Ecotoxicology and Environmental Safety 132 (2016) 295–303

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

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

Ecological impact and recovery of a Mediterranean river after receiving the effluent from a textile dyeing industry

Nicole Colin [a,b], Alberto Maceda-Veiga [b,c,*], Núria Flor-Arnau [d,e], Josep Mora [e], Pau Fortuño [e], Cristiana Vieira [f], Narcís Prat [e], Jaume Cambra [d,e], Adolfo de Sostoa [a,b]

[a] Department of Animal Biology, Facultat de Biologia, Universitat de Barcelona (UB), 08028 Barcelona, Spain
[b] Biodiversity Research Institute (IRBio), Facultat de Biologia, Universitat de Barcelona, 08028 Barcelona, Spain
[c] Department of Integrative Ecology, Estación Biológica de Doñana (EBD-CSIC), 41092 Sevilla, Spain
[d] Department of Plant Biology, Facultat de Biologia, Universitat de Barcelona (UB), 08028 Barcelona, Spain
[e] Grup de Recerca Freshwater Ecology and Management (FEM), Departament d'Ecologia, Facultat de Biologia, Universitat de Barcelona (UB), 08028 Barcelona, Spain
[f] CIBIO-InBIO, Universidade do Porto, Campus Agrário de Vairão, Rua Padre Armando Quintas, 4485-661 Vairão, Portugal

ARTICLE INFO

Article history:
Received 30 November 2015
Received in revised form
21 May 2016
Accepted 14 June 2016
Available online 23 June 2016

Keywords:
Bioindicators
Ecosystem health
River self-depuration
Community structure
Multiple stressors
Seasonal effects

ABSTRACT

The textile industry is one of the largest sectors globally, representing up to 20% of industrial water pollution. However, there is limited insight into how fluvial ecosystems respond and recover from this impact. From summer 2012 to spring 2013, we examined water quality and ecological status upstream and 1.5 km downstream the input of a textile industry wastewater treatment plant (WWTP) in Ripoll River, NE Spain. The ecological status was determined via diversity measures and 10 biotic indices based on diatoms, macrophytes, macroinvertebrates and fish. Our results showed that the WWTP severely deteriorated water quality and biological communities at the discharge site, but that they improved at 1.5 km downstream. Severity also varied across taxa and seasons, being fish the most affected taxa and spring the season with the best ecological status. The strong correlation amongst water quality variables and many biotic indices across taxa indicated that this is a chronic pollution event affecting multiple trophic levels. Thus, this study suggests that there is an urgent need to invest in wastewater treatment in this industry to preserve the ecological integrity of Ripoll River and especially its fish fauna. Likewise, it illustrates the diagnostic power of biotic indices based on diatoms, macroinvertebrates and fish, as driven by the European Water Framework Directive.

1. Introduction

The textile industry is one of the largest sectors globally, representing up to 20% of total industrial water pollution (Keenan et al., 2004; Zaffalon, 2010). Effluents from textile industries contain many pollutants including heavy metals, dyes, acids, and flame retardants that do not naturally degrade and are discharged into surface waters after a conventional wastewater treatment (WWTP) (Zaffalon, 2010). In semi-arid regions, such as the Mediterranean area, the environmental risk is particularly acute because the low dilution ability of rivers intensifies pollution stress, especially in the drought season (Petrovic et al., 2011). Seasonal changes in temperature also modulate the toxic action of pollutants on the aquatic biota, including algae (Chalifour and Juneau, 2011), plants (Chawla et al., 1991), invertebrates (Maceda-Veiga et al., 2015a), and fish (Chandra et al., 2012). Thus, inter-seasonal studies examining how aquatic communities respond to the effluents from textile industries are central to fully determine their ecological impact.

Driven by the international legislation such as the EU's Water Framework Directive (2000/60/EC), biological indices (BI) are widely used in official monitoring schemes to appraise the ecological impact of anthropogenic insults, including sewage discharges, on aquatic communities (Barbour et al., 1999; Bonada et al., 2006; Friberg et al., 2011). These procedures based their diagnostics in comparing community structure attributes (metrics) of sentinel taxa, mostly diatoms, macroinvertebrates, and fish, in tested sites against those expected in reference conditions (Karr, 1981; Munné and Prat, 2009; Hering et al., 2010; Birk et al., 2012; Feio et al., 2014). Despite criticisms and caveats (Bonada et al., 2006; Friberg et al., 2011), BIs continued popularity can be explained by their simplicity (Dallas, 1997; Chessman et al., 1997). A major concern is when BIs developed initially to detect organic

* Corresponding author at: Department of Integrative Ecology, Estación Biológica de Doñana (EBD-CSIC), ES-41092 Sevilla, Spain.
E-mail address: albertomaceda@gmail.com (A. Maceda-Veiga).

http://dx.doi.org/10.1016/j.ecoenv.2016.06.017
0147-6513/

pollution are used as generic water quality indicators (but see Sabater, (2000), Carafa et al. (2011) and Munné and Prat (2011)). Further, the use of multiple taxa may be seen as an unjustified increase in monitoring costs, as relatively few studies have compared the diagnostic value of BIs using more than two taxa in Europe (Hering et al., 2006), including Mediterranean rivers (e.g. Blanco et al., 2007; Benejam et al., 2008; Marzin et al., 2012). As conservation budgets are increasingly constrained, there is an urgent need to gain insight into how multiple BIs across taxa respond to different combinations of stressors; this will also help resource managers to identify the most vulnerable taxa at an age when freshwater diversity is declining at unprecedented rates (Strayer and Dudgeon, 2010).

