Mycorrhizal fungi and other symbionts as drivers of plant geography and implications for invasions

Island biogeography has traditionally focused on abiotic drivers of colonization, extinction and speciation, but the establishment on islands can be also limited by biotic drivers, such as the absence of symbionts. Here we provide evidence for a mycorrhizal filter (i.e., the filtering out of mycorrhizal plants on islands), with mycorrhizal associations less common among native island plants than native mainland plants. We also show that naturalized floras show a greater proportion of mycorrhizal plant species on islands than in mainland regions (1, Fig. 1). Mycorrhizal plant species, both arbuscular (AM) and ectomycorrhizal (ECM), are more likely to be naturalized, and naturalize to a greater extent than non-mycorrhizal plants, the effect being stronger for AM. In addition, species with facultative mycorrhizal associations were more successful than those with obligate mycorrhizal associations, but both groups tended to have a greater chance of being naturalized than non-mycorrhizal species. These results indicate that facultative association with AM provides plant species with a naturalization advantage. For the first time we have shown that being mycorrhizal contributes not only to the size of the naturalized range, reflecting the ability to spread, but also to the ability to become naturalized in the first instance (2). Overall, we identify the mycorrhizal association as an overlooked driver of global plant biogeographical patterns with implications for contemporary island biogeography and our understanding of plant invasions (1). As to other symbionts, we found that cointroduction of Australian acacias and their rhizobia is more prevalent than previously thought. A single rhizobium cointroduction event may be sufficient to facilitate the establishment of effective mutualisms in numerous Acacia species, potentially leading to an invasion meltdown (3).

1. Delavaux C. S., Weigelt P., Dawson W., Duchicela J., Ess F., van Kleunen M., König C., **Pergl J.**, **Pyšek P.**, Stein A., Winter M., Schultz P., Kreft H. & Bever J. D. (2019) Mycorrhizal fungi influence global plant geography. Nature Ecology and Evolution 3:424–429. – 2. **Pyšek P.**, Guo W.-Y., **Štajerová K.**, Moora M., Bueno C. G., Dawson W., Essl F., Gerz M., Kreft H., **Pergl J.**, van Kleunen M., Weigelt P., Winter M. & Zobel M. (2019): Facultative mycorrhizal associations promote plant naturalization worldwide. Ecosphere 10:e02937. – 3. Warrington S., Ellis A., **Novoa A.**, Wandrag E. M., Hulme P. E., Duncan R. P., Valentine A. & Le Roux J. J. 2019. Cointroductions of Australian acacias and their rhizobial mutualists in the Southern Hemisphere. Journal of Biogeography 46:1519-1531

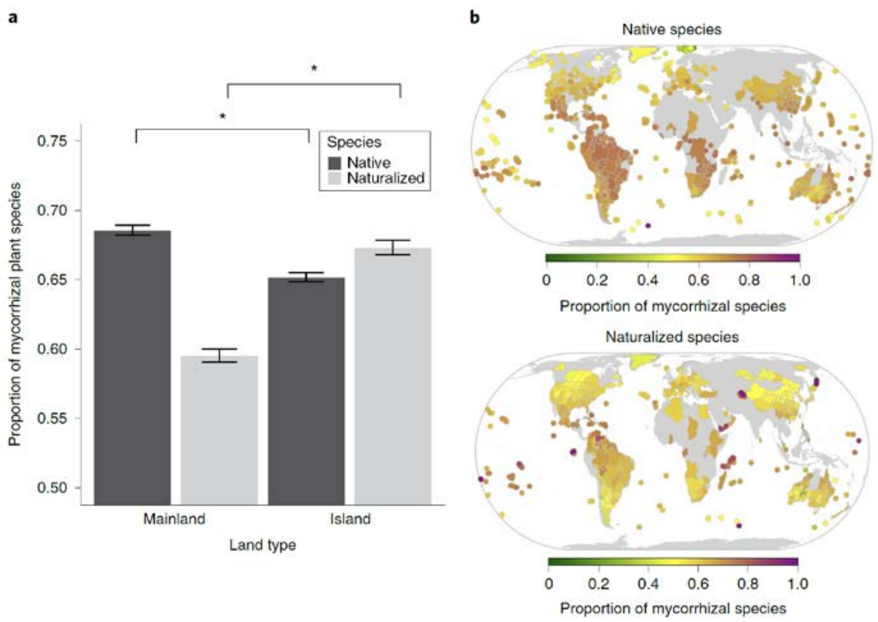


Fig. 1 Naturalized floras show a greater proportion of mycorrhizal plant species on islands than in mainland regions, as expected from the anthropogenic co-introduction of plants with their symbionts to islands and anthropogenic disturbance of symbionts in mainland regions. Taken from Delavaux et al., Nature Ecology and Evolution 2019.

