

Remapping Hydroecoregion Boundaries: A Proposal for Improving the Base of the Running Water Monitoring Procedures

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Abstract: Inland waters are constituted by a lot of seriously threatened habitats. The increasing need to safeguard these ecosystems led European Union Member States to propose the Water Framework Directive which decided the creation of homogeneous areas characterized by very similar geology, topography and climate, known as hydroecoregions (HER) and firstly proposed by the French National Research Institute of Science and Technology for Environment and Agriculture (Cemagref). Watercourses reference conditions had to be defined within any HER in order to confront any sampling site. HERs are consistent with European scale maps but important local reinterpretations in order to define more precise boundaries and extensions for each hydroecoregion are required and this point constitutes the main goal of this manuscript.

Latium is a climatically very homogeneous region and it's roughly divided into three major portions confirming Cemagref's proposal. Geological and topographical maps were then used in order to achieve a more detailed characterization of this region in order to obtain a more defined map. All our results allow to better define similarities and differences both between streams and within the same stream allowing to entirely locate each water course within the same HER. It would be important to follow up this study by proposing a similar approach for the entire national territory based on an appropriate region knowledge.

Keywords: Freshwater, HER, Latium region, river management, water framework directive.

INTRODUCTION

Inland waters represent important ecosystems, unfortunately threatened [1-3] by anthropic activities that cause a worldwide rapid decline of freshwater biological diversity mainly in the last decade [4]. This impact is also reflected on aquatic organisms making them vulnerable [5, 6] particularly in highly heterogeneous systems, such as Mediterranean freshwaters [7, 8]. The importance of safeguarding these ecosystems represent a fundamental issue of concern for achieving a sustainable exploitation leading to a lot of actions to ensure the maintenance of water and aquatic resources. At this regard, in the last decades, the UE countries proposed different European Directives but the most important step was represented by the well-known Water Framework Directive (WFD) [9]. This Directive is aimed to the management and the protection of freshwater ecosystems that sets the target to achieve a good level of water managing before 2015. The WFD proposed chances both in monitoring activities (such as the use of different biological groups to obtain a biological quality evaluation of rivers status) and in management activities. In particular, one of the WFD requirement is to plan managing activities for all the river basin

districts based on water quality maps obtained by several biological multiparametric approaches. To do this, the concept of hydroecoregion (HER), analogous to that of terrestrial ecoregion [10], was applied to European watercourses. This approach was firstly tested in the Loire Basin by the French National Research Institute of Science and Technology for Environment and Agriculture (Cemagref) in partnership with the Direction de l'Eau et l'Agence Loire-Bretagne [11-14], and then applied to the whole European territory by the WFD [9]. HERs are homogeneous areas characterized by very similar geology, orography and climate [14-17]. Inside HERs, watercourses may show low variation of chemical physical and biological parameters (although this latter aspect was mainly developed in France) [14]. River catchments of diverse HERs should differ in at least one of the four above-mentioned parameters [14].

The great problem of HER's characterization was represented by their scale. Cemagref defined low resolution scale HER boundaries for Europe and particularly for France [14]. In fact, the first low resolution of HER definition causes some practical problems in the abiotic and biotic data collection due to the absence of the exact HER limits.

Therefore, in the next step every single member state should carefully define the HER boundaries at fine level also by using local experts knowledge. This fundamental aspect for the river monitoring activities

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has been hitherto ignored. In Italy the state delegated regions and local authorities to deal this step as required by national legislation [18].

The main feasible purpose was to better define the HER boundaries according to local heterogeneity. The main aspects which should be revisited regard both the borderline rivers, which fall into different HERs, and the local discontinuities obviously neglected on a larger scale characterization. Therefore, boundaries should be better calibrated following an expert judgement proposed by people who better know the regional territory. In Europe and in particular in Italy, this step has not yet been done and this is evident observing the unclear aberrations at fine scale.

