Ecological Engineering 53 (2013) 173–182

Contents lists available at SciVerse ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Ecological status of rivers in preserved areas: Effects of meteorological parameters

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ARTICLE INFO

Article history:
Received 2 August 2012
Received in revised form 8 November 2012
Accepted 3 December 2012
Available online 29 December 2012

Keywords:
Brown trout
Environmental status
Habitat suitability models (HSMs)
Minimum environmental flow
Non-parametric tests
Surface waters
Water quality

ABSTRACT

The assessment of aquatic ecosystem health has been totally revised in European countries, driven mainly by the European water framework directive (WFD), which requires member states to assess the quality of rivers. Watercourses quality is strongly influenced by both meteorological conditions and human activities; aim of the present work is to investigate potential links between meteorological parameters and ecological quality of a river. In order to reduce surrounding interferences due to the human presence, the study has been focused into a preserved area.

The work deals with the case study of the Calore Irpino river, in the Regional Park of "Monti Picentini" (Southern Italy), where ecological quality of the watercourse has been monitored for 5 years, together with meteorological parameters. Ecological quality has been evaluated through the introduction of a set of macroindicators that have been monthly screened for 5 years, according to European and Italian legislation. Based on the hydrological and weighted usable area (WUA) method, the minimum environmental flow was then evaluated considering the most dominant fish species (Brown Trout) as target organisms, and the related habitat suitability models (HSMs) for water depth, current velocity and substrate. These elements are connected with meteorological parameters such as rainfall, therefore the WUA method may better explain causative links between meteorological and water quality parameters, biological and hydrological ones, which have been investigated and discussed in this work. Results confirm the presence of a mutual bond between meteorological and water quality that should raise awareness of both academics and professionals. This knowledge contributes to both the definition of water quality protection plans, supported by a specific chemical and biological monitoring plan, and environmental restoration activities, to foster the river hydrological-hydraulic states variability and to support the living communities.

1. Introduction

River water is an essential renewable resource for both human beings and environment, and it is important for civil (irrigation, transportation), industrial (processing and cooling, energy production, fishery) and recreational purposes (Vicente et al., 2011, Mostert, 2003). Sustainable use of water resources requires the coupling of surface waters assessment monitoring programs (Nikolaou et al., 2008, Naddeo et al., 2007), decision making (Postel and Richter, 2003) and management tools (Acreman and Dunbar, 2004; Chen et al., 2009; Naddeo et al., in press). It is, therefore, mandatory their ecological quality assessment, as required in several legislations, e.g. Water Framework Directive (WFD) 2000/60/EC, and Italian Executive Order No. 152/2006. In addition, water managers and researchers are nowadays dealing with climate changes: for instance, temperature and rising sea level may produce significant impacts over the hydrosphere (Mitsch et al., 2008; Park et al., 2010). Scientific community has to investigate on the potential effects of climate change over the ecological quality of watercourses and vice versa (Pedersen et al., 2007; Naddeo et al., 2008; Marttila and Klove, 2010; Wilson and Weng, 2011).

Climate change in IPCC (Intergovernmental Panel on Climate Change) usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This differs from what reported in the framework convention on climate change, where climate change refers to a change of meteorological parameters that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere (Mc Carthy et al., 2001). Available observational evidence indicates that regional changes in meteorological parameters, particularly increases in temperature, have already affected a diverse set of physical and biological systems in many parts of the world (Petrovic

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http://dx.doi.org/10.1016/j.ecoleng.2012.12.039

et al., 2011). Reduction of river flows in a dry season would result in more extensive and severe marine intrusion, which in turn would lead to reduction of areas available for plantation, crop losses, reduced yields, severe local socio-economy and environmental impacts and major negative consequences for the national economy. Water quality, however, also will be affected by stream flows (Zhai et al., 2010), as well as both pollutants concentrations and total loads. Research (Frisk et al., 1997; Kallio et al., 1997) indicates that changes in stream water quality, in terms of eutrophication and nutrient transport, are very dependent on changes in stream flow. Alexander et al. (1996) suggest that nutrient loadings to receiving coastal zones would vary primarily with stream flow volume. Long drought period may have a noticeable effect on water quality, e.g. with regards to temperature, DO, BOD_5, NH_4^+ and chlorine concentration (Mimikou et al., 2000; Senhorst and Zwolsman, 2005). A reduction in stream flow might lead to increase in peak concentrations of certain chemical compounds.

The attention is also focused on applying the scientific knowledge to determine the environmental flow, defined as the water volume, through time, required to maintain river health in a good state, and to guarantee the water biocoenoses survival, water body protection, and the multiple resource uses (Junk et al., 1989; Hill and Beschta, 1991; Poff et al., 1997; Norris and Thoms, 1999; Acreman and Dunbar, 2004).

