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INVASION OF RIPARIAN HABITATS BY *BUDDLEJA DAVIDII*: A CASE STUDY FROM THE NORTHERN APENNINES

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Abstract - *Buddleja davidii* Franch. is one of the most aggressive invasive plants across the world, especially in riparian ecosystems. However, the invasion processes and the impacts of this species are still poorly known. Here we report a case of massive invasion in the valley of a montane stream of the Tusco-Emilian Apennines, started around the year 1990. In this study, the species was recorded along a corridor of 4.3 km, representing 60% of the total streambed length. Invasion intensity was low in the early herbaceous stage of the succession, while it was highest in the woody pre-forest stage with *Salix eleagnos* and *S. purpurea*. Intermediate intensity occurred in the riparian forest with *Alnus incana*. Plot-level Shannon diversity and evenness of these plant communities were negatively related to *B. davidii* cover, as well as abundance of woody and herbaceous species. Hence, our findings indicate a negative impact on the diversity of local riparian vegetation. Minimizing the human-mediated disturb to the riparian habitat may help to limit the spread of this alien species in similar habitats of the area.

Keywords: plant diversity; invasive species; riparian forests; vegetation dynamics; succession

Introduction

Riparian habitats are particularly fragile and prone to biological invasions worldwide (Planty-Tabacchi et al., 1996; Tickner et al., 2001). Anthropic disturbances of the riparian vegetation caused by the management of watercourses are among the drivers that favour plant invasions, as many alien species take competitive advantage from any factor that alters the vegetation structure and local ecological conditions (Richardson et al., 2007). At the global scale, the most serious threats to the integrity of riparian systems are borne by the alteration of the flooding regime through the construction of dams and of infrastructures, land use changes and clearcuttings and industrial and urban development, all of them potentially favouring the introduction (propagule pressure) and establishment of alien plants (Hughes & Rood, 2003; Catford et al., 2014). Assessing the dynamics of the invasion processes and the consequent changes in structure, species composition and diversity of the native vegetation is crucial to understand the overall impact of the invasion.

Since the end of 19th century, *Buddleja davidii* Franch, the Butterfly bush, has been introduced from China to many regions of the world, mainly for ornamental purposes (Tallent-Halsell & Watt, 2009). However, its remarkable morphological plasticity, ability to tolerate various types of stress, reproductive ability and physiological efficiency (Feng et al., 2007) have favoured its uncontrolled spread in large areas of Australia, New Zealand (Kriticos et al., 2011), North America, South Africa (Ream, 2006; Tallent-Halsell & Watt, 2009) and Europe (Sheppard et al., 2006). In the latter continent, it is particularly widespread in the central and western countries (Ebeling et al., 2007), but its occurrence

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extends also to more southern ones, including Spain (Sheppard et al., 2006) and Italy (Celesti-Grapow et al., 2009; Galasso et al., 2018). In Italy, it is considered invasive especially in the northern regions from Piemonte to Friuli-Venezia Giulia (Celesti-Grapow et al., 2010), while in Tuscany it is reported to have only a limited invasive potential of natural habitats (Arrigoni et al., 2010). Indeed, *B. davidii* is especially invasive in anthropogenic disturbed sites (Owen & Whiteway 1980) as well as on walls and rock faces (Smale, 1990), while it is more rarely able to penetrate into semi-natural ecosystems (Tallent-Halsell & Watt 2009). In particular, whether *B. davidii* is able to persist in older and more advanced forest stages of riparian vegetation is still unclear (Tallent-Halsell & Watt, 2009). Similarly, whether and how presence of *B. davidii* can influence diversity of invaded riverbed communities in Europe has not been investigated so far.

Here, we describe a local but remarkable case of invasion of a riparian ecosystem in the northern Apennines in Tuscany. After assessing the extent of the invaded area and the local population density of *B. davidii*, we identified the plant community types affected by the invasion and their alpha-diversity in relation to the abundance of the invasive species. Results of this study, though preliminary, help to identify possible strategies to limit the further spread of *B. davidii* along the Orsigna Stream and other similar riparian habitats of the River Reno Valley and its tributaries.

Materials and Methods

The invasive species

Buddleja davidii (Scrophulariaceae) is a perennial, semi-deciduous, multi-stemmed shrub native to central and southwestern China where it grows in thickets along mountain slopes at elevations up to 3.500 m a.s.l. (Tallent-Halsell & Watt, 2009). Ecological amplitude, tolerance to various types of stress, fast growth and reproductive efficiency contribute to the highly competitive capacity of this species in various habitats (Owen & Whiteway, 1980; Stuart, 2006). Despite its relative longevity (ca. 20 years; Smale, 1990), individuals of *B. davidii* can start flowering and fruiting since the first or second year after seed germination (Tallent-Halsell & Watt, 2009). Inflorescences, that can reach up to 30 cm in length, usually consist of hundreds of lilac or purple flowers (Tallent-Halsell & Watt, 2009). Cross pollination is by insects and especially butterflies (Miller, 1984). Seed production in this species is exceptionally high, as a single mature individual may produce several millions of seeds each year (Campbell, 1984). A medium-sized individual may form up 300-350 inflorescences, each of them bearing from about 100 to more than 1700 capsules, each including from 28 to 75 seeds (Ebeling et al., 2007). Seeds are long-winged at both ends, extremely light and easily dispersed by both wind and water (Campbell, 1984). Plants readily reproduce also asexually from stem and root fragments (Smale, 1990).