Most research into the ecological impact of textile industry waste is based on bioassays (e.g. Graça et al., 2002; Sharma et al., 2007; Tigini et al., 2011). There is also some evidence of the effects of textile effluents on particular taxa in the field (Giorgi and Malacalza, 2002; Gómez et al., 2008) but, as far as we are aware, the entire structure of the aquatic community has not been specifically investigated. In this study, we examine in detail the combined effects of season and the effluent from a textile dyeing industry WWTP on water quality and the structural integrity of the aquatic community along 1.5 km in a Mediterranean river. While chemical surveys only identify a fraction of environmental pollutants, biological indicators assess the overall effects of measured and unmeasured pollutants interacting with natural and other anthropogenic stressors in the complexity of natural systems (Munné and Prat, 2009; Friberg et al., 2011). In this regard, we used diversity measures and scores of 10 BIs based on diatoms, macrophytes, macroinvertebrates and fish to test three hypothesis. First, we expected that proximity to the discharge site, particularly in low flow conditions, would intensify the impact of the effluent on the river, as defined by poor water quality, low diversity of aquatic taxa and low BI scores. Second, if all indicators have the same diagnostic value, we expected them to show similar patterns. Finally, as rivers can self-depurate (e.g. Cerqueira et al., 2008), we predicted an increase in the water quality and ecological status of the river downstream the discharge site.

2. Materials and methods

2.1. Study area

This study was carried out along a 1.5 km reach in the Ripoll River, Spain, exposed to the effluent of a textile dyeing industry built in 1960s (41°37′27″N, 2°04′22″E, Fig. 1). To assess its ecological and environmental impact, we sampled seasonally water quality and four sentinel taxa at the same time in one upstream sampling site (reference site, R1) and three downstream sites (P1, P2 and P3) in July 2012 (summer), November 2012 (autumn), February 2013 (winter) and early June 2013 (spring). Previous studies examining water quality and ecological status confirm the reference status of R1 (e.g. Prat and Rieradevall, 2006). Our study area is unique in enabling us to assess the effects of a textile industrial effluent on the aquatic biota, as a nearby urban area discharge their waste water into a sewage treatment plant downstream our study area. This area has calcareous geology and a typical Mediterranean climate, with torrential floods in autumn and spring. Water abstraction for industry and human consumption reduces further river water flow, ranging from 0.005 m^3/s to 2.8 m^3/s in the nearest downstream town to our study area over the last 10 years (ACA, 2016). Whilst data on the volume of the industrial effluent was not available to us, it represents a large fraction of river water flow, especially during drought, as occurs in many Mediterranean rivers (Prat and Munné, 2000). The substrate was mainly composed of cobbles, and no physical barriers exist between the discharge site and our last downstream sampling site. Riparian area is dominated by evergreen oak trees (*Quercus ilex*) and Aleppo pines (*Pinus halepensis*), with patches of giant reed (*Arundo donax*), wild blackberry (*Rubus ulmifolius*) and small crops. The fish fauna consisted of two native species, the Mediterranean barbel (*Barbus meridionalis*) and the Ebro chub (*Squalius laietanus*), and two exotic species, the common carp (*Cyprinus carpio*) and the pumpkinseed (*Lepomis gibbosus*).

2.2. Water and physical habitat quality

Prior to survey the aquatic community, we analysed water quality in each sampling site using a multi-parametric digital

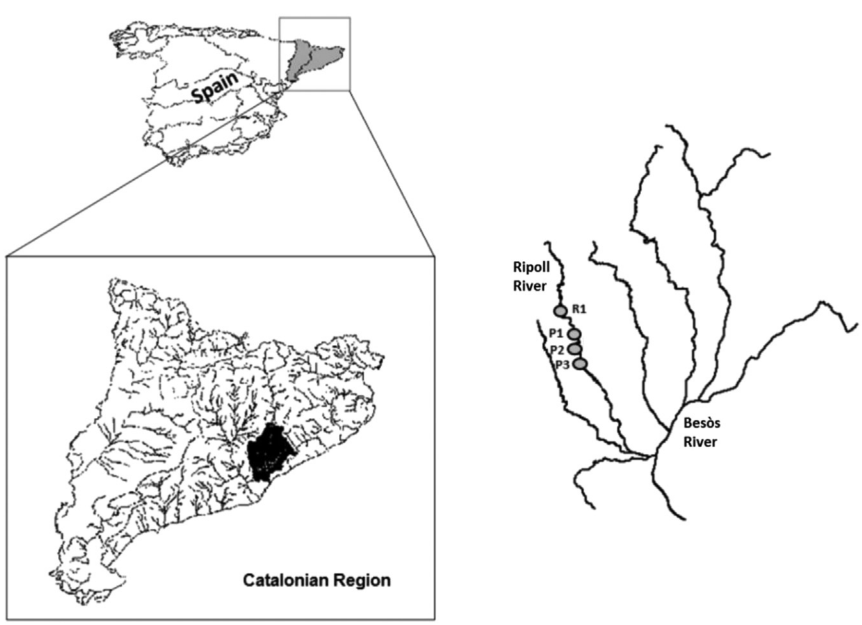

Fig. 1. Location of sites sampled from summer 2012 to spring 2013 in NE Spain. Upstream (R1) and downstream sites (P1, P2 and P3) of the discharge site of the effluent from a textile industry wastewater treatment plant were evenly distributed along a 1.5 km river reach.