Changes in species richness in the Anthropocene: from theoretical concepts to global inventories

Biological invasions are a defining feature of the Anthropocene, but the factors that determine the spatially uneven distribution of alien plant species are still poorly understood. The first global analysis of the effects of biogeographic factors, the physical environment and socioeconomy on the richness of naturalized and invasive alien plants revealed that socioeconomic factors were more important in explaining the levels of invasion than levels of naturalization. On average, islands have more naturalized and invasive species compared to mainland regions, ad 26% of all islands harbour more naturalized alien than native plants (1). The analysis was based on public release of the Global Naturalized Alien Flora (GloNAF) database, version 1.2, including 13,939 naturalized taxa and their distribution in 1,029 regions of the world (including 381 islands) (2). To contribute to the global data on plant invasions we developed global inventory of two functional groups, terrestrial alien true ferns (3) and tall stature naturalized grasses (4). A separate analysis revealed that North and South America might face contrasting challenges in terms of potential threats to biodiversity posed by alien plant species, because of the different past and present dynamics of invasions and predictions of future development. In North America and South America additions of naturalized species to the native flora from other continents make up 6.9 and 1.4 %, respectively. Since considerable increases in naturalized plant numbers are expected in the next 20 years for emerging South American economies, the present state be reversed (5). As a theoretical concept we argue that it is important to distinguish species for which human-induced environmental changes are important indirect drivers of range expansion into new regions, and that such species will become an essential feature for biodiversity management and science in the Anthropocene. We propose the term neonative for these taxa (6)

1. Essl F., Dawson W., Kreft H., **Pergl J.**, **Pyšek P.**, van Kleunen M., Weigelt P. et al. (2019) Drivers of the relative richness of naturalized and invasive plant species on the Earth. AoB Plants 11: plz051. – 2. van Kleunen M., **Pyšek P.**, Dawson W., Essl F., Kreft H., **Pergl J.**, Weigelt P. et al. (2019) The Global Naturalized Alien Flora (GloNAF) database. Ecology 100:e02542. – 3. Jones E. J., Kraaij T., Fritz H. & **Moodley D.** 2019. A global assessment of terrestrial alien ferns (Polypodiophyta): species' traits as drivers of naturalisation and invasion. Biological Invasions 21:861-873. – 4. Canavan S., Meyerson L. A., Packer J. G., **Pyšek P.**, Maurel N., Lozano V., Richardson D. M., Brundu G., Canavan K., Cicatelli A., **Čuda J.**, Dawson W., Essl F., Guarino F., Guo W-Y, van Kleunen M., Kreft H., Lambertini C., **Pergl J.**, **Skálová H**., Soreng R. J., Visser V., Vorontsova M. S., Weigelt P., Winter M. & Wilson J. R. U. 2019. Tall-statured grasses: a useful functional group for invasion science. Biological Invasions 21:37-58. – **5. Pyšek P.**, Dawson W., Essl F., Kreft H., **Pergl J.**, Seebens H., van Kleunen M., Weigelt P. & Winter M. (2019): Contrasting patterns of naturalized plant richness in Americas: numbers are higher in the North but expected to rise sharply in the South. Global Ecology and Biogeography 28:779–783. – 6. Essl F., Dullinger S., Genovesi P., Hulme P. E., Jeschke J., Katsanevakis S., Kühn I., Lenzner B., Pauchard A., **Pyšek P.**, Rabitsch W., Richardson D. M., Seebens H., van Kleunen M., van der Putten W., Vilà M. & Bacher S. (2019) A conceptual framework for range-expanding species that track human-induced environmental change. BioScience (doi: 10.1093/biosci/biz101)

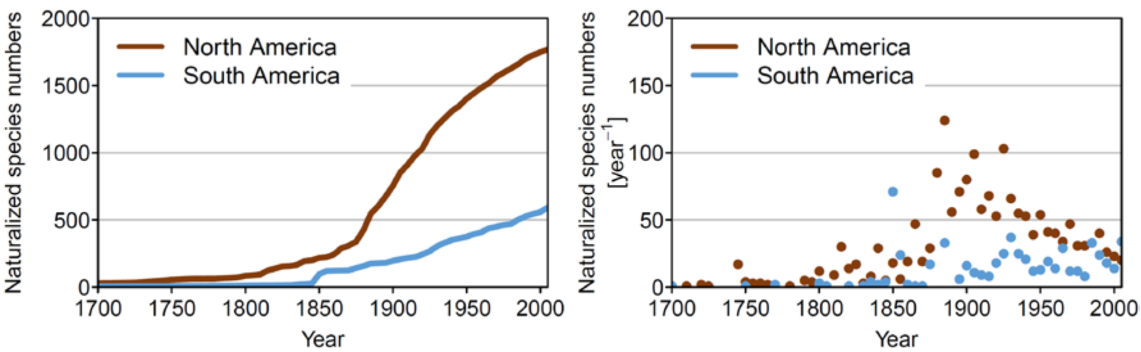


Fig. 2. Dynamics over time of new species introductions to North and South America. (A, left panel) cumulative numbers of species, (B, right panel), numbers recorded as per year. Taken from Pyšek et al., Global Ecology and Biogeography 2019

Stakeholders' perceptions of plant invasions and implications for management

Biological invasions, as most other environmental drivers of change, are embedded within a suite of socio-ecological systems. Therefore, to develop effective IAS management actions it is necessary to study both the social and environmental domains along with interdisciplinary collaborated research. However, most research on IAS has focused exclusively on their ecological aspects. We illustrated some of the crucial research contributions relating to the human and social dimensions of invasion science and their implications for management (1). Working with an interdisciplinary team, we also produced a synthesis of the key factors that influence people's perceptions of invasive alien species (2) and highlighted the four main issues that should be addressed to ensure a better integration of stakeholder engagement in invasion research, thereby contributing to more effective management of invasive species (3). We then applied these results to identify the challenges and opportunities associated with the management of terrestrial plant invasions in Ireland (4) and develop a set of actions that can help to improve the management of cactus invasions globally (5).

