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**Author:**
Carli, Emanuela
D'Alessandro, Evelina
Di Marzio, Piera
Giancola, Carmen
Paura, Bruno
Salerno, Giovanni
Blasi, Carlo

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interventions on the river water flow have drastically reduced the riparian forests of Molise. Our results show that in areas in which forest structure and floristic composition have been substantially modified, certain alien plant species, particularly Robinia pseudoacacia, Amorpha fruticosa and Erigeron canadensis, have spread extensively along rivers. In the management of riparian forests, actions aimed at maintaining the stratification of the forest, its uneven-agedness and tree species richness may help to ensure the conservation status, as well as favour the restoration, of habitat 92A0.

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# Monitoring Natura 2000 habitats: habitat 92A0 in central Italy as an example

EMANUELA CARLI[1,*], EVELINA D'ALESSANDRO[2], PIERA DI MARZIO[3], CARMEN GIANCOLA[3], BRUNO PAURA[2], GIOVANNI SALERNO[4], CARLO BLASI[1]

[1] *Dipartimento di Biologia Ambientale, 'Sapienza' Università di Roma (Italy)*

[2] *Dipartimento di Agricoltura, Ambiente e Alimenti, Università del Molise (Italy)*

[3] *Dipartimento di Bioscienze e Territorio, Università del Molise (Italy)*

[4] *Dipartimento di Scienze per la Biologia, la Geologia e l'Ambiente, Università degli Studi del Sannio (Italy)*

* *e-mail corresponding author: piera.dimarzio@unimol.it*

Keywords: alien species, Article 17, conservations status, plant community indicators, plant species indicators, riparian forests.

SUMMARY

The evaluation and the subsequent monitoring of the conservation status of habitats is one of the key steps in nature protection. While some European countries have tested suitable methodologies, others, including Italy, lack procedures tested at the national level. The aim of this work is to propose a method to assess the conservation status of habitat 92A0 (*Salix alba* and *Populus alba* galleries) in central Italy, and to test the method using data from the Molise region. We selected parameters that highlight the conservation status of the flora and vegetation in order to assess habitat structures and functions at the site level. After selecting the parameters, we tested them on a training dataset of 22 unpublished phytosociological relevés taken from the whole dataset, which consists of 119 relevés (49 unpublished relevés for the study area, and 70 published relevés for central Italy). We detected the most serious conservation problems in the middle and lower course of the Biferno river: the past use of river terraces for agriculture and continual human interventions on the river water flow have drastically reduced the riparian forests of Molise. Our results show that in areas in which forest structure and floristic composition have been substantially modified, certain alien plant species, particularly *Robinia pseudoacacia, Amorpha fruticosa* and *Erigeron canadensis,* have spread extensively along rivers. In the management of riparian forests, actions aimed at maintaining the stratification of the forest, its uneven-agedness and tree species richness may help to ensure the conservation status, as well as favour the restoration, of habitat 92A0.

Abbreviations: FV = favourable; SCI = Site of Community Importance; SPA = Special Protection Area; U1 = unfavourable inadequate; U2 = unfavourable bad.

## INTRODUCTION

According to European Directive 92/43/EEC, better known as the Habitat Directive, member states are required to preserve, or restore to a favourable conservation status, habitats within the Natura 2000 Network, that is Sites of Community Importance (SCIs) and Special Protection Areas (SPAs). The conservation of such habitats can only be guaranteed by effective monitoring. The Habitat Directive requires the identification and evaluation of the defining characteristics of the habitats, as well as the threats that affect their current status or that may damage them in the future. According to Article 17 of the Directive, the conservation status of a natural habitat is considered favourable when its area of natural distribution is stable or expanding, when the structure and functions specific to its long-term maintenance exist and are not exposed to future threats, and when the conservation status of its typical species is favourable. While some European countries (JNCC 2004, BfN 2006, Calleja 2009, Carnino 2009) have already designed appropriate methods to monitor the conservation status of habitats, others have yet to introduce standard procedures adopted on a national level. The latter group of countries includes Italy, even though evaluations of Italian habitats, based on expert knowledge, have been performed and were published in the 3rd National Report ex-art. 17 Habitat Directive (92/43/EC) (www.sinanet.isprambiente.it/Reporting_Dir_Habitat).

Riparian habitats represent one of the ecosystems threatened most by human activities, particularly by changes in water regimes, the management of riparian vegetation and pollution (Allan & Flecker 1993, Liendo et al. 2015), as recently highlighted also in central Italy by Viciani et al. (2014). Indeed, nearly 20% of the research projects that have been conducted in recent years have focused on freshwater habitats, as highlighted by the EuMon database on monitoring methods and systems of surveillance for species and habitats of community interest (http://eumon.ckff.si/index1.php).

Changes in water regimes, as well as other types of human disturbance, can facilitate the spread of invasive alien species (Liendo et al. 2015). Indeed, riparian environments are, owing to their inherent predisposition to disturbance, among the environments most prone to invasions of non-native species (Stohlgren et al. 1998, Chytrý et al. 2008). Since the publication of the Italian checklist of non-native flora (Celesti-Grapow et al. 2009, 2010), which raised considerable interest in plant invasions among local botanists, an increasing amount of attention has been paid to alien plant species in Italy. Despite this, the amount of information available in Italy is still incomplete, as highlighted by Assini (2000) for wet areas, and the experience limited, particularly for riparian habitats, if compared with other European and non-European countries (Pyšek and Prach 1993, Richardson et al. 2007, Schnitzler et al. 2007).

