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BIODIVERSITY IMPACTS OF HIGHLY INVASIVE ALIEN PLANTS: MECHANISMS, ENHANCING FACTORS AND RISK ASSESSMENT

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Biodiversity

FINAL REPORT PHASE 1
SUMMARY

BIODIVERSITY IMPACTS OF HIGHLY INVASIVE ALIEN PLANTS: MECHANISMS, ENHANCING FACTORS AND RISK ASSESSMENT

ALIEN IMPACT

SD/BD/01A

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January 2009

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Introduction and goals

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. Developing effective prevention stategies and management solutions, requires that impacts are characterized beyond the anecdotic level of (mostly single-invader) case studies. To what extent do impacts follow general patterns across alien species and invaded communities? Which environmental factors mitigate or aggravate impact?

The ALIEN IMPACT proposal aims to provide a first integrated study of patterns and mechanisms of impact by alien invasive species in Belgium. It considers multiple, highly invasive plant species (HIPS), and combines 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 are studied. The main objectives are:

(1) Identify the **effect of HIPS on the diversity of native plant communities**, characterizing communities that experience greatest impact and characterizing sensitive species that might serve as bio-indicators for impact. Analyze whether critical invader densities exist above which impacts enhance disproportionately, and whether low densities can already induce high impact.

(2) Identify **mechanisms of HIPS impact on native plants**, and quantitatively disentangle the pathways involved through manipulation experiments:

- Are effects of HIPS mediated primarily by competition for soil resources, by competition for pollinator resources, or by other mechanisms such as secretion of allelochemicals?
- Does modification of ecosystem properties (soil) triggered by HIPS reinforce impact on native plant species?

(3) **Impacts at other trophic levels**: Assess whether HIPS impact on native plant diversity is associated with diversity loss or changes in community structure in other trophic groups, notably soil fauna (bacterivores, fungivores, detrivores, omnivores/predators, ...) and macro-invertebrates in water and sediment. Are such changes mediated by modification of ecosystem properties?

(4) Analyse **factors that may modify HIPS impacts on native plant species** in the future:

- Does eutrophication aggravate impacts of invasion by modifying the outcome of HIPS competition with native species?
- Does climate warming alter HIPS impact on native species?

Partner 1 (UA) studies direct mechanisms of impact on native terrestrial plants via competition and how climate warming modifies this. Partner 2 (ULB) investigates indirect mechanisms of impact on native plants via soil modification, impact on soil fauna, and how soil eutrophication influences impact (all terrestrial). Partner 3 (VUB) focuses on

impact on aquatic plant communities and associated other trophic levels, and on how eutrophication of water will modify impact. Partner 4 (FUSAGx) studies patterns of impact on native terrestrial plant communities at larger scale (up to landscape) and, together with partner 5 (UCL), indirect mechanisms of impact on terrestrial plants via pollination. To integrate these divergent types of information, a twofold strategy was adopted:
(1) Partners work with a common set of species for terrestrial plants, and organize the field work in the same landscape/sites when relevant. For most studies, there is an aquatic counterpart to allow comparison with terrestrial invaders. Experimental protocols are shared when possible.
(2) Data from different experiments are combined in additional, integrated analysis.

This report of phase 1 presents results for the majority of the above-mentioned studies, together with preliminary conclusions and recommendations.

Effect of HIPS on the diversity of native plant communities

Concerning impacts on biodiversity, the study that tested whether species diversity was affected by HIPS in terrestrial communities, found a reduction in mean species richness of the native vegetation following invasion by three target HIPS: *Fallopia* spp., *Impatiens glandulifera* and *Solidago gigantea*. There was no plant species richness loss associated with invasion for *Senecio inaequidens*. Impact increased with HIPS density except for *I. glandulifera*. It would thus be possible to prioritize HIPS for control measures depending on species. HIPS invade heterogeneous habitats, and, somewhat contrary to expectation, also frequently invade nature reserves (though not necessarily the vulnerable habitats). In spite of the severe diversity loss induced by most HIPS, our results did not confirm the generally accepted hypothesis of plant communities homogenisation, except for *Solidago gigantea*.

The aquatic counterpart study revealed that the presence of all studied HIPS (*Ludwigia grandiflora*, *Hydrocotyle ranunculoides* and *Myriophyllum aquaticum*) negatively affected both submerged and emergent native vegetation, but the submerged vegetation had significantly lower cover with increasing HIPS cover. This knowledge can help select invaded ponds for control: ponds with those growth forms may require priority. Multivariate analysis revealed a pollution gradient, with *H. ranunculoides* at higher eutrophication levels than *L. grandiflora* or *M. aquaticum*.

We conlude that HIPS can severely endanger species diversity both in terrestrial and aquatic communities, but differences exist, which can be exploited to guide control.

Mechanisms of HIPS impact on native plants

A study on indirect impacts by HIPS via pollinators in terrestrial systems investigated whether HIPS affect reproductive success of native plant species and whether those impacts are mediated by modification of pollinator services. For two HIPS, *I. glandulifera* and *S. inaequidens*, native counterparts were found that share similar habitats and insect visitors and have overlapping flowering periods. From a controlled experiment with three species pairs (*I. glandulifera* - *E. angustifolium*, *I. glandulifera* - *A. napellus* and *S. inaequidens* – *S. jacobaea*) it was clear that pollinator-mediated impacts of HIPS on native species were specific to each pair. For *S. inaequidens* – *S. jacobaea*, only a slight negative impact on the number of flowers visited per trip by an insect was detected. This change in the insect foraging behavior had no impact on the reproductive success of *S. jacobaea*. The presence of *I. glandulifera*, on the other hand, influenced the pollinator guild of *E.*

angustifolium and *A. napellus* by highly increasing the proportional similarity between native – invasive. Despite this modification in pollinator guild, *I. glandulifera* had no impact on the reproductive success of *A. napellus*, while it had a global facilitative impact on *E. angustifolum*. The first results thus indicate that the observed negative impacts of the HIPS on native cover may not be realized via this indirect pathway.