1. Shackleton R. T., Larson B. M., **Novoa A.**, Richardson D M. & Kull C. A. (2019) The human and social dimensions of invasion science and management. Journal of Environmental Management 229:1-9. – **2.** Shackleton R. T., Richardson D. M., Shackleton C. M., Bennett B., Crowley S. L., Dehnen-Schmutz K., Estevez R. A., Fischer A., Kueffer C., Kull C. A., Marchante E., **Novoa A**., Potgieter L. J., Vaas J., Vaz A. S. & Larson B. M. H. (2019) Explaining people's perceptions of invasive alien species: A conceptual framework. Journal of Environmental Management 229:10-26. – 3. Shackleton R. T., Adriaens T., Brundu G., Dehnen-Schmutz K., Estevez R. A., Fried J., Larson B. M. H., Liu S., Marchante E., Marchante H., Moshobane M. C., **Novoa A**., Reed M. & Richardson D. M. (2019) Stakeholder engagement in the study and management of invasive alien species. Journal of Environmental Management 229:88-101. – 4. **Gioria M**., O'Flynn C. & Osborne B. (2019) Managing invasions by terrestrial alien plants in Ireland: challenges and opportunities. Biology and Environment, Proceedings of the Royal Irish Academy. 119B:37-61. – 5. **Novoa A**., Brundu G., Day M. D., Deltoro V., Essl F., Foxcroft L. C., Fried G., Kaplan H., Kumschick S., Lloyd S., Marchante E., Marchante H., Paterson I. D., **Pyšek P**., Richardson D. M., Witt A., Zimmermann H. G. & Wilson J. R. U. (2019) Global action for managing cactus invasions. Plants 8:421 (10.3390/plants8100421).

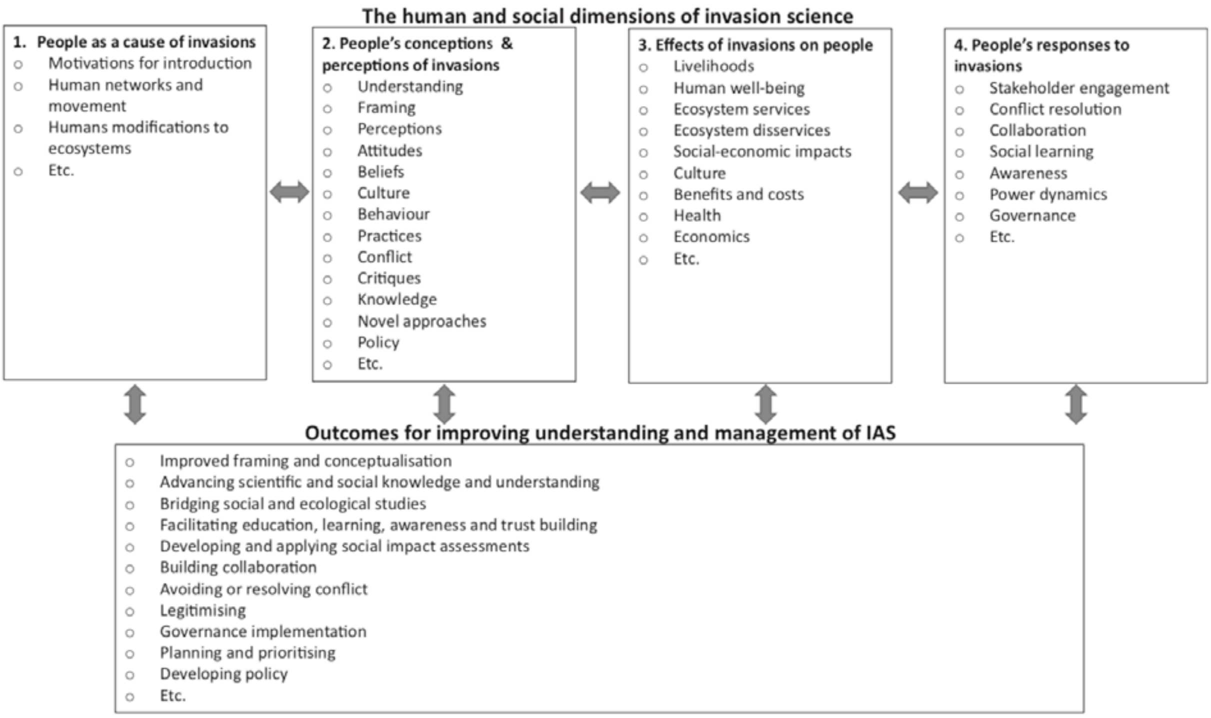


Fig. 3. The human and social dimensions of invasion science and how they can help to improve understanding and management of biological invasions. Taken from Shackleton et al., Journal of Environmental Management 2019.

Seed-related functional traits as drivers of plant invasion

The ability to form persistent seed banks contributes to the invasion potential of alien plants in their new distribution ranges. Using the largest seed bank dataset collated to date, comprising 14,293 records for 2566 species, we revealed a lower probability of forming a persistent seed bank in the alien range. However, invasive woody species formed denser seed banks in the alien range, suggesting greater seed production and/or lower seed predation or mortality there. Invasive species consistently showed a higher probability of forming persistent seed banks as well as denser seed banks than their non-invasive congeners in their native range, but not in their alien range. These findings provide the first quantitative evidence of preadaptation with respect to species life-history traits resulting in the formation of a persistent seed bank in invasive species. The fact that both invasive and non-invasive congeners have similar probabilities of forming persistent seed banks abroad suggests that this might be an important attribute for the establishment of alien species in new ranges (naturalization phase), but not for their spread (invasion phase) (1). Among Asteraceae, heteromorphic species were more likely to naturalize outside their native range than monomorphic, but both groups did not differ in the number of world regions where they became naturalized. However, when life history and height were included in the models, the effect of fruit heteromorphism on the ability to naturalize became non-significant. Nevertheless, among tall plants, heteromorphic ornamental species were significantly more likely to become naturalized and do so in more regions than monomorphic species (2). Data collected during a five-year field experiment indicate that invasive *Impatiens* species seed resistance to environmental factors and high germination contribute to their wide distribution (3).

