

Alpine rivers and their ligneous vegetation with *Myricaria germanica* and riverine landscape diversity in the Eastern Alps: proposing the Isel river system for the Natura 2000 network

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Abstract

The setting up of the European network of protected areas (Natura 2000) is nearing completion. Alpine rivers with near-natural morphology and dynamics have become rare and are highly endangered. *Myricaria germanica*, an endangered indicator species of Alpine rivers, reflects riverine landscape diversity. The study is based upon an evaluation of literature as well as upon new data. The analysis of the actual distribution of habitat 3230 Alpine rivers and their ligneous vegetation with *M. germanica* identifies the river Isel and its tributaries Schwarzach, Kalserbach and Tauernbach as an important addition to the Natura 2000 network.

Introduction

In 2012 the European Union (EU) celebrated 20 years of protecting biodiversity by means of the Habitat Directive. The EU biodiversity strategy up to 2020 defines the target that *Member States and the Commission will ensure that the phase to establish Natura 2000 [...] is largely complete by 2012* (EU 2011).

Nevertheless, some additional site nominations for a few habitat types and species – for the Alpine as well as for other biogeographical regions – are still missing, such as additional protected areas for habitat 3230, especially in Austria (ETC / BD 2012; Kudrnovsky 2011).

European directives

Natura 2000 is an ecological coherent European network of important protected areas aiming to preserve species diversity and to maintain natural habitats in EU member states, based upon Directive EEC/92/43 (*Fauna-Flora-Habitat Directive*, FFH, EU 1992) and Directive 2009/147/EC (*Directive on the conservation of wild birds*, EU 2009a).

In the year 2000 the EU Water Framework Directive (WFD) was finally adopted (EU 2000). It introduces a new legislative approach to managing and protecting water, not based on national or political boundaries but on natural geographical and hydrological formations, the river basins.

All these European directives establish a legal framework and set out action plans to maintain or restore a favourable conservation status of Alpine rivers and associated habitats and species of community interest.

Natura 2000

River stretches with high nature value are integrated into the Natura 2000 network of protected areas. For the Alpine biogeographical region three typical habitats are listed and can be seen as a succession from highly dynamic (3220 Alpine rivers and the herbaceous vegetation along their banks) to medium dynamic (3230 Alpine rivers and their ligneous vegeta-



Figure 1 – Riverine landscape Isel © Kudrnovsky 2010

tion with *Myricaria germanica*) and moderately dynamic (3240 Alpine rivers and their ligneous vegetation with *Salix elaeagnos*) pioneer sites.

The conservative status of a habitat is favourable if:

- its natural range and the areas it covers within that range are stable or increasing, and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable as defined in paragraph (i) of the directive.

For the period 2001–2006 (article 17 report; ETBC/BD 2008a), the conservation status of these habitats is reported as *unfavourable – inadequate* (3220, 3240) and even *unfavourable – bad* for the habitats of *M. germanica* (3230) (ETBC / BD 2008a).

Myricaria germanica

M. germanica is an endangered indicator species of Alpine and pre-Alpine gravel-bed rivers influenced by floods (Bill et al. 1997; Müller & Scharm 2001). The dense root system of the shrubs firmly anchors them in the substrate and thus reduces soil erosion. Flexible

Table 1 – Geocoded species and habitat 3230 distribution data

Alpine country	Data type	Data source
Switzerland/ Liechtenstein	literature	Broggi in prep.; Endress 1975; FORNAT 2005, 2011; Tinner & Waldburger 2008; Werth & Scheidegger 2011; Werth et al. 2011, 2012
	floristic data	Infloflora 2012; Zentrum des Datenverbundnetzes der Schweizer Flora (ZDSF) 2008
	pers. comm.	M. Broggi, F. Lener, P. Voser
Italy	literature	Bachmann 1997; Buffa & Lasen 2010; Lasen et al. 2008; Masutti & Battisti 2007; Kiem 1992, 1997; Michielon & Sitzia 2010; Müller 2005; Oriolo & Poldini 2002; Poldini 2002; Regione autonoma Friuli Venezia Giulia 2008; Ringler 2011; Tomasi 2007
	floristic data	Museo Civico di Rovereto – Cartografia Floristica 2009, Naturmuseum Südtirol in Bozen 2009
	pers. comm.	J. Auer, K. Tockner, C. Lasen, G. Salogni, L. Poldini, F. Prosser, A. Scariot, T. Sitzia, Ch. Wallnöfer, Th. Widhalm,
Germany	literature	Bill 2000, 2001; Bill et al. 1991; Floraweb 2005; Graß 2009; Jerz 1986; Karl et al. 1998; Koch 2011; Koch & Kollmann 2012a, 2012b; LfU 2011; Margraf & Lindeiner 2005; Müller 1988, 1990, 1995; Müller & Scharm 2001; Reif et al. 2006; Schönfelder & Bresinsky 1990; Seibert & Zielonkowski 1972; Spahn 1993
	floristic data	Artenschutzkartierung (ASK) Bayern 2009, 2012
	pers. comm.	M.-A. Fritze, I. Grass, A. Zehm
Austria	literature	Bohle 1987; Cerny 2000; Digitale Flora Kärnten 2005; Digitale Flora Salzburg 2005; Egger et al. 2007, 2010; Ellmauer & Traxler 2000; Ellmauer 2005; Essl 2004; Essl et al. 2000, 2002; Hartl et al. 1992; Kammerer 2003, 2009; Kerber 2003; Kerber et al. 2007; Kudrnovsky 2002, 2005, 2007, 2011; Michor 1989; Neuner & Polatschek 2001; Nikowitz 2010; Polatschek 2001; Petutschnig 1994, 2009; Schletterer & Scheiber 2008; Wittmann et al. 1987; Wittmann & Rucker 2006
	floristic data	Floristische Kartierung 2008
	pers. comm.	Ch. Anfang, H. Angerer, G. Egger, W. Franz, S. Gewolf, H. Hartl, M. Hotter, H. Kammerer, D. Kreiner, S. Latzin, F. Lener, K. Michor, G. Nowotny, C. Pachschwöll, M. Schletterer, L. Schratt-Ehrendorfer, O. Stöhr, W. Petutschnig, H. Wittmann
Slovenia	literature	Čušin & Šilc 2006; Dobravec & Jogan 2004; Jogan et al. 2001; Martinčič et al. 1999; Šilc & Čušin 2004; Wraber et al. 1989
	floristic data	Atlas flore Slovenije 2009
	pers. comm.	B. Frajmann, S. Kaligarič, St. Jarau, U. Šilc, M. Žvikart