The invaded site

The invaded site is located in the Orsigna valley (Pistoia province, Tuscany) in the northern Apennines (Fig. 1A). Orsigna is a short mountain creek (ca. 8 km long), with a drainage basin of ca. 1,250 ha, flowing in NW-SE direction at an altitudinal range from 600 to 1700 m a.s.l. The valley is recognized as of high conservation value under the "Habitat" Directive 92/43/EEC and is part of the SCI (Site of Community Importance) 'Tre Limentre-Reno' (cod. IT5130009). It includes 21 habitats of community importance and 138 species of conservation relevance. The bio-climate of the area is humid meso-thermic, with about 2,000 mm of mean annual rainfall mainly concentrated in the autumn, no drought period, and 9.5° C of mean annual temperature. The locally dominant geological formation is a fine-grained sandstone of siliceous nature. Based on direct information from local people, *B. davidii* was introduced in this valley for ornamental purposes in private gardens, ca. 30 years ago; then it rapidly escaped from cultivation and started to spread at the end of the nineties (F. Selvi, pers. obs.).

Assessment of the invasion status

We examined the invasion status in 2015-2016 by mapping the invaded area through points and polygons with a global navigation satellite system (GNSS) 'Trimble Juno' (Fig. 1B). Polygons were used to delimit invaded areas larger than 5 m^2 and points were used to locate single plants. Data were processed by FLOSS QGIS (QGIS Development Team, 2019) to produce a detailed map of the invaded area (Fig. 1C). Three invasion intensity classes were defined based on the percentage of aboveground cover and plant density. The latter variable was estimated by counting the number of individuals in one randomly established quadrat of 5 x 5 m for each interval of ground cover (3 plots in total to estimate plant density). The estimated total number of individuals (total population size) was obtained from the multiplication of the number of individuals by the respective population area. Aboveground cover was estimated by visual assessment. The invasion intensity classes were low (<30% cover, <2000 individuals/ha), intermediate (30-60% cover, 2000-3000 individuals/ha), and high (>60% cover, 3000-4500 individuals/ha). Next, we calculated the rate of invasion spread of *B. davidii*