Forests dominated by *Salix alba* or *Populus alba* are widespread in the majority of Mediterranean EU member states, though their distribution is scattered (http://natura2000.eea.europa.eu/) owing to their ecological requirements. A specific monitoring strategy for *Salix alba* and *Populus alba* forests based on plant species and community indicators may prove useful to other member states in the Mediterranean area insofar as such forests are azonal. The aim of this study is to help fill this gap by proposing a suitable method to assess the conservation status of habitat 92A0 (*Salix alba* and *Populus alba* galleries) by testing field data from the Molise region, and to shed light on the reasons underlying the expansion of invasive plant species in these environments.

We believe that our case study may be considered a useful example of conservation status assessment of fresh water habitats in central Italy.

## MATERIALS AND METHODS

In Table 1, we list the Natura 2000 sites (SCI/SPAs) included in the study area (Fig. 1), together with the area of the sites and the area covered by the study habitat in each site, derived from the Natura 2000 database (update 2012) (http://www.eea.europa.eu/data-and-maps/data/natura-2000). Although the majority of the sample plots were selected from Natura 2000 sites, some fall within the Biferno river basin and are located outside of the Natura 2000 Network. Owing to the scattered distribution of residual areas with riparian forests belonging to habitat 92A0, for the sampling design, we identified the sites for the sample plots after selecting potential areas referred to these forests by integrating the map of the Natura 2000 habitats in Molise (http://www3.regione.molise.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/657) and the map of the Nature (http://www.isprambiente.gov.it/en/environmental-services/map-of-the-nature-system?set_language=en). Although the number of relevés is not particularly high, we believe that this selection process yields a fairly accurate representation of the current situation of riparian forests in the Molise region.

The vegetation sampling was performed mainly by means of the phytosociological method (Braun-Blanquet 1931, Dengler et al. 2008, Biondi 2011). This method, based on relevés conducted in areas with homogeneous vegetation, records the species and their coverage (as of percentage of the relevé area) and describes the local environment (Mucina et al. 2000). These relevés are aimed at characterising plant communities and identifying the habitat (Biondi et al. 2009).

We first carried out 22 relevés, with a mean area of 70 $m^2$, located in the courses of the all the main rivers in the region except the Volturno and Fortore rivers. A vegetation database was created in Turboveg 2.0 (Hennekens 1995), starting from these 22 original relevés, which were then integrated using a further 27 unpublished relevés conducted along the Biferno river (B. Paura and collaborators, unpublished data), and 70 from the Adriatic side of the Apennines in central and southern Italy, derived from literature (Pedrotti 1970, 1984, Pedrotti and Cortini-Pedrotti 1978, Pirone 1981, 2000, Pirone et al. 1997, Manzi 1988, 1993, Biondi et al. 2002, Baldoni and Biondi 1993, CUM 2002, Allegrezza 2003, Allegrezza et al. 2006).

The 49 unpublished relevés were classified by means of cluster analysis using Past 2.1 (algorithm UPGMA, and Ochiai distance on species cover/presence) (Hammer et al. 2001).

The conservation status was assessed in each site by estimating the characteristics of the habitat and the threats it was exposed to. We focused on the type of data that can be collected from flora and vegetation surveys, adopting those parameters proposed in other member states (JNCC 2004, BfN 2006, Calleja 2009, Carnino 2009) that we considered to apply most to our study area. We then obtained the threshold values for the parameters by using our whole dataset (119 relevés), classifying them according to natural breaks (Jenks 1967). We decided to use natural breaks for classification purposes because we considered them to be more representative of the variation of our data. Table 2 summarizes the three types of parameters and the threshold values of the corresponding indicators used to assess the conservation status.

To assess the structure of the forest vegetation, we selected the following indicators: (i) the cover of the native tree layer and of the shrub layer (h 2-5 m) to highlight the stratification of the vegetation (JNCC 2004, Calleja 2009); (ii) the number of diameter classes of the tree trunks, which provide information on the uneven-agedness of the forest and the presence and type of forest management (BfN 2006, Carnino 2009); (iii) the presence of dead wood (relative cover in each relevé of woody debris and/or standing dead wood, and the presence of fallen old trees), to highlight the absence of management or natural forest management (BfN 2006, Carnino 2009).

