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Invasion by *Fallopia* spp. in a French upland region is related to anthropogenic disturbances

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Abstract

Within Europe, mountain ecosystems are generally less invaded by exotic plant species than are lowland areas. This pattern is commonly attributed to climatic harshness, which limits invasive species presence, and higher propagule pressure and rates of disturbance in lowlands, which favours dissemination. However, the extent to which anthropogenic and natural disturbances contribute to invasive species presence in mountain and lowland environments remains unclear. We conducted field observations in a lowland and an upland region in France and measured environmental variables, estimated the natural and anthropogenic disturbance of plots invaded by *Fallopia* spp. and compared them to non-invaded plots. Based on generalised linear mixed models, the predictors of *Fallopia* spp. presence in the upland area only included anthropogenic elements such as the presence of a road or trail and frequentation by humans, whereas both anthropogenic parameters and natural components (light penetration, slope, presence of a road and of a watercourse) were retained as predictors for the lowland region. We calculated the odds of *Fallopia* spp. presence for the increase of one unit of each predictor. We conclude that the spread of *Fallopia* spp. in upland areas was mainly linked to human activity whereas dissemination of the species occurred both through humans and in natural ways in lowland areas, and this may be due to a more recent colonisation in the mountains. We therefore advise stakeholders to undertake actions in mountain areas to specifically limit the dissemination of exotic species by humans and to monitor areas of high invasion risk by exotic species, such as areas neighbouring trails and roads highly frequented by humans.

Zusammenfassung

In Europa werden Gebirgsökosysteme im Allgemeinen weniger stark von invasiven Pflanzenarten besiedelt als tiefer gelegene Gebiete. Dieses Muster wird gemeinhin mit dem rauen Klima erklärt, das die invasiven Arten limitiert, aber auch mit der höheren Einfuhrrate von Diasporen und der größeren Störungshäufigkeit in der Ebene, was die Verbreitung fördert. Indessen ist unklar, in welchem Ausmaß anthropogene und natürliche Störungen zum Auftreten von invasiven Arten in Berg- und Flachlandgebieten beitragen. Wir führten Feldbeobachtungen in einer Berg- und einer Flachlandregion Frankreichs durch und maßen Umweltvariablen, schätzten die natürliche und anthropogene Störung von Flächen, die von *Fallopia*-Arten besiedelt worden

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waren, und verglichen diese mit unbesiedelten Flächen. Nach generalisierten linearen gemischten Modellen waren die Faktoren, die das Auftreten von *Fallopia* im Bergland vorhersagten, allein anthropogene Landschaftselemente wie Straßen und Wanderwege sowie die Frequentierung durch Menschen, wohingegen sowohl die anthropogenen Parameter als auch natürliche Faktoren (Lichteinfall, Hangneigung, Nähe von Fließgewässern) als Vorhersagefaktoren für das Flachland beibehalten wurden. Wir berechneten die Wahrscheinlichkeit des Auftretens von *Fallopia* spp. für die Erhöhung um eine Einheit für alle Vorhersagefaktoren. Wir schließen, dass die Verbreitung von *Fallopia* spp. im Bergland hauptsächlich mit menschlichen Aktivitäten zusammenhing, während die Verbreitung der Arten im Flachland sowohl durch den Menschen als auch auf natürliche Weise erfolgte. Dies könnte auf eine eher rezente Besiedelung im Bergland zurückzuführen sein. Wir raten deshalb den Akteuren, im Bergland Maßnahmen zu ergreifen, die speziell die Verbreitung exotischer Arten durch den Menschen begrenzen, und Gebiete mit hohem Invasionsrisiko, wie Flächen entlang von stark von Menschen frequentierten Wanderwegen und Straßen zu überwachen.
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Introduction

The growing frequency of human exchanges is leading to the spread of more species' propagules worldwide. Some exotic species become established and proliferate in their new range, leading in many cases to competition with native species, to modifications of ecosystem functioning and to substantial losses in agricultural production (Pyšek & Hulme 2005). Because of the impacts of invasive species, many management plans intend to prevent further spread. However, data to assess the invasibility of some ecosystems is often lacking, which hampers predictions of the future distribution of invasive species. For that purpose, key factors involved in the invasion risk have to be identified. Knowledge of the current distribution, related to landscape or environmental characteristics of invaded ecosystems, may help to identify these factors.

Invasion is the result of the interaction between propagule pressure, abiotic characteristics of the invaded ecosystem, and biotic characteristics of the recipient community and the invading species. These drivers fluctuate across space and time, and are likely to be influenced by humans (Catford, Jansson, & Nilsson, 2009). Among abiotic factors, disturbance is noted as a key factor favouring the colonisation and establishment of invasive species because it creates niche opportunities (Hobbs & Huenneke 1992), and sometimes dispersal opportunities (for example during the construction of roads and buildings, Arévalo et al. 2010). Disturbance can be caused by natural events, such as floods and herbivory, or can be anthropogenic, such as changes in land use, management and fertilisation (Lockwood, Hoopes, & Marchetti 2007). In Europe, human population density and intensity of human activities appeared to well explain plant invasions (Pyšek et al., 2010), showing the great impact of anthropogenic disturbances.

In temperate areas, it appears that invasive plant species richness is lower in mountain ecosystems than in lowlands, but tends to increase (Pauchard et al. 2009). It is not clear whether this is a result of a time lag (stage of invasion), of reduced propagule pressure or of abiotic and biotic conditions in mountains. Indeed, along altitudinal gradients, the relative importance of factors influencing invasions is likely to change (Pauchard et al. 2009). For example, decreasing temperature constrains invasive plant richness in elevated regions (Marini, Gaston, Prosser, & Hulme, 2009). The effects of disturbances are uncertain, because anthropogenic disturbances, together with human population density, are assumed to decrease with elevation, while natural physical disturbance, such as landslide or rock falls, are assumed to increase (Pauchard et al. 2009). Moreover, it remains unclear whether the effects of both anthropogenic and natural disturbances on the presence of invasive species are the same in mountain and lowland environments (Pauchard et al. 2009). Thus, studies comparing links between disturbances and presence of invasive species in lowland and upland sites are needed to clarify the role of disturbances in invasibility along an altitudinal gradient. Japanese knotweeds *s.l.* (*Fallopia japonica* (Houtt.) Ronse Decraene (Japanese knotweed *s.s.*), *Fallopia sachalinensis* (F. Schmidt ex Maxim.) Ronse Decraene and the hybrid *Fallopia* x *bohemica* (Chrtek and Chrtková); herein after referred to as *Fallopia* spp. or knotweed) are widespread invaders in North America (Shaw & Seiger 2002) and Europe (Child & Wade 2000) where they are classified among the 20 most frequent weeds (Lambdon et al., 2008). Large economic (Crowhurst 2006), faunistic and floristic (Gerber et al., 2008) impacts have been identified following its invasion. Studying *Fallopia* spp. in the context of disturbances in elevated areas is interesting because they are pioneer species, which regenerate easily from rhizomes and stem fragments (Bímová, Mandák, & Pyšek, 2003). These plants generally occur in their invasive range in riparian habitats and in many types of anthropogenically disturbed habitats, mainly along roads and railways (Bailey, Bímová & Mandák, 2009). In addition, in elevated areas, *Fallopia* spp. are not likely to be constrained by climate, as they seem to be cold tolerant (absolute minimum temperature −30.2 °C, Beerling, Huntley, & Bailey 1995).

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