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Original article

# How complete is our knowledge of the ecosystem services impacts of Europe's top 10 invasive species?

C. McLaughlan*,[1], B. Gallardo [1], D.C. Aldridge [1]

*Aquatic Ecology Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, United Kingdom*

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ABSTRACT

Invasive non-native species have complex multilevel impacts on their introduced ecosystems, leading to far-ranging effects on fundamental ecosystem services, from the provision of food from that system, to human health and wellbeing. For this reason, there is an emerging interest in basing risk assessments not only on the species' ecological and economic impacts, but also on the effects related to ecosystem services. We investigated the quality and extent of baseline data detailing the effects that the top 10 of the 'worst' invasive species in Europe are having on their adopted ecosystems. The results were striking, as the 10 species showed a wide range of impacts on ecosystem services, a number of which were actually positive for ecosystems and human well-being. For instance, the bivalve *Dreissena polymorpha* is a prolific biofouler of pipes and boats, but it can improve water quality through its filtration of nuisance algae, a valuable effect that is often overlooked. We found that negative effects, particularly economic ones, were often assumed rather than quantitatively evidenced; for example, the cost of crop damage by species such as *Myocastor coypus* and *Branta canadensis*. In general, the evidence for impacts of these 'worst' invaders was severely lacking. We conclude that invasive species management requires prioritization, which should be based on informed and quantified assessment of the potential ecological and economic costs of species (both positive and negative), considered in the proper context of the invader and ecosystem. The Millennium Ecosystem Approach provides a useful framework to undertake such prioritization from a new perspective combining ecological and societal aspects. However, standard guidelines of evaluation are urgently needed in order to unify definitions, methods and evaluation scores.


## 1. Introduction

Invasive species have numerous multilevel impacts, with notable effects on societal well-being, including human, animal and plant health, the production of foods, fuel and fibre, and the regulation of vital processes including climate, water quality, soils and pollination (Simberloff et al., 2013; Perrings, 2010). The Millennium Ecosystem Assessment (MEA, 2005) identified 11 groups of ecosystem services that are most vital for human well-being and most affected by ecosystem changes. They include provisioning (e.g. food, timber, fibre and fuel), regulating (climate, floods, fires, nutrient cycling) and cultural services. Concerned with the impact of invasive species on ecosystem services, the Council of Europe has promoted action including the control of invasive species as one of the six strategic biodiversity targets for 2020 (EC, 2011). At an international level, the upcoming Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the international conference on invasive species and ecosystem functioning (BIOLIEF, Mar del Plata, Argentina, November 2011) reflects a growing awareness of the negative effects of biodiversity change upon human well-being. While these initiatives reflect the concern of the international community, they also illustrate the need to evaluate the many ways in which invasive species impact ecosystem services (Pejchar and Mooney, 2009).

Successful prioritisation of resources is dependent on the quality of information that can be fed into the decision-making process. A pan-European project, DAISIE, provided in 2009 one of the most exhaustive inventories of non-native species in Europe (DAISIE, 2009; www.europe-aliens.org) and their most recent figure for the total number of non-native species is 12,177. The DAISIE project revealed that we only know the ecological and economic impacts of approximately 10% of the invasive species in Europe (Vila et al., 2010). Where impacts on ecosystem services are

* Corresponding author. Tel.: +44 1223 336617; fax: +44 1223 336676.
*E-mail addresses:* cm645@cam.ac.uk (C. McLaughlan), bg306@cam.ac.uk (B. Gallardo), da113@cam.ac.uk (D.C. Aldridge).
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concerned, this figure is much lower. Such paucity of data makes prioritisation a challenge and risks the inappropriate allocation of resources towards management programmes. Furthermore, there is an increasing realisation that many invasive species can have a positive effect on the functionality of an invaded ecosystem, especially where the invaded system is already heavily degraded (Schlaepfer et al., 2011). Such positive effects must also be balanced against impacts when assessing the risks of a particular species within a particular region.

In their review, Vila et al. (2010) identified 10 of the worst European invasive species in terms of ecological and ecosystem services impacts. The list could be seen as controversial, as many other species may well deserve their position amongst the worst, although it is a fair representation of a range of taxonomic groups (mammals, plants, marine and fresh water organisms), regions of origin (Americas, Asia, Africa, Europe) and impacts. In this study, we build on Vila et al.'s study to provide a comprehensive review of the main impacts (both negative and positive) of 10 of the worst invasive species on ecosystem services. We further assessed the quality of baseline data in terms of reliability and geographic coverage of studies supporting the purported impacts and economic valuation of costs. In other words, we asked: was an effect noted in only one study or factsheet or reported multiple times in different locations? Were economic as well as ecological effects quantified, and can costs be extrapolated over different geographies? Were there any positive, as well as negative consequences for ecosystems or human well-being? Ultimately, this study aimed to identify knowledge gaps in ecosystem services related investigations, and provide guidelines for future research.

## 2. Methods

In a review of invasive species in Europe, Vila et al. (2010) identified 10 of the worst European invasive species in terms of ecological and economic impacts. The list included four terrestrial: the Canada goose (*Branta canadensis*), sika deer (*Cervus nippon*), coypu (*Myocastor coypus*) and New Zealand buttercup (*Oxalis pes-caprae*); three fresh water: the zebra mussel (*Dreissena polymorpha*), red swamp crayfish (*Procambarus clarkii*) and brook trout *(Salvellinus fontinalis*); and three marine organisms: the bay barnacle (*Balanus improvises*), green sea fingers (*Codium fragile*) and Japanese kelp (*Undaria pinnatifida*).

The provisioning, regulatory and cultural ecosystem services impacts of each of the 10 worst invaders were reviewed. The subcategories listed in the Millennium Ecosystem Assessment (MEA, 2005) were used (1. Provisioning: Fresh Water, Food, Timber, Fibre, Fuel; 2. Regulating: Biological Regulation of Ecosystem services, Nutrient Cycling, Climate and Air Quality, Human Health, Waste Processing, Regulation of Natural Hazards; 3. Cultural Services: Cultural and Amenity Services). Data were compiled first by reference to the DAISIE factsheets (www.europe-aliens.org) and the IUCN's Invasive Species Specialist Group (www.issg.org). This was followed by a Web of Knowledge search by Latin name (references up to 15 March 2012). No keywords specifying particular ecosystem services were included to avoid missing articles that describe such impacts under a different name. In order to highlight the number of studies related to ecosystem functioning available for a given species, