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1 **Local versus landscape spatial influency on biodiversity: a case study across five European**  
2 **industrialized areas**

3 **Piano E<sup>1</sup>, Isaia M<sup>\*1</sup>, Falasco E<sup>1</sup>, La Morgia V<sup>2</sup>, Soldato G<sup>1</sup>, Bona F<sup>1</sup>**

4 <sup>1</sup>Department of Life Sciences and Systems Biology, University of Turin, Via Accademia Albertina 13, 10123  
5 Turin, Italy

6 <sup>2</sup> ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale, Via Ca' Fornacetta 9, Ozzano  
7 dell'Emilia (BO), Italy

8 \*corresponding author: marco.isaia@unito.it ; 011/6704544

9

10 **Abstract**

11

12 Land use change—mostly habitat loss and fragmentation—has been recognized as one of the major drivers  
13 of biodiversity loss worldwide. According to the habitat amount hypothesis, these phenomena are mostly  
14 driven by the habitat area effect. As a result, species richness is a function of both the extent of suitable  
15 habitats and their availability in the surrounding landscape, irrespective of the dimension and isolation of  
16 patches of suitable habitat. In this context, we tested how the extent of natural areas, selected as proxies of  
17 suitable habitats for biodiversity, influences species richness in highly anthropogenic landscapes. We defined  
18 five circular sampling areas of 5 km radius, including both natural reserves and anthropogenic land-uses,  
19 centred in five major industrial sites in France, Italy and Germany. We monitored different biodiversity  
20 indicators for both terrestrial and aquatic ecosystems, including breeding birds, diurnal butterflies, grassland  
21 vegetation, odonata, amphibians, aquatic plants and benthic diatoms. We studied the response of the different  
22 indicators to the extent of natural land uses in the sampling area (local effect) and in the surrounding  
23 landscape (landscape effect), identified as a peripheral ring encircling the sampling area. Results showed a  
24 positive response of 5 out of 7 biodiversity indicators, with aquatic plants and odonata responding positively  
25 to the local effect, while birds, vegetation and diatoms showed a positive response to the landscape effect.  
26 Diatoms also showed a significant combined response to both effects. We conclude that surrounding  
27 landscapes act as important biodiversity sources, increasing the local biodiversity in highly anthropogenic  
28 contexts.

29

30 **Keywords:** habitat amount hypothesis, biodiversity indicators, land use, species richness

## 31 **Introduction**

32

33 Land use change has been recognized as one of the major drivers of biodiversity loss worldwide (Sala et al.  
34 2000; MEA 2005), causing species loss and biotic homogenization (Hendrickx et al. 2007; Billeter et al.  
35 2008; McKinney 2008; Johnson et al. 2013; Tudesque et al. 2014; Turrini and Knop 2015; Knop 2016). In  
36 particular, the conversion of natural areas into agricultural lands, the intensification of agricultural practices  
37 and the increase of urban areas are among the most frequent land use changes (Kleijn et al. 2006; Kleijn et  
38 al. 2009; Parris 2016). This process also affects freshwater ecosystems since humans live disproportionately  
39 near waterways (Sala et al. 2000), consequently altering water quality because of increased nutrient input and  
40 chemicals run-off (Foley et al. 2005).

41 Anthropogenic landscape alteration negatively influences biodiversity through habitat loss—reduction in the  
42 proportion of a landscape composed of suitable habitat for focal species—and habitat fragmentation—  
43 changes in the arrangement or configuration of the remaining habitat (Chhabra et al. 2006; Vitousek et al.  
44 2008; Smith et al. 2009; Hooke et al. 2012). However, because habitat loss and fragmentation are highly  
45 correlated, it is difficult to disentangle the contribution of each process to biodiversity loss (Smith et al.  
46 2009). This constraint is overcome in the context of the “habitat amount hypothesis”, which considers these  
47 phenomena to be driven by a single underlying process, the habitat area effect (Fahrig 2013). According to  
48 this hypothesis, species richness is a function of both the extent and the availability of suitable habitats in the  
49 surrounding landscape, irrespective of the dimension and the isolation of patches of suitable habitat. The  
50 effects of land use change on biodiversity can thus be measured by focusing on the amount of suitable  
51 habitats. In consequence of that, the preservation of natural land use areas, even in small isolated patches,  
52 may be considered a key management aspect for the preservation of biodiversity in human-dominated  
53 landscapes.

54 In the present paper, we aim at the identification of general patterns of species richness across different taxa,  
55 both terrestrial and aquatic, in order to investigate the habitat amount hypothesis in human-dominated  
56 landscapes. We here considered areas with high ‘naturalness’, i.e. internal characteristics of low local  
57 intensity of human disturbance (Kappes et al. 2011), as proxies of suitable habitats in five anthropogenic  
58 landscapes across Europe, characterized by the co-occurrence of natural reserves and industrial complexes.  
59 In particular, we tested how the extent of natural land use areas in anthropogenic landscapes influences  
60 biodiversity measured in terms of species richness of multiple taxa from both terrestrial and aquatic  
61 ecosystems. We considered i) the influence of the extent of natural land use on the local biodiversity within a  
62 5 km radius circular sampling area (*local effects*) and whether ii) the local biodiversity was influenced by the  
63 extent of natural land use occurring in the surrounding landscape defined as a ring buffering the sampling  
64 area (*landscape effects*).