branches exhibit only minimal resistance to floodwaters and thus prevent the plants from being dislodged.

Since natural river dynamics continuously alter the sites the plants rarely reach more than 15–20 years of age. Injured and buried plants show a high ability to regenerate, an important adaptation to repeatedly shifting gravel banks. The most vulnerable part of the plant's life cycle is germination (Lener 2011). The species has the capability to germinate immediately in suitable conditions, e.g. on wet sediment of newly created gravel bars with a high proportion of silty fine sand (Müller & Scharm 2001), but germination ability is more limited after a few days (Bill et al. 1997; Lener 2011).

Historically *M. germanica* was common along most (pre-)Alpine rivers, including parts of the Danube (Koch & Kollmann 2012a; Latzin & Schratt-Ehrendorfer 2005). In recent studies the historical and actual distribution is often outlined at local, regional or national level (compare Table 1 with selected sources).

The actual distribution of *M. germanica* in the Eastern Alps is fragmented and can be considered as restricted to rivers (stretches) with near-natural site conditions and dynamics. Diversity in ecological niches has decreased along many running waters across the Alps, mainly caused by man-made alterations in hydrology, sediment load and floodplain extent. This thinning of riverine landscape diversity induced a decline of *M. germanica* and other typical species for Alpine river systems.

Due to an increasing awareness of the problems arising from regulated rivers, stimulated by the WFD, river restoration has become a significant element of biological conservation. Such river recovering projects facilitate the restoration of floodplain biodiversity,

for instance by re-introducing endangered species, to some extent.

A few resettlement projects of *M. germanica* (see Figure 3a) across the Alps met with variable success (e.g. Egger et al. 2010; Kammerer 2003, 2009; Nikowitz 2010; Petutschnig 2009; Schletterer & Scheiber 2008; Wittmann & Rucker 2006).

Important research questions regarding a re-introduction concern the (dis)advantage of different propagation methods (seeds, seedlings, adults or clonal fragments: e.g. Benkler & Bregy 2010; Koch & Kollmann 2012a; Lanz & Stecher 2009; Lener 2011; Oppitz 1993), the ecophysiology of the species (e.g. Kerber 2003; Kerber et al. 2007) and genetic diversity (e.g. Werth & Scheidegger 2011).

Alpine river systems

River ecosystems are connected on large spatial scales, have varied drivers, strong, and often conflicting, societal interests, and interacting management processes (Kingsford et al. 2011).

Riparian ecosystems are topographically unique systems occupying the lowest position in landscape, thereby integrating upstream catchment-scale processes (Habersack 2000; Mangelsdorf et al. 1980; Schober 2006). Furthermore the diverse topographic, geologic and biogeographic characteristics of the Alps support unique riverine landscapes colonized by a specific fauna and flora (Muhar et al. 2011b).

Rivers and riverine landscapes are ecosystems significantly shaped by recurrent natural disturbances. These dynamic processes initiate a complex mosaic of habitats resulting in a remarkable high diversity of aquatic, amphibious and terrestrial organisms linked

to these aquatic systems (Arscott et al. 2002; Gurnell et al. 2005; Richards et al. 2002; Tockner et al. 2000, 2006; Ward et al. 1999). Without such natural disturbances and with a decline of riverine landscape area, habitat unification and species loss in flora and fauna can be observed in river systems.

As a result, rivers with near-natural morphology and dynamics, along with their natural riparian vegetation, have become rare and are highly endangered not only in the Alps but throughout Europe (e.g. Gurnell et al. 2009; PSAC 2009).

A Europe-wide assessment reports that more than half of European rivers and lakes are not in a favourable ecological status. Hydro-morphological pressures resulting in altered habitats are the most common impact on water bodies, affecting around 40% of European rivers (EEA 2012c).