Two experiments that examined underlying mechanisms of HIPS impact on native terrestrial plants via soil modification have been conducted. One study investigated organic matter and nitrogen cycling in *F. japonica* and native competitors. Litter of native species decomposed four times faster than litter of *F. japonica*, which could be explained by initial differences in chemical composition. The invasion of *F. japonica* also seems to influence decomposition by modifying micro-environmental conditions. Concerning N dynamics, immobilization occurs in *F. japonica* litter, while the species has an efficient resorption in belowground organs. Another experiment studied impacts of *S. gigantea* on phosphorus. Labile P pools were always higher and soil pH always lower in invaded stands. Soil pH is one of the most important parameters determining adsorption/desorption equilibria of phosphate in soils. Also the concentrations of bioavailable P were higher in the invaded topsoil, which might be due to higher turnover rates of P in belowground organs and mobilization of soluble P through rhizosphere acidification. The observed increase in P pools of belowground organs is due to both increased biomass and increased P concentrations in invaded plots. The highly invasive *S. gigantea* thus clearly alters the phosphorus cycle in native ecosystems. We conclude that HIPS have clear impacts on soils, but use different mechanisms related to different soil elements. Control measures may exploit this information, e.g. liming could be considered in the case of *S. gigantea*.

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. However, both in invaded and uninvaded soil, the native competitor *C. arvense* grew better in pure culture in the absence of charcoal 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

Regarding impacts at other trophic levels, we found an influence of *F. japonica* on soil fauna assemblages. Although soil fauna diversity was not affected, soil fauna density strongly declined under *F. japonica*: the total number of individuals was 50 tot 60% lower in invaded plots. This decrease might be explained by reduced habitat heterogeneity and resource diversity in *F. japonica* stands. Altered microclimatic conditions might, in part, explain shifts in faunal assemblages. Data analysis about the effect of *S. gigantea* on soil fauna will be accomplished in phase 2.

In aquatic systems, the presence of alien plants and their detritus appears to have a negative impact on the structure of the macro-invertebrate community. Ponds invaded with *L. grandiflora* suffered the most in terms of loss of both macro-invertebrate abundance and diversity. Later identification of phytoplankton and zooplankton will allow us to verify whether effects can be generalised to more trophic levels in both water and detritus.

On the basis of this partial assessment, we conclude that effects of HIPS can strongly proliferate to other trophic levels.

Factors that may modify HIPS impacts on native plant species

Research on factors that may modify HIPS impact on native plants focused on the effects of eutrophication and climate warming on competition between invasive and native plant species.

Data to characterize a possible enhancing or mitigating influence of eutrophication on impact will be provided in phase 2 of the project. A preparatory experiment for aquatic systems showed the competitive superiority of the invasive *L. minuta* over the native *L. minor*. Model analysis showed this was due to *L. minuta*'s higher relative growth rate. The next step is to assess whether different nutrient levels will affect competition in this system.

Simulated climate warming significantly modified current competitive interactions between native and invasive terrestrial plants. However, the way in which the balance between HIPS and native species was altered, depended on the studied species pair. In the current climate, in one pair (*S. inaequidens – P. lanceolata*) the HIPS dominated, and in the other pair (*S. gigantea – E. hirsutum*) the native species. Climate warming reduced the HIPS dominance in the first species pair, but stimulated the supressed HIPS in the second. Most of these changes could be ascribed to warming influences on root specific nitrogen uptake capacity, again confirming the importance of belowground processes. From the species pairs examined, it appears that the sensitivity of the native-invasive interaction to climate warming does not necessarily mirror the intrinsic (monoculture) sensitivities of the species. This would imply that predicting the outcome may be complex. In a second experiment, the influence of higher temperatures and associated changes in water availability on competition between native and invasive species was investigated (data analysis in progress).

Conclusions and phase 2 prospects

Our results up to now support that HIPS do more to ecosystems than merely suppress native competitors. There are strong indications for a wide range of HIPS impacts, both in terrestrial and aquatic systems, in magnitude and pathway, and at different scales and levels of biological organisation (individual, population, community, ecosystem). A number of these impacts are severe. Surprisingly, impacts higher up in the foodweb are not necessarily weak, and the soil is a key compartment for understanding impacts. The data also provide experimental support for the widespread hypothesis that climate change is likely to alter alien plant invasions.

During phase two, we will finish data analysis for some of the above-mentioned studies and we will investigate observed effects in more detail. On the other hand, several new experiments will be conducted. Regarding mechanisms of HIPS impact on native plants, a field experiment will be conducted to assess whether niche overlap can explain the outcome of terrestrial native-invasive competition at microscale. A similar experiment about indirect impacts of HIPS on native plants mediated by pollinators as done for terrestrial plants will also be conducted for aquatic systems. In addition, a study to investigate the effects of eutrophication on competition between native and invasive species in terrestrial systems will start.

When the experimental work is phasing out, we will conduct combined analyses on data from different work packages to disentangle impact pathways and compare impact at different spatial scales.