1. **Gioria M.**, Le Roux J. J., Hirsch H., **Moravcová L.** & **Pyšek P.** (2019) Characteristics of the soil seed bank of invasive and non-invasive plants in their native and alien distribution range. Biological Invasions 21:2313–2332. – 2. Fenesi A., Sándor D., **Pyšek P.**, Dawson W., Ruprecht E., Essl F., Kreft H., **Pergl J.**, Weigelt P., Winter M. & van Kleunen M. (2019) The role of fruit heteromorphism in naturalization of Asteraceae. Annals of Botany 123:1043–1052. – 3. **Skálová H., Moravcová L., Čuda J.** & **Pyšek P.** (2019) Seed-bank dynamics of native and invasive *Impatiens* species during a five year field experiment under various environmental conditions. NeoBiota 50:75–95

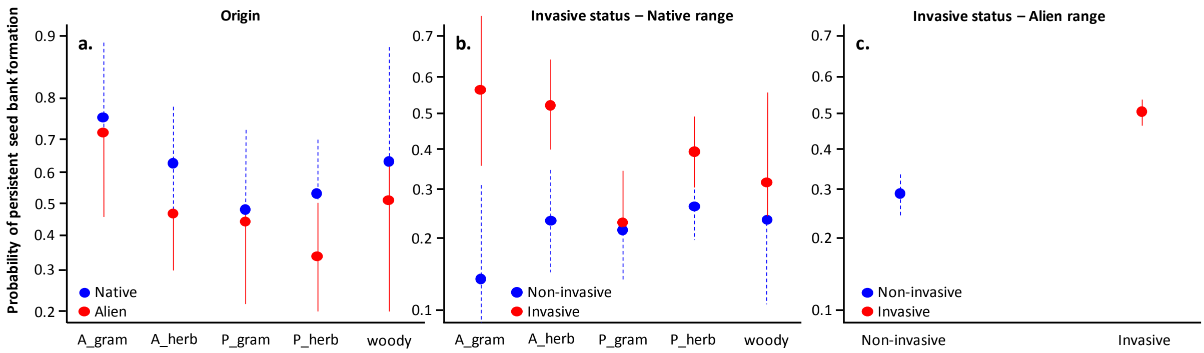


Fig. 4. Results of GLMMs showing the differences in the probability of forming a persistent soil seed between (a) 140 invasive species in their native vs alien range (4336 records), (b) 955 invasive vs non-invasive congeneric species in their native range (6824 records), and (c) 162 invasive vs non-invasive congeneric species in their alien range (1149 records). Species were grouped as annual graminoids (A_gram) and herbs (A_herb), perennial graminoids (P_gram) and herbs (P_herb), and woody species (woody). Taken from Gioria et al., Biological Invasions 2019.

Predicting impacts: from field data to large-scale impact assessment

Most studies on the impacts of plant invasions focus on species richness or diversity of invaded communities, but much less attention has been paid to structural changes such as the representation of species with different traits. To bridge this knowledge gap, we assess the impact of dominant species on the trait composition of recipient communities in vegetation that comprised three species native to Eurasia and invasive in North America (i.e. *Agrostis capillaris, Bromus tectorum, Cirsium arvense*) and three species native to North America and invasive in Europe (i.e. *Aster novi-belgii, Lupinus polyphyllus, Solidago canadensis*), in both their native and invaded ranges. A general trend was that dominant species with an impact on species richness also had an impact on trait composition, especially in North America. The impact of Eurasian dominants in North America was stronger than that associated with the opposite direction of invasion (1). Information on impact collected in the field such this or another study (2) needs to be incorporated into impact assessment schemes. One such exercise we were involved in was a horizon scanning procedure to derive a ranked list of potential future invaders to Europe. From an initial working list of 329 species, a list of 66 species not yet established in the EU that were considered to be very high (8 species), high (40 species) or medium (18 species) risk species was derived (3). In a related study a consistency of impact assessment protocols was tested (4).

1. **Hejda M., Štajerová K., Pergl J.** & **Pyšek P.** (2019) Impacts of dominant plant species on trait composition of communities: comparison between the native and invaded ranges. Ecosphere 10:e02880 . – 2. **Gioria M.**, O'Flynn C. & Osborne B. A. (2019) A review of the impacts of major terrestrial invasive alien plants in Ireland. Biology and Environment-Proceedings of the Royal Irish Academy 118B:157-179. – 3. Roy H. E. & al. (2019) Developing a list of invasive alien species likely to threaten biodiversity and ecosystems in the European Union. Global Change Biology 25:1032-1048. – 4. Gonzales-Moreno & al. (2019) Consistency of impact assessment protocols for non-native species. NeoBiota 44:1-25

