ALIEN IMPACT - Results

Biodiversity impacts of highly invasive alien plants: mechanisms, enhancing factors and risk assessment

DURATION OF THE PROJECT
15/12/2006 - 31/08/2011

BUDGET
1.131.945 €

KEYWORDS
Biological invasions, highly invasive plant species, terrestrial ecosystems, aquatic ecosystems, biodiversity.

CONTEXT

Information on the impacts of alien invasive plant species on ecosystems is scarce, but critical to protecting biodiversity and ecosystem functions in a world with increasing trade, travel and transport. Impacts seem to vary with spatial scale (from microsite to landscape) and ecological complexity (individual, population, community, ecosystem), and both direct and indirect underlying mechanisms have been suggested. Information is especially scarce on the subtle effects of invasive plants that cannot readily be observed (e.g. on other trophic groups), yet this is highly needed to estimate the full threat to biodiversity.
Forecasting the impact of Belgian alien invasive plants faces the challenge that detailed studies (by necessity limited to few species/sites) are needed to disentangle the coupling of response mechanisms at different ecological scales, whereas general trends can only be derived from assessments with simple measures over a large scale (many sites).

OBJECTIVES

The ALIEN IMPACT project aimed to provide a first integrated study of patterns and mechanisms of impact by alien invasive species in Belgium. It considered multiple, highly invasive plant species (HIPS), and combined large-scale screening of invader impact (to characterize patterns) with highly mechanistic studies at fixed sites to characterize impact pathways. Both terrestrial and freshwater ecosystems were studied. The main objectives were:

(1) To identify the **patterns of HIPS impact** on the diversity of native plant communities, by characterizing communities that experience greatest impact and characterizing target native species, both in aquatic and terrestrial ecosystems. (2) To identify **mechanisms of HIPS impact** on native plants, both direct and indirect via pollinators or soil modification. (3) To estimate the **impacts at other trophic levels** by investigating whether HIPS impact on native plant diversity is associated with diversity loss or changes in community structure in other trophic groups, notably soil fauna and macro-invertebrates in water and sediment. (4) To analyse **factors that may modify HIPS impacts** on native plant species in the future.
Does eutrophication or climate warming alter the competitive ability of HIPS?

CONCLUSIONS

Patterns of HIPS impact on the diversity of native plant communities
We examined the effect of seven highly invasive plant species (4 terrestrial plants: *Fallopia* spp., *Senecio inaequidens*, *Impatiens glandulifera* and *Solidago gigantea* and 3 aquatic plants: *Hydrocotyle ranunculoides, Ludwigia grandiflora and Myriophyllum aquaticum)* on native species richness, abundance and composition. In terrestrial systems, especially *Fallopia* spp. and *S. gigantea* exhibited a strong impact on native species richness, starting already at low densities. *Impatiens glandulifera* and *Senecio inaequidens*, on the other hand, had less impact, except for the latter species at high density. In aquatic ecosystems all HIPS induced strong declines in native species richness, mainly affecting native submerged and floating species because these occupy the same position in the water column as the invaders. Across terrestrial and aquatic systems, impact generally correlated well with density of the invasive species.

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Mechanisms of HIPS impact on native plants

A study on indirect impacts by HIPS via pollinators in terrestrial and aquatic systems investigated whether HIPS (*Fallopia* spp., *S. inaequidens*, *I. glandulifera*, *S. gigantea*, *L. grandiflora*) affect reproductive success of native plant species and whether those impacts are mediated by modification of pollinator services. The results show that both terrestrial and aquatic HIPS are highly attractive to a large number of native pollinators and are well integrated in native plant-pollinator networks. There was however no strong evidence of invader impact on native pollinator services. Weak facilitation effects were detected for *L. grandiflora* and *I. glandulifera*. The reproductive success of the native species was not affected by the studied HIPS.

Two experiments examined the underlying mechanisms of HIPS impact on native terrestrial plants via soil modification. One study investigated the impact of *F. japonica* on nitrogen cycling and another experiment studied impacts of *S. gigantea* on phosphorus. The results show that both these invasive species influence specific processes in the cycling of nutrients in the plant-soil system, resulting in alterations in topsoil nutrient pools. *F. japonica* produces recalcitrant litter that immobilizes N, while the species has an efficient resorption in belowground organs and greater internal recycling of N than native plants. This results in a decreased N availability to native species. *S. gigantea* increases the available P pool, most likely due to a pH decrease and its fine root dynamics. In conclusion, manipulation of key limiting resources appears to play a prominent role in the competitive superiority of both species.

In an experiment on the impact of HIPS on competing native species via modification of soil properties, the hypothesis of a positive feedback of *F. japonica* on its own competitive success was tested but rejected. No significant difference was observed between plant performance in invaded and uninvaded soils, suggesting there is no memory effect of past invasion by this species. However, both in invaded and uninvaded soil, the native competitor *C. arvense* grew better in pure culture in the absence of charcoal (charcoal immobilizes soluble organic compounds, like allelopathic substances, in the soil) while it grew better in mixed culture in soil amended with charcoal. This indicates that the competitive superiority of *F. japonica* is probably partially due to allelopathic properties.