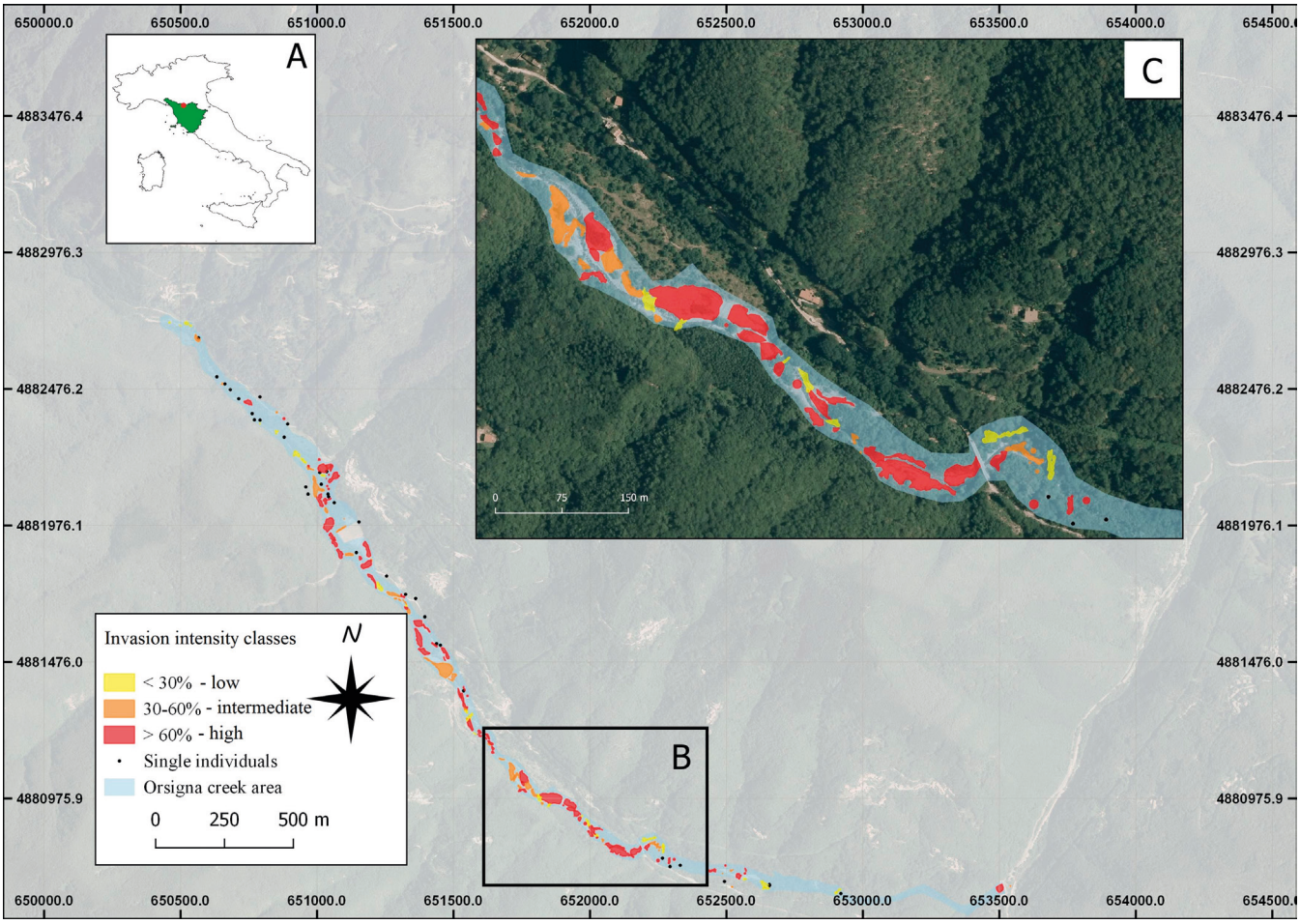

Figure 1. Map of the invaded area with distribution and extent of three intensity levels of invasion by *Buddleja davidii*. Inset (A) shows the geographical location of the study site; inset (C) shows an enlarged view of (B).

following Trueman et al. (2014), i.e. we calculated the mean linear rate of spread as the square root of the area occupied at that date divided by the number of years since the most likely date of introduction into the study area (i.e. 1990).

Vegetation sampling

To characterize the invaded plant communities in terms of structure, species composition and diversity, ten 5 x 5 m plots were randomly located in early summer 2016 in sites with low, intermediate and high invasion intensity. The experimental design consisted of 4 plots for the low and high intensity levels, and 2 plots for the intermediate intensity level. The limited extent of the community type with intermediate invasion intensity did not allow to increase the number of plots. All vascular plant species in the plots were identified and visually scored for percentage of ground cover.

Data analyses

First, GNSS data were differentially corrected in post-processing (average positioning error of about 2-5 m) and then elaborated with the open source software QGIS (QGIS Development Team, 2019). Vegetation data from the 6 plots were first subject to non-metric multidimensional scaling (NMDS; Oksanen, 2008) to summarize and display in the compositional differences among the groups of plots, based on the cover-weighted Bray-Curtis dissimilarity matrix. Differences were tested by permutational analysis of variance (PERMANOVA) with 999 permutations (R Adonis function in Vegan). The three groups of plots were then referred to major syntaxonomical units following the classification system of the Italian vegetation by Biondi et al. (2014). Next, alpha-diversity was calculated for each plot as Species Richness (SR), Shannon index (H') and species evenness (J); differences among invasion intensity classes were evaluated by ANOVA and Tukey test after

testing for normality by the Lilliefors (Kolmogorov-Smirnov) test for normality of distributions and the Bartlett test for homogeneity of variances. Variation of each index in relation to the relative abundance of *B. davidii* in the community samples (calculated as the ratio *B. davidii* cover %: total cover) was examined using a GLM regression analysis with function glm (H~cover + habitat, family), where family is Binomial for SR and Gaussian for H' and J. Similarly, the effect of *B. davidii* was analysed in terms of cover variation of three main plant functional groups (or growth forms), namely woody species, herbs, and graminoids (the latter including species of Poaceae, Cyperaceae and Juncaceae). All analyses were conducted in R (R Development Core Team, 2011).

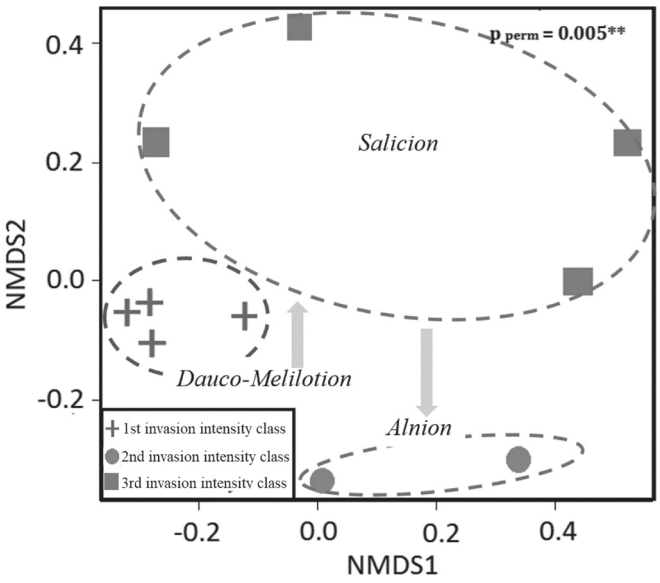

Figure 2. Non-metric multidimensional scaling showing the compositional dissimilarity among plots (Bray-Curtis distance); p perm indicates the significance of the difference between the composition of the three community plots, based on PERMANOVA with 999 permutations. Vegetation types corresponding to three levels of *Buddleja davidii* invasion intensity are indicated, together with the direction of their successional relationships (grey arrows).

Results

Presence of the Butterfly bush was recorded along a corridor of 4.3 km, representing 60% of the total streambed length (7.7 km) over a surface of ca. 3.3 ha. The estimated total number of individuals (total population size) was 13,310. The mean density of the population was estimated in 3,100 ± 737 individuals/ha. The estimated mean rate of linear spread was 32 m/year along the invaded corridor. The three invasion levels – low, intermediate and high – covered respectively 10%, 25% and 65% of the invaded area (Fig. 1). PERMANOVA and NMDS analyses showed significant differences in the species composition of the community types each with a different level of invasion (p perm < 0.01; Fig. 2).