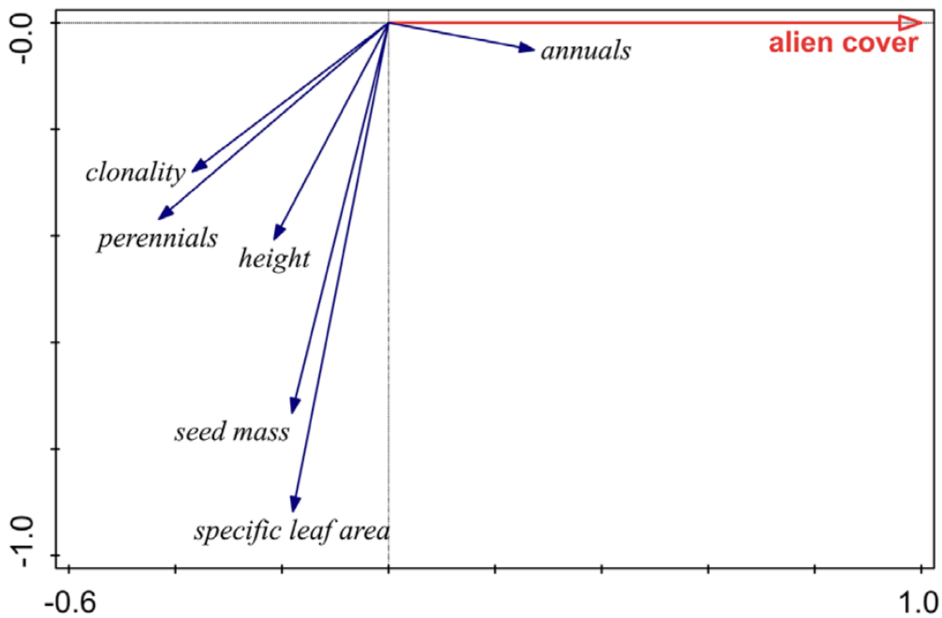
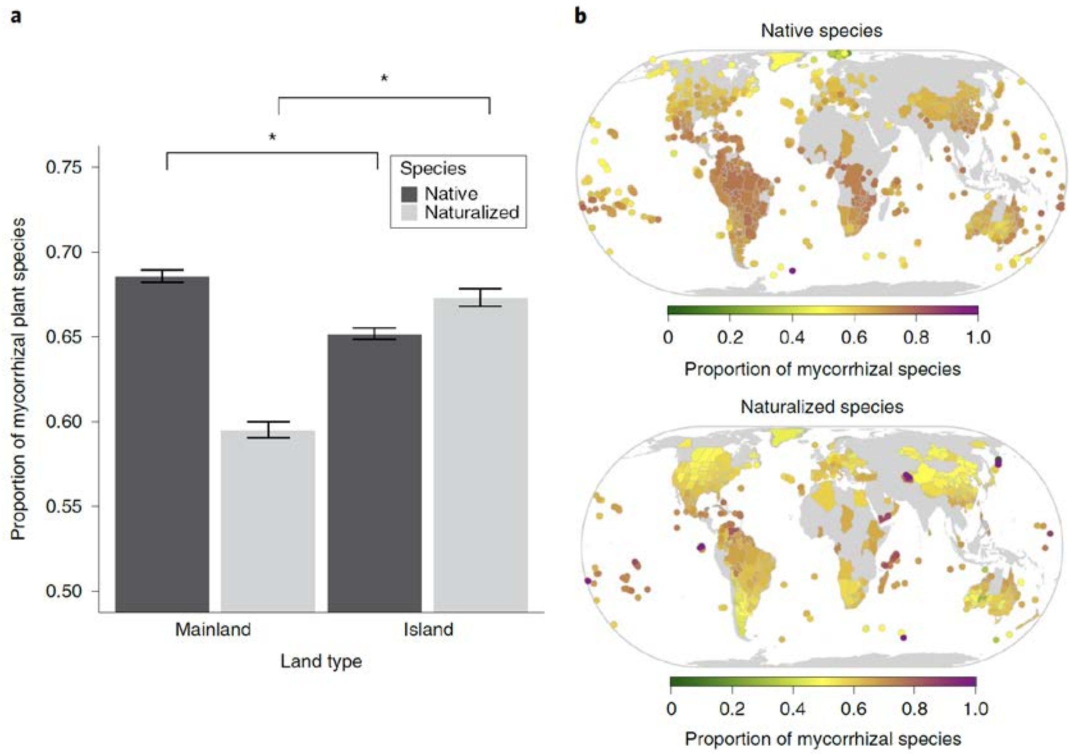


Fig. 5. Ordination plot (RDA, pseudo-F = 8.0, P = 0.002, first axis explains 6.4% of variability, the second axis explains 49.1%) on the distribution of individual species' traits in relation to the cover of the target invasive aliens of Eurasian origin in North America (i.e., *Agrostis capillaris, Bromus tectorum*, and *Cirsium arvense*). The plot shows a positive relation between the cover of Eurasian invaders and the share of annuals and a negative relation with the share of clonal and perennial species. Taken from Hejda et al., Ecosphere 2019

Mykorhizní houby a ostatní symbionti ovlivňují rozšíření rostlin a jejich invazní potenciál

Mezi původními rostlinami na ostrovech je méně mykorhizních než na pevnině, zatímco u naturalizovaných ostrovních flór je tomu naopak. Pravděpodobnost, že mykorhizní rostlina úspěšně zdomácní, je vyšší než pro nemykorhizní, nejvýhodnější strategií je fakultativní mykorhiza, která umožňuje na rozdíl od obligátní větší flexibilitu. Význam mykorhiz pro globální biogeografii rostlin a jejich vliv na invaze není plně nedoceněn.