65

## 66 **Materials and methods**

67

### 68 Sampling design

69

70 This work was developed in collaboration with FCA Group and CNH Industrial, in the framework of the  
71 Biodiversity Value Index project (BVI), aiming at evaluating the state of biodiversity in five industrial sites  
72 in Europe (Fig. 1). We selected five industrial areas (hereinafter study sites), constituted by the aggregation  
73 of several industrial buildings: FPT Powertrain Verrone, Magneti Marelli Venaria and IVECO Suzzara in  
74 Italy, FPT Industrial Bourbon-Lancy in France and IVECO Magirus Ulm in Germany (Tab. 1). All industrial  
75 complexes were located in the nearby (<5 km) of natural reserves within the same biogeographic area  
76 (continental), i.e. areas protected according to the national legislation — National Natural Reserves — or to  
77 the European Natura 2000 Network — Sites of Community Importance and Special Areas of Conservation.

78 For each study site, we defined a circular sampling area of 5 km radius, centred in the industrial complex.  
79 We chose to work in an area buffering the main source of disturbance in accordance with the guidelines for  
80 the environmental implication assessment provided for Natura 2000 Network sites (European Commission  
81 Environment 2002). The surface occupied by industrial complexes was always inferior to 4% of the total  
82 area. However, other types of anthropogenic land uses were present, i.e. urban and agricultural.

83 We obtained land cover data from the Corine Land Cover 2006 project (European Environmental Agency  
84 2006, <http://www.eea.europa.eu/publications/COR0-landcover>). We used Quantum Gis Desktop (Quantum  
85 Gis Development Team 2015, software version 2.10.1) to calculate the percentage of coverage of each land  
86 use type inside the sampling areas by taking the following steps: i) drawing of the sampling area of 5 km  
87 radius around each industrial complex; ii) overlap of the sampling area with the Corine Land Cover data and  
88 intersection; iii) calculation of the percentage of each land use.

89 We differentiated Corine data in artificial land use (urban and industrial), intensive agriculture, extensive  
90 agriculture and natural land use (forested classes, wetlands and water bodies). For each land use category, we  
91 extrapolated the areas and summed together to obtain a measure of their extent. We focused on natural land  
92 use and we expressed the surface data in percentages. The same land use measure was extrapolated for the  
93 surrounding landscape identified as a ring of 2.071 km of semi-radius extending around each sampling area.  
94 The 2.071 km semi-radius was chosen in order to obtain a surrounding landscape covering the same surface  
95 of the sampling area. It is important to notice that the extent of natural land use does not necessarily  
96 correspond to the extent of protected reserves, since anthropogenic land uses may be included in protected  
97 areas (Fig. 1).

98 Inside the sampling area (i.e. the 5 km radius circle), we considered both terrestrial and aquatic ecosystems.  
99 For terrestrial ecosystems, we focused on open field habitats, while for aquatic ecosystems we considered  
100 both lentic and lotic habitats. For each habitat, 10 sampling plots located inside the protected reserves  
101 included in the sampling area were randomly selected. We chose seven taxonomic groups that proved to be  
102 valuable biodiversity indicators according to literature. These are breeding birds, diurnal butterflies and  
103 grassland vegetation for open field habitats (Overmars et al. 2014; Manning et al. 2015; Van Swaay et al.  
104 2015), odonata, amphibians and aquatic plants for lentic habitats, i.e. ponds (Oertli et al. 2005; Angélibert et  
105 al. 2010; Menetrey et al. 2011), and benthic diatoms for the lotic habitats, i.e. rivers, streams and channels  
106 (Falasco & Bona 2011; Falasco et al. 2012).

107

108 Data collection

109

110 All biodiversity indicators were identified at the species level and sampled in accordance with standard  
111 protocols as follows.

112 *Breeding birds*

113 For the evaluation of the bird community, point counts were performed in accordance with Bibby et al.  
114 (2000). In each sampling plot, the operator listened to songbirds and looked for individuals for 10 minutes  
115 within a 100 m<sup>2</sup> area. All individuals surveyed or heard were identified and counted. Surveys started few  
116 minutes after dawn and ended before 10 AM. Surveys in rainy or windy days were avoided. Bird surveys  
117 were conducted during late spring and repeated in early summer, in order to assure that only breeding birds  
118 were recorded (Tab. 2).

119 *Diurnal butterflies*

120 We sampled diurnal butterflies along linear transects with a semi-quantitative method: a straight 100 m path  
121 was covered at a constant speed, while counting butterflies in an area of 5 m in height and 2.5 m to the right  
122 and to the left of the operator (Pollard and Yates, 1993; van Swaay et al. 2012). Surveys were performed  
123 during the warmest hours of the day (late morning - early afternoon), when the butterflies are most active,  
124 avoiding the collection of data on days with bad weather (strong wind or heavy rain). Surveys were repeated  
125 at least three times over the warm season (Tab. 2). Individuals were captured and subsequently released after  
126 their identification by means of field characters. When a butterfly could not be identified in the field,  
127 specimens were collected and subsequently identified in the laboratory.

128 *Grassland vegetation*

129 Grassland vegetation was investigated with the method of Braun-Blanquet (1964). For each sampling plot,  
130 we defined a 50x50 m square in a homogeneous area, avoiding ecotones in order to have standardized  
131 surveys in all sites. The presence of all species inside the square was recorded in order to get a  
132 comprehensive list. Surveys were repeated at least three times over the vegetative season (Tab. 2). Species  
133 were identified according to Tutin et al. (2001) and Pignatti (1982).

#### 134 *Odonata*

135 Odonata were sampled by visual census, in accordance with Bouwman et al. (2009). The presence of adult  
136 specimen was detected along transects on the perimeter of the ponds. Zygopteran and *Sympetrum* species  
137 were counted respectively within 2 m from the shore and 3 m from the water; the other species were  
138 considered within 5 m from the water. Surveys lasted half an hour and were performed during the warmest  
139 hours of the day (late morning - early afternoon) when Odonata are most active, avoiding the collection of  
140 data on days with bad weather (strong wind or heavy rain). Flying individuals were identified *in situ*. In each  
141 plot, two surveys were performed — a spring session and a summer session (Tab. 2) — in accordance with  
142 Angélibert et al. (2010).