The key components of hydro-morphological pressure are changes in hydrological regime, interruption of river and habitat continuity, disconnection from adjacent wetlands / floodplains, and changes in erosion and sediment transport (ETC/ICM 2012).

Aims

This study is based on literature analysis and the author's own field research. The aims are (a) to illustrate riverine landscape diversity by means of *M. germanica* (b) to outline the actual distribution of this species and habitat 3230 in the Eastern Alps, (c) to evaluate the actual set of protected areas related to habitat 3230 and (d) to propose the Isel river system as an addition to Natura 2000 in order to ensure the functional and ecological coherence of the protected area network.

Study area

The study area (Figure 2) comprises the European Eastern Alps (centre 46° 54' N, 12° 24' E) and covers approx. 100 000 km² at altitudes ranging from 100 m to nearly 4000 m above sea level. A virtual line between Bodensee and Lago di Lugano forms the western boundary of the study area (following Ozenda 1988).

Material and methods

GIS analysis

Spatial analyses were performed by GRASS GIS 6.4.2 (GRASS Development Team 2012b) and ArcGIS Desktop 10.1 (ESRI 2012).

Many analysis and visualization steps were based upon processing GIS data for the entire study area, see Table 2.

Analysis of literature and other sources

In a review literature was screened for occurrence data of *M. germanica* and for distribution of habitat 3230. This information, floristic and personally communicated data (see Table 1) were geocoded in GIS for preparing field work and further analysis.

Table 2 – GIS data and deduced spatial information. Raster (r) and vector (v) data

data	GIS data (source)	deduced spatial information
elevation	SRTM vers. 4.1 (r) (CGIAR-CSI 2008) approx. 100 m x 100 m	altitude, altitudinal range, inclination, river basins
	ASTER GDEM vers. 2.1 (r) (J-SPACESYSTEMS 2012) approx. 30 m x 30 m	
climate	WORLDCLIM (r) min., max., mean temperature, precipitation (Hijmans et al. 2005)	seasonal precipitation variability, probability of precipitation as rain or snow
geologic	IGME 5000 (v) 1:5 million International Geological Map of Europe (Asch 2003)	geologic units in river basin
	OneGeology-Europe (v) 1:1 million scale surface and bedrock geological map data (OneGeology-Europe 2012)	
river system	CCM River and Catchment Database vers 2.1 (CCM2) (De Jager & Vogt 2010; Vogt et al. 2007a, b, 2008)	river system characteristics, ordering system
	European catchments and rivers network system Ecrins vers. 1.1 (v) (EEA 2012a)	
land cover	Corine Land Cover 2006 seamless vector data vers. 16 (v) glaciers and perpetual snow (EEA 2012d)	potential glacial influence on bed load, sediment and runoff
Natura 2000	Natura 2000 data (v) (EEA 2012b)	spatial information of <i>M. germanica</i> related to the Natura 2000 network of protected areas
	Article 17-data (EEA 2009)	
	European reference grid 1 km x 1 km, 10 km x 10 km (EEA 2011)	geo-referencing of species and habitat distribution

River preselection

M. germanica is often observed in river stretches with gentle slopes and expanded riverine landscape. The river system homogeneously modeled in GIS across Europe (CCM2, Ecrins) reports the inclination for every river line segment.

For a cross-check and to identify such slightly inclined sections, the GIS river system was laid over the digital elevation model (DEM) and a dimensionless slope value (slope steepness) was calculated for every vector line in GIS (GRASS Development Team 2012b). The inclination threshold was determined in an iterative, empirical process.

The geocoded occurrence data were laid over the river subset mentioned above and over ortho-images in order to visually determine river sections focused on pronounced riverine landscapes (see Figure 2 for surveyed river systems).

Field work

GIS data of these visually selected river sections – located in Austria, Germany, Switzerland, Italy and Slovenia (see Figure 2) – were uploaded to GPS. In the years 2007 to 2012, these Alpine running waters were surveyed for *M. germanica*.

If the species was present, the parameters situatedness within the riverine landscape, site conditions and population structure were recorded, but also river sections with species absence were traced.