Plots with low invasion intensity were representative of the alliance *Dauco carotae-Melilotion albi* Görs 1966, a pioneer herbaceous community that is typical of the early stages of riverbed successions on dry and nutrient-poor soils with large amounts of gravel or debris. The plots with intermediate invasion intensity were forest stands with *Alnus incana* and *A. glutinosa* and could be referred to the alliance *Alnion incanae* Horvat; this represents the final stage of the local riverbed succession. Finally, the most intensely invaded community type could be referred to the alliance *Salicion eleagni* Aichinger 1933; it was dominated by the shrubby willows *Salix eleagnos* and *S. purpurea* which characterize a pre-forest stage following the herbaceous stage and preceding the forest *Alnion* stage, thus occupying an intermediate position in the local succession.

In the three community types we recorded a total of 134 species of herbaceous, graminoid and woody plants (Appendix). Regression analysis (Fig. 3) showed that the overall abundance of woody species declined with increasing cover of *B. davidii* ($r^2 = 0.79$; $p < 0.01$).

Similarly, the overall abundance of herbs tended to decrease with increasing cover of *B. davidii* ($r^2 = 0.51$; $p < 0.05$). By contrast, graminoids were not affected. Species richness in each functional group showed no relationship with *B. davidii* cover (data not shown). Total SR tended to decrease with increasing abundance of *B. davidii*, though not significantly (*Dauco-Melilotion:* SR=41±7.44; *Alnion:* 36.5±2.12; *Salicion:* 32.5±5.74). On the contrary, values of both H' and J were significantly lower (p=0.006 and p=0.007 respectively) in the more intensely invaded plots of the *Salicion* (H'=1.25±0.14; J=0.36±0.5) and *Dauco-Melilotion* (H'=2.27±0.57; J=0.61±0.14) community compared with the *Alnion* forest (H'=2.63±0.11; J=0.73±0.01). Indeed, linear regression (Figure 4) supported that increasing relative cover of *B. davidii* is associated with a significant decline of Shannon diversity H' ($r^2 = 0.895$; $p < 0.01$; Figure 4a) and species evenness J ($r^2 = 0.911$; $p < 0.01$; Figure 4b). The *Alnion* plots showed the highest values of H' and J.

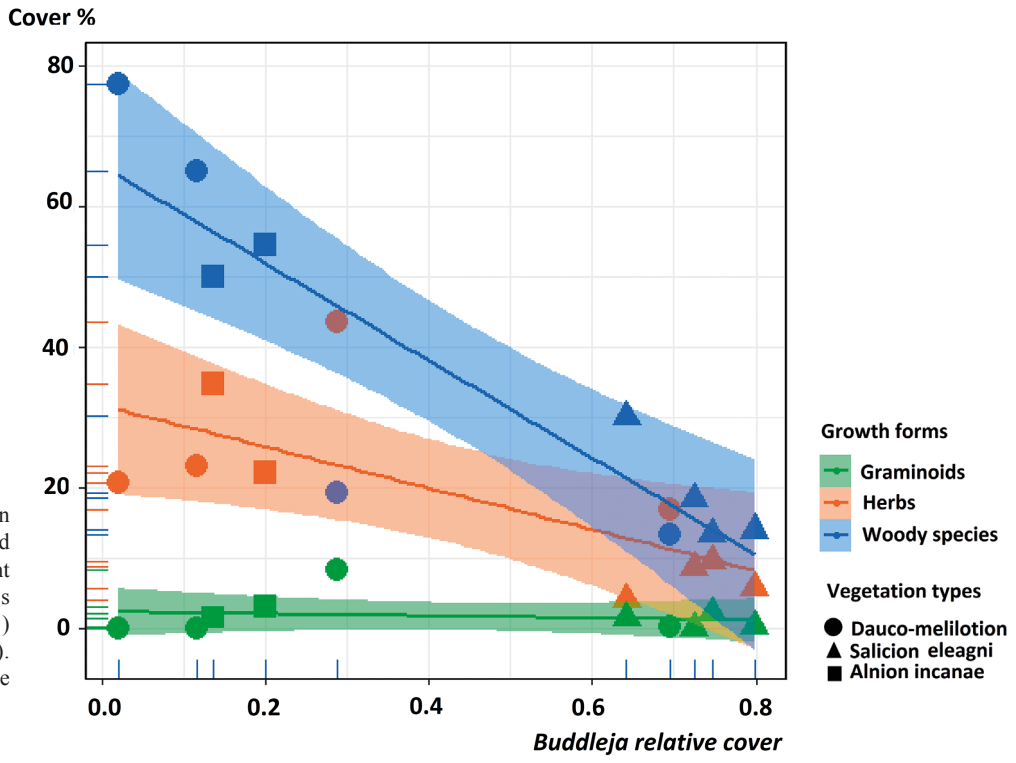

Figure 3. Relationship between ground cover of *Buddleja davidii* and relative cover of three major plant functional groups: woody species (p-value = 0.0009); herbs (p = 0.0201) and graminoids (non significant). Three different symbols indicate the three different vegetation types.

