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FIRE AND INVASIVE PLANT SPECIES IN THE MEDITERRANEAN BASIN

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ABSTRACT

Invasive species often have ecological and economic impacts. They can threaten biological diversity in various ways, from reducing genetic variation and eroding gene pools, through the extinction of endemic species, to altering habitat and ecosystem functioning. Biological invasions also have economic impact. Vascular plants are among the most ubiquitous invasive organisms. The majority of alien plants have been introduced for agricultural, silvicultural, ornamental, or medicinal purposes, while many have been accidental introductions. Some plant invaders can significantly alter fire regimes by changing plant fuel properties. Research on biological invasions and fire is rather limited in the Mediterranean Basin compared to othe mediterranean areas of the world; this is probably because plant invasions occur mainly in human-made and disturbed habitats or in wet areas, which are not regularly subjected to fires. On the contrary, dry, fire-prone habitats of the Mediterranean region seem not to be so susceptible to alien plant invasions. However, the expansion of perennial grasses over shrubs in areas frequently burned has been reported as a critical issue related to invasions. Two examples come from Spain. The local abundance of the exotic *Cortaderia selloana* has been related to fire. *Ampelodesmos mauritanica* is considered as non-native to Catalonia and it has been reported to expand in areas with high fire frequencies. Finally, in areas of Southern Europe with less dry climates, such as northern and central Portugal, woody invasive species such as *Acacia* and *Eucalyptus* seem to become a problem and an increased concern for forest managers in burned areas.

Keywords: alien plants, flammability, fire, natural ecosystems, Mediterranean Basin

INTRODUCTION

Biological invasions have been a scientific topic for some time (Elton, 1958). However, it has only been during the last two decades that the ecological consequences of these invasions have been researched extensively. This is due to the fact that some invasive

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species are causing significant ecological and economic impact (Mack et al., 2000; Mooney and Hobbs, 2000; Vilà et al., 2010). Invasive species can threaten biological diversity in various ways, from reducing genetic variation and eroding gene pools, through the extinction of endemic species, to altering habitat and ecosystem functioning (Hulme, 2007; Vilà et al., 2010). Biological invasions also cause economic impact that can be evaluated financially, based on expert extrapolations of high-profile alien pests (Pimentel et al., 2001, 2005; Born et al., 2005; Colautti et al., 2006; Lovell et al., 2006; Olson, 2006). Vascular plants are among the most ubiquitous invasive organisms. The majority of these plants have been introduced for agricultural, silvicultural, ornamental, or medicinal purposes (Williamson, 1996), while others have been accidental introductions (Newsome and Noble, 1986).

The aim of the current paper is to review and comment on the existing literature on the relationships between fire and alien plant species in the Mediterranean Basin. For clarity reasons, it is necessary to recall those terms that are used in the following sections and provide their definitions.

Alien, *introduced*, *non-native*, *non-indigenous*, or *exotic* species are those species which are found in a given area other than their original distribution and whose presence there is due to intentional or unintentional human actions (Lambdon et al., 2008a). Alien species may be *casual* if they are reproduced occasionally outside an area but that eventually die out because they do not form self-replacing populations, relying instead on continuous introductions for their persistence over time. *Naturalized* species are those species that sustain self-replacing populations and reproduce without direct human intervention, being recruited from seeds or vegetatively. *Invasive* species are naturalized alien plants that produce reproductive offspring, often in very large numbers, at considerable distances from the parent plants and thus have the potential to spread over and invade into a large area (Richardson et al., 2000).

In regard to their introduction pathways, alien species may have been introduced deliberately into the wild (for example, for the enrichment of the native flora, landscaping, etc.) and are called *released,* whereas species that have escaped into the wild from cultivation are referred as *escaped* (such as *Eucalyptus* spp. in plantations, *Ailanthus altissima for* ornamental purposes, *Acacia* spp. for soil stabilization).

PLANT INVASIONS IN THE MEDITERRANEAN BASIN

The degree of invasion by alien plants in the Mediterranean basin has been studied at different spatial scales. It has been the focus of analysis which has compared the native and the alien floras mainly in Mediterranean islands (Vilà and Muñoz, 1999; Lambdon and Hulme, 2006; Lambdon et al., 2008b). There have also been comparisons of alien floristic similarities between Mediterranean Basin countries (Arianoutsou et al., 2010) and between Mediterranean and central European regions (Chytrý et al., 2008b; Lambdon et al., 2008a). Emphasis has also been given to the effects of alien invasions on coastal dune ecosystems (for example, Bar (Kutiel) et al., 2004; Acosta et al., 2006; Carboni et al., 2010) because of their conservation value.