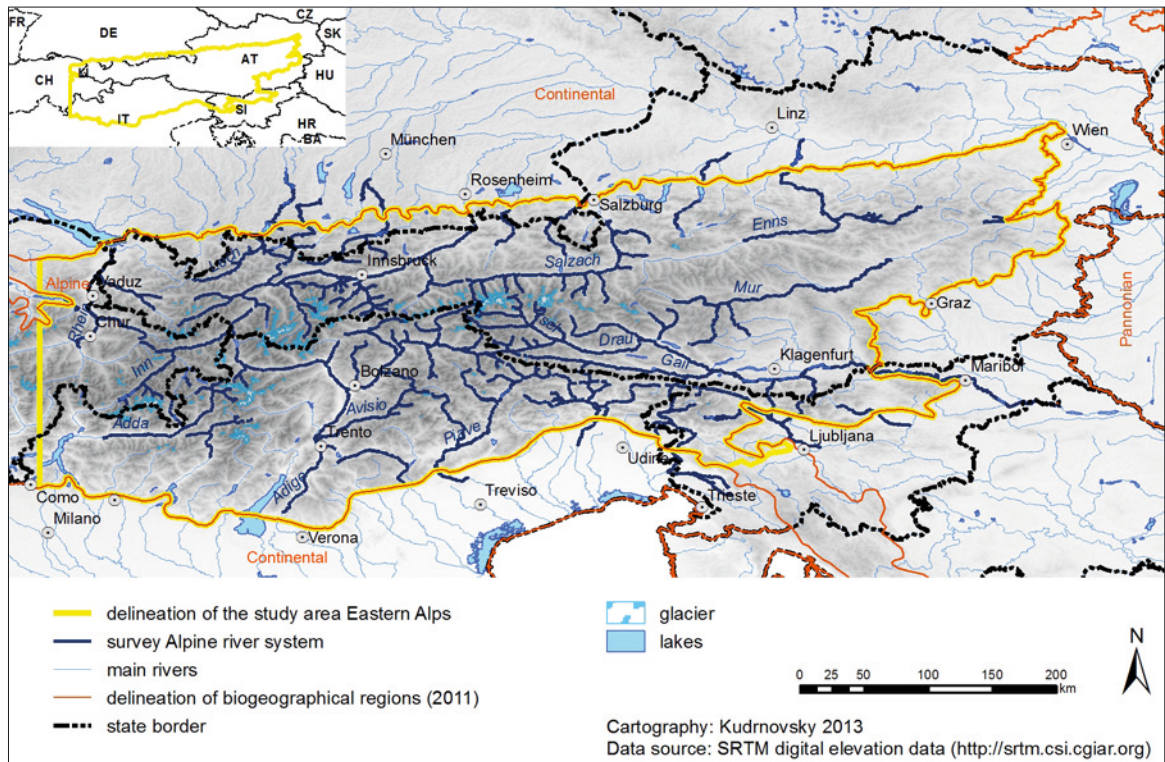


Figure 2 – Study area Eastern Alps and surveyed river systems

Analysis of field data

In GIS, sampled field data are geo-referenced as point vectors (information about the situation within the riverine landscape and population structure as attributes) to determine the location within the study area (northern, central, southern part of the Eastern Alps; see Figure 3a, b).

Then catchments are calculated for the sample point data to obtain upstream river basin characteristics as approximation indicators of riverine landscape diversity (e.g. altitude, altitude range, geology, glacial influence, precipitation – compare Table 2).

The Ecrins data set reports Strahler's stream ordering number (Strahler 1952, 1957) consistently across Europe for every vector segment. This information facilitates locating *M. germanica* occurrences within the river network. In mountain areas low Strahler numbers are indicating upper river sections at higher altitudes.

Linking such environmental information with field experience allows identifying patterns in habitat variants by means of expert knowledge.

Habitat 3230 and the evaluation of the Natura 2000-network

Spatial data as well as information related to habitat types and conservation status are available for the Natura 2000 network (see Table 1, EEA 2012b). The distribution map of habitat 3230 offered by the Article 17 report seems to be incomplete. Although this map is used as base data in the evaluation, it is not displayed in the final map.

The designated protected areas and the actual distribution of *M. germanica* presented in this paper (see

Figure 3a, b) were overlaid in GIS with the aim of evaluating the spatial coherence of the actual protected area network.

The results of the field work are integrated in the evaluation of the network's ecological coherence (degree of representativeness of the natural habitat type on the site; degree of conservation of the structure and functions of the natural habitat type and restoration possibilities; global assessment of the value of the site for conservation of the natural habitat type).

GIS visualization

Species and habitat 3230 observations gathered in field work from 2007–2012 are represented as 1 km x 1 km grid in the actual distribution map. The 10 km x 10 km grid includes the former and also evaluated literature and floristic data.

Results

Myricaria germanica – an indicator species of natural riverine landscape diversity

Alpine rivers, and braided rivers in particular, are characterized by great spatial and temporal variability on a wide range of scales in properties such as flow depth, grain size, bar stability or connectivity between channels. Tockner et al. (2000) extended the flood pulse concept and coined the term *flow pulse* to emphasize the importance of below-bankfull events in connecting different areas within the riverine landscape. These events are particularly important for braided rivers, where the multiple bars and channels can all be at slightly different elevation levels, and where modest