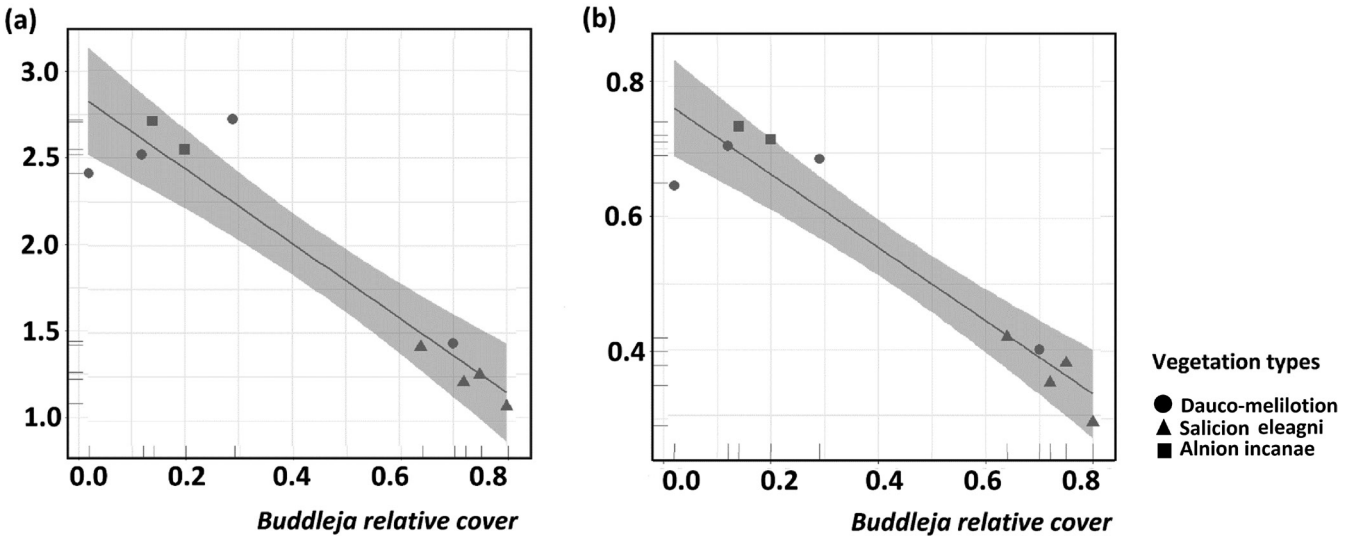

Figure 4. Linear regression showing negative relationship between *B. davidii* relative cover and: a) Shannon index H' (p-value = 0.0056); b) evenness index J of the invaded communities (p = 0.0033).

Discussion

Our findings show that *B. davidii* is able to penetrate and persist into three dynamically connected vegetation stages of the streambed succession. The invasion process starts in the pioneer herbaceous community of the *Dauco-Melilotion*, where sparse plant cover and light availability represent key factors for the establishment of the alien seedlings (Humphries & Guarino, 1987). Further advantage to them is given by soil characteristics of this community, rich in gravel and sand, hence well-drained but with low levels of nutrients; its siliceous nature is not a limiting factor, since the species can flourish also on calcium-deficient substrates (Tallent-Halsell & Watt, 2009). Deviation from the natural

succession trajectory was dramatic in the following shrub stage, that was anticipated by the fast growth of the Butterfly bush. As a consequence of the strong increase in density and cover of the invasive species, the *Salicion* community was largely reduced in extent. A similar process was observed in the floodplain vegetation of New Zealand, where the native colonizer shrub *Kunzea ericoides* (Myrtaceae) highly suffers the competition of *B. davidii* (Smale, 1990). Unexpectedly, the Butterfly bush was found also in the shrub layer of the *Alnion* forest, showing that reduction in light availability, soil enrichment in organic matter and nutrient levels in this habitat (especially N because of fixation activity in the *Alnus* roots) were not enough to prevent its persistence from the late stages of the riparian succession.

Concerning alpha-diversity in the three impacted community types, we found that Shannon index and diversity tend to decrease with increasing cover of the Butterfly bush. This is in line with other studies showing reduction of plant taxonomic diversity in forest ecosystems invaded by non-native trees and shrubs (Lorenzo et al., 2012; Fukami et al., 2013; Selvi et al., 2016, 2017; Lazzaro et al., 2018). Interestingly, Shannon diversity in our study declined because the abundance proportions between the native species became increasingly unbalanced under the influence of the alien species. Loss of species evenness under *B. davidii* cover suggests that this shrub can have both an inhibitory and facilitative influence on co-occurring native plants (Tallent-Halsell & Watt, 2009). In our study, both woody and herbaceous species were negatively affected by the increasing dominance of *B. davidii*, while the proportion of graminoids was not influenced. Ability of the graminoids to thrive in intensely disturbed sites has been reported also from riparian ecosystems in North America, along with a decline of woody species (Biswas & Mallik, 2010).