All these studies agree that habitats most affected by human activities exhibit the highest levels of plant invasions as a result of higher propagule pressure and higher disturbance levels (Chytrý et al., 2005, 2008a). Of the natural habitats, those that are mostly susceptible to plant invasions are the "wet" ones such as wetlands, river banks, etc. The number of naturalized plant species occurring in wet natural habitats of the Mediterranean Basin is always higher than those occurring in natural habitats influenced by the Mediterranean summer drought (Arianoutsou et al., 2010). The difference in the degree of invasion between wet and dry habitats might be due to two main reasons. First, resources available in wet environments are more abundant; and second, the majority of wet habitats are highly disturbed, rivers being one example (Planty-Tabacchi et al., 1996). It is reasonable to assume that these wet habitats are not regularly subjected to fires because of their conditions. Therefore, dry, fire-prone habitats of the Mediterranean region seem not to be so susceptible to alien plants invasions.

Most Mediterranean environments have experienced a high degree of human interference and disturbance, a process that dates back over ten thousand years, and this has resulted in a marked transformation of the vegetation (Heywood, 1995; Thompson, 2005). In contrast to other mediterranean regions of the world, such as California and South Africa, where large areas of relatively intact vegetation still remain, much of the Mediterranean Basin has been transformed from its native state (Mooney, 1988). The result is that Mediterranean plant communities are rather resistant to biological invasions since native species are likely to be good competitors under the strong selection regime imposed by humans on the Mediterranean flora. Furthermore, multiple stresses posed by drought, fire, and grazing might limit prospective alien plant species from establish ing and going on to become invasive (Hulme et al. 2007; Arianoutsou et al., unpublished data).

FIRE AND ALIEN SPECIES IN THE MEDITERRANEAN BASIN

The Mediterranean Basin could be considered a particularly interesting area for the investigation of the relationship between invasive species and fire, since it is the donor area of numerous invasive annual grasses that produce serious problems (known as grass fire cycles) in other Mediterranean Climate Regions (MCRs) (Keeley et al., 2012).

Several studies, performed mostly outside the Mediterranean Basin, have proven that some plant invaders, mainly grasses, can significantly alter fire regimes (Keeley, 2001; Brooks et al., 2004; Mandle et al., 2011). This is due to the potential complete change in fuel properties resulting from the replacement of existing plant communities by invasive species. Changes in fire regimes after invasion often develop into complete alteration of the community, from woody species dominance to grassland (D'Antonio and Vitousek, 1992). For example, in the western USA, fire frequency has increased dramatically over the past century because of invasion of shrublands by annual grasses from the Mediterranean region (e.g., *Bromus tectorum*). This has resulted in widespread conversion of shrublands to grasslands, with effects on biodiversity (for example, D'Antonio and Vitousek, 1992). In addition to altering fire frequency, invaders can also increase fire in-

tensity. This can occur in particular in habitats already shaped by fire (such as dry woodlands), but with an invader that is more productive than the native species it replaces and, thereby, increases the fuel load of the ecosystem (Brooks et al., 2004). Depending on the species concerned and on the fire regime, this "fire cycle" may be extremely difficult to break and is probably one of the most difficult issue to solve in post-fire management. Furthermore, alien species may be an important post-fire management issue in situations where fire promotes their seed germination, particularly if they become invasive and compromise the regeneration of native vegetation (Wilson et al., 2011).

Very few similar cases are reported for the Mediterranean Basin, however. The local abundance of the exotic *Cortaderia selloana*, pampas grass, has been related to fire occurrence (Doménech et al., 2005) in Spain but this has not been demonstrated. Pampas grass is a South American long-lived perennial grass native to Argentina, Brazil, and Uruguay that is considered invasive worldwide. It was first introduced as ornamental to Europe between 1775 and 1862 (Bossard et al., 2000). It has since escaped from cultivation and is invading abandoned farmlands, roadsides, shrublands and wetlands. Pampas grass is considered to increase fire hazard because of the accumulation of dry leaves and flowering stalks on the plant. However, in the Mediterranean Basin its distribution is probably more related to disturbances linked to land-use changes than to wildfires (Pausas et al., 2006). In Catalonia (Spain) some fires have been associated with the local expansion of the evergreen resprouting tussock grass *Ampelodesmos mauritanica* (Vilà et al., 2001). The natural distribution range of *A. mauritanica* stretches across the Mediterranean Basin from west to east, but it is reported as non-native to Catalonia, where it may have been introduced from the Balearic Islands during the middle ages. This grass appears to be expanding in areas with high fire frequency (Vilà et al., 2001), largely because of its reproductive pulses after fire (Vilà and Lloret, 2000), and it may produce nearly pure stands in sites previously occupied by a shrubby cover. Analysis using Rothermel's fire propagation model predicted increased fire risk in stands invaded by *A. mauritanica* and, thereby, potential for a fire-grass feedforward process (Vilà et al., 2001). Grigulis et al. (2005) have further documented that invasion success of *A. mauritanica* and its contribution to community biomass increased with decreasing fire return intervals.