1. Delavaux C. S., Weigelt P., Dawson W., Duchicela J., Ess F., van Kleunen M., König C., **Pergl J.**, **Pyšek P.**, Stein A., Winter M., Schultz P., Kreft H. & Bever J. D. (2019) Mycorrhizal fungi influence global plant geography. Nature Ecology and Evolution 3:424-429. – 2. **Pyšek P.**, Guo W.-Y., **Štajerová K.**, Moora M., Bueno C. G., Dawson W., Essl F., Gerz M., Kreft H., **Pergl J.**, van Kleunen M., Weigelt P., Winter M. & Zobel M. (2019) Facultative mycorrhizal associations promote plant naturalization worldwide. Ecosphere 10:e02937. – 3. Warrington S., Ellis A., **Novoa A.**, Wandrag E. M., Hulme P. E., Duncan R. P., Valentine A. & Le Roux J. J. (2019) Cointroductions of Australian acacias and their rhizobial mutualists in the Southern Hemisphere. Journal of Biogeography 46:1519-1531.

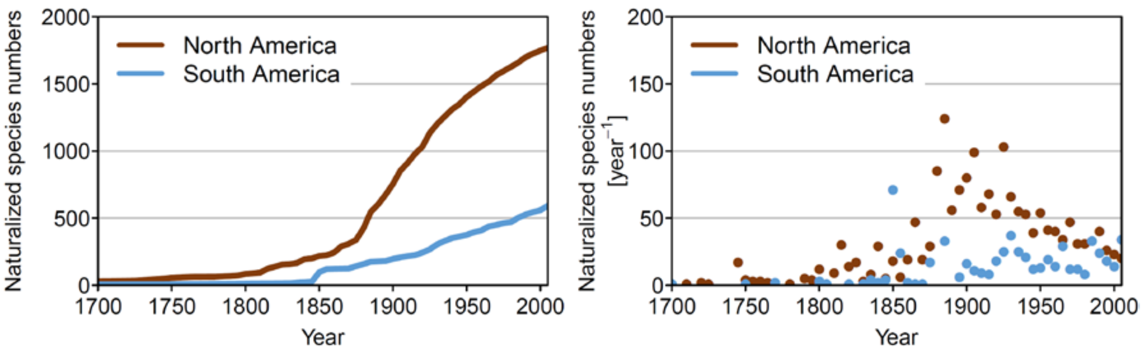


Obr. 1. V naturalizovaných flórách je větší podíl mykorhizních rostlin na ostrovech než na pevnině, v důsledku člověkem podmíněných kointrodukcí. Podle Delavaux et al., Nature Ecology and Evolution 2019.

Změny druhové bohatosti v Antropocénu: od globálních databází k teoretickým konceptům

První globální analýza vlivu biogeografických faktorů, environmentálních proměnných prostředí a socioekonomických faktorů na bohatost naturalizovaných a invazivních nepůvodních rostlin ukázala, že socioekonomické faktory jsou důležitější pro vysvětlení počtu invazních rostlin než jako prediktor počtu naturalizovaných (1). Analýza byla založena na letos zveřejněné databázi Global Naturalized Alien Flora (GloNAF), obsahující rozšíření 13 939 naturalizovaných taxonů v 1029 regionech světa (2). Zpracovali jsme také globální soupisy dvou funkčních skupin, nepůvodních kapradin (3) a naturalizovaných trav (4). Další analýza odhalila, že Severní a Jižní Amerika čelí odlišné hrozbě, pokud jde o ohrožení biodiverzity rostlinnými invazemi, a to z důvodu rozdílné historie a současné dynamiky invazí. V Severní Americe mají naturalizované druhy na původní flóře kontinentu mnohem vyšší podíl (6,9 % vs 1,4 %) (5). Zpracovali jsme také teoretický koncept založený na tom, že je důležité rozlišovat druhy, které se šíří v důsledku člověkem způsobených změn prostředí, aniž by byly přímo zavlékány. Pro tyto taxony navrhujeme termín ‘neonative’ (6).

1. Essl F., Dawson W., Kreft H., **Pergl J.**, **Pyšek P.**, van Kleunen M., Weigelt P. et al. (2019) Drivers of the relative richness of naturalized and invasive plant species on the Earth. AoB Plants 11:plz051. – 2. van Kleunen M., **Pyšek P.**, Dawson W., Essl F., Kreft H., **Pergl J.**, Weigelt P. et al. (2019) The Global Naturalized Alien Flora (GloNAF) database. – Ecology 100:e02542. – 3. Jones E. J., Kraaij T., Fritz H. & **Moodley D.** (2019) A global assessment of terrestrial alien ferns (Polypodiophyta): species’ traits as drivers of naturalisation and invasion. Biological Invasions 21:861-873. – 4. Canavan S., Meyerson L. A., Packer J. G., **Pyšek P.**, Maurel N., Lozano V., Richardson D. M., Brundu G., Canavan K., Cicatelli A., **Čuda J.**, Dawson W., Essl F., Guarino F., Guo W-Y, van Kleunen M., Kreft H., Lambertini C., **Pergl J.**, **Skálová H**., Soreng R. J., Visser V., Vorontsova M. S., Weigelt P., Winter M. & Wilson J. R. U. (2019) Tall-statured grasses: a useful functional group for invasion science. Biological Invasions 21:37-58. – 5. **Pyšek P.**, Dawson W., Essl F., Kreft H., **Pergl J.**, Seebens H., van Kleunen M., Weigelt P. & Winter M. (2019) Contrasting patterns of naturalized plant richness in Americas: numbers are higher in the North but expected to rise sharply in the South. Global Ecology and Biogeography 28:779-783. – 6. Essl F., Dullinger S., Genovesi P., Hulme P. E., Jeschke J., Katsanevakis S., Kühn I., Lenzner B., Pauchard A., **Pyšek P.**, Rabitsch W., Richardson D. M., Seebens H., van Kleunen M., van der Putten W., Vilà M. & Bacher S. (2019) A conceptual framework for range-expanding species that track human-induced environmental change. BioScience 69:908-919