Impacts at other trophic levels

In terrestrial systems, impacts on soil fauna were examined for *F. japonica*, *S. gigantea*, *S. inaequidens* and *I. glandulifera*. Soil fauna density most strongly declined under *F. japonica*, while under *I. glandulifera* the total number of individuals increased. Observed impacts could be explained by altered microclimatic conditions, by changes in litter chemical composition and by decreased native plant diversity. In aquatic systems we investigated whether the invasive *H. ranunculoides*, *L. grandiflora* and *M. aquaticum* modify the invertebrate, phytoplankton and zooplankton abundance and diversity. There was no clear support for impacts of HIPS on overall species diversity. All three HIPS negatively affected invertebrate and zooplankton abundance, which could be explained by reduced space, sunlight and oxygen exchange in invaded ponds. Phytoplankton density increased in highly invaded ponds, which may be caused by the entrapment capacity of the invasive species.

Factors that may modify HIPS impact on native plant species

We investigated the effect of soil eutrophication on the competitive balance between terrestrial native and invasive alien plant species (*F. japonica*, *S. gigantea* and *S. inaequidens*) and the effect of water eutrophication on the competition between the invasive *Lagarosiphon major* and the native *Ceratophyllum demersum*. For both terrestrial and aquatic invasive species, the results do not support the hypothesis that eutrophication consistently shifts the competitive balance in favour of the invasive species. In terrestrial communities, the trends varied with the studied species. The competitive superiority of the invasive species decreased with fertility in the case of *F. japonica* while it increased for *S. inaequidens*. Eutrophication did not affect the competitive ability of *S. gigantea*. Nutrient inputs into soils thus favour specific HIPS but suppress others. In the aquatic communities, the invasive *L. major* had a better performance than its native competitor, and eutrophication did not modify this balance.

Simulated climate warming had different effects on the competitive interactions between terrestrial invasive and native species depending on the studied species pair and on the experimental climate conditions. In an experiment where all plants received optimal water supply, climate warming reduced the invader dominance of *S. inaequidens*, but stimulated the suppressed invader *S. gigantea*. These responses could mostly be traced to root specific nitrogen uptake capacity. In an experiment where warming was associated with soil drought, climate change tended to increase the dominance of *S. inaequidens*, in agreement with the warmer and drier climate in its native range and with its significantly enhanced photosynthetic rates observed in the experiment. The competitive balance of the other two studied HIPS (*S. gigantea* and *F. japonica*) and their native competitors was not influenced by warming. The observed warming effects on the competitive interactions in these two experiments could for many cases be explained by the intrinsic warming responses of the species.

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CONTRIBUTION OF THE PROJECT TO A SUSTAINABLE DEVELOPMENT POLICY

Overall, our results support that HIPS do more to ecosystems than merely suppress native competitors. A wide range of HIPS impact exist, both in terrestrial and aquatic systems, and a number of these are severe.
HIPS severely endanger species diversity both in terrestrial and aquatic communities, but differences exist which could be useful to guide control. In terrestrial systems, even low densities of *Fallopia* spp. and *S. gigantea* exhibited a strong impact on native species diversity, so for those species, management at the very beginning of invasion is necessary to prevent impact on native plant communities. The presence of HIPS in nature reserves seems to be rather linked to common habitats, characterized by ruderal species. This points to the importance of avoiding disturbance in sites of high biological value to limit nascent foci of invasion. In aquatic systems, regarding negative impacts on diversity, one group of native species was particularly sensitive: submerged species. Ponds with those growth forms may require priority for control.
The HIPS in this study did not have clear negative impacts on the reproductive success of selected native species. However, our results cannot be generalized to all native and invasive species. Recent literature shows that pollinator-mediated impacts of invasive species on natives are species-specific and identifying invasion-sensitive native plant species is crucial to improve conservation strategies.
The soil compartment plays a key role regarding mechanisms of HIPS impact on terrestrial systems. *F. japonica* had a negative impact on organic matter cycling and the data suggest that this impact may last after *F. japonica* is removed, possibly requiring topsoil removal to restore invaded sites after control. *S. gigantea* decreases soil pH and enhances P availability. For this species, liming could be considered as a control measure.
Effects of HIPS can strongly proliferate to other trophic levels in both aquatic and terrestrial ecosystems. The strongest impact was found for *F. japonica*. The impact of this species was greater in open habitat than in closed vegetation, suggesting that open habitat should be given priority in control of this species.

A final word of warning concerns human-induced factors that may modify HIPS impact. We specifically refer to *S. inaequidens*, which currently exhibits more modest impacts than the other HIPS that we examined. Our climate change experiments suggest that this may change in the future as climate warming tends to increase the competitive superiority of this species. At the same time, *S. inaequidens* reacted well to eutrophication. These characteristics warrant close surveillance of the future evolution of this species.

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