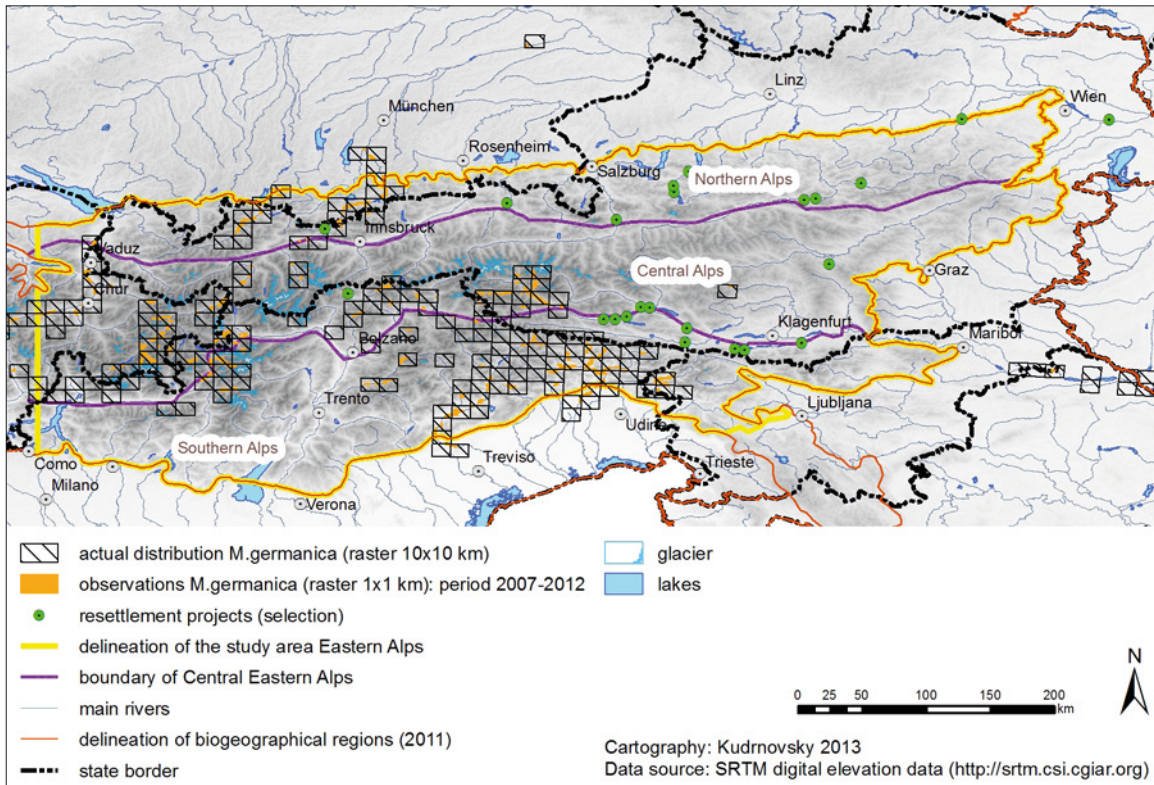


Figure 3a – Actual distribution of *M. germanica* in the Eastern Alps: 1 km×1 km raster – observations 2007–2012, 10 km×10 km raster – observations, literature and floristic data included