The main goal of this study is to evaluate the reliability of HERs proposed by Cemagref and to propose a new map for the central Italy HERs by using the region Latium as case study in order to promote adequate management planning and environmental monitoring activities which are more coherent with the considered topographic diversity. To do this, we will use local maps in order show a local territory classification using the same criterion used by Cemagref. Than, we compare the two maps to evaluate how Cemagref map is consistent for Latium and to improve map according to local heterogeneity.

MATERIALS AND METHODS

HER boundaries were redefined in a central Italy region (Latium) covering an area of 17,207 km². It is placed on the middle Tyrrhenian side, extending from the Apennines to the Tyrrhenian Sea and mainly characterized by hill and mountain landscapes. Lowlands are mainly confined near the coast. Main Latium rivers are highlighted in Figure 1a.

The regional heterogeneity is the main driver for the HER division. In particular, Latium region is principally covered by three hydroecoregions: HER13 (Central Apennines), HER14 (Rome and Tuscia) and HER15 (Lower Latium). Furthermore Latium has minimal portions marginally involved in the hydroecoregions HER11 (Tuscany) and HER18 (Southern Apennines).

Hydroecoregional boundaries were modified according to a more accurate identification of regional heterogeneity, also obtained by a detailed knowledge of the study area. In particular, large scale differences were mostly confirmed whereas local boundaries have been revised. Major changes concern water courses

belonging to different HER. The new boundaries were re-drawn avoiding to split the same river with same geological condition in two different hydroecoregions according to [14].

The new HER map was obtained by the geospatial analysis overlapping the hydrogeological map of Latium [19] and the phytoclimate map of Latium [20] within ArcGis 9.3 ESRI software. Reference system was ED50 with 33N fuse for both maps. These maps were comparable with maps used by Cemagref although the most important difference regard scale. More detailed scale maps used for this study allowed to highlight local territory or climatical discontinuity not detected by using low resolution detailed maps as made by the Cemagref. Than, the resulting map was subsequently compared with the old Cemagref HER map to evaluate differences and to better define HER boundaries [14].

RESULTS

Both Cemagref and new maps are shown in Figure 1. Results highlight that the division of the Latium HERs proposed by Cemagref is almost confirmed even taking a study based on more detailed scale maps into account. Main differences concern the exact boundary placement of the four squares in Figure 1c-f. These focal points were evenly distributed throughout the region. The first two concern the definition of HER11 (Tuscany). Its boundaries were identified by the River Fiora in the NW part of the region (Figure 1c). This area was redefined to entirely include the river within the HER11. In fact, Fiora river sources fall within the same hydroecoregion. Something similar was proposed for the Tiber river. The river was entirely included within the HER11 to up to the confluence of the Farfa river by the Cemagref map. This representation was confirmed but the included strip of territory was reduced. Indeed, only the territory closely connected with the same water course was included into HER11 while the tributaries from the left and right side were fully included into the HER13 and HER14, respectively (Figure 1d). The third spot area correspond to the central part of Latium region. The border area between HER13, HER14 and HER15, corresponding to the central-southern zone of the region, was partially modified as shown in Figure 1e. The entire Aniene river was included into HER13 including its terminal portion and all the tributaries. The last revised critical area concerns the Sacco river. This river was watershed between the HER13 (upstream portion from the source to the 22nd km) and the

