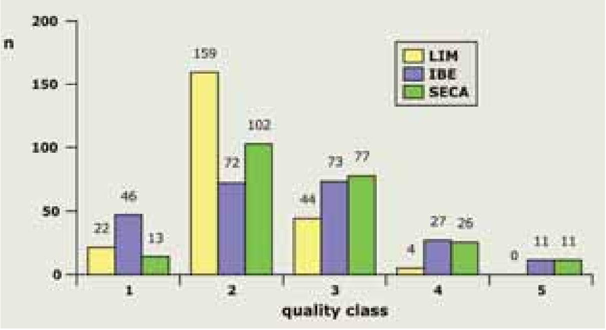


Figure 3 - IBE, LIM and SECA classification of the 229 samples from 38 water courses in the Abruzzo administrative region (data from the 2002 monitoring year).

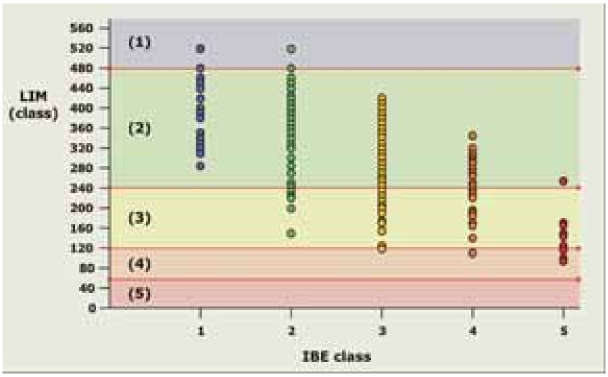


Figure 4 - Quality class comparison between the IBE and LIM indices. Color codes as in Fig. 1.

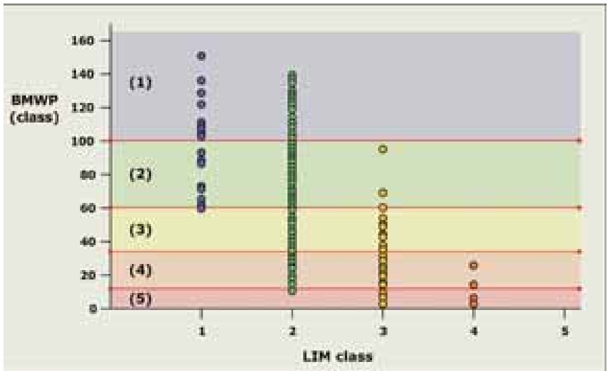


Figure 5 - Quality class comparison between the BMWP and LIM indices. Color codes as in Fig. 1.

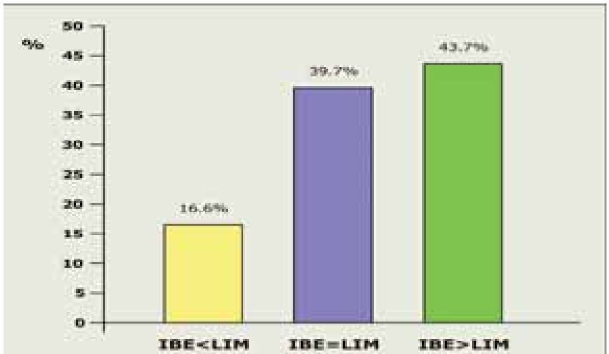


Figure 6 - Comparison of LIM- and IBE- based class-values as percent of the 229 samples examined.

categorized as class-1 to class-5 according to the macroinvertebrate-based IBE and BMWP indices (Figs. 4 and 5). The IBE and LIM results agreed for only ~39% of the investigated monitoring events, and the IBE index alone defined the comprehensive ecological status (SECA) for 100 out of the 229 events (~44%) (Fig. 6).

The overrepresentation of class-2 samples in the LIM classification system (Fig. 3), along with limited, inadequate validation efforts with respect to the better-tested biological indices, suggest that the latter are a more reliable tool to estimate water course ecological status. Therefore, we have expanded our investigation to include other biological indices.

The BMWP, EPT, ASPT, and IBE indices were closely interrelated (Fig. 7). R^2 values ranged from 0.71 and 0.88, while R^2 between such biological indices and the LIM index was only in the 0.31- 0.39 range, further highlighting the discrepancy between biology-based indices and the