It is interesting to note that the same genera of annual forbs and grasses that are invasive in other MCRs are also present and established in the Mediterranean Basin. However, shrublands of the Mediterranean Basin are very resilient even to frequent fires and seem resistant to alien invasions (Keeley et al., 2012). This has been reported earlier by Trabaud (1990), who studied the resilience of a series of Mediterranean Basin shrublands to recurrent fires and their potential to resist alien plant invasions. He claimed that although a certain number of naturalized alien plant species were able to colonize recent burns, their presence was very brief and they did not manage to persist under frequent fire events. Similarly, field studies performed in burned forests of *Pinus halepensis* in Greece report that *Vicia sativa* spp. *sativa* (Papavassiliou and Arianoutsou, 1993), *Trigonella foenum-graecum*—both legume species—and *Antirhinum majus* (Kazanis, 2005) were the only herbaceous species recorded in early stages of early post-fire

communities. Those species were representing less than 1% of the regenerating annual flora, and their abundance was not substantial. In addition, and exactly as reported also by Trabaud (1990), they were gradually retreating at more mature stages of the recovering vegetation. Possible explanations for this may be related either to the traits of the potential invaders, which seem to be not so aggressive, or to the quick recovery process of the native shrubby plants, which are mostly resprouters. Canopy cover increases rapidly and by the time it closes, not many opportunities are offered to the alien herbaceous plants to establish. Even in the cases where seedling recruitment may be the prominent post-fire regeneration mode, as it is in the Cistacaeae and Convolvulaceae families, young saplings grow very fast, reaching their maturity in a couple of years (Arianoutsou and Margaris, 1981; Roy and Sonie, 1992) and quickly covering the ground as well.

Shifts in plant community composition as a result of disturbance, frequent fires included, have been reported from the Mediterranean Basin (Delitti et al., 2005; Arianoutsou et al., 2011). It has been found that whenever the fire regime is altered towards more frequent intervals, natural vegetation consisting of trees, shrubs, and herbs other than grasses can not cope with this situation, because of lack of regeneration sources (either seeds or root carbohydrates), a phenomenon referred to as "immaturity risk" (Zedler, 1995; Vallejo et al., 2012, for a Mediterranean review). Under these situations, perennial grasses seem to be among the most successful survivors or colonizers, because of their perennial life habit and their resprouting recovery mechanism (Arianoutsou et al., 2011). However, no alien plant invasions have been reported for those areas either.

There is evidence that in areas of southern Europe with less dry climates, woody invasive species are becoming a problem in burned areas. In northern and central Portugal, for example, the genera *Acacia*, *Hakea*, *Ailanthus*, and *Eucalyptus* are an increased concern for forest managers, since their prevalence in burned areas is notoriously increasing (Catry et al., 2010). Marchante et al. (2003) report on the spread of *Acacia longifolia* in accidentally burned sand dunes of Portugal. Before fire, *A. longifolia* was a component of the pine plantations already existing on the dunes, and its higher occurrence after fire is explained by massive seed germination (Marchante et al., 2011). It seems, however, that although *Acacia* took over the local vegetation this has occurred on a human-made habitat again.

Several alien tree species are used in plantations in order to provide raw material for industrial purposes. In many cases these are managed using intensive short-rotation silviculture. Among the species most commonly used in commercial plantations are *Eucalyptus* spp., *Picea sitchensis*, *Pinus radiata*, *P. contorta*, *Pseudotsuga menziesii*, and *Tsuga heterophylla* (Silva and Marchante, 2012). Although they are not invasive, because of their fire-stimulated seed germination, many of them may become invasive in the future (Wilson et al., 2011).

CONCLUSIONS—DIRECTIONS FOR FUTURE RESEARCH

Human activities and altered fire regimes may affect the structure of natural habitats and hence their resilience towards disturbances. In this perspective, plant invasions should

not be overlooked, despite the fact that up to now this has not been considered so critical and is thus a neglected topic in the ecology of plant invasions in the dry habitats of the Mediterranean Basin.

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