#### 143 *Amphibians*

144 The field protocol followed the method by Schmidt (2005). Surveys lasted one hour each and were repeated  
145 at least twice over the reproductive season (Tab. 2), under standardized weather conditions, i.e. mild  
146 temperatures, with no wind or rain. Surveys after long periods of drought were avoided. Amphibians —  
147 adults, subadults, larvae — were surveyed by means of (i) visual census, (ii) identification of calls, and (iii)  
148 dip netting. The two species *Rana esculenta* and *Rana lessonae* were considered as one single taxon (green  
149 frog complex).

#### 150 *Aquatic plants*

151 We sampled aquatic plants according to the European standard protocol UNI EN 15460:2007. For each  
152 sampling plot we defined a sampling transect on the shore along which we compiled an exhaustive list.  
153 Surveys were repeated twice during the vegetative season (Tab. 2).

#### 154 *Diatoms*

155 We sampled benthic diatoms following the standard procedure (European Committee for Standardization,  
156 2003; UNI EN 14407:2004) and we performed one sampling session in spring (Tab. 2). Diatom  
157 identification was based on several diatom floras and monographies, as well as on recent taxonomic papers  
158 (Krammer and Lange-Bertalot 1986-1991a, b; Krammer 1997a, b; Reichardt 1999; Lange-Bertalot 2001;  
159 Krammer 2002, 2003; Blanco et al. 2010; Hofmann et al. 2011; Bey and Ector 2013; Falasco and Bona,  
160 2013; Falasco et al. 2013; Ector et al. 2015).

161

162 Statistical analysis

163

164 We firstly explored species richness data in accordance with Zuur et al. (2009, 2010). We used Cleveland  
165 dotplots and boxplots to assess the presence of extreme values and avoid unusual observations to exert an  
166 undue influence on estimated parameters. We evaluated multicollinearity among predictors, namely  
167 percentage of surface covered by natural land use in the sampling areas and surrounding landscapes, using  
168 Pearson correlation test and variance inflation factors (VIFs) (Zuur et al. 2009). Given their low correlation  
169 ( $r = 0.10$ ,  $p = 0.06$ ) we include all predictors in the same model.

170 The contribution of the local and landscape effects to biodiversity was tested by means of generalized linear  
171 mixed models (GLMMs). Percentage of natural land use in the sampling areas (*local effect*), in the  
172 surrounding landscapes (*landscape effect*) and their interaction were used as fixed factors, which were  
173 standardized in order to achieve homogenization of their distribution. Given the spatial dependence of the  
174 data — 10 sampling plots for each sampling site —, we applied the mixed procedure to include the grouping  
175 variable “Site” as a random factor in order to account for the variation it introduced in our samples, rather  
176 than to test for its direct effect on the dependent variables. Models were fitted with a Poisson error  
177 distribution (link function: log) which is able to deal with count data as recommended in Zuur et al. (2009).  
178 Models were tested for over-dispersion and were validated by constructing standard validation plots using  
179 the model residuals (Zuur et al. 2009). Statistical models were performed with the package *lme4* (Bates et al.  
180 2014) in R environment (R Core Team 2015).

181

## 182 **Results**

183

184 During the surveys, an amount of 190 sampling plots was visited and 340 biological samples were collected.  
185 Altogether, we identified 928 species (see ESM\_1 for the list of all recorded species). The five study sites  
186 showed different values in terms of land use coverage (Fig. 2) as well as of species richness for each  
187 biodiversity indicator (Tab. 3). Considering land use, Suzzara (Italy) showed the highest coverage of  
188 intensive agriculture, while Ulm (Germany) presented the highest level of industrialization and urbanization.  
189 Bourbon-Lancy (France) and Verrone (Italy) showed the highest coverage of extensive agriculture and  
190 natural land use respectively.

191 The response to the extent of natural land use in the sampling areas (*local effect*) and in the surrounding  
192 landscape (*landscape effect*) differed consistently among biodiversity indicators (Tab. 4).

193 Diurnal butterflies and amphibians did not show any significant response. Species richness of odonata and  
194 aquatic plants was positively influenced by the local effect, while grassland vegetation and breeding birds  
195 showed a positive response to the landscape effect (Figs. 3 and 4).

196 Diatoms showed a more complex combined response since they were significantly influenced by the  
197 landscape effect but also by the interaction of local and landscape effects. In particular, when setting the  
198 extent of natural land use in the sampling area at low values, the response to the landscape effect was  
199 positive. On the other hand, this response was negative when the extent of natural land use in the sampling  
200 area reached high values (Fig. 5).

201

## 202 **Discussion and conclusions**

203

204 In this work, we showed how biodiversity indicators responded to the extent of natural land use locally and  
205 at the landscape level. Aquatic and terrestrial ecosystems were simultaneously analysed at similar spatial  
206 scales with a standardized statistical approach in order to shed light on similarities and differences in the  
207 response to the land use (Siqueira et al. 2015). In particular, we highlighted a common trend across the  
208 different taxonomic groups, since natural land use affected positively species richness in five out of seven  
209 biodiversity indicators, both at the local and the landscape level.