Overall, our findings suggest that maintaining a continuous cover of natural forest vegetation, wherever still present in the valley, may help to limit the spread of the Butterfly bush. Native forest cover is in fact a natural barrier to the spread of invasive plants (Sitzia et al., 2016). Silvicultural measures in the area should promote the natural dynamic progression of the vegetation towards the forest stage, while clear cuts and coppicing should be avoided. In the long-term, *B. davidii* stands under tree canopy may reduce their flowering and fruiting potential because of light limitation and changes in soil conditions. In addition, mechanized works in the streambed and its surroundings should be reduced at minimum in order to avoid the creation of new open spaces where the invasion process can start.

Conclusions

This work provides first insights into the process and effects of invasion by *B. davidii* along a watercourse of a south European mountain area with riparian vegetation. Invasion involves the pioneer, herbaceous community and largely displaces by competition the subsequent successional stage dominated by native *Salix* species. Whether the final stage of this succession dominated by *Alnus* species (especially *A. incana*) can still develop from the invading *Buddleja* thickets remains unclear, but this study shows that the species can penetrate and persist even in this vulnerable and protected forest type despite non-optimal light and soil conditions. A further detrimental consequence of the invasion that we observed is the decrease of community alpha-diversity with increasing cover of *Buddleja*, due to reduction of native species evenness. Woody plants and herbs decreased in abundance while the proportion of graminoids remained unaltered. Overall, such findings provide support to plan management strategies for monitoring and contrasting the further spread of the Butterfly bush in nearby valleys of the region.

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Appendix

Complete matrix of vegetation sampling in the three invasion intensity classes. For each plot main site morphological characteristics are indicated.

	1st invasion intensity class				2nd invasion intensity class		3rd invasion intensity class			
Plot n°	1	6	7	8	3	4	5	2	9	10
Coordinates [latitude (N) / longitude (E)]	4880661.9 / 622641.0	4885213 / 657983.9	4882714.8 / 650457.1	482309.5 / 650851.5	4880772.9 / 652268.8	4880807.7 / 652082.5	4880889.1 / 651970.6	4880746.6 / 657450.2	4881463.3 / 651483.1	4881183.7 / 651624.1
Altitude a.s.l. [m]	686	620	896	828	687	693	704	685	764	724
Slope [C°]	0	0	4	2	0	3	0	0	0	0
Vegetation cover [%]	42	42	80	60	87	70	97	65	85	98
***Buddleja* cover [%]**	20	29	15	1.3	34	50	91	60	80	89
Acer campestre	0.1	0.1	0	0	0	0.1	0	0	0	0
Acer pseudoplatanus	0.1	0	0	0.1	0	0	0	0.1	0	0.1
Adenostyles australis	0	0	0	0	0	0.2	0	0	0	0
Agrimonia eupatoria	0	0	0	0	0	0	0.1	0	0	0
Agrostis stolonifera	0	0	0	0	0	0	0	1	0.1	0
Alliaria petiolata	0.1	0	0	0	0	0	0	0	0	0
Alnus cordata	0	0.5	2	11	0	1	4	8	1	13
Alnus glutinosa	0	0	0	0	8	0	0	0	0	0
Alnus incana	6	0	5	0	9	53	0	0.3	0	3
Angelica sylvestris	0	0	0	0	5	7	0	0	0	0
Arabis sp.	0	0	0	0	0.1	0	0	0	0	0
Arabis turrita	0	0	0	0.1	0	0	0.2	0	0	0
Arctium nemorosum	0	0	0	0	0	0.5	0	0	0	0
Arenaria bertolonii	0	0	0.1	0.1	0	0	0	0	0.3	0
Arenaria serpylllifolia	0	0.5	0	0	0	0	0	0	0	0
Arrhenatherum elatius	0	0	0.2	0	0	0	0	0	0.1	0
Artemisia vulgaris	0.1	0	0	0	0	0	0	0	0	0
Barbarea vugaris	4	0	0	2.5	0.2	0	0	0.1	0.5	0
Brachypodium rupestre	0	0	0	0	3.5	0	0	0	0.2	0
Brachypodium sylvaticum	0.5	0	0.1	0	0	0	0	0	0	0
Bromus ramosus	0	0	0	0	0	5	2	0.1	0	0
Bromus squarrosus	0	0	0.1	0	0	0	0	0	0	0
Bryonia dioica	0	0	0	0	0	0	0.5	0	0	0
Calamagrostis varia ssp.corsica	0	0	0	0	0	0	0	0	0	0.1
Campanula trachelium	0	0.1	3	0	0	0	0	0	0.1	0
Cardamine impatiens	0.3	0	0	0	1	1	0	0	0	0.1
Cardus nutans	0	0.2	0	0	0	0	0	0	0	0
Carex divulsa	0	0	0	0	0	0	0.1	0	0	0
Carex pendula	4	0	0	0	0	0	0	0.1	0	0
Carex remota	0.5	0	0	0	0	0	0	0	0	0
Carex sylvatica	0	0	0	0	0	0	0.1	0	0	0
Cerastium fontanum	0.1	0	0	0	0	0	0.1	0	0	0