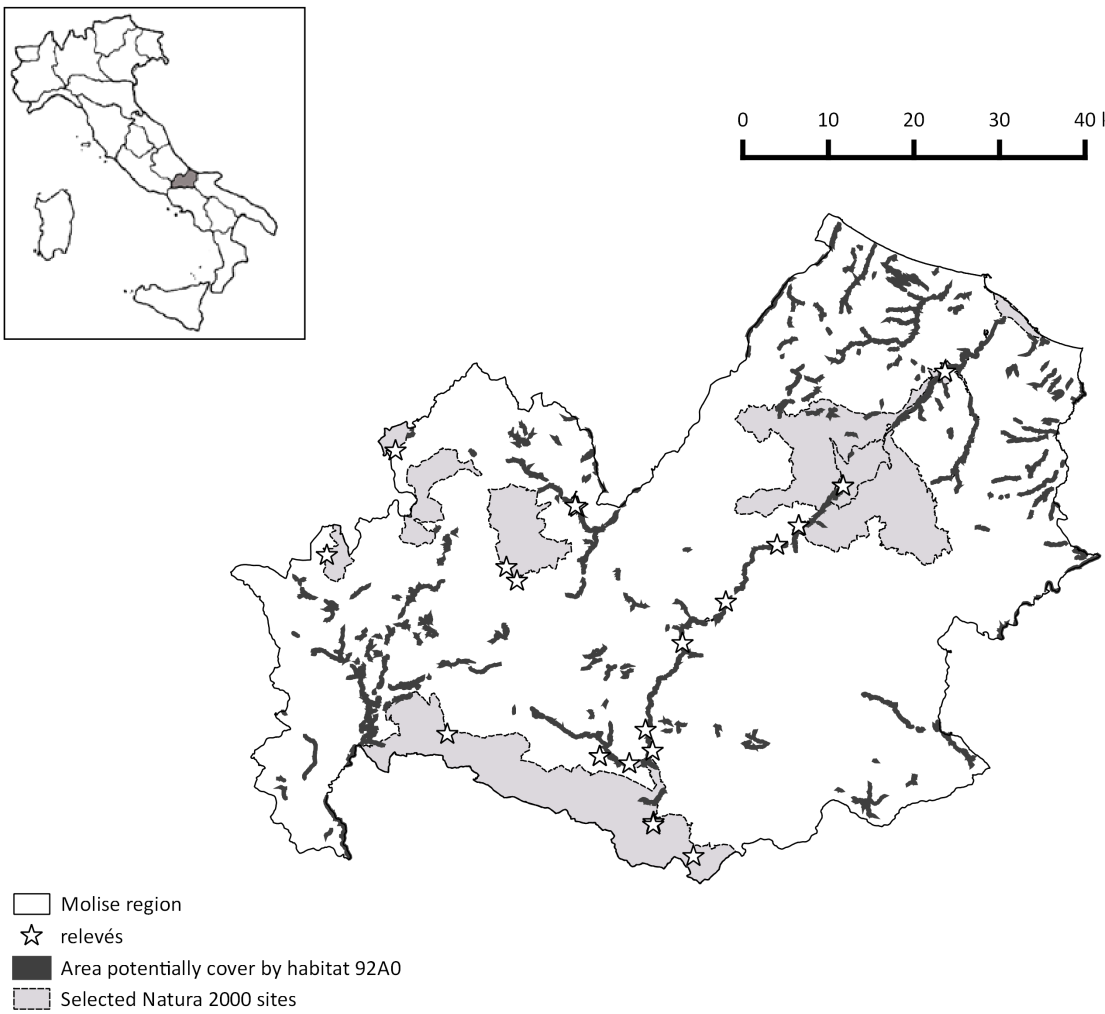


FIGURE 1. Study area showing the location of the 22 relevés (white stars) assessed and the selected Natura 2000 sites in Molise region (grey areas). The inlet shows the position of Molise in Italy.

TABLE 1. List of Natura 2000 sites included in the study area, showing the area covered by each site and the area covered by habitat 92A0 (including other habitat types that may form a mosaic of riparian vegetation with habitat 92A0) (http://www.eea.europa.eu/data-and-maps/data/natura-4).

| Site_code | Site_name | Habitat_code | Site_area | Habitat_cover_ha |
|---|---|---|---|---|
| IT7211120 | Torrente Verrino | 92A0, 3280 | 93 | 34.41 |
| IT7212124 | Bosco Monte di Mezzo - Monte Miglio - Pennataro - Monte Capraro - Monte Cavallerizzo | | 3954 | |
| IT7212126 | Pantano Zittola - Feudo Valcocchiara | 92A0, 3260 | 1246 | 14.95 |
| IT7212134 | Bosco di Collemeluccio - Selvapiana - Castiglione - La Cocozza | | 6239 | 62.39 |
| IT7218213 | Isola della Fonte della Luna | 92A0 | 867 | 86.7 |
| IT7222247 | Valle Biferno da confluenza Torrente Quirino al Lago Guardalfiera - Torrente Rio | 92A0, 3260 | 368 | 228.16 |
| IT7222249 | Lago di Guardialfiera - M. Peloso | 92A0 | 2848 | 56.96 |
| IT7222287 | La Gallinola - Monte Miletto - Monti del Matese | 92A0 | 25002 | 50 |
| IT7228229 | Valle Biferno dalla diga a Guglionesi | 92A0, 3260, 3280 | 356 | 106.8 |
| IT7222237 | Fiume Biferno (confluenza Cigno - alla foce esclusa) | 92A0, 3280 | 133 | 42.56 |
| IT7228230 | Lago di Guardialfiera - Foce fiume Biferno | | 28724 | |

TABLE 2. Parameters used in the study to assess the conservation status and their relative indicator values. List of the abbreviations: tree_cov = tree cover; sh_cov = shrub cover; ages = number of diameter classes; dead = dead wood; FC = floristic consistency; tree-rich = tree species richness; alien = presence of alien species; interest = presence of species of interest; FV = favourable; U1 = unfavourable inadequate; U2 = unfavourable bad.

| Parameters | Threshold value | Assessment |
|---|---|---|
| tree_cov | ≥ 60% | F |
| | | U1 |
| | < 30% | U2 |
| sh_cov | ≥ 60% | F |
| | | U1 |
| | < 20% | U2 |
| ages | ≥ 3 | F |
| | | U1 |
| | 1 | U2 |
| dead | fallen old trees | F |
| | woody debris and standing dead wood | F |
| | woody debris and standing dead wood | U1 |
| | absent | U2 |
| FC | ≥ 40% | F |
| | | U1 |
| | < 15% | U2 |
| weed_alien | absent | F |
| | < 5% | U1 |
| | > 5% | U2 |
| tree_rich | ≥ 3 | F |
| | | U1 |
| | < 3 | U2 |
| interest | present | F |
| | absent | - |

We selected the following floristic and vegetation indicators: (i) the floristic consistency of the communities detected (JNCC 2004, BfN 2006, Calleja 2009, Carnino 2009) with the vegetation of reference, by comparing the presence of diagnostic and frequent species for the alliances (Biondi et al.

2014; http://www.prodromo-vegetazione-italia.org/); (ii) the presence and cover of exotic species, which reduce the degree of naturalness (JNCC 2004, Carnino 2009); (ii) the native tree species richness, which is particularly marked in Italian old-growth forests (Burrascano et al. 2009), and known to be a good proxy for the total richness (Abbate et al. 2015); (iv) the presence of species of biogeographic or conservation interest, selected from Red Lists and other lists of protected or rare species (Table 3), which highlight the peculiarities of the site (BfN 2006).