The environmental flow is usually determined through different methods, mainly classified into four categories: hydrological method, hydraulic method, habitat method and holistic method (Thame, 2003; Ahmadi-Nedushan et al., 2006; Halleraker et al., 2007). Among these, habitat method based on quantitative biological information integrates flow-related changes with the preferred hydraulic habitat conditions for target assemblages, so it is currently regarded as the most widely used evaluation method (Thame, 2003; Yang and Zhang, 2003). Instream flow incremental methodology is one of the most widespread and advocated habitat methods, which combines a large amount of hydrological in situ data and specific aquatic organisms (e.g. fish, benthic macroinvertebrate, and macrophyte) information to assess the effect of flow variation on biological habitat available over a possible range of flows (Stalnaker et al., 1995). This method is widely used in more than 20 countries, including the US, Italy, France, Germany, Japan, China, Czech Republic and the UK (Thomas, 1998; Thame, 2003; Belgiorno et al., 2004; Li et al., 2009). For further calculation of instream environmental flow, development of a particular and veracious site-specific habitat suitability model (HSM), repeatedly built for water depth, current velocity, and substrate is necessary. Therefore, other investigations are needed concerning the river hydromorphological characteristics, its physical and chemical quality, water biocoenoses and phytocoenoses, as well as the natural landscape.

According to European (WFD) and Italian (Executive Order No.152/2006) legislation, this study has been focused on the characterization of water quality of the Calore Irpino River, which partially flows in the Regional Park of "Monti Picentini", and the minimum environmental flow assessment by the hydrological and weighted usable area (WUA) methods, choosing the brown trout (*Salmo trutta fario* L.), which is the predominant fish species, as river target organism (Qu et al., 2005). After the definition of its ecological quality of the river in 5 consecutive years, an assessment of potential interactions between meteorological parameters and water quality has been performed. This correlation can be properly assessed especially in areas such as natural parks and wildlife reserves, where human activities are still scarce. Therefore, in this work a correlation analysis has been performed in a preserved area context, namely the "Monti Picentini" regional park. This choice has led to find an association between changes in water parameters (e.g. BOD_5, DO, etc.) and elements that are regarded as expressions of meteorological change, such as rainfall, air temperature or humidity.

2. Materials and methods

2.1. Territorial framework

Calore Irpino river originates from the ridge of Accellica, Serralonga and Sovero Mountains in the Regional Park of "Monti Picentini" and it is one of the main rivers in the Campania Region (Southern Italy, Fig. 1). Calore Irpino river is a Volturno river tributary, having a length of 115 km, a catchment area of 3058 km^2 and a mean daily flow that ranges from 2 to 32 $m^3 s^{-1}$. The basin upper part is characterized by predominantly limestone reliefs. The middle and lower basin area is characterized by tertiary flysch formations and pliocene and quaternary land. The river bed is mainly pebbly with local sand banks. Silt deposits are quickly colonized by herbaceous essences; the surrounding alluvial areas are covered by bushes, herbaceous vegetation and discontinuous riparian formations, consisting mainly of willows and poplars.

Regarding the flow regime, in the basin upper part, the continuous water abstraction for potable use makes the river flow strongly influenced by the rainfall in autumn and winter. Near the Cassano Irpino wastewater treatment plant, the river receives potable water due to release of Pollentina sources abstractions superabundance. After that, the Calore crosses an industrial area with a substantially straight course and rectangular sections (width exceeding 40 m and height greater than 4 m) stabilized by sheet piling. In its last part, the river crosses a floodplain where tobacco cultivation, that requires large amounts of irrigation water–especially in the period from May to September–is widespread.

2.2. River water quality

2.2.1. Monitoring network

Sampling sites number and location were established taking into account the presence of urban settlements, production plants and all polluting loads, hydrological nature and environmental impacts due to water abstractions and discharges (Fig. 1).

Section C1 is located near the confluence of a tributary characterized by a flow greater than the main channel in summer. Section C2 corresponds to the mouth of the river mountain stretch in the main valley. Sections C3 and C4 are located downstream from a tributary confluence and just upstream from an abstraction by hydroelectric plant, as well as Cassano Irpino sources derivations. Section C6 is placed downstream from the Cassano Irpino sources derivations, and is hardly affected by a flow reduction induced by human activities. Sections C5 and C6 are respectively located upstream an industrial area and downstream the hydroelectric plant discharge point. Section C5 is characterized by a bridle. The first sampling station (C1) is located into the preserved area, and is close to the Montella weather station, where meteorological parameters are continuously monitored.

2.2.2. Analytical methods

According to the Italian river monitoring procedure (Naddeo et al., 2007), during the period from January 2005 to December 2009, the water quality was monthly analyzed monitoring river flow, pH, suspended solids (SS), water temperature and 7 macroindicators: NH_4-N, NO_3-N, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total phosphorus (P) and *Escherichia coli*, using analytical methodologies set out by the Italian Research Council (IRSA-CNR, 1994; USEPA, 1994, 1996, 1998, 2006).