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Impacts of plant invasion on species diversity in Mediterranean islands

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ABSTRACT: The relationship between plant invasion and the diversity of native plant communities was investigated in six Mediterranean islands and in different habitats. Species abundances were recorded in close-paired plots. One was a control and the other was invaded by one of these three target invaders: *Ailanthus altissima*, *Oxalis pes-caprae* or *Carpobrotus spp.* The diversity and the intensity of the change between the control and the invaded plot were calculated. The presence of *Carpobrotus spp.* was clearly associated with a decrease of diversity between the control and the invaded plots on the dune, on the rocky coast and in all the islands. The intensity of the change was similar whatever the island and the habitat. For *Ailanthus altissima* and *Oxalis pes-caprae*, differences of diversity between control and invaded plots occurred only in few islands and habitats. For *Oxalis pes-caprae*, the intensity of change of diversity was different between the islands and the habitats.

1 INTRODUCTION

Introduced exotic plants that invade natural areas can threaten native communities and reduce native species diversity by forming monospecific stands or altering ecosystem functions (Williamson 1996). The Mediterranean ecosystems, which contain 20% of the planet's known plant species (Cowling et al. 1996), are particularly threatened by plant invasions (di Castri et al. 1990). The Mediterranean islands are particularly vulnerable to plant invasions and the impacts on plant diversity may be especially severe because they comprise major centres of plant diversity and endemism in Europe (Davis et al. 1994, Delanoë et al. 1996).

While biological invasion are large-scale phenomena, there are few studies about plant invasion in various vegetation type over large continental area (Crawley 1987). The appropriate conservation and sustainable management of ecosystems threatened by exotic plant species must be undertaken at a regional scale. Large-scale studies, such as this study ranging over the entire Mediterranean basin, are particularly adapted to the study of the association between the presence of exotics plants and community traits because they are not restricted to one particular habitat or human presence regime. We showed here preliminary results of a large-scale survey in Mediterranean island plant communities within the framework of the EU funded project

EPIDEMIE (Exotic Plant Invasions: Deleterious Effects on Mediterranean Island Ecosystems). It addresses the following questions: are the relationships between plant invasion and diversity different according to (i) the life form of the invasive species? (ii) the island where this invasion occurred? (iii) the habitat invaded?

2 METHODS

2.1 *Study area and target species*

The study was conducted between 2001 and 2003 in Lesbos (Greece), Sardinia (Italy), Corsica and/or Porquerolles (France) depending of the invasive species, and Menorca and Mallorca (Spain).

The history of Mediterranean exotic plant introduction reaches far into the past, nevertheless a set of relatively recently introduced species seem particularly aggressive and/or becoming more widespread. Such is the case for *Ailanthus altissima* Miller and *Oxalis pes-caprae* L. over the entire Mediterranean basin and for the Aizoaceae *Carpobrotus acinaciformis* (L.) L. Bolus and *C. edulis* (L.) in the western half. This species are clonal plants. *Oxalis pes-caprae* is a geophyte species with bulbs. This Oxalidaceae was accidentally introduced from South Africa and has invaded many Mediterranean regions of the world at the beginning of the nineteenth century. *Carpobrotus* taxa are perennial, mat-forming succulents, also native to South Africa (Wisura and Glen, 1993). They are considered a threat to several endemic species and coastal habitats (Suehs et al., 2001). The Simaroubaceae *Ailanthus altissima* is a tree native to China and able to develop dense root networks and clonal stands (Hu, 1979).

2.2 *Experimental design*

In order to detect possible relationships between the three target species invasions and the islands' habitat characteristics, 2 m by 2 m plots were laid out in pairs before the spring season. One plot of each pair was first centred on spontaneously established clones of the target species (*Ailanthus altissima*, *Carpobrotus* spp. or *Oxalis pes-caprae*) detected and localised after dedicated land surveys. The other plot of each pair was then placed at approximately 2 m distance from the edge of the target species clone both in a randomly chosen cardinal direction and in a place where the target invader was not yet present (control). This paired-plot design was then repeated thirty times per target species per island across different habitats (Table 1). Each plot was divided into sixteen 50 cm by 50 cm subplots, and the presence/absence of each invaders was recorded for each subplot. The ground flora was assessed in spring, at maximum cover and diversity, on all focal islands. A few plots were loosed preventing vegetation recording. The abundance of each plant species was scored as the number of subplots in which it occurred. From these data the Shannon index of species diversity was calculated for each plot (the target invaders were not considered). The magnitude of the diversity difference between the control and the invaded plot was calculated as follows: (diversity in the control - diversity in the invaded plot)/ diversity in the control.

