> SPABIO

Dynamic spatialized bioeconomy of biological invasions: proof of concept for the management of Ludwigia sp. in Brière

Métaprogramme BIOSEFAIR

Project report: 2021 - 2024

May 2025

The management of invasive alien species (IAS) poses complex problems requiring interdisciplinary approaches that combine ecology and economics. Bioeconomic decision-making tools are still underdeveloped, and existing models suffer from a lack of ecological realism, significant complexity that makes them difficult to apply to specific cases, and a relative disconnect from the issues and needs faced by environmental managers. In other words, although these models have all the ingredients needed to define decision-making tools, they remain mainly focused on the academic sphere and produce general results that have relatively little impact in the field.

To address these shortcomings, SPABIO relies on transdisciplinary collaboration between ecologists, economists and natural environment managers to (1) develop a new class of bio-economic models that are ecologically realistic and directly applicable to the concrete problems encountered by managers, (2) provide proof of concept for this new theoretical framework using the case of water primrose (*Ludwigia sp*) in the Brière Regional Nature Park, and (3) prepare the application of the theoretical framework to other IAS problems in various contexts.

SPABIO required a significant amount of work to digitise the spatial records of water primrose abundance and removal in Brière.

In fact, effort and cost data were only available in paper format. We then developed a Bayesian model adapted to the structure of the data collected by managers. The ecological model is a multi-state (4 abundance classes), dynamic (22 years) and spatialised (17,000 square cells of 1 ha) model. the model of the cost-effort relationship for removal is a multiple linear regression, and the bio-economic coupling of the two models is carried out via a cost-effectiveness calculation (cost weighted by the probability of reducing the abundance of water primrose).

The ecological model suggests that the effect of weeding effort depends on the abundance of the plant. When water primrose is very abundant in the environment, weeding promotes a transition to lower abundances. On the other hand, when the environment is not heavily invaded, uprooting accelerates the invasion. This unexpected result calls into question the universality of management measures based on the 'invasion curve', which stipulates that the earlier management intervenes during the invasion, the more likely eradication is. The economic model suggests a quasi-linear cost-effort relationship and therefore no economies of scale. Finally, the bio-economic coupling suggests that uprooting is bio-economically effective only in heavily invaded areas.

Results

Our findings on water primrose in Brière suggest that the strategy of attempting to eradicate the plant while it is still relatively scarce (known as the 'invasion curve' strategy) may be counterproductive. This is an extremely interesting and original finding that challenges the main golden rule of invasion management, namely the imperative to prioritise control in areas with low levels of invasion in order to respond cost-effectively to the dynamics of invasion.

In Brière, uprooting the plant when it was at a low level of abundance prevented a spontaneous return to a lower level of abundance. We conclude that the measures implemented in Brière no longer allowed the manager to control the plant once it had begun to invade the environment (1 ha cell invaded at level 1), and only accelerated the invasion. Only uprooting in heavily invaded areas (level 3) led to an improvement in the situation (transition to level 2). In terms of public policy, this result, without calling into question the importance of early management actions, puts the golden rule into perspective and calls for its application on a case-by-case basis, categorising the invasions to which it applies and those to which it does not apply.

In practical terms, and for the management of water primrose in particular, this result should lead to the abandonment of interventions in areas with low levels of infestation in favour of prioritising efforts in areas with high levels of infestation. The reduction in resources allocated to water primrose removal and the increasing invasion of the marsh reinforce this recommendation, which recognises the advantage of maintaining the main uses of the marsh by focusing removal efforts on large, heavily invaded canals (i.e. waterways). However, this recommendation came as a great surprise to the partner manager (Brière Regional Nature Park), who had not perceived the negative effect of weeding at low abundance, the leitmotif of the park's management policy over the last twenty years.

SPABIO also showed that only the availability and quality of managers' data could limit the implementation of bio-economic models adapted to their needs. In Brière, the abundance data for water primrose was already in GIS format, and formatting it for modelling did not pose a major problem. On the other hand, digitising the removal sites (spatial footprint, costs) was a long and difficult task, and the data obtained is of average quality, particularly with regard to the spatial footprint of the sites. The future development of bio-economic models to support managers requires them to acquire a greater understanding of scientific data.

With a view to developing management tools, another outcome of SPABIO was the implementation of a nationwide survey aimed at gaining a better understanding of managers' knowledge of management support tools and anticipating their expectations and needs in terms of scientific support. The main results of the survey highlighted limited knowledge and use of existing tools, although the recommendations of the invasion curve advocating early action in areas with low levels of invasion had been assimilated. It also highlighted the need for support tools to prioritise species and sites for treatment, taking into account invasion dynamics on the one hand and management costs on the other.

Scientific prospects

The questioning of the systematic application of invasion curve recommendations is an important finding insofar as (1) prioritising efforts in areas with low levels of invasion is a golden rule that is rarely or never questioned in the literature, and (2) our survey highlights that this rule is the main insight that natural area managers retain from invasion science. While our analysis does not invalidate the merits of early action, it does temper this golden rule by highlighting the existence of invasive situations for which it is harmful. This is particularly the case with water primrose, which, once established in an environment, cannot be removed, as early uprooting efforts facilitate its spread. An obvious extension of this work would be to deploy our proof of concept in other natural environments and, above all, to apply it to other invasive species. The challenge would be to better understand for which types of species/environments the golden rule applies or does not apply.

Our bioeconomic analysis has produced fundamental results in terms of spatial prioritisation of management efforts, taking into account dispersion dynamics on the one hand and spatialised management costs on the other. In addition, our survey of natural environment managers has produced fundamental results in terms of species prioritisation. A further extension of this work would be to extend our analysis to multi-species cases. Another avenue that we find particularly interesting would be to add the 'impact ingredient' to our analysis. We have focused so far on the objective of minimising the prevalence of invasion at the lowest cost, and it could be interesting to broaden this conceptual framework to include minimising the impacts of invasion on biodiversity at the lowest cost.

Publications

Courtois, P., Figuières, C., Martinez, C., Thébaud, G et Thomas, A. (2023) L'économie des invasions biologiques: vers une hiérarchisation des stratégies de gestion. *In* Christian

Lannou, Jean-Yves Rasplus, Samuel Soubeyrand, Mathieu Gautier, Jean-Pierre Rossi (Ed coord.) Crises sanitaires en agriculture, les espèces invasives sous surveillance, collection savoirs faire, Versaille (France): Editions Quae.

Technology transfer

The digitised datasets in GIS format (biological and management/economic data) and the annotated scripts will be published in an open repository (Zenodo) in accordance with the principles of open science.