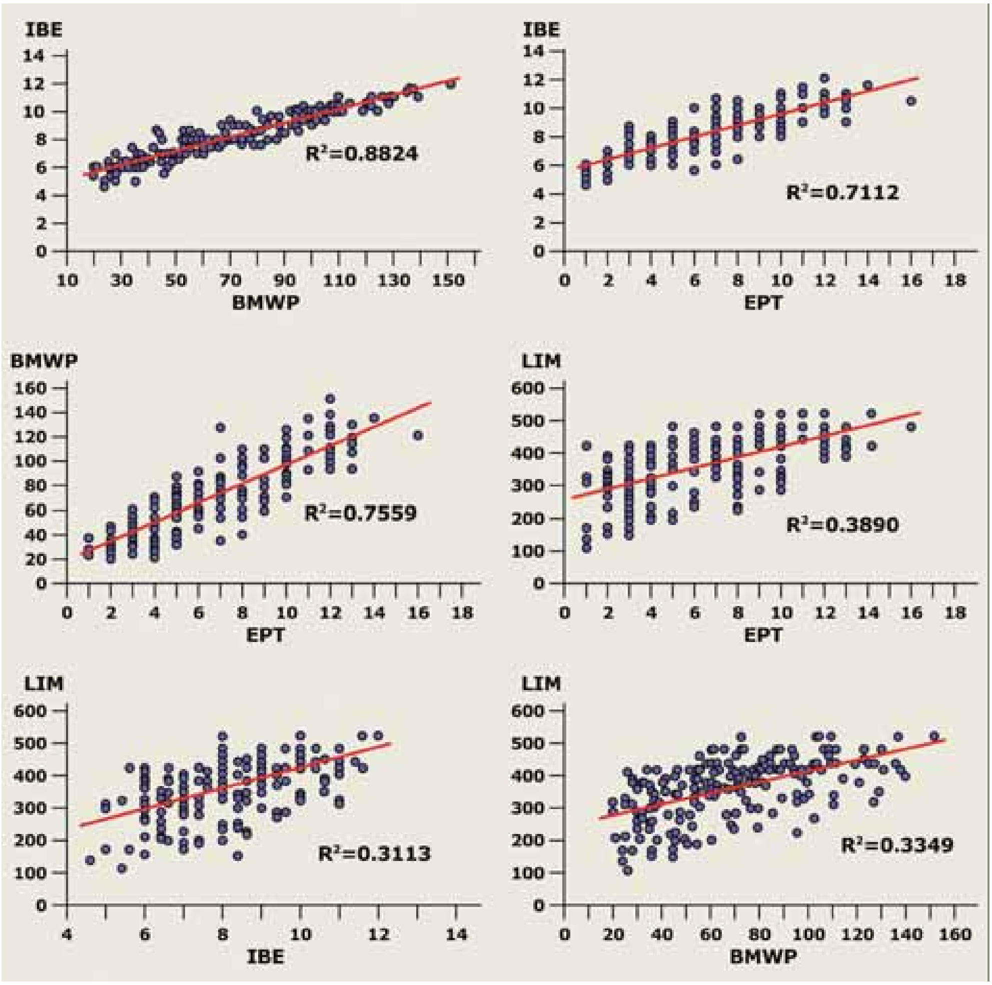


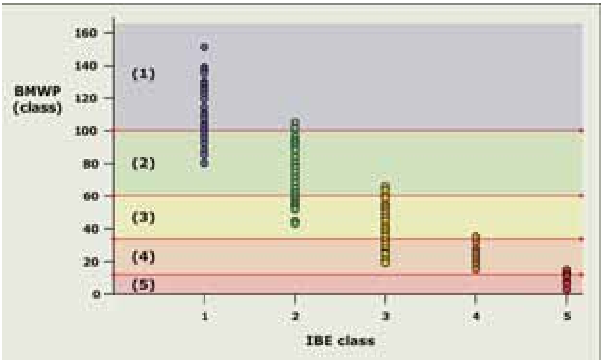
Figure 7 - Pairwise correlations between biological (IBE, BMWP, EPT) and physicochemical indices (LIM) (n = 229 for each).

physicochemical metric used to define ecological status in Italy.

The small discrepancies between BMWP- and IBE-based class identification (Fig. 8) may be due to the yet undertested BMWP within-class range values in Italian running waters, or to a better performance of either index in describing the ecological status of a water course.

Ongoing research (Buffagni *et al.* 2005; Hering *et al.*, 2004; Sandin and Hering, 2004) suggests a broader applicability of the BMWP and the derived ASPT index (intercalibra-

Figure 8 - Quality class comparison between the BMWP and IBE indices. Color codes as in Fig. 1.



ted across several MSs) than the Italy-based, non-WFD compliant, IBE.

The most controversial and difficult aspect of the WFD is the choice of an appropriate reference condition for each category of running-water ecosystem. Reference conditions should represent the basis, the "expected value" upon which comparisons are to be made and threshold values for each class are to be chosen for each parameter (Bailey *et al.* 2003; Wallin *et al.* 2003; Nijboer *et al.* 2004).

