# New tools for the hydromorphological assessment of European streams

## Des nouveaux outils pour l'évaluation hydromorphologique des rivières européennes

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## RÉSUMÉ

Une série de méthodes et outils pour l'évaluation intégrée de l'hydromorphologie a été développée en Italie et successivement adaptée à d'autres pays Européens dans le contexte du projet REFORM (REstoring rivers FOR effective catchment Management). L'Indice de Qualité Morphologique (*MQI*) est basé sur un système de notation ayant l'objectif d'évaluer et classifier les conditions morphologiques actuelles d'un tronçon de rivière. L'indice de Qualité Morphologique pour le Monitoring (*MQIm*) est un outil spécifique pour surveiller la tendance des conditions morphologiques (amélioration ou dégradation) dans le court terme, applicable dans l'évaluation des impacts environnementaux d'interventions comme les projets de restauration. La plupart des indicateurs du *MQIm* sont basés sur des fonctions mathématiques continues plutôt que sur des classes discrètes comme pour le *MQI*. Enfin, Le Système de classification et analyse des Unités Géomorphologiques (*GUS*) a été développé afin d'intégrer le *MQI* à travers la caractérisation des unités géomorphiques typiques d'un tronçon donné et donc permettant d'établir le lien entre les unités mêmes et les conditions morphologiques à l'échelle du tronçon. Les trois nouveaux outils, appliqués en synergie, apportent une évaluation globale des tronçons fluviaux utile pour classifier et surveiller leur conditions hydromorphologiques, comprendre leur fonctionnement, et permettre l'identification d'actions de gestion appropriées.

## ABSTRACT

A series of methods and tools for an integrated and synergic assessment of hydromorphology have been initially developed in Italy, and then expanded to other European countries in the context of REFORM (REstoring rivers FOR effective catchment Management). The Morphological Quality Index (*MQI*) is a tool based on a scoring system, designed to assess the overall morphological conditions of a stream reach and to classify its current morphological state. The Morphological Quality Index for monitoring (*MQIm*) is a specific tool for monitoring the tendency of morphological conditions (enhancement or deterioration) in the short term, and is particularly suitable for the environmental impact assessment of interventions, including restoration projects. Most of the *MQIm* indicators are based on continuous mathematical functions rather than on discrete classes as for the *MQI*. Finally, the Geomorphic Units survey and classification System (*GUS*) has been designed to integrate the *MQI* by characterising the typical assemblage of geomorphic units of a given reach and establishing links between geomorphic units and morphological river conditions at reach scale. The three new tools, used synergically, can provide an overall assessment of stream reaches useful for classifying and monitoring hydromorphological conditions, for understanding their functioning, and supporting the identification of appropriate management actions.

## KEYWORDS

GUS, Hydromorphological assessment, Morphological alteration, MQI, MQIm

# 1 INTRODUCTION

In European countries, the Water Framework Directive (WFD) has introduced the importance of hydrological and morphological (abbreviated to 'hydromorphological') monitoring, assessment and classification of water bodies, development of understanding of their functioning, and identification of appropriate management actions. Numerous hydromorphological assessment methods have been developed during recent decades, with notable differences in their aims, scales, and approaches. Strengths and limitations of existing methods have been recently reviewed by Belletti et al. (2014), who highlighted that the main gaps in most methods are the poor consideration of the physical processes, the lack of a temporal component of the assessment, and the insufficient inclusion of the investigated site in an appropriate catchment context. As a result of these previous limitations, a series of methods and tools for an integrated and synergic assessment of hydromorphology have been initially developed in Italy (Rinaldi et al., 2013), and then expanded to other European countries in the context of the EU FP7 project REFORM (REstoring rivers FOR effective catchment Management). This paper briefly synthesizes the general characteristics and aims of these assessment methods.

# 2 OVERALL HYDROMORPHOLOGICAL ASSESSMENT FRAMEWORK

The methods presented in this paper are embedded within a multi-scale, process-based, hierarchical framework developed within the context of the REFORM project. They are part of a broader, spatio-temporal assessment framework comprising four stages: (1) catchment-wide delineation and spatial characterization of the fluvial system; (2) assessment of temporal changes and current conditions; (3) assessment of scenario-based future trends; (4) identification of possible hydromorphological restoration or management actions. The three interlinked methods briefly presented in the following sections are mainly a part of stage 2, as they are specifically used for the assessment and monitoring of current conditions, but can be also used to support stages 3 and 4 for the assessment of scenario-based future conditions and for the evaluation of the morphological effects of possible restoration projects.