Table 1: Number of habitats and land-use types sampled for each species

Habitat – Land use type	*Ailanthus altissima*	*Carpobrotus spp.*	*Oxalis pes-caprae*
Abandoned field	24		40
Orchard, vineyard and olive grove	3		14
Roadside, ruderal and urban	38		22
Temporary stream	32		
Forest, shrubland	5		61
Sand dune		38	
Rocky coast		74	

2.3 *Statistical analysis*

Diversity values in the control and invaded plots were compared for each species using a paired t-test within each island and habitat. An ANCOVA was performed to test for island and habitat effects on the magnitude of the diversity difference between the control and the invaded paired plots while using diversity values as a covariable. The normality of each modality was first tested using Kolmogorov-Smirnov test with a Lilliefors option. Post-hoc Tukey tests were also used to pinpoint differences among islands and among habitats for the magnitude of diversity differences between control and invaded plots. All statistical analyses were conducted with SYSTAT (version 7.0).

3 RESULTS

3.1 *Ailanthus altissima*

In Menorca, the mean diversity was significantly (df=16, t=3.24, p=0.005) lower in the invaded plots (H'=2.79) than in the control plots (H'=3.38) but not in the other islands (figure 1a). There were no differences of diversity between control and invaded paired plots within abandoned fields, ruderal habitats or temporary streams (Fig. 1b).

There was a significant island ($F_{3,82}$=2.97, p=0.036) and habitat ($F_{2,75}$=6.21, p=0.003) effect on the intensity of the change of diversity between the control and the invaded paired plots (figures 1c and d). Nevertheless, the post hoc test of Tukey didn't show differences between islands and habitats.

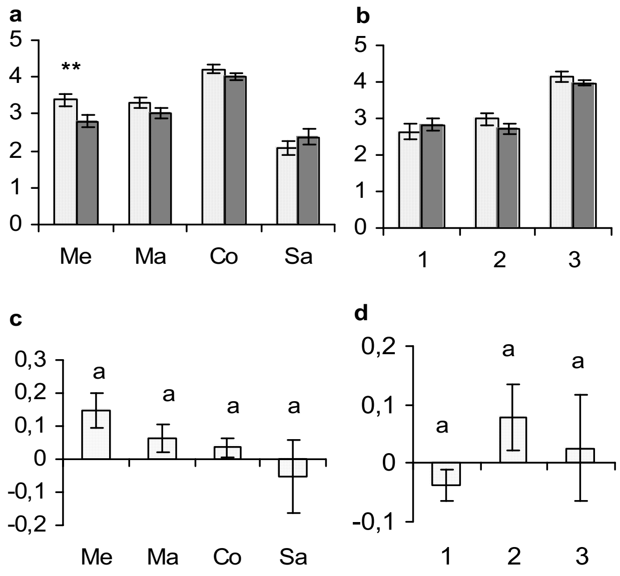

Figure 1: Diversity in the control plots (clear bars) and in the plots invaded by *Ailanthus altissima* (dark bars) a) in the different Islands (Me = Menorca, Ma = Mallorca, Co = Corsica, Sa = Sardinia) b) in the different habitats (1 = Abandoned field, 2 = Roadsides, ruderal and urban habitats, 3: Temporary stream) (*** p<0.001, ** p< 0.01, * p<0.05). Intensity of change of the diversity between the control plots and the plots invaded by *Ailanthus altissima* c) in the different Islands, d) in the different Habitats. Different letters indicate significant differences between the islands and the habitats (Tukey test, p< 0.05).