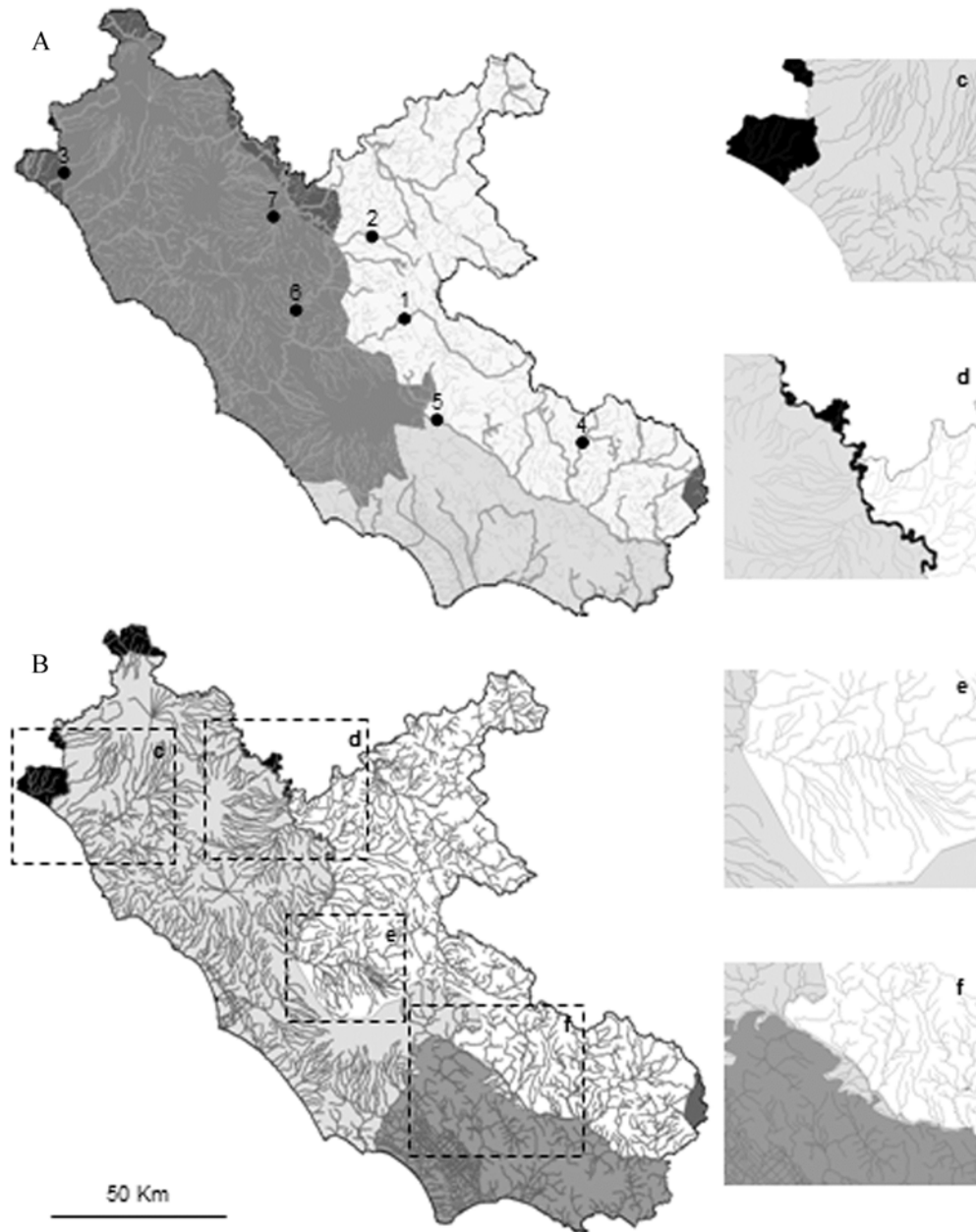


Figure 1: HER's location within the study area as proposed by Cemagref (a) and revised (b). c = Particular of HER11 including River Fiora; d = Particular of HER11 including River Tiber; e = Particular of HER13 including River Aniene; f = Particular of HER14 including River Sacco; 1 = River Aniene; 2 = River Farfa; 3 = River Fiora; 4 = River Liri; 5 = River Sacco; 6 = River Tiber; 7 = River Treia.

HER15 (the remaining portion until the confluence into the Liri river). Considering the uniformity of the territory in which the Sacco river flows, it was entirely placed in HER14 for the entire section (Figure 1f). Actually, the entire stream flows within an acidic area very similar to that which characterizes the HER14. The remaining course of this river continued flowing into HER13.