210 When focusing on *local effects* (i.e. on the response of biodiversity to the extent of natural areas occurring in  
211 a 5 km radius circle areas), we detected a positive influence for aquatic plants and odonata. These results  
212 may suggest the positive role played by natural land use at the local scale for maintaining species diversity in  
213 human-altered landscapes. Such positive response of aquatic plants is in accordance with Bolpagni and Piotti  
214 (2015), who detected high species diversity of aquatic plants in natural lentic habitats. The similar positive  
215 response of odonata species richness possibly indicates an indirect relationship with aquatic plants. Indeed,  
216 odonata are influenced by the structure of the shoreline vegetation (Buchwald, 1992), which is necessarily  
217 more complex and species-rich where ponds are surrounded by natural land use, as suggested by Declerck et  
218 al. (2006). More generally, aquatic vegetation is crucial for many aspects of the ecology of the odonata,  
219 including habitat heterogeneity required by the larval stages (e.g., protection from predators), emergence  
220 supports during metamorphosis, as well as important substrates for oviposition and perching for adult  
221 odonata (Corbet and Brooks 2008; Honkanen et al. 2011).

222 When considering *landscape effects* (i.e the response of biodiversity to the extent of natural areas  
223 surrounding the 5 km radius circle area), we detected a positive response of the local assemblages of  
224 breeding birds and grassland vegetation. These results suggest how surrounding natural areas represent  
225 important key factors for preserving biodiversity, especially of terrestrial organisms. These results are in



226 accordance with literature, where a positive effect of surrounding natural land use has been reported for both  
227 birds and grassland vegetation (Wright & Wimberly 2013; Winsa et al. 2015). This positive effect might be  
228 due to the possible increase of source of colonists and connectivity. Furthermore, a negative relationship  
229 between isolation and bird diversity has been reported, especially for agricultural landscapes (Bailey et al.  
230 2010). This might also have indirect repercussions on vegetation since higher landscape connectivity could  
231 guarantee a higher bird-mediated seed dispersal (Herrmann et al. 2016).

232 A response to the *landscape effect* was also observed for diatoms, which also showed a significant response  
233 to the interaction between the local and the landscape effect, i.e. landscape effect became significantly major  
234 when the extent of natural land use in the sampling area was low. Given that diatom communities are  
235 strongly shaped by water quality (van Dam et al. 1994; Rott et al. 1999; Delgado et al. 2012), we interpreted  
236 this result as an indirect top-down cascade effect, which relates land cover to diatoms through the indirect  
237 influence of water quality (Tudesque et al. 2014). Indeed, anthropogenic land uses in the surrounding  
238 environment may cause nutrients increase in waterbodies, consequently favouring tolerant species and  
239 possibly increasing diatom diversity (Blanco et al. 2012). This may explain the negative effect of this  
240 interaction, since high naturalness leads towards oligotrophic aquatic environments, which could result in  
241 low species richness of diatoms.

242 A second reason could be that riverine biodiversity indicators integrate the response of the entire upstream  
243 area (Tudesque et al. 2014). For these reasons, despite diatoms are widely recognised as effective indicators  
244 for measuring water quality (Álvarez-Blanco et al. 2012; Delgado et al. 2012), according to our results  
245 diatom species richness proved not to be a reliable metric for detecting the effect of land use on biodiversity  
246 in anthropogenic landscapes, in accordance with Blanco et al. (2012).

247 Surprisingly, diurnal butterflies and amphibians did not show any significant effect to the extent of natural  
248 land use both in the sampling areas and in the surrounding landscapes. Concerning amphibians, similar  
249 results were obtained in Menetrey et al. (2011), who excluded species richness of amphibians from a  
250 multimetric index aimed at the evaluation of pond integrity, since this parameter did not discriminate  
251 between different environmental conditions. For diurnal butterflies, Collinge et al. (2003) revealed little  
252 influence of landscape composition on butterfly communities. A further issue might be that in our sample  
253 amphibians and diurnal butterflies showed the lowest variation in species richness among plots.  
254 Consequently, the detected pattern that amphibian and diurnal butterfly species richness are not affected by  
255 natural land use must be considered cautiously.

256 In conclusion, our results are in agreement with the habitat amount hypothesis, which also apply to  
257 industrialized and highly anthropogenic contexts.

258

259

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261

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268

269 **Bibliography**

270

271 Álvarez-Blanco, I., Blanco, S., Cejudo-Figueiras, C., & Bécares, E. (2013). The Duero Diatom Index (DDI)  
272 for river water quality assessment in NW Spain: design and validation. *Environmental Monitoring and*  
273 *Assessment*, 185(1), 969-981.

274 Angélibert, S., Rosset, V., Indermuehle, N., & Oertli, B. (2010). The pond biodiversity index “IBEM”: a new  
275 tool for the rapid assessment of biodiversity in ponds from Switzerland. Part 1. Index development.  
276 *Limnetica*, 29(1), 93-104.

277 Bailey, D., Schmidt- Entling, M. H., Eberhart, P., Herrmann, J. D., Hofer, G., Kormann, U., & Herzog, F.  
278 (2010). Effects of habitat amount and isolation on biodiversity in fragmented traditional orchards. *Journal of*  
279 *Applied Ecology*, 47(5), 1003-1013.

280 Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using Eigen  
281 and S4. R package version 1.0-6. <http://CRAN.R-project.org/package=lme4>

282 Bey, M.Y., & Ector, L. (2013). *Atlas des diatomées des cours d'eau de la region Rhône-Alpes. Tome 1-6.*  
283 Direction régionale de l'Environnement, de l'Aménagement et du Logement Rhône-Alpes.

284 Bibby, C.J., Burgess, N.D., Hill, D.A., & Mustoe, S.H. (2000). *Bird census techniques – 2<sup>nd</sup> edition.*  
285 Academic Press, London, UK, 302 pp.