# 3 THE MORPHOLOGICAL QUALITY INDEX

As a consequence of the various limitations of existing hydromorphological assessment methods (Belletti et al., 2014), the initial scope of this research was to develop a method based on a more robust geomorphological approach, with a stronger consideration of physical processes at appropriate spatial and temporal scales. For this aim, the Morphological Quality Index (*MQI*) has been developed and applied in Italy (Rinaldi et al., 2013), and then improved and expanded to other European countries after appropriate verification and modifications within the context of the project REFORM.

The *MQI* is applied at the reach-scale by an integration of remote sensing – GIS analysis and field survey. It includes a set of twenty-eight indicators assessing longitudinal and lateral continuity, channel pattern, cross section configuration, bed structure and substrate, and vegetation in the riparian corridor. These characteristics are evaluated in terms of three components: geomorphological functionality, artificiality, and channel adjustments. The evaluation is based on a scoring, where three discrete classes are generally defined for each indicator: (A) undisturbed conditions or negligible alterations; (B) intermediate alterations; (C) very altered conditions. For each indicator, we started by defining reference conditions for that indicator, corresponding to the absence or negligible presence of alterations (class A), whereas increasing scores were assigned to classes B and C (highest alteration), depending on the relative importance attributed to each indicator (see Rinaldi et al., 2013). A total score is then calculated as the sum of the scores of all the indicators. The *MQI* has been widely applied in Italy and has been tested for various rivers in Europe to represent different condition in terms of physical characteristics and human alterations.

# 4 THE MORPHOLOGICAL QUALITY INDEX FOR MONITORING

The *MQI* was mainly designed to assess the overall current morphological conditions of a stream reach (i.e., a relatively homogeneous portion of the river with a length of the order of some km), reflecting alterations over a long time scale (i.e., last 50 years or longer periods). Therefore, the *MQI* may not be suitable for monitoring short-term changes of channel conditions, in particular if such changes refer to a short period of time or if changes occur in small portions of the reach. To address this limitation, a new version of the *MQI*, named Morphological Quality Index for monitoring (*MQIm*), was specifically designed to take into account small changes (e.g. relative to small portions of a reach) and short time scales (i.e., a few years). Therefore, *MQIm* is particularly suitable for the environmental

impact assessment of interventions, including either flood mitigation and restoration actions.

Some of the main differences and integrations between *MQI* and *MQIm* are the following two: (1) the *MQI* is the tool for the evaluation, classification, and monitoring of the morphological state (i.e., good, poor, etc.), whereas the *MQIm* is a specific tool to evaluate the tendency of morphological conditions (enhancement or deterioration); (2) the *MQI* scores are based on discrete classes, whereas the scores of many *MQIm* indicators are based on continuous mathematical functions; as a consequence, *MQIm* is more sensitive to changes occurring at a temporal scale of few years.

## 5 SURVEY AND CLASSIFICATION OF GEOMORPHIC UNITS

The spatial scales of geomorphic unit and smaller (hydraulic units and river elements) are the most appropriate to assess physical habitats. Geomorphic units (e.g., riffles, pools, etc.) constitute distinct habitats for aquatic fauna and flora, and may provide temporary habitat requirements (refugia from disturbance or predation, spawning, etc.). Procedures to assess physical habitat need to be ecologically and geomorphologically meaningful, so that ecologically relevant scales and physical variables must be framed into a geomorphological characterization template. Because geomorphic units constitute the physical basis for habitat units, an assessment of the assemblage of geomorphic units will provide information about the existing range of habitats occurring in a given a reach. In response to such needs, a novel Geomorphic Units survey and classification System (*GUS*) has been designed to integrate the Morphological Quality Index (*MQI*) by characterising the typical assemblage of geomorphic units of a given reach and better establishing links between geomorphic units and morphological river conditions at reach scale. More details on this system are reported in Belletti et al. (2015).

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