DISCUSSION

The new HER assessment focused the attention on aquatic ecosystems and their characteristics in relation

to terrestrial ecosystems. This is based on an approach in which global control factors (mainly geology, topology and climate) determine the conditions observed in the rivers [14].

As climate concerns, Latium is a climatically very homogeneous region and it's roughly divided into three major portions [20]: (i) the Mediterranean area including the great part of HER15, (ii) the Mediterranean transition area including the HER14 area, (iii) the temperate zone involving HER13 also according to Cemagref proposal [14]. In fact, climate

was the first factor used to represent European heterogeneity. As a consequence a first regionalization was obtained. Geological and topological maps were then exploited in order to achieve a more precise and detailed characterization of the investigated area.

The Cemagref hydroecoregions are consistent with European scale maps. Important local revisitation in order to define more precise boundaries and extensions for each hydroecoregion are required. The WFD provided several basic points, a most important one regarded watercourses reference conditions within any HER. The concept of reference conditions is related to the "naturalness" of the biota, such as rivers showing the absence of human alteration [21, 22] and, as such, represent a target for remediation and restoration. Reference conditions vary according to HER and this is a basic aspect to led to better define HER boundaries according to fine territory and climate heterogeneity. For these reason, reference condition will then serve as a comparison parameter for all subsequent measurements representing a target for remediation and restoration [22]. As this aspect concerns, stream size and source distance descriptors resulted required elements as defined by the WFD [9]. As Italy concerns, the Water Research Institute belonging to the National Research Council (IRSA - CNR) proceeded to characterize italian watercourses according to WFD and as Cemagref underlined in its hydroecoregionalization approach. This led to subdividing streams into distance bands based on source distance: a) 1-5 km; b) 6-25 km; c) 26-75 km; d) 75-150 km; e) >150 km [23]. This is an essential management purposes because reference conditions (also called reference sites) must be defined for anyone of these bands. In particular, each reference site must be valid for the entire HER and an optimum reference condition for all HERs must be established for any band. This is a focal point as all sites must be compared with others belonging to the same band [9]. All these aspects highlight how the necessity to better define HERs boundaries is a fundamental aspect for the implementation of management plans of internal watercourses. The allocation of a river (or a river trait) in a specific HER is therefore fundamental to its classification and need to be done consistently with the existing similarities and heterogeneities. The WFD delegated each Member State to take actions in order to carry out all these points, as it has been done by Cemagref in France. Cemagref showed that a local study conducted by the signatory states of the WFD was a fundamental step for the correct definition of

HER boundaries at a local scale. It underlined also that evaluating the detailed knowledge of a study area (along with the previously mentioned key parameters) was a useful and necessary requirement to include locally natural discontinuity in these studies [14]. Italy implemented this input only in 2006 [18] but has not still taken significant actions in this regard. In particular, it delegated Regions and local authorities to carry out this step (each in its own territory).

The correspondence between the Cemagref map and our one emphasizes how maps used by the authors were actually valid to propose a comparison at different scale. Similarly, the greater local knowledge was fundamental to remove some inconsistencies not observed to a less detailed analysis allowing to more precisely define HER boundaries.

Our study responded to this necessity on a fine scale in order to fulfil the European Commission requests [9]. The more detailed scale map obtained is more in line with regional heterogeneity and climate. All this considerations allows to better define similarities and differences both between streams and within the same stream. A critical component is to correctly and entirely locate each water course within the same HER. Indeed, management and monitoring activities vary according to the HER in which a river (or a portion of a river) is located since reference conditions and, consequently, water quality judgment may change [21, 22]. This can lead to an incorrect definition of the environmental status of a river which does not allow to better manage this resource. All these may be valuable tools to use to implement watercourses management and monitoring plans. These could constitute the scopes for further investigations on HER biotic differences, overlapping biotic maps informations. It would be important to follow up this study by proposing a similar approach for the entire national territory. This step requires interaction between experts and people who know the single regions. In fact, the knowledge of each region is a fundamental, not negligible requirement.

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