	1st invasion intensity class				2nd invasion intensity class		3rd invasion intensity class			
Plot n°	1	6	7	8	3	4	5	2	9	10
Coordinates [latitude (N) / longitude (E)]	4880661.9 / 622641.0	4885213 / 657983.9	4882714.8 / 650457.1	482309.5 / 650851.5	4880772.9 / 652268.8	4880807.7 / 652082.5	4880889.1 / 651970.6	4880746.6 / 657450.2	4881463.3 / 651483.1	4881183.7 / 651624.1
Altitude a.s.l. [m]	686	620	896	828	687	693	704	685	764	724
Slope [C°]	0	0	4	2	0	3	0	0	0	0
Vegetation cover [%]	42	42	80	60	87	70	97	65	85	98
***Buddleja* cover [%]**	20	29	15	1.3	34	50	91	60	80	89
Chaenorrhinum minus	8	0.1	0	0	0	0	0	0	0	0
Chaerophyllum temulum	0	0	0	0	0	1	0	0	0	0
Circaea lutetiana	0.1	0	0	0	8	1	0	0.2	0	0
Clematis vitalba	0.5	0.5	3	10	6	24	2	1	1	0.8
Clinopodium vulgare	0	0.1	0	0	0	0	0	0	0	0
Coronilla emerus	0	0	0.1	0	0	0.2	0	0	0	0
Corylus avellana	0	0	0	0	0.1	0	0	0	0	0
Cruciata laevipes	0	0	0	0.2	0	0	0	0	0	0
Cynoglossum officinale	0	0	0	0	0	0.2	0	0	0	0.4
Dactylis glomerata	0	0.1	1	0.1	0	5	0.5	0	0	0
Daucus carota	0.2	0.1	0	0.1	0	0	0	0.5	0	0.1
Digitalis lutea	0	0	0	0	0	0	0	0	0.1	0
Digitalis micrantha	0.2	0.2	0	0	0	0.2	0	0	0	0
Diplotaxis tenuifolia	0.1	1.5	0	0	0	0	0	0	0	0
Equisetum ramosissimo	0	0	0	0	0.1	0	0	0	0	0
Equisetum sp.	0	0.1	0	0	0	0	0	0	0	0
Eupatorium cannabinum	3.1	0	13	2	7	2	4	0	0.4	3
Euphorbia cyparissias	0	0.2	0	1	0.2	0	0.2	0	0	0.2
Fagus sylvatica	0	0	0	0.1	0	0	0	0	0.1	0
Fallopia convolvulus	0	0	0.1	0	0	0	0	0	0	0
Fraxinus excelsior	0.1	0	0	0.5	1	2	0	0	0	0
Galeopsis angustifolia	0	1.5	0	0	0	0	0	0.1	0	0
Galeopsis speciosa	0	0	0.5	0	0	0	0	0	0	0
Galium album	2	0.5	2	0.5	3	0	0.2	0.2	0.3	1
Galium sp.	0	0	0	0	0	0	0	0	0.3	0
Geranium lucidum	0.1	0	0	0	0	0	0	0	0	0
Geranium nodosum	0	0	0	0	0.5	0	0	0	0	0
Geranium robertianum	0.2	0.2	3	0.3	5	10	0.5	0	0.1	0.7
Hedera helix	0	0	0	0	0	0.5	0.2	0	0	0.1
Holcus lanatus	0	0.2	0	0	0	0	0	0	0	0
Humulus lupulus	0	0	0	0	0	0.5	0	0	0	0
Hypericum montanum	0.1	0	0	0	0.1	0	0	0	0	0
Hypericum perforatum	0.1	0.1	0.1	0.5	0.1	0	0	0	0.2	0.1
Hypericum richerii	0	0	0	0.2	0	0	0	0	0	0
Impatiens noli-tangere	3	0	0	0	0	0	0	0	0	0

	1st invasion intensity class				2nd invasion intensity class		3rd invasion intensity class			
Plot n°	1	6	7	8	3	4	5	2	9	10
Coordinates [latitude (N) / longitude (E)]	4880661.9 / 622641.0	4885213 / 657983.9	4882714.8 / 650457.1	482309.5 / 650851.5	4880772.9 / 652268.8	4880807.7 / 652082.5	4880889.1 / 651970.6	4880746.6 / 657450.2	4881463.3 / 651483.1	4881183.7 / 651624.1
Altitude a.s.l. [m]	686	620	896	828	687	693	704	685	764	724
Slope [C°]	0	0	4	2	0	3	0	0	0	0
Vegetation cover [%]	42	42	80	60	87	70	97	65	85	98
***Buddleja* cover [%]**	20	29	15	1.3	34	50	91	60	80	89
Impatiens parviflora	0	0	0.5	0	0.1	0	0	0	0	0
Inula coniza	0	0	0	0	0	0	0	0	0.1	0
Laburnum alpinum	0	0.1	0	0	0	0	0	0.1	0	0
Laburnum anagyroides	0	0	2	0.7	0	0	0	0	0.2	0.1
Linaria vulgaris	0	0	0	0	0	0	0.8	0	0	0
Lotus corniculatus	0	0	0	0	0	0	0	0	0	0.1
Medicago lupulina	0	0.1	0	0	0	0	0	0	0.2	0.1
Melica uniflora	0	0	0	0	2	4	1	0	0	0
Melilotus albus	1	0.2	0	0	0	0	0	1	0	0
Menhta suaveolens	0	0	2	0	0.1	0	0	0	0.2	0
Moehringia trinervia	0.7	0	0	0	0	0	0	0.1	0	0
Mycelis muralis	1	0	2	0.7	1	4	0	0.1	0.1	0.5
Myosotis scorpioides	0.1	0	0	0	0	0	0	0	0	0
Ostrya carpinifolia	0	0	2	1	1	3	1	5	2	0
Petasites albus	0.5	0	0.3	0	20	0	0	0.8	0	0.3
Picris hieracioides	0	0.2	0.2	0.3	0	0	0	0	0.2	0.3
Plantago major	2	0	0	0	0	0	0	0	0.1	0
Poa nemoralis	0	0	0	0	0	3	0	0	0	0
Poa pratensis	0	0.1	0	0	0	0	0.5	0.2	0	0.2
Poa trivialis	0.8	0	0	0	0	0	0	0	0	0
Populus tremula	0.1	0	0	0	0	0	0	0	0	0
Primula veris	0	0	0.1	0	0	0	0	0	0	0
Prunella vulgaris	0	0	0	0	0	0	0	0	0.2	0.5
Reseda luteola	0.1	0	0	0	0	0	0	0	0	0
Robinia pseudoacacia	0	0.1	2	0.3	0	0	0	0.1	0.4	0
Rosa canina	0	0	0	1	0	0	0	0	0.2	0
Rubus hirtus	0	0	0	0	10	0	0	0	0	0
Rubus ulmifolius	0	0.2	0	1	0	2	3	0	1	0
Rumex acetosa	0	0	0.5	0.6	0	0	0	0	0.4	0
Rumex sanguineus	0.7	0	0	0	0	0	0	0	0	0
Sagina procumbens	0.4	0	0	0	0	0	0	0	0	0
Salix alba	0	0	15	0.3	0	0	0	0	3	0
Salix caprea	3	0	30	0.3	33	0	0	0.1	0	0
Salix elaeagnus	3.5	0	20	23	35	20	5	9.5	5	5.5
Salix purpurea	0	5	3	2	5	30	1	4	0.2	0.2