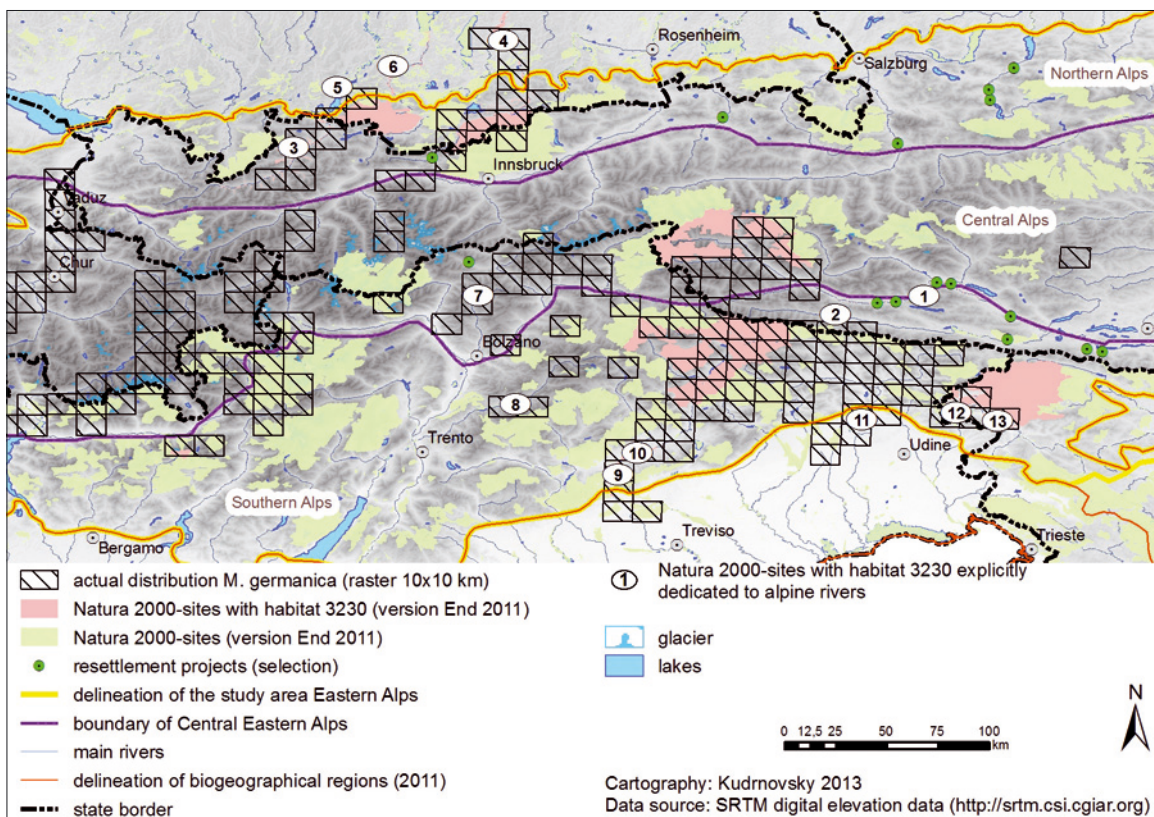


Figure 3b – Actual distribution of *M. germanica* and the Natura 2000 network (EEA 2012b); sites explicitly dedicated to Alpine rivers: 1 Upper Drau, 2 Gail/ Lesachtal, 3 Tyrolean Lech, 4 Lower Isar-valley, 5 Lower Halblech, 6 Ammer – pre-Alpine to the southern part of lake Ammersee, 7 Biotopo Gisser floodplain, 8 Lake Val di Fiemme, 9 Lago di Busche – Vinchetto di Cellarda – Fontane, 10 Fiume Piave dai Maserot alle Grave di Pederobba, 11 Valle del Medio Tagliamento, 12 Nadiža s pritoki, 13 Soèa z Volarjo

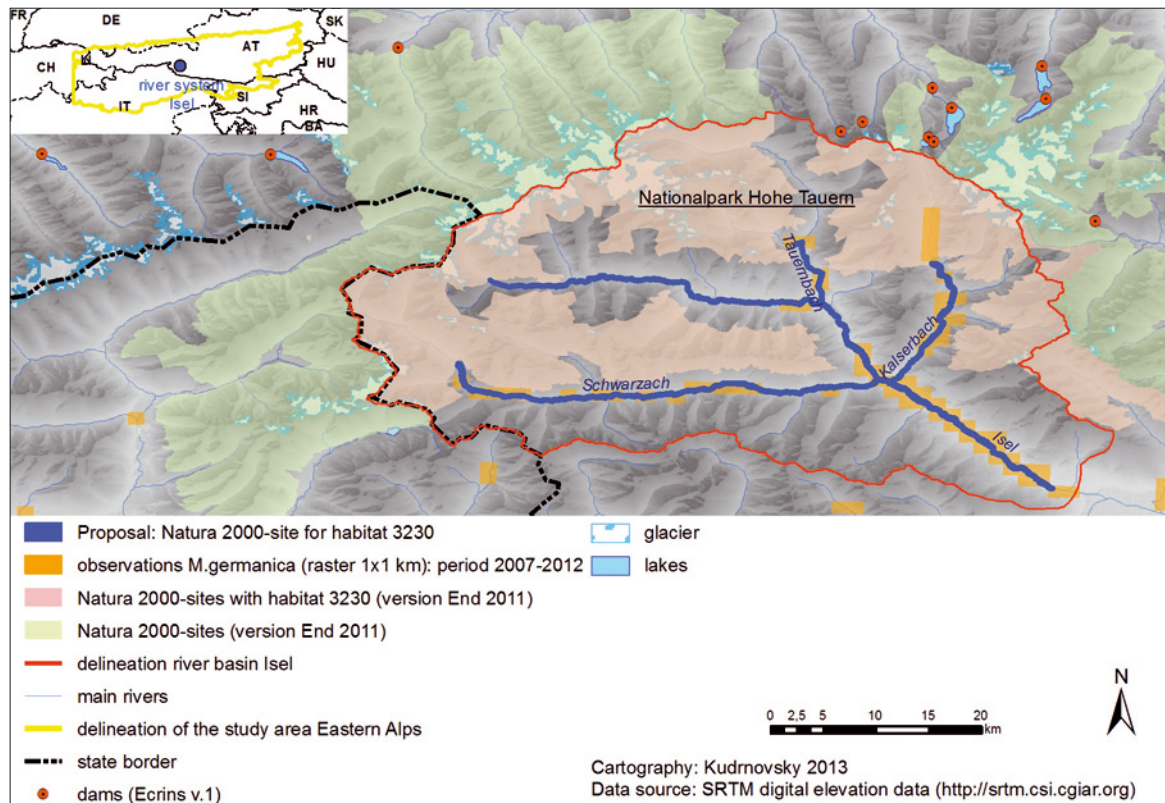


Figure 4 – Proposal of a Natura 2000 site along the river Isel and tributaries including a vital metapopulation of *M. germanica* on all four running waters (Kudrnovsky 2007, 2011; Stallegger et al. 2012)

changes in discharge can lead to significant differences in connectivity between the different parts of the riverine landscape.

The nature and complexity of this connectivity determines the exchange of sediments and organisms (Sambrook Smith et al. 2006). Riparian vegetation plays some active, autogenic role in modifying its environment, distribution, zonation and succession (Gurnell & Petts 2002).

The species *M. germanica* features a narrow ecological niche depending on sites with a high proportion of fine sand and sufficient water supply for seed germination.

As a result of the field studies three variants of how this ecological niche can be realized are identified (Table 3).

Variant 1

At higher altitudes (~1300 m and above), the stocks on sandy sites are openly structured and accompanied by dense cushions of *Saxifraga aizoides* (variant 1; e.g. Bachmann 1998; Bäumler 1988; Burga 1999a, 1999b; Burga et al. 2010). These sites are located in the riverine landscape of Alpine running waters with a glacial / nival runoff showing low Strahler numbers. The catchments are mostly characterized by siliceous, occasionally alkaline rocks.