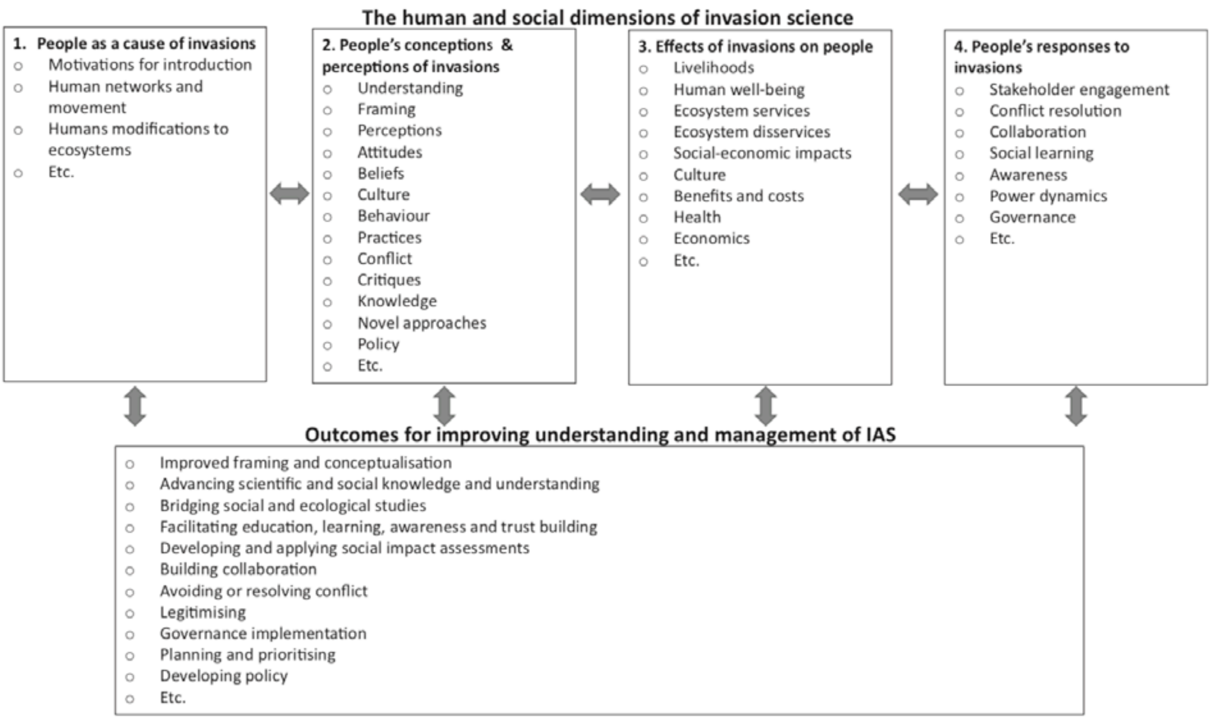


Obr. 2. Dynamika introdukcí nepůvodních rostlin do Severní a Jižní Ameriky, vyjádřená jako kumulativní počet (vlevo), a počet později naturalizovaných druhů zavlečených v příslušném roce (vpravo). Podle Pyšek et al., Glonal Global Ecology and Biogeography 2019

Rozdíly ve vnímání invazí zúčastněnými stranami a důsledky pro management

Biologické invaze jsou, jako většina procesů souvisejících s globálními změnami, součástí sociálně-ekologických systémů. Podmínkou vypracování účinných přístupů řešení tohoto globálního problému je proto zaměřit pozornost na sociální i environmentální oblast výzkumu, včetně mezioborových přesahů. Výzkum invazí je však dosud zaměřen především na jejich ekologické aspekty. Vytvořili jsme proto koncepční rámec, podchycující lidský a sociální rozměr studia invazí (1). Ve spolupráci s interdisciplinárním týmem jsme také vymezili klíčové faktory, které ovlivňují, jak lidé invaze nepůvodních druhů vnímají (2). Zdůraznili jsme čtyři hlavní problémy, které by se měly řešit, má-li dojít k užšímu propojení zúčastněných stran při výzkumu invazí (3). Tyto výsledky jsme poté použili k vymezení problémů a příležitostí spojených s managementem rostlinných invazí v Irsku (4) a k vypracování souboru činností, které mohou pomoci ke zlepšení managementu invazí kaktusů v celosvětovém měřítku (5).