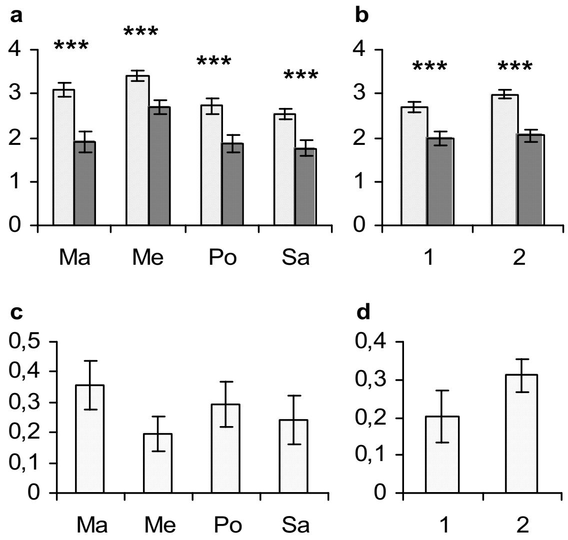

Figure 2: Diversity in the control plots (clear bars) and the plots invaded by *Carpobrotus spp.* (dark bars) a) in the different Islands (Me = Menorca, Ma = Mallorca, Po = Porquerolles, Sa = Sardinia) b) in the two habitats (1 = Dune, 2 = Rocky coast) (*** p<0.001, ** p< 0.01, * p<0.05). Intensity of change of the diversity between the control plots and the plots invaded by *Carpobrotus spp.* c) in the different Islands, d) in the different habitats.

3.2 *Carpobrotus spp.*

The mean diversity was significantly lower in the invaded plots than in the control plots in all the islands (with a difference ranging from 0.71 in Menorca to 1.17 in Mallorca), and also within the two habitats (Fig. 2a and 2b).

There was not a significant effect of island ($F_{3,104}$=1.84, p=0.145) and habitat ($F_{1,106}$=0.395, p=0.531) on the intensity of the change between the control and the invaded paired plots.

3.3 *Oxalis pes-caprae*

The diversity was significantly lower in the invaded plots than in the control plots only in Lesbos (df=29, t=9.11, p<0.001) and in Sardinia (df=29, t=3.85, p=0.001) but not in the other islands (figure 3a). Diversities differed between the control and invaded paired plot in the abandoned fields (df=32, t=7.04, p<0.001), in the ruderal habitats (df=14, t=2.18, p=0.046) and in the forest or shrubland habitats (df=57, t=2.22, p=0.039) but not in the orchards (df=11, t=0.15, p=0.886) (figure 3b).

The intensity of the change between the control and the invaded paired plots was significantly ($F_{4,112}$=19.08, p<0.000) influenced by the island (figure 1c). The positive values in Lesbos or Sardinia were associated to a decrease of the diversity. In Porquerolles, the intensity of change was negative. There is significant effect ($F_{3,113}$=4.89, p=0.003) of the habitat on the intensity of the change between the control and the invaded paired plots (figure 1d). The positive values in abandoned field and ruderal habitats were associated to a decrease of the diversity.

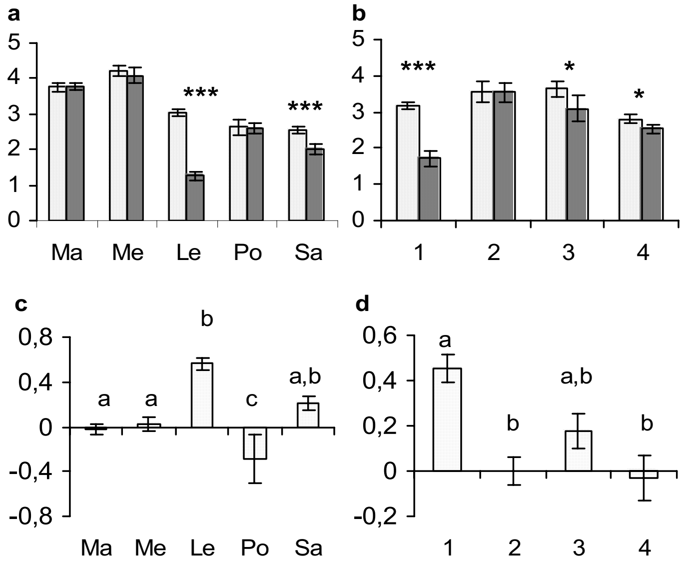

Figure 3: Diversity in the control plots (clear bars) and the plots invaded by *Oxalis pes-caprae* (dark bars) a) in the different Islands (Me = Menorca, Ma = Mallorca, Le = Lesbos, Po = Porquerolles, Sa = Sardinia) b) in the different habitats (1 = Abandoned field, 2 = Orchard, vineyard and olive grove, 3: Roadsides, ruderal and urban habitats, 4: Forest, shrubland) (*** $p<0.001$, ** $p< 0.01$, * $p<0.05$). Intensity of change of the diversity between the control plots and the plots invaded by *Oxalis pes-caprae* c) in the different Islands, d) in the different habitats. Different letters indicate significant differences between the islands and the habitats (Tukey test, $p< 0.05$).