Variant 2

Habitat variant 2 is characterized by more or less dense *M. germanica*-stocks on top of sandy gravel

banks and exhibits a slight tendency towards river basins dominated by siliceous rocks (e.g. Kudrnovsky 2001, 2007). To some extent the dense stocks work as sediment traps and in this way facilitate seed germination near the mother plants. The sites are often situated close to the main river channel. The runoff is mostly glacial or nival. The altitudinal range of this variant in the Eastern Alps is between ~500 m and ~1800 m Strahler numbers according to the Ecrins river system model are medium (3–6).

Variant 3







Loose *M. germanica* stocks along flood lines or in slight depressions, integrated into variant 3, are often observed in river systems with a nival / pluvial runoff and dominated by limestone / carbonate-rich geology in the catchment (e.g. Müller 1988; Schnauder & Moggridge 2009). In the riverine landscape, the sites are often situated at some distance to the main river channel. This habitat variant can be found in the Eastern Alps along running waters with medium Strahler numbers at an altitudinal range between ~100 m and ~1200 m.

The density of these described niches along running waters – as potential *M. germanica*-sites – is low in the Eastern Alps nowadays because of hydro-morphological modifications in the river system (canalized rivers, loss of dynamic riverine landscape).

Actual distribution of *M. germanica*

The field results (see Figure 3a) confirm that the actual distribution is fragmented and reduced to a few

Table 3 – Identified habitat variants of *M. germanica* sites. © Kudrnovsky 2006–2012

Variant 1	Variant 2	Variant 3
Open-structured <i>M. germanica</i> stocks at higher altitudes with <i>Saxifraga aizoides</i> (e.g. Morteratsch, Kalserbach, Suldenbach, Talfer)	<i>M. germanica</i> on top of sandy gravel banks (e.g. Isel, Inn, Rhein)	<i>M. germanica</i> along flood lines or in slight depressions (e.g. Lech, Isar, Piave, Tagliamento)
		
Glacier forefield Morteratsch (CH)	Isel (AT)	Chiarzo (IT)
		
Kalserbach (AT)	Isel (AT)	Isar (DE)

remaining near-natural Alpine river systems and river stretches (cf. Bachmann 1997; Bill et al. 1997; Endress 1975; Kudrnovsky 2005).

Such river systems in the Eastern Alps are parts of the rivers Lech (AT), Isar (DE), Inn (Graubünden (CH)/Oberes Gericht (AT)), Alpenrhein, Isel and tributaries (AT), Piave and Tagliamento and their tributaries (all IT), Soča (SI).

Along smaller running waters the populations are often isolated and narrowed to upper sections, e.g. Öztaler Ache, Flattnitzbach (all AT), Adda, Talfer, Suldenbach, Pfitscherbach, Avisio (all IT), Landquart (CH).

Habitat 3230 and the Natura 2000 network

A synopsis of the Article 17 report shows an approximate coverage of 42% for habitat 3230 stands at Natura 2000 sites throughout Europe (ETC/BD 2008b, 2008c). In the Eastern Alps this habitat is listed in 24 Natura 2000 sites (EEA 2012b), including 13 protected areas explicitly dedicated to Alpine rivers or river stretches (see Figure 2b).

Most of these 24 sites are representative for the northern (8) or southern (13) part of the Eastern Alps (often dominated by limestone / carbonate-rich geology, nival / pluvial runoff regimes), including parts of the known near-natural rivers Lech, Isar (both northern part), Piave, Tagliamento and Soča (all southern part).

In contrast, core *M. germanica* populations in riverine landscapes of the central Eastern Alps are underrepresented in the network (e.g. at river Isel and tributaries (AT); ETC / BD 2012b; Kudrnovsky 2002, 2005, 2007, 2011; Retter 2007; Stallegger et al. 2012). There are only 3 sites (including *Obere Drau* with re-introduced plants) in this central region (Figure 3b).

Discussion

The management of protected freshwater areas needs to be implemented across large spatial scales, beyond protected area boundaries, sometimes from the top of the catchment to the ocean and beyond (Kingsford et al. 2011).

Variability and completion of the network

Due to current multi-sectorial challenges (demand for hydro-energy production, climate change, vulnerability and rarity of near-natural river systems, unfavourable conservation status) the set of protected areas in the network should be screened for completion in terms of Alpine river habitats (Ringler 2005, 2011).

The network should represent the high variability and diversity of Alpine rivers, also in terms of references for the implementation of the WFD. The use of conservation values and conservation criteria, defined for the whole Alpine biogeographic region, could help to identify valuable additions of near-natural rivers. Moreover, it is important to consider the different spatial scales of the ecological (e.g. shifting habitat mosaic, Tockner et al. 2000), hydrological (e.g. runoff regime, surface / subsurface flow interaction) and biogeochemical processes relevant to preserving the abiotic conditions and hence species composition and habitat characteristics of river ecosystems (Verhoeven et al. 2008). An Alps-wide treatment would ensure the coherence of the network of protected areas.

Conflicts of interests

The utilization of running waters is intensifying at both global and national level. This process is increasingly affecting aquatic ecosystems and is threatening

those ecosystems of running water bodies which are still intact albeit substantially reduced already in number and size (Muhar et al. 2011a).