TABLE 3. List of species of biogeographic or conservation interest selected from Red Lists (Conti et al. 1992, 1997, Rossi et al. 2013) and other lists of protected or rare species (Directive 92/43/EC, http://www.societabotanicaitaliana.it/cites/index.asp, Lucchese 1995, 1996, Regione Molise 1999, Fortini e Viscosi 2008); List of abbreviations: CR = Critically Endangered; EN = Endangered; LR = Low Risk; NT = Near Threatened; VU = Vulnerable.; HD = Council Directive 92/43/EEC; CITES = Council Regulation (EC) No 338/97; Reg. = Regione Molise, Legge Regionale 23 febbraio 1999 n°9.

| Species | Conti et al. 1992 or Rossi et al. 2013 | Conti et al. 1997 | Protected species | Rare species |
|---|---|---|---|---|
| *Acer cappadocicum* Gled. subsp. *lobelii* (Ten.) A.E.Murray (≡ *Acer lobelii* Ten.) | LR | LR | | |
| *Alopecurus bulbosus* Gouan | | EN | Reg. | x |
| *Anacamptis palustris* (Jacq.) R.M. Bateman, Pridgeon & M.W.Chase (≡ *Orchis palustris* Jacq.) | EN | CR | Reg. | x |
| *Asparagus acutifolius* L. | | LR | | |
| *Caltha palustris* L. | | EN | Reg. | x |
| *Carex paniculata* L. subsp. *paniculata* | | CR | Reg. | x |
| *Carex pseudocyperus* L. | | CR | Reg. | x |
| *Cicuta virosa* L. | | EN | | |
| *Clematis viticella* L. | | EN | | |
| *Cucubalus baccifer* L. | | LR | | |
| *Dactylorhiza incarnata* (L.) Soó subsp. *incarnata* | | EN | Reg. | x |
| *Dactylorhiza maculata* (L.) Soó (≡ *Orchis maculata* L.) | | | HD, CITES | |
| *Dichoropetalum schottii* (Besser ex DC.) Pimenov & Kljuykov (≡ *Peucedanum schottii* Besser ex DC.) | | CR | Reg. | x |
| *Epilobium palustre* L. | | CR | | |
| *Epipactis palustris* (L.) Crantz | NT | CR | Reg. | x |
| *Euphorbia palustris* L. | | CR | Reg. | x |
| *Helosciadium inundatum* (L.) W.D.J.Koch (≡ *Apium inundatum* (L.) Rchb. f.) | | EN | Reg. | x |
| *Isoëtes durieui* Bory | | CR | Reg. | x |
| *Limniris pseudacorus* (L.) Fuss (≡ *Iris pseudacorus* L.) | | VU | | |
| *Lomelosia graminifolia* (L.) Greuter & Burdet (≡ *Scabiosa graminifolia* | | LR | | |

| Species | Conti et al. 1992 or Rossi et al. 2013 | Conti et al. 1997 | Protected species | Rare species |
|---|---|---|---|---|
| L.) | | | | |
| *Menyanthes trifoliata* L. | | CR | Reg. | x |
| *Myosurus minimus* L. | | EN | Reg. | x |
| *Ophioglossum vulgatum* L. | | EN | Reg. | x |
| *Orobanche flava* Mart. ex F.W. Schultz | | EN | Reg. | x |
| *Persicaria amphibia* (L.) Delarbre (≡ *Polygonum amphibium* L.) | | CR | Reg. | x |
| *Peucedanum officinale* L. subsp. *officinale* | | CR | Reg. | x |
| *Ranunculus flammula* L. | VU | EN | Reg. | x |
| *Ranunculus lingua* L. | VU | CR | Reg. | x |
| *Ruscus aculeatus* L. | | | HD | |
| *Salix cinerea* L. | | LR | | |
| *Salix fragilis* L. | | VU | | |
| *Salix pentandra* L. | EN | CR | Reg. | x |
| *Sparganium emersum* Rehmann | | CR | Reg. | x |
| *Thelypteris palustris* Schott | | EN | Reg. | x |
| *Triglochin bulbosum* L. subsp. *barrelieri* (Loisel.) Rouy | | EN | Reg. | x |
| *Trollius europaeus* L. subsp. *europaeus* | | EN | Reg. | x |
| *Utricularia vulgaris* L. | | CR | | x |

We tested the parameters we selected on a training dataset, i.e. 22 relevés that we carried out in the Molise Region. In this way, we only considered the most recent relevés, for conservation status assessment purposes.

When assessing the conservation status of forests in the Mediterranean area, it should be noticed that, owing to the impact of man over the millennia, forest habitats that have either never been used by humans or were only used in very ancient times are extremely rare. We cannot consequently expect the best-preserved context to be represented by a primeval forest (Carnino 2009). This is why we decided to determine the threshold values of the parameters for the best-conserved situations based on our whole dataset.

The resulting synthetic assessment for each relevé is determined by the condition of the worst parameter, as suggested by Article 17 of the Habitat Directive (92/43/EEC).

## RESULTS

The cluster analysis led to the identification of two main types of riparian forests, referred to *Salicion albae* Soó 1930 (55% of the 49 unpublished relevés) and to *Populion albae Br.-Bl.* ex Tchou 1948 (45%).

The species recorded in more than 40% of the relevés are *Salix alba*, *Rubus ulmifolius*, *Brachypodium sylvaticum*, *Salix purpurea*, *Populus nigra*, *Cornus sanguinea* and *Urtica dioica* (see Supplementary Table S1 for the complete list).