1. Shackleton R. T., Larson B. M., **Novoa A.**, Richardson D M. & Kull C. A. (2019) The human and social dimensions of invasion science and management. Journal of Environmental Management 229:1-9. – 2. Shackleton R. T., Richardson D. M., Shackleton C. M., Bennett B., Crowley S. L., Dehnen-Schmutz K., Estevez R. A., Fischer A., Kueffer C., Kull C. A., Marchante E., **Novoa A**., Potgieter L. J., Vaas J., Vaz A. S. & Larson B. M. H. (2019) Explaining people's perceptions of invasive alien species: A conceptual framework. Journal of Environmental Management 229:10-26. – 3. Shackleton R. T., Adriaens T., Brundu G., Dehnen-Schmutz K., Estevez R. A., Fried J., Larson B. M. H., Liu S., Marchante E., Marchante H., Moshobane M. C., **Novoa A**., Reed M. & Richardson D. M. (2019) Stakeholder engagement in the study and management of invasive alien species. Journal of Environmental Management 229:88-101. – 4. **Gioria M**., O'Flynn C. & Osborne B. (2019) Managing invasions by terrestrial alien plants in Ireland: challenges and opportunities. Biology and Environment, Proceedings of the Royal Irish Academy. 119B:37-61. – 5. **Novoa A**., Brundu G., Day M. D., Deltoro V., Essl F., Foxcroft L. C., Fried G., Kaplan H., Kumschick S., Lloyd S., Marchante E., Marchante H., Paterson I. D., **Pyšek P**., Richardson D. M., Witt A., Zimmermann H. G. & Wilson J. R. U. (2019) Global action for managing cactus invasions. Plants 8: 421 (10.3390/plants8100421).

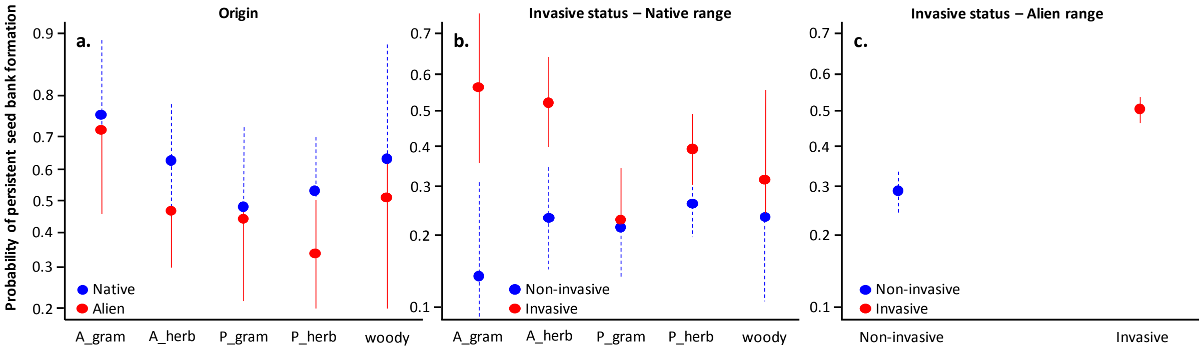


Obr. 3. Lidské a sociální aspekty biologických invazí a jak mohou přispět k pochopení procesu a managementu invazních druhů. Podle Shackleton et al., Journal of Environmental Management 2019.

Fukční vlastnosti semen jako faktor přispívající k invazivnosti

Schopnost vytvářet perzistentní semennou banky přispívá k invaznímu potenciálu nepůvodních rostlin v jejich nových areálech. Použili jsme dosud největší databázi semenných bank, obsahující 14 293 záznamů pro 2566 druhů, a zjistili jsme, že nepůvodní druhy po zavlečení vytvářejí semennou banku méně často než doma. Invazní druhy tvoří perzistentní semennou banku s vyšší hustotou semen častěji než neinvazní druhy téhož rodu, ale pouze v původním areálu; po zavlečení toto ve srovnání s tamními původní druhy neplatí (1). Mezi druhy čeledi Asteraceae heterokarpní druhy častěji naturalizují mimo svůj původní areál než monokarpní, ale obě skupiny se nelišily v počtu světových regionů, kde naturalizovaly. U rostlin vysokého vzrůstu jsou heterokarpní okrasné druhy úspěšnější než monokarpní druhy, což se odráží ve vyšším počtu regionů, kde zdomácněly (2). Údaje shromážděné během pětiletého terénního experimentu naznačují, že odolnost semen vůči faktorům prostředí a vysoká klíčivost invazních druhů rodu *Impatiens* přispívají k jejich rozšíření (3).

1. **Gioria M.**, Le Roux J. J., Hirsch H., **Moravcová L.** & **Pyšek P.** (2019) Characteristics of the soil seed bank of invasive and non-invasive plants in their native and alien distribution range. Biological Invasions 21:2313-2332. – 2. Fenesi A., Sándor D., **Pyšek P.**, Dawson W., Ruprecht E., Essl F., Kreft H., **Pergl J.**, Weigelt P., Winter M. & van Kleunen M. (2019) The role of fruit heteromorphism in naturalization of Asteraceae. Annals of Botany 123:1043-1052. – 3. **Skálová H., Moravcová L., Čuda J.** & **Pyšek P.** (2019) Seed-bank dynamics of native and invasive *Impatiens* species during a five year field experiment under various environmental conditions. NeoBiota 50:75-95.



Obr. 4. Rozdíly v pravděpodobnosti vytváření trvalé perzistentní semenné banky mezi (a) 140 invazními druhy v původním a invadovaném areálu (n = 4336), (b) invazními druhy (n = 995) a neinvazními druhy ze stejných rodů v původním areálu (n = 6824), (c) invazními druhy (n = 162) a neinvazními druhy ze stejných rodů v invadovaném areálu (n = 1149). A_gram = jednoleté trávy, A_herb = jednoleté byliny, P_herb = vytrvalé byliny, woody = dřeviny. Podle Gioria et al., Biological Invasions 2019.