Directive 2009/28/EC, for instance, establishes a common framework for the production and promotion of energy from renewable sources (EU 2009b). Each Member State has a target calculated according to the share of energy from renewable sources in its gross final consumption for 2020. This implies a continuation of a forced development of hydropower. In addition to the demand for energy, agriculture (e.g. irrigation, land use), tourism (e.g. technical snow production) and natural hazard prevention (e.g. protection measures) are further driving forces with an impact on river systems (PSAC 2009). Climate change and the associated increasing spatial and temporal variance of rainfall / precipitation will exacerbate such pressure.

On the other hand, Habitat Directive EEC/92/43 (EU 1992) claims that a favourable conservation status of the habitats and species of community interest is to be maintained or restored and that protected areas must be established.

Conservation criteria

To cope with these conflicting drivers and to provide an essential basis for establishing a coherent network of protected areas along rivers, plus comprehensive management strategies at a supranational scale, a hierarchical prioritization approach for river-floodplain conservation and restoration is required (Muhar et al. 2011b).

In a few rivers or stretches some moderate use of water resources is possible in principle; the ecological integrity must have priority in rivers with high nature value. In terms of habitat 3230, a favourable conservation status must be maintained in such riverine landscapes.

A process based on defined conservation values and criteria to identify such rivers (stretches) should be initiated at the biogeographical level of the Alps. Naturalness, diversity, rarity, representativeness for an endangered habitat type and vulnerability are proposed as important conservation values to derive refined criteria (Muhar et al. 2011a, 2011c).

Myricaria germanica – an endangered species

M. germanica is an indicator species of Alpine gravel-bed rivers of European interest and reflects riverine landscape diversity. An appropriate number of dynamically created and suitable sites along the river basin (habitat shift mosaic; Arscott et al. 2002) are essential for the development and preservation of stable populations (Kudrnovsky 2011; Werth et al. 2011; Wittmann & Rucker 2006). The thinning of suitable sites for *M. germanica* in recent decades is the main reason for the current fragmented distribution of the endangered species (Ellmauer 2005). Protection and preservation of primary sites should have the highest priority.

Hence in resettlement projects, along with the right propagation method (Koch & Kollmann 2012a), the screening for available suitable sites along a river (section) should be a basic prerequisite to building a stable population with the critical self-maintaining size for the long term. Isolated re-introduction locations are of no use in the long term and should therefore be avoided.

Designation of the Isel river system as Natura 2000 site for network completion

The coherence of the Natura 2000 network is ensured if the entire geographical and ecological variability of habitats of community interest is covered by representative populations in protected areas.

Most of the current occurrences of *M. germanica* in the Eastern Alps are isolated sites. Important *wild rivers* or sections thereof, including core populations (e.g. Lech, Isar, Soča, Piave, Tagliamento), are already included in the Natura 2000 network. These river systems are representative for the northern and southern part of the study area and often show habitat variant 3.

In general the river system of Isel and tributaries Tauernbach, Kalserbach and Schwarzach (AT) exhibits a vital and core metapopulation of *M. germanica* (see Figure 4) typical for a glacial-characterized river basin of the central siliceous Eastern Alps. The *M. germanica* sites in this river system represent habitat variants 1 and 2 (see also Table 3).

The river Isel is further known as one of the last more or less unaffected glacial rivers in the Alps and unique in the Eastern Alps (Retter 2007). In the Austrian Red List of biotope types, braided rivers like the river Isel are listed as rare and critically endangered (IUCN category; Essl et al. 2008).

Applied to the Isel river system, the conservation criteria rare / threatened species, rare / endangered river habitat, natural runoff regime, representative river type, intact hydro- and morphodynamic processes, intact river functions, intensity of current human impacts in river ecosystems and magnitude of future human threats to river ecosystems indicate a river system of high nature value.

Conclusion

Considering these conservation values and refined criteria, a new designation of the river system Isel (Figure 1) as a Natura 2000 site (Figure 4) means an important addition to the protected area network in scientific terms (Kudrnovsky 2001, 2005, 2011).

Taking into account the importance of the catchment area as an ecological unit (sound metapopulation of *M. germanica* on all four running waters) as well as a management unit (hydrology and sediment conditions), the inclusion of the tributaries Schwarzach, Tauernbach and Kalserbach is strongly recommended (Kudrnovsky 2007, 2011; Stallegger et al. 2012).

This additional protected area would improve the ecological coherence of the network by then cover-

ing the entire geographical and ecological variability of riverine landscape diversity in the Eastern Alps through representative core *M. germanica* populations.

It would also provide a functional connection between the Natura 2000 sites Hohe Tauern National Park (located in the Alpine region of the Isel basin and with *M. germanica* at Kalser Dorferbach; see Figure 4) and Obere Drau (see Figure 3b) downstream. In this latter protected area, the species was successfully reintroduced in some locations (Egger et al. 2011; Moritsch et al. 2012). The Natura 2000 site Obere Drau would also benefit from an intact hydrology and sediment regime in the river Isel basin, particularly as the upper section of the river Drau itself is impacted by a hydropower plant.

The European Commission, in its supervisory function for the implementation of directives, supports the assessment from experts in the Member States on the need for designating the Isel river system as Natura 2000 site (EU 2012).

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