	1st invasion intensity class				2nd invasion intensity class		3rd invasion intensity class			
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Coordinates [latitude (N) / longitude (E)]	4880661.9 / 622641.0	4885213 / 657983.9	4882714.8 / 650457.1	482309.5 / 650851.5	4880772.9 / 652268.8	4880807.7 / 652082.5	4880889.1 / 651970.6	4880746.6 / 657450.2	4881463.3 / 651483.1	4881183.7 / 651624.1
Altitude a.s.l. [m]	686	620	896	828	687	693	704	685	764	724
Slope [C°]	0	0	4	2	0	3	0	0	0	0
Vegetation cover [%]	42	42	80	60	87	70	97	65	85	98
***Buddleja* cover [%]**	20	29	15	1.3	34	50	91	60	80	89
Salvia glutinosa	0.5	0	0	0.8	6	5	1	0	0	0.3
Sambucus ebulus	0	0.1	0	0	0	0	0	0.1	0	0
Sambucus nigra	0	0	0	0	0	0	0.2	0	0	0
Sanguisorba minor	0	0.1	0	0	0	0	0	0	0	0
Saponaria officinalis	0	0.3	0	0.3	0.2	1	2	0.2	0.1	0.7
Scabiosa columbaria	0	0.1	0	0	0	0	0	0	0	0
Scrophularia canina	0.1	0.2	0	0.8	0	0	0	0	0.5	0.1
Scrophularia nodosa	0.2	0	0	0	0.1	0.5	0	0	0	0
Sedum cepaea	0.1	0	0	0	0	0	0	0	0	0
Senecio fuchsii	0	0	0	0.1	0	0	0	0	0.1	0
Senecio rupestris	0	0	0	0	0	0	0	0	0.1	0
Senecio vulgaris	0.1	0	0	0	0	0	0	0	0	0
Sesleria argentea	0	0.5	0	0	5	5	0	0	0.3	0.6
Silene vulgaris	0	0.5	0.5	0	0	0	0.2	0	0	0
Solanus dulcamara	0	0	0.5	0	5	0	0.5	0	0	0
Stachys germanica	0	0	0	0.6	0	0	0	0	0.4	0
Stachys sylvatica	0.1	0.1	0	0.1	0	2	0	0	0	1
Stellaria media	0.1	0	0	0	0	0	0	0	0	0
Synphytum tuberosum	0	0	0	0	0	0	0	0	0	0.1
Tanacetum parthenium	0.1	0	0	0.8	0	0	0	0	0.3	0
Taraxacum sp.	0	0	0	0.3	0.1	0	0	0	0.1	0.2
Teucrium scorodonia	0	0	0	0	0	0	0	0.4	0	0.2
Torilis arvensis	0	0	0	0.2	0.2	0	0	0	0	0.2
Urtica dioica	0.1	0	0	0	5	5	0	0	0	0
Valeriana tripteris	0	0	0	0	0	0.5	0	0	0	0
Verbascum pulverulentum	0	0.2	0	0	0	0	0	0	0	0
Verbascum tapsus	0.2	0	0	0	0	0	0	0	0	0
Veronica hederifolia	0.1	0	0	0	0	0	0	0.1	0	0
Veronica serpyllifolia	0.2	0	0	0	0	0	0	0	0	0
Vicia bithynica	0	0	0	0.1	0	0	0	0	0	0
Vicia cracca	0	0	0.2	0.1	0	0	0	0	0	0
Viola versicolor	0	0	0	0.3	0	0	0	0	0	0