286 Billeter, R., Liira, J., Bailey, D., Bugter, R., Arens, P., Augenstein, I., Aviron, S., Baudry, J., Bukacek, R.,  
287 Burel, F., Cerny, M., De Blust, G., De Cock, R., Diekotter, T., Dietz, H., Dirksen, J., Dormann, C., Durka,  
288 W., Frenzel, M., Hamersky, R., Hendrickx, F., Herzog, F., Klotz, S., Koolstra, B., Lausch, A., Le Coeur, D.,  
289 Maelfait, J.P., Opdam, P., Roubalova, M., Schermann, A., Schermann, N., Schmidt, T., Schweiger, O.,  
290 Smulders, M.J.M., Speelmans, M., Simova, P., Verboom, J., van Wingerden, W.K.R.E., Zobel, M., &

- 291 Edwards, P.J. (2008). Indicators for biodiversity in agricultural landscapes: a pan-European study. *Journal of*  
292 *Applied Ecology*, 45, 141-150.
- 293 Blanco, S., Cejudo-Figueiras, C., Tudesque, L., Bécares, E., Hoffmann, L., & Ector, L. (2012). Are diatom  
294 diversity indices reliable monitoring metrics? *Hydrobiologia*, 695, 199-206.
- 295 Blanco, S., Cejudo-Figueiras, C., Álvarez-Blanco, I., Bécares, E., Hoffmann, L., & Ector, L. (2010). Atlas de  
296 las Diatomeas de la cuenca del Duero - Diatom Atlas of the Duero Basin. 1a ed., Área de Publicaciones,  
297 Universidad de León, León, 382 pp.
- 298 Bolpagni, R., & Piotti, A. (2015). The importance of being natural in a human-altered riverscape: role of  
299 wetland type in supporting habitat heterogeneity and the functional diversity of vegetation. *Aquatic*  
300 *Conservation: Marine and Freshwater Ecosystems*, DOI: 10.1002/aqc.2604
- 301 Bouwman, J., Groenendijk, D., Termaat, T., & Plate, C. (2009). *Dutch Dragonfly Monitoring Scheme. A*  
302 *Manual*. Report number VS2009.015, Dutch Butterfly Conservation, Wageningen & Statistics Netherlands,  
303 Den Haag, Netherlands.
- 304 Braun-Blanquet, J. (1964). *Pflanzensoziologie, Grundzüge der Vegetationskunde. (3. Auflage)*. Springer  
305 Verlag, Wien, 865 pages.
- 306 Buchwald, R. (1992). Vegetation and dragonfly fauna – characteristics and examples of biocenological field  
307 studies. *Vegetatio*, 101, 99-107.
- 308 CEMAGREF (1982). *Etude des Méthodes Biologiques d'Appréciation Quantitative de la Qualité des Eaux*.  
309 Ministère de l'Agriculture, CEMAGREF, Division Qualité des Eaux, Pêche et Pisciculture, Lyon: 218 pp.
- 310 Chhabra, A., Geist, H., Houghton, R. A., Haberl, H., Braimoh, A. K., Vlek, P. L., Patz, J., Xu, J.,  
311 Ramankutty, N., Coomes, O., & Lambin, E. F. (2006). Multiple impacts of land-use/cover change. In:  
312 Lambin, E. F., & Geist, H. (eds.). *Land-use and land-cover change*. Springer Berlin Heidelberg.
- 313 Collinge, S.K., Prudic, K., & Oliver, J. (2003). Effects of local habitat characteristics and landscape context  
314 on grassland butterfly diversity. *Conservation Biology*, 17, 178-187.
- 315 Corbet, P., & Brooks, S. (2008). *Dragonflies*. HarperCollins, UK, 312 pp.
- 316 Declerck, S., De Bie, T., Ercken, D., Hampel, H., Schrijvers, S., Van Wichelen, J., Gillard, V., Mandiki, R.,  
317 Losson, B., Bauwens, D., Keijers, S., Vyverman, W., Goddeeris, B., De Meester, L., Brendonck, L.,  
318 Martens, K., & Keijers, S. (2006). Ecological characteristics of small farmland ponds: associations with land  
319 use practices at multiple spatial scales. *Biological Conservation*, 131(4), 523-532.
- 320 Delgado, C., Pardo, I., & García, L. (2012). Diatom communities as indicators of ecological status in  
321 Mediterranean temporary streams (Balearic Islands, Spain). *Ecological Indicators*, 15, 131-139.

- 322 Ector, L., Wetzel, C.E., Novais, M.H., & Guillard, D. (2015). *Atlas des diatomées des rivières des Pays de la*  
323 *Loire et de la Bretagne*. DREAL Pays de la Loire, Nantes, 649pp.
- 324 European Commission Environment (2002). *Assessment of plans and projects significantly affecting Natura*  
325 *2000 sites. Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive*  
326 *92/43/EEC*. Luxembourg: Office for Official Publications of the European Communities, ISBN 92-828-  
327 1818-7.
- 328 European Committee for Standardization (2003). *Water Quality Guidance Standard for the Routine*  
329 *Sampling and Pretreatment of Benthic Diatoms from Rivers. European Standard EN 13946*. European  
330 Committee for Standardization, Brussels, 14 pp.
- 331 European Environmental Agency (2006). Corine Land Cover. [http://www.eea.europa.eu/publications/COR0-](http://www.eea.europa.eu/publications/COR0-landcover)  
332 [landcover](http://www.eea.europa.eu/publications/COR0-landcover)
- 333 Fahrig, L. (2013). Rethinking patch size and isolation effects: the habitat amount hypothesis. *Journal of*  
334 *Biogeography*, **40(9)**, 1649-1663.
- 335 Falasco, E., & Bona F. (2011). Diatom community biodiversity in an Alpine protected area: a study in the  
336 Maritime Alps Natural Park. *Journal of Limnology*, **70(2)**, 157-167.
- 337 Falasco, E., & Bona, F. (2013). Recent findings regarding non-indigenous or poorly known diatom taxa in  
338 north-western Italian rivers. *Journal of Limnology*, 72(1): 35-51.
- 339 Falasco, E., Ector, L., Ciaccio, E., Hoffmann, L., & Bona, F. (2012). Alpine freshwater ecosystems in a  
340 protected area: a source of diatom diversity. *Hydrobiologia*, **695(1)**, 233-251.
- 341 Falasco, E., Piano, E., & Bona, F. (2013). Guida al riconoscimento e all'ecologia delle principali diatomee  
342 fluviali dell'Italia nord occidentale. *Biologia Ambientale*, 27(1), 292pp.
- 343 Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T.,  
344 Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C.,  
345 Patz, J. A., Prentice, I. C., Ramankutty, N., & Snyder P.K. (2005). Global consequences of land use. *Science*,  
346 **309(5734)**, 570-574.
- 347 Hendrickx, F., Maelfait, J.P., van Wingerden, W., Schweiger, O., Speelmans, M., Aviron, S., Augenstein, I.,  
348 Billeter, R., Bailey, D., Bukacek, R., Burel, F., Diekötter, T., Dirksen, J., Herzog, F., Liira, J., Roubalova,  
349 M., Vandomme, V., & Bugter, R. (2007). How landscape structure, land-use intensity and habitat diversity  
350 affect components of total arthropod diversity in agricultural landscapes. *Journal of Applied Ecology*, *44*,  
351 340–351.