Fourteen of the 22 relevés were found to have an Unfavourable-Bad (U2) conservation status. The worst parameters, indicating a bad conservation status, were mainly richness of the native trees species and shrub cover.

TABLE 4. Assessment of the conservation status of habitat 92A0 in our study area. List of the abbreviations: tree_cov = tree cover; sh_cov = shrub cover; ages = number of diameter classes of the tree trunks; dead = dead wood; FC = floristic consistency; tree-rich = tree species richness; alien = presence of alien species; interest = presence of species of interest; FV = favourable; U1 = unfavourable inadequate; U2 = unfavourable bad.

| relevé | type of vegetation | tree_ cov | sh_ cov | ages | dead | char_ab u | tree_ rich | weed_a lien | interest | general assessment |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | forest of *Salix alba* | FV | FV | FV | FV | FV | FV | FV | FV | FV |
| 2 | forest of *Populus alba* | FV | FV | FV | FV | FV | FV | FV | - | FV |
| 3 | forest of *Populus alba* | FV | FV | FV | FV | FV | FV | FV | - | FV |
| 4 | forest of *Populus alba* | U1 | FV | FV | FV | FV | U1 | FV | - | U1 |
| 5 | forest of *Populus alba* | FV | FV | FV | U1 | FV | U1 | FV | - | U1 |
| 6 | forest of *Salix alba* | FV | FV | FV | U1 | FV | U1 | FV | FV | U1 |
| 7 | forest of *Populus alba* | FV | FV | FV | U1 | FV | U1 | FV | - | U1 |
| 8 | forest of *Populus alba* | FV | FV | FV | U1 | FV | U1 | U2 | - | U2 |
| 9 | forest of *Populus alba* | FV | FV | U1 | U2 | FV | FV | U2 | - | U2 |
| 10 | forest of *Populus alba* | FV | FV | FV | FV | FV | U2 | U2 | - | U2 |
| 11 | forest of *Populus alba* | U1 | FV | FV | - | FV | FV | U2 | - | U2 |
| 12 | forest of *Populus alba* | FV | FV | U1 | FV | FV | U2 | U2 | - | U2 |
| 13 | forest of *Populus alba* | FV | FV | FV | FV | U2 | U2 | U2 | - | U2 |
| 14 | forest of *Salix alba* | FV | FV | U1 | U1 | FV | U2 | U2 | - | U2 |
| 15 | forest of *Salix alba* | U1 | FV | FV | U1 | U2 | FV | U2 | - | U2 |
| 16 | forest of *Populus alba* | FV | U2 | U1 | U2 | U1 | FV | U2 | - | U2 |
| 17 | forest of *Populus alba* | U2 | U2 | U1 | FV | FV | U2 | U2 | - | U2 |
| 18 | forest of *Salix alba* | FV | U2 | U1 | U2 | U2 | U2 | U2 | - | U2 |
| 19 | shrub veg. (*Salix* sp. pl.) | - | - | - | - | FV | - | FV | FV | U1 |
| 20 | shrub veg. (*Salix* sp. pl.) | - | - | - | - | FV | - | U2 | - | U2 |
| 21 | shrub veg. (*Salix* sp. pl.) | - | - | - | - | 2 | - | U2 | - | U2 |
| 22 | shrub veg. (*Salix* sp. pl.) | - | - | - | - | -1 | - | U2 | - | U2 |

We detected a marked difference between the western and eastern parts of the region (relevés n° 1 and 2 in Table 4). The site with the best conservation status was located in SCI IT7218213, where the native tree species richness and the presence of woody debris, two surrogates for the natural or seminatural evolution of the forest, are very good. The majority of the relevés in the Campobasso province (in the east) were found to have an unfavourable conservation status. In the surroundings of IT7222287 lies the only riparian forest in which we found a favourable conservation status (relevé n° 3), particularly as regards the native tree species richness and the presence of woody debris, which were comparable to those detected in the aforementioned site n° 2.

## DISCUSSION

The Molise region is characterized by a strong altitudinal gradient and by the presence of large river valleys (e.g. Volturno and Biferno) that connect the two sides of the Apennines. These valleys have always allowed the migration of plant species (Lucchese 1995, Paura et al. 2010b). These migrations are now represented by invasive exotic species. Indeed, it is along the rivers that the greatest spread of invasive species has been witnessed in the region (Lucchese 2010). Rivers play an important role in the invasion of plant species insofar as their waters act as important agents of propagule dispersal, just as aquatic birds do. In addition, periodic disturbance events, due to floods, create openings in plant cover that can easily be colonized by alien plant species thanks to the availability of nutrients. Low water periods also provide areas that are exposed to colonization by pioneer annual plants. Lastly, the rivers are subject to anthropogenic disturbance (agriculture, urbanization, water regimentations, etc.), which also promotes the spread of invasive species (Stohlgren et al. 1998, Schnitzler et al. 2007).

Riparian forests are known to be azonal formations that are conditioned mainly by the water level and water regime (Pedrotti and Gafta 1996). Although such forests are very dynamic owing to the natural disturbance to which they are subjected, they remain relatively stable if the hydrogeological conditions do not change. Riparian forests belonging to habitat 92A0 can be divided in two types, as described in the national interpretation manual (Biondi et al. 2012). They differ in dominant tree species and from an ecological point of view. Willow groves are located on the lower terraces, which are affected regularly by the ordinary flooding of the river, while poplar forests colonize the upper terraces, which are only sporadically affected by extraordinary flooding. The aforementioned manual recognized two different alliances of reference: *Populion albae* Br.-Bl. ex Tchou 1948 and *Salicion albae* Soó 1930 (Biondi et al. 2014).