4 DISCUSSION

The spread of exotic plants in natural and semi-natural habitats may often be associated with a decline of native plant diversity (Richardson et al. 1989, Pyšek 1995, Dunbar and Facelli 1999, Levine et al. 2003), although this relationship is somewhat controversial (Alpert et al. 2000). In this study the presence of *Carpobrotus* spp. mats was clearly associated with a decrease of diversity from the control to the invaded plots on sand dunes, on rocky coast sites and in all the six islands. The intensity of this potential impact was similar whatever the island and the habitat. D'Antonio and Mahall (1991) showed that *Carpobrotus edulis* can directly compete with native coastal California shrub species for soil resources particularly by reducing soil water availability, soil pH value, and consequently limiting their growth and reproduction (D'Antonio 1990, Mack et al., 2000). This species has a shallow root system that overlap when plants grow adjacent to each other. On coastal grassland in California, Vivrette and Muller (1977) also showed that the exotic plant, *Mesembryanthemum crystallinum* L., another species of the Aizoaceae family, dramatically altered the composition and density of native plant communities.

On the contrary, *Ailanthus altissima* and *Oxalis pes-caprae* showed a lower potential impact on native plant diversity in comparison with *Carpobrotus*. The presence of these two species was not necessarily linked to lower native diversity in the invaded plots compared with the control plots. The different life forms and phenology of these three target alien species can contribute to explain these results. *Carpobrotus species,* in the studied invaded sites, have a very fast clonal growth, thus they cover large patches of soil with very dense and thick mats. *Oxalis pes-caprae* is a geophyte with a relative short growing season. In spring, at the maximum plant diversity, *Oxalis pes-caprae* is dying. Moreover, this plant tends to disappear from agricultural fields if they are abandoned for a long time. *Ailanthus altissima* is a leaf-shedder tree and its fast growing clonal stands tend to invade sites where the native plant diversity and cover is usually low. When established, *Ailanthus altissima* stands are able to reduce the establishment of other species by inhibiting seed germination with allelopathic substances (Heisey 1990). Nevertheless, *Ailanthus altissima* (such as *Oxalis pes-caprae*) is frequently associated with disturbances, which also may promote diversity of native species. A similar trend has been described in a disturbed Mediterranean shrubland in California, where invasion by *Cortaderia jubata* (Lemoine) Stapf is associated with a decrease in the abundance of native shrub species (Lambrinos 2000). On the other hand, the greater richness of both native and alien herbaceous species made overall richness in *C. jubata* grassland indistinguishable from maritime chaparral.

In the case of *Oxalis pes-caprae* and *Ailanthus altissima* the intensity of the change in diversity was different between the islands and the habitats. Factors specific of each island could explain this pattern – land use practices, disturbances - but stay to explore. For *O. pes-caprae*, in abandoned fields, the intensity of the change was higher than in the other habitats. This result does contradict with other results found in abandoned fields. In abandoned agricultural lands, Meiners et al. (2001) showed that most invasions have little to no effect on the diversity of plant communities. Williamson and Fitter (1996) showed that invasions by most species in post-agricultural succession do not have significant influence on species richness.

5 CONCLUSION

The three species considered in this study are clonal plants. Nevertheless, these preliminary results show that the relationship with community diversity and the potential impact on native plant diversity can be different depending on the target alien species. It differs also according to the island and the habitat. This has been mainly observed for *Oxalis pes-caprae* a species that occur in habitats and land-use types were the frequency of periodic human disturbance (e.g. soil tillage) is normally higher, such as in agricultural fields and crops, olive groves and orchards. In these sites the frequency of disturbance is often higher than in sites invaded by *Ailanthus altissima*, and always very higher than that occurring in sites invaded by *Carpobrotus* spp. Therefore it is possible that the same factors promote both native species richness and invasion.

Further analysis integrating environmental parameters and target alien performances are in progress in the framework of the EPIDEMIE project could better help in explaining these differential impacts on native plant diversity. Nevertheless, these first results could be useful to elaborate recommendations for local and regional management of invasive plants, mitigation of impacts, monitoring and removal interventions.

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