- 352 Herrmann, J. D., Carlo, T. A., Brudvig, L. A., Damschen, E. I., Haddad, N. M., Levey, D. J., Orrock, J. L., &  
353 Tewksbury, J. J. (2016). Connectivity from a different perspective: comparing seed dispersal kernels in  
354 connected vs. unfragmented landscapes. *Ecology*, **97**(5), 1274-1282.
- 355 Hofmann, G., Werum, M., & Lange-Bertalot, H. (2011). *Diatomeen im Süßwasser-Benthos von*  
356 *Mitteleuropa*. Koeltz Scientific Books, Königstein, 908 pp.
- 357 Honkanen, M., Sorjanen, A-M., & Mönkkönen, M. (2011). Deconstructing responses of dragonfly species  
358 richness to area, nutrients, water plant diversity and forestry. *Oecologia*, *166*, 457–467.
- 359 Hooke, R. L., Martín-Duque, J. F., & Pedraza, J. (2012). Land transformation by humans: a review. *GSA*  
360 *today*, **22**(12), 4-10.
- 361 Johnson, P.T.J., Hoverman, J.T., McKenzie, V.J., Blaustein, A.R., & Richgels, K.L.D. (2013). Urbanization  
362 and wetland communities: applying metacommunity theory to understand the local and landscape effect.  
363 *Journal of Applied Ecology*, *50*, 34-42.
- 364 Kappes, H., Sundermann, A., & Haase, P. (2011). Distant land use affects terrestrial and aquatic habitats of  
365 high naturalness. *Biodiversity and Conservation*, **20**(10), 2297-2309.
- 366 Kleijn, D., Baquero, R. A., Clough, Y., Diaz, M., Esteban, J. D., Fernández, F., Gabriel, D., Herzog, F.,  
367 Holzschuh, A., Jöhl, R., Knop, E., Kruess, A., Marshall, E. J. P., Steffan-Dewenter, I., Tschardtke, T.,  
368 Verhulst, J., West, T. M., & Yela J. L. (2006). Mixed biodiversity benefits of agri- environment schemes in  
369 five European countries. *Ecology Letters*, **9**(3), 243-254.
- 370 Kleijn, D., Kohler, F., Báldi, A., Batáry, P., Concepción, E. D., Clough, Y., Díaz, M., Gabriel, D.,  
371 Holzschuh, A., Knop, E., Kovács, A., Marshall, E. J. P., Tschardtke, T., & Verhulst, J. (2009). On the  
372 relationship between farmland biodiversity and land-use intensity in Europe. *Proceedings of the Royal*  
373 *Society of London B: Biological Sciences*, **276**(1658), 903-909.
- 374 Knop, E. (2016). Biotic homogenization of three insect groups due to urbanization. *Global Change Biology*,  
375 *22*, 228-236.
- 376 Krammer, K. (1997a). *Die cymbelloiden Diatomeen. Teil 1. Allgemeines und Encyonema Part*. Bibliotheca  
377 Diatomologica, *36*, 382 pp.
- 378 Krammer, K. (1997b). *Die cymbelloiden Diatomeen. Teil 2. Encyonema part, Encyonopsis and*  
379 *Cymbellopsis*. Bibliotheca Diatomologica, *37*, 469 pp.
- 380 Krammer, K. (2002). *Cymbella*. In: Lange-Bertalot, H. (ed). *Diatoms of Europe. 3*. A.R.G. Gantner Verlag  
381 KG, Rugell, 584pp.