The most recent European Interpretation Manual describes habitat 92A0 as "Riparian forests of the Mediterranean basin dominated by *Salix alba*, *Salix fragilis* or their relatives. Mediterranean and Central Eurasian multi-layered riverine forests with *Populus* spp. [...]" (European Commission 2007). The name of the habitat makes explicit reference to gallery forests, sometimes generating difficulty in recognizing the habitat where riparian forest conservation does not preserve this aspect. In Spain, Calleja (2009) has proposed extending the definition to include the intermediate stages of vegetation dominated by shrubby willows with sparse trees of *Salix alba* and *Populus alba*. We agree with this proposal and have included forests of *Populus alba*, *Populus nigra* and *Salix alba* and shore vegetation dominated by shrubby willows, with some willow trees or poplars, in this study.

Our study identified two types of riparian forests, as expected for habitat 92A0: *Salicion albae* and *Populion albae* (Biondi et al. 2009, 2014). The main difference between these two types of forest lies in the dominant tree species (*Salix* or *Populus* species), there being little difference in the understory flora. Our findings are confirmed by data in the literature. Indeed, as shown in previous works on riparian vegetation (Pirone 1981, 2000, Pedrotti 1984, Manzi 1988, 1993), the general impoverishment of the flora of poplar forests in central Italy, due to the past use of this habitat by humans for agricultural purposes, makes it somewhat difficult to distinguish them from willow forests. Furthermore, the forests of *Populus alba*, which are affected to a lesser extent by river flooding, are also characterized by species that belong to oak forests, as highlighted in Molise by Paura et al. (2010a). It is likely that ISPRA (Institute for Environmental Protection and Research) included the Mediterranean tall willow galleries (EUNIS code 44.41) in the Italian poplar galleries (EUNIS code 44.614) on account of the floristic similarity between poplars and willows forests in the Apennines (for more information see http://www.isprambiente.gov.it/files/carta-della-natura/catalogo-habitat.pdf).

The rivers in central and southern Italy do not tend to create large floodplains that lend themselves to intensive agriculture. Human activities in these two regions have resulted in substantial changes in the flora and vegetation, particularly as a result of works related to riverbank reinforcement and to the production of electricity. These changes have often promoted the establishment and spread of exotic plant species (Lucchese 2010). The riparian forests of willows and poplars examined in this study revealed a peculiar susceptibility to human intervention and displayed considerably different features if compared with the past (Pedrotti and Cortini-Pedrotti 1978, Pedrotti 1984).

The most serious conservation problems were detected along the lower course of the Biferno river, in the Campobasso province. The past land use of river terraces and the continual human interventions have led to only small portions of what was once likely to have been the richest lowland forest in Molise being left, such as that near Colle d'Anchise, which lies out of the Natura 2000 Network (relevés n° 3 in Table 3), and where a well-preserved forest still exists. This area has not yet been included as a Natura 2000 site. It is a very rich poplar forest that is well stratified and contains a large amount of woody debris, standing dead wood and fallen old trees. In order to promote the natural evolution of this forest and its conservation, the boundaries of SCI IT7222247 "Valle Biferno da confluenza Torrente Quirino al Lago Guardalfiera - Torrente Rio" should be redrawn in such a way as to include the forest of Colle d'Anchise in the Natura 2000 network.

A better state of preservation is found in the areas that lie in the upper course of the rivers, where human impact is less marked and there are few exotic species. The site with the best conservation status is SCI IT7218213 "Isola Fonte della Luna" (relevés n°2 in Table 4), which has been unmanaged for approximately 30 years. As shown in Table 4, the structure of the forest is fairly well preserved and nine tree species were been found, which is the highest number recorded in the study area.

Exotic species tend to be promoted in areas in which the structure and floristic composition of the forest are substantially compromised. This is particularly evident in relevés n°17 in the Biferno valley (in the proximity of Morgia dell'Eremita), where the poplar layer has been completely replaced by *Robinia pseudoacacia*. The poor conservation status of the poplar forests in the lower course of the Biferno river may have been caused by the overall reduction in the size of this habitat, following the replacement in many areas of riparian forests by cultivated fields, a trend first observed in the 1970s in central and southern Italy (Pedrotti 1970, 1984, Manzi 1988, 1993). It is in the woods in this area that we observed the greatest spread of alien plant species such as *Robinia pseudoacacia*, *Amorpha fruticosa* and *Erigeron canadensis.* A similar trend has been observed for the willow forests in the Po Plain (Poldini et al. 2011). We should not forget that the success of invasive plant species is often the result of a poor conservation status of riparian habitats (Stohlgren et al. 1998, Chytrý et al. 2009, Liendo et al. 2015).

The introduction and spread of these invasive species appear to be promoted in areas in which trees and shrub layers are not well developed. Indeed, alien species were not recorded in sites with a favourable conservation status, particularly as regards the structure. In conclusion, we believe that forest management should focus on maintaining the stratification of the forest, its uneven-agedness and tree species richness because a forest can withstand the invasion of alien species only as long as its structure is well preserved and strong.

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SUPPLEMENTARY TABLE S1. List of species, number of relevés in which they are present, and relative frequency.