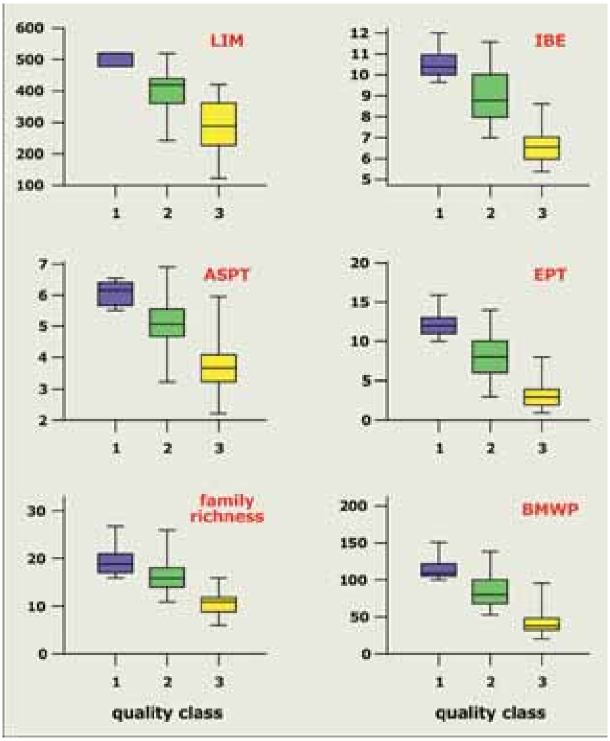
Our dataset identified only 13 samples, out of the 229 examined, with physicochemical and biological parameters agreeing on a class-1 SECA categorization. Though too few to allow a reliable statistical elaboration, such class-1 samples may be chosen as reference sites. After an analysis of the variability of the individual indices within each of the first three SECA classes, we have defined reference site values and class value ranges by adopting the same procedures used by the Intercalibration WGs (EC 2003; Wallin *et al.* 2004): the median of each index across the 13 class-1 samples was chosen as the reference value upon which to carry out data normalization, and the 25th percentile within each class was chosen as the class lower threshold value (Tab. 2). Non-overlapping index scores within each class (Fig. 9) legitimated our choice.

Ranges and threshold values were also expressed as EQR by applying the same principles to all indices (Fig. 10). Furthermore, the minimum threshold value can be

Table 2- Median and interquartile range of biological and physicochemical indices for the first three SECA qality classes.

	quality class 1 (n=13)			quality class 2 (n=102)			quality class 3 (n=77)		
	75th percentile	median	25th percentile	75th percentile	median	25th percentile	75th percentile	median	25th percentile
fam	21	19	17	18	16	14	12	11	9
IBE	11	10.4	10	10	8.8	8	7	6.6	6
LIM	520	480	480	440	420	360	360	290	225
BMWP	122	109	106	99.7	80.5	68.25	47	37	31
ASPT	6.42	6.14	5.6	5.56	5.08	4.66	4.07	3.66	3.25
EPT	13	12	11	10	8	6	4	3	2
%EPT	0.56	0.53	0.5	0.47	0.39	0.33	0.33	0.27	0.18

Figure 9 – Box plot showing the variability of selected indices in the first three SECA quality classes.



identified for each individual index above which a site can be classified as in "good ecological status" sensu WFD, thus becoming exempt from ameliorative intervention (Fig. 11).

EQR	fam	BMWP	ASPT	IBE	EPT	%EPT	LIM
high	>0.89	>0.97	>0.92	>0.96	>0.92	>0.95	≥1
good	0.73–0.89	0.62–0.97	0.67–0.92	0.77–0.96	0.51–0.92	0.62–0.95	0.75–0.99
moderate	0.47–0.72	0.35–0.61	0.48–0.66	0.58–0.76	0.17–0.50	0.35–0.61	0.47–0.74
bad							
poor							
reference condition (median value from reference sites)	19	109	6.14	10.4	12	0.53	480

Figure 10 - Range-values expressed as EQR for selected indices.

EQR	fam	BMWP	ASPT	IBE	EPT	%EPT	LIM
high							
good							
moderate	13.68	67.58	4.05	7.9	5.9	0.32	355
bad							
poor							

Figure 11 - Minimum threshold value of selected indices above which a site should be classified as in "good state".

Conclusions

Utilization of historical data, from successive monitoring years, will enlarge the database upon which a statistically more robust EQR can be extrapolated. Furthermore, the same approach could be adopted by other Administrative Regions. Harmonization of methods across the Regional agencies responsible for the WFD-related monitoring programs, but with regionally-calibrated class ranges and threshold values, should lead to a relatively fine-scale, Region-based, yet comparable, nationwide identification of reference sites. Ultimately, this cost- and time-effective approach would lead to the establishment of reference conditions across river typologies.

Acknowledgements

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