- 382 Krammer, K. (2003). *Cymbopleura, Delicata, Navicymbula, Gomphocymbellopsis, Afrocybella*. In: Lange-  
383 Bertalot, H. (ed). *Diatoms of Europe. 4*. ARG Gantner Verlag KG, Rugell, 530pp.
- 384 Krammer, K., & Lange-Bertalot, H. (1986). *Bacillariophyceae Teil: Naviculaceae. 1*. In: Ettl, H., Gerloff, J.,  
385 Heynig, H., & Mollenhauer, D. (eds). *Süßwasserflora von Mitteleuropa. 2*. Fischer Verlag, Stuttgart, 876 pp.
- 386 Krammer, K., & Lange-Bertalot, H. (1988). *Bacillariophyceae Teil: Bacillariaceae, Epithemiaceae,*  
387 *Surirellaceae. 2*. In: Ettl, H., Gerloff, J., Heynig, H., & Mollenhauer, D. (eds). *Süßwasserflora von*  
388 *Mitteleuropa. 2*. Fischer Verlag, Stuttgart, 610 pp.
- 389 Krammer, K., & Lange-Bertalot, H. (1991a). *Bacillariophyceae Teil: Centrales, Fragilariaceae,*  
390 *Eunotiaceae. 3*. In: Ettl, H., Gerloff, J., Heynig, H., & Mollenhauer, D. (eds). *Süßwasserflora von*  
391 *Mitteleuropa. 2*. Fischer Verlag, Stuttgart, 598 pp.
- 392 Krammer, K., & Lange-Bertalot, H. (1991b). *Bacillariophyceae Teil: Achnantheaceae. Kritische*  
393 *Erg.anzungen zu Navicula (Lineolatae) und Gomphonema. 4*. In: Ettl, H., Gerloff, J., Heynig, H., &  
394 Mollenhauer, D. (eds). *Süßwasserflora von Mitteleuropa. 2*. Fischer Verlag, Stuttgart, 437 pp.
- 395 Lange-Bertalot, H. (2001). *Navicula sensu stricto, 10 Genera separated from Navicula sensu lato, Frustulia*.  
396 In: Lange-Bertalot, H. (ed.). *Diatoms of Europe. 2*. A.R.G. Gantner Verlag K.G., Rugell, 526 pp.
- 397 Manning, P., Gossner, M. M., Bossdorf, O., Allan, E., Zhang, Y. Y., Prati, D., Nico Blüthgen, Boch, S.,  
398 Böhm, S., Börschig, C., Jung, K., Klaus, V. H., Klein, A. M., Kleinebecker, T., Krauss, J., Lange, M.,  
399 Müller, J., Pašalić, E., Socher, S. A., Tschapka, M., Türke, M., Weiner, C., Werner, M., Gockel, S., Hemp,  
400 A., Renner, S. C., Wells, K., Buscot, F., Kalko, E. K. V., Linsenmair, K. E., Weisser, W. W., & Hölzel, N.  
401 (2015). Grassland management intensification weakens the associations among the diversities of multiple  
402 plant and animal taxa. *Ecology*, **96(6)**, 1492-1501.
- 403 McKinney, M.L. (2008). Effects of urbanization of species richness: a review of plants and animals.  
404 *Urban Ecosystems*, **11**, 161-176.
- 405 Menetrey, N., Oertli, B., & Lachavanne, J.B. (2011). The CIEPT: A macroinvertebrate-based multimetric  
406 index for assessing the ecological quality of Swiss lowland ponds. *Ecological Indicators*, **11**, 590-600.
- 407 Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis*. Island  
408 Press, Washington DC. [www.millenniumassessment.org/documents/ document.356.aspx.pdf](http://www.millenniumassessment.org/documents/document.356.aspx.pdf).
- 409 Oertli, B., Auderset Joye, D., Castella, E., Juge, R., Lehmann, A., & Lachavanne, J. B. (2005). PLOCH: a  
410 standardized method for sampling and assessing the biodiversity in ponds. *Aquatic Conservation: Marine*  
411 *and Freshwater Ecosystems*, **15(6)**, 665-679.

- 412 Overmars, K. P., Schulp, C. J., Alkemade, R., Verburg, P. H., Temme, A. J., Omtzigt, N., & Schaminée, J.  
413 H. (2014). Developing a methodology for a species-based and spatially explicit indicator for biodiversity on  
414 agricultural land in the EU. *Ecological Indicators*, **37**, 186-198.
- 415 Parris, K.M. (2016). *Ecology of Urban Environments*. Wiley-Blackwell, Chichester, West Sussex,  
416 UK.
- 417 Pignatti S. (1982). *Flora d'Italia*. Edagricole, 2324 pp.
- 418 Pollard, E., & Yates, T.J. (1993). *Monitoring butterflies for ecology and conservation. The British butterfly*  
419 *monitoring scheme*. Springer Science & Business Media, 274 pp.
- 420 Quantum GIS Development Team (2015). *Quantum GIS Geographic Information System*. Open Source  
421 Geospatial Foundation Project. <http://qgis.osgeo.org>.
- 422 R Core Team (2015). *R: A Language and Environment for Statistical Computing*. R Foundation for  
423 Statistical Computing, Vienna. <http://www.R-project.org>.
- 424 Reichardt, E. (1999). *Zur Revision der Gattung Gomphonema. Die Arten um G. affine/insigne, G.*  
425 *angustum/micropus, G. acuminatum sowie gomphonemoide Diatomeen aus dem Oberoligozän in Böhmen.*  
426 In: Lange-Bertalot, H. (ed). *Iconographia Diatomologica*. 8. A.R.G. Gantner Verlag K.G., Rugell,
- 427 Rott, E., Binder, N., Van Dam, H., Ortler, K., Pall, K., Pfister, P., & Pipp, E. (1999). *Indikationslisten für*  
428 *Aufwuchsalgen. Teil 2. Trophieindikation und autökologische Anmerkungen*, Bundesministerium für Land-  
429 und Forstwirtschaft, Wien, pp. 1–248.
- 430 Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke,  
431 L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L.,  
432 Sykes, M. T., Walker, B. H., Walker, M., & Wall D. H. (2000). Global biodiversity scenarios for the year  
433 2100. *Science*, **287(5459)**, 1770-1774.
- 434 Schmidt, B.R. (2005). Monitoring the distribution of pond-breeding amphibians when species are detected  
435 imperfectly. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *15(6)*, 681-692.
- 436 Siqueira, T., Bini, L.M., Thomaz., S.M., Fontaneto, D. (2015). Biodiversity analyses: are aquatic ecologists  
437 doing any better and differently than terrestrial ecologists? *Hydrobiologia*, *750*, 5-12.
- 438 Smith, A. C., Koper, N., Francis, C. M., & Fahrig, L. (2009). Confronting collinearity: comparing methods  
439 for disentangling the effects of habitat loss and fragmentation. *Landscape Ecology*, **24(10)**, 1271-1285.