| **Species** | **N° relevés** | **frequency** |
|---|---|---|
| *Acer campestre* L. | 9 | 0.41 |
| *Acer cappadocicum* Gled. subsp. *lobelii* (Ten.) A.E.Murray | 2 | 0.09 |
| *Acer opalus* Mill. subsp. *obtusatum (*Waldst. & Kit. ex Willd.) Gams | 2 | 0.09 |
| *Acer pseudoplatanus* L. | 7 | 0.32 |
| *Aegopodium podagraria* L. | 2 | 0.09 |
| *Agrostis stolonifera* L. | 7 | 0.32 |
| *Alisma plantago-aquatica* L. | 7 | 0.32 |
| *Alnus glutinosa* (L.) Gaertn. | 4 | 0.18 |
| *Alopecurus myosuroides* Huds. | 5 | 0.23 |
| *Alopecurus utriculatus* (L.) Pers. | 5 | 0.23 |
| *Amorpha fruticosa* L. | 11 | 0.50 |
| *Anisantha diandra* (Roth) Tutin ex Tzvelev | 6 | 0.27 |
| *Anisantha sterilis* (L.) Nevski | 3 | 0.14 |
| *Anthoxanthum odoratum* L. | 5 | 0.23 |
| *Artemisia verlotorum* Lamotte | 5 | 0.23 |
| *Artemisia vulgaris* L. | 5 | 0.23 |
| *Arum italicum* Miller | 2 | 0.09 |
| *Arundo pliniana* Turra | 7 | 0.32 |
| *Berula erecta* (Huds.) Coville | 9 | 0.41 |
| *Bidens frondosa* L. | 11 | 0.50 |
| *Bolboschoenus maritimus* (L.) Palla | 2 | 0.09 |
| *Brachypodium sylvaticum* (Huds.) P.Beauv. | 18 | 0.82 |
| *Bromopsis benekenii* (Lange) Holub | 2 | 0.09 |
| *Bromus hordeaceus* L. | 6 | 0.27 |
| *Bryonia dioica* Jacq. | 7 | 0.32 |
| *Calystegia sepium* (L.) R.Br. | 7 | 0.32 |
| *Carex hirta* L. | 5 | 0.23 |
| *Carex otrubae* Podp. | 7 | 0.32 |
| *Carex pendula* Huds. | 8 | 0.36 |
| *Cerastium holosteoides* Fr. | 5 | 0.23 |
| *Chenopodium album* L. | 3 | 0.14 |
| *Cirsium creticum* (Lam.) d'Urv. | 5 | 0.23 |
| *Clematis vitalba* L. | 11 | 0.50 |
| *Convolvulus arvensis* L. | 5 | 0.23 |
| *Cornus mas* L. | 6 | 0.27 |
| *Cornus sanguinea* L. | 16 | 0.73 |
| *Corylus avellana* L. | 3 | 0.14 |
| *Cota tinctoria* (L.) J.Gay | 2 | 0.09 |
| *Crataegus monogyna* Jacq. | 15 | 0.68 |

| Species | N° relevés | frequency |
|---|---|---|
| *Crepis vesicaria* L. | 5 | 0.23 |
| *Cucubalus baccifer* L. | 6 | 0.27 |
| *Cynosurus cristatus* L. | 5 | 0.23 |
| *Dactylis glomerata* L. | 6 | 0.27 |
| *Dactylorhiza incarnata* (L.) Soó | 5 | 0.23 |
| *Daphne laureola* L. | 2 | 0.09 |
| *Daucus carota* L. | 4 | 0.18 |
| *Digitalis micrantha* Roth | 2 | 0.09 |
| *Dioscorea communis* (L.) Caddick & Wilkin | 2 | 0.09 |
| *Dipsacus laciniatus* L. | 3 | 0.14 |
| *Dittrichia viscosa* (L.) Greuter | 3 | 0.14 |
| *Doronicum orientale* Hoffm. | 2 | 0.09 |
| *Eleocharis palustris* (L.) Roem. & Schult. | 5 | 0.23 |
| *Epilobium hirsutum* L. | 10 | 0.45 |
| *Equisetum arvense* L. | 3 | 0.14 |
| *Equisetum ramosissimum* Desf. | 3 | 0.14 |
| *Equisetum telmateja* Ehrh. | 7 | 0.32 |
| *Erigeron canadense* L. | 8 | 0.36 |
| *Euonymus europaeus* L. | 13 | 0.59 |
| *Eupatorium cannabinum* L. | 4 | 0.18 |
| *Euphorbia amygdaloides* L. | 5 | 0.23 |
| *Euphorbia helioscopia* L. | 2 | 0.09 |
| *Foeniculum vulgare* Mill. | 2 | 0.09 |
| *Fraxinus ornus* L. | 3 | 0.14 |
| *Galium aparine* L. | 5 | 0.23 |
| *Galium palustre* L. | 5 | 0.23 |
| *Geranium robertianum* L. | 9 | 0.41 |
| *Geranium versicolor* L. | 5 | 0.23 |
| *Geum urbanum* L. | 11 | 0.50 |
| *Glyceria plicata* Fries | 5 | 0.23 |
| *Hedera helix* L. | 10 | 0.45 |
| *Helianthus tuberosus* L. | 2 | 0.09 |
| *Helleborus foetidus* L. | 3 | 0.14 |
| *Helminthotheca echioides* (L.) Holub | 2 | 0.09 |
| *Heracleum sphondylium* L. | 6 | 0.27 |
| *Holcus lanatus* L. | 9 | 0.41 |
| *Hordeum bulbosum* L. | 5 | 0.23 |
| *Humulus lupulus* L. | 6 | 0.27 |
| *Hypericum tetrapterum* Fries | 7 | 0.32 |
| *Juglans regia* L. | 2 | 0.09 |
| *Juncus articulatus* L. | 5 | 0.23 |

| **Species** | **N° relevés** | **frequency** |
|---|---|---|
| *Juniperus communis* L. | 2 | 0.09 |
| *Lactuca muralis* (L.) Gaertn. | 3 | 0.14 |
| *Lactuca serriola* L. | 3 | 0.14 |
| *Lapsana communis* L. | 7 | 0.32 |
| *Lepidium campestre* (L.) R.Br. | 2 | 0.09 |
| *Ligustrum vulgare* L. | 11 | 0.50 |
| *Lycium europaeum* L. | 2 | 0.09 |
| *Lycopus europaeus* L. | 14 | 0.64 |
| *Lysimachia vulgaris* L. | 3 | 0.14 |
| *Lythrum salicaria* L. | 7 | 0.32 |
| *Malus sylvestris* Mill. | 5 | 0.23 |
| *Melica uniflora* Retz. | 2 | 0.09 |
| *Melilotus alba* Medicus | 3 | 0.14 |
| *Mentha aquatica* L. | 8 | 0.36 |
| *Mentha longifolia* (L.) Huds. | 8 | 0.36 |
| *Mentha pulegium* L. | 5 | 0.23 |
| *Muscari comosum* (L.) Mill. | 5 | 0.23 |
| *Myosotis scorpioides* L. | 5 | 0.23 |
| *Oenanthe pimpinelloides* L. | 5 | 0.23 |
| *Paspalum paspaloides* (Michx.) Scribner | 10 | 0.45 |
| *Persicaria amphibia* (L.) Delarbre | 7 | 0.32 |
| *Persicaria hydropiper* (L.) Delarbre | 2 | 0.09 |
| *Petasites hybridus* (L.) G.Gaertn., B.Mey. & Scherb. | 6 | 0.27 |
| *Petasites pyrenaicus* (L.) G.López | 3 | 0.14 |
| *Phalaris paradoxa* L. | 2 | 0.09 |
| *Phragmites australis* (Cav.) Trin. | 7 | 0.32 |
| *Picris hieracioides* L. | 4 | 0.18 |
| *Pimpinella peregrina* L. | 2 | 0.09 |
| *Plantago lanceolata* L. | 6 | 0.27 |
| *Plantago major* L. | 4 | 0.18 |
| *Poa trivialis* L. | 11 | 0.50 |
| *Populus alba* L. | 14 | 0.64 |
| *Populus nigra* L. | 17 | 0.77 |
| *Potentilla reptans* L. | 6 | 0.27 |
| *Prunus spinosa* L. | 9 | 0.41 |
| *Pulmonaria apennina* Cristof. & Puppi | 4 | 0.18 |
| *Pyrus communis* L. subsp. *pyraster* (L.) Ehrh. | 5 | 0.23 |
| *Quercus cerris* L. | 2 | 0.09 |
| *Quercus pubescens* Willd. | 6 | 0.27 |
| *Ranunculus lanuginosus* L. | 3 | 0.14 |
| *Ranunculus repens* L. | 8 | 0.36 |

| Species | N° relevés | frequency |
|---|---|---|
| *Ranunculus sardous* Crantz | 5 | 0.23 |
| *Ranunculus serpens* Schrank | 2 | 0.09 |
| *Ranunculus trichophyllus* Chaix | 6 | 0.27 |
| *Rhinanthus alectorolophus* (Scop.) Pollich | 5 | 0.23 |
| *Robinia pseudoacacia* L. | 9 | 0.41 |
| *Rorippa sylvestris* (L.) Besser | 5 | 0.23 |
| *Rosa arvensis* Huds. | 2 | 0.09 |
| *Rubus caesius* L. | 6 | 0.27 |
| *Rubus ulmifolius* Schott | 20 | 0.91 |
| *Rumex conglomeratus* Murray | 3 | 0.14 |
| *Rumex crispus* L. | 5 | 0.23 |
| *Salix alba* L. | 22 | 1.00 |
| *Salix eleagnos* Scop. | 5 | 0.23 |
| *Salix fragilis* L. | 5 | 0.23 |
| *Salix pentandra* L. | 5 | 0.23 |
| *Salix purpurea* L. | 17 | 0.77 |
| *Salix triandra* L. | 4 | 0.18 |
| *Salvia glutinosa* L. | 2 | 0.09 |
| *Sambucus nigra* L. | 11 | 0.50 |
| *Saponaria officinalis* L. | 3 | 0.14 |
| *Scirpoides holoschoenus* (L.) Soják | 4 | 0.18 |
| *Scrophularia umbrosa* Dumort. | 7 | 0.32 |
| *Sherardia arvensis* L. | 2 | 0.09 |
| *Sinapis alba* L. | 4 | 0.18 |
| *Solanum dulcamara* L. | 4 | 0.18 |
| *Sonchus asper* (L.) Hill | 6 | 0.27 |
| *Sparganium erectum* L. | 6 | 0.27 |
| *Stachys sylvatica* L. | 10 | 0.45 |
| *Stellaria media* (L.) Vill. | 2 | 0.09 |
| *Symphyotrichum squamatum* (Spreng.) G.L.Nesom | 5 | 0.23 |
| *Taraxacum* F.H.Wigg. sect. *Taraxacum* | 5 | 0.23 |
| *Tordylium maximum* L. | 9 | 0.41 |
| *Torilis nodosa* (L.) Gaertn. | 2 | 0.09 |
| *Trifolium brutium* Ten. | 5 | 0.23 |
| *Trifolium pratense* L. | 6 | 0.27 |
| *Trifolium repens* L. | 7 | 0.32 |
| *Trifolium resupinatum* L. | 5 | 0.23 |
| *Typha angustifolia* L. | 2 | 0.09 |
| *Typha latifolia* L. | 8 | 0.36 |
| *Ulmus minor* Mill. | 9 | 0.41 |
| *Urtica dioica* L. | 16 | 0.73 |

| Species | N° relevés | frequency |
|---|---|---|
| *Valeriana officinalis* L. | 5 | 0.23 |
| *Veronica anagallis-aquatica* L. | 2 | 0.09 |
| *Veronica beccabunga* L. | 4 | 0.18 |
| *Veronica catenata* Pennell | 5 | 0.23 |
| *Vicia sepium* L. | 2 | 0.09 |
| *Viola alba* Besser | 5 | 0.23 |
| *Xanthium italicum* Moretti | 4 | 0.18 |
| *Xanthium spinosum* L. | 2 | 0.09 |