- 440 Tudesque, L., Tisseuil, C., Lek, S. (2014). Scale-dependent effects of land cover on water physico-chemistry  
441 and diatom-based metrics in a major river system, the Adour-Garonne basin (South Western France). *Science*  
442 *of the Total Environment*, 466-467, 47-55.
- 443 Turrini, T., & Knop, E. (2015). A landscape ecology approach identifies important drivers of urban  
444 biodiversity. *Global Change Biology*, 21(4), 1652-1667. doi: 10.1111/gcb.12825
- 445 Tutin, T.G., Heywood, V.H., Burges, N.A., Valentine, D.H., Walters, S.M., & Webb, D.A. (2001). *Flora*  
446 *Europaea*. Cambridge University Press, 2392 pp.
- 447 UNI EN 14407:2004. *Qualità dell'acqua - Linea guida per l'identificazione, il conteggio e la classificazione*  
448 *di campioni di diatomee bentoniche da acque correnti.*  
449 <http://webstore.uni.com/unistore/public/productdetails?productId=UNIN1440700IEEN>.
- 450 UNI EN 15460:2007. *Water Quality - Guidance Standard for the Surveying of Macrophytes in Lakes.*  
451 <http://shop.standards.ie/nsai/details.aspx?ProductID=691842>
- 452 van Dam, H., Mertens, A., & Sinkeldam, J. (1994). A coded checklist and ecological indicator values of  
453 freshwater diatoms from the Netherlands. *Netherlands Journal of Aquatic Ecology*, 28, 117–133.
- 454 van Swaay, C.A.M., Brereton, T., Kirkland, P., & Warren, M.S. (2012). *Manual for Butterfly Monitoring.*  
455 Report VS2012.010, De Vlinderstichting/Dutch Butterfly Conservation, Butterfly Conservation UK &  
456 Butterfly Conservation Europe, Wageningen.
- 457 van Swaay, C., van Strien, A., Aghababayan, K., Astrom, S., Botham, M., Brereton, T., Chambers, P.,  
458 Collins, S., Domenech Ferre, M., Escobes, R., Feldmann, R., Fernandez-Garcia, J. M., Fontaine, B.,  
459 Goloshchapova, S., Gracianteparaluceta, A., Harpke, A., Heliola, J., Khanamirian, G., Julliard, R., Kuhn, E.,  
460 Lang, A., Leopold, P., Loos, J., Maes, D., Mestdagh, X., Monasterio, Y., Munguira, M. L., Murray, T.,  
461 Musche, M., Ounap, E., Pettersson, L., Popoff, S., Prokofev, I., Roth, T., Roy, D., Settele, J., Stefanescu, C.,  
462 Svitra, G., Teixeira, S. M., Tiitsaar, A., Verovnik, R., & Warren, M. (2015). *The European Butterfly*  
463 *Indicator for grassland species: 1990-2013*. Wageningen, The Netherlands, De Vlinderstichting, 37pp.  
464 (Report VS2015.009).
- 465 Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (2008). Human domination of Earth's  
466 ecosystems. In *Urban Ecology*. Springer US. pp. 3-13.
- 467 Winsa, M., Bommarco, R., Lindborg, R., Marini, L., & Öckinger, E. (2015). Recovery of plant diversity in  
468 restored semi- natural pastures depends on adjacent land use. *Applied Vegetation Science*, **18**(3), 413-422.
- 469 Wright, C. K., & Wimberly, M. C. (2013). Recent land use change in the Western Corn Belt threatens  
470 grasslands and wetlands. *Proceedings of the National Academy of Sciences*, **110**(10), 4134-4139.



471 Zuur, A.F., Ieno, E.N., Walker, N.J., Savaliev, A.A., & Smith, G.M. (2009). *Mixed effect models and*  
472 *extensions in ecology with R*. Berlin, Springer, 574 pp.

473 Zuur, A.F., Ieno, E.N., & Elphick, S.C. (2010). A protocol for data exploration to avoid common statistical  
474 problem. *Methods in Ecology and Evolution*, 1(1), 3-14. DOI: 10.1111/j.2041-210X.2009.00001.x

475

476 **Figure captions**

477 **Fig. 1** Map representing the location of the five industrial sites and a detailed view of their land use in the  
478 sampling area (internal circle, continuous line) and the surrounding landscape (external circle, dashed line). a  
479 = Bourbon-Lancy; b = Venaria; c = Verrone; d = Suzzara; e = Ulm

480 **Fig. 2** Percentage of land use coverage calculated for the sampling areas (a) and surrounding landscapes (b).  
481 Artificial = percentage of urban and industrial land uses; Intensive = percentage of intensive agriculture;  
482 Extensive = percentage of extensive agriculture; Natural = percentage of natural land use

483 **Fig. 3** Predicted values (blue continuous line) and confidence intervals (95%, light grey area) for (a) aquatic  
484 plants and (b) odonata against the extent of natural land use in the sampling area (*local effect*)

485 **Fig. 4** Predicted values (blue continuous line) and confidence intervals (95%, light grey area) for (a)  
486 breeding birds, (b) grassland vegetation and (c) diatoms against the extent of natural land use in the  
487 surrounding landscape (*landscape effect*)

488 **Fig. 5** Predicted species richness of diatoms and the interaction between the extent of natural land use in the  
489 sampling areas and surrounding landscapes. Lines represent the *landscape effect* at low (0%, continuous  
490 line), intermediate (15%, dashed line) or high (30%, dotted line) cover of natural land use in the sampling  
491 area. Major landscape effects are seen at low extent of natural land use in the sampling area, conversely they  
492 become negligible at higher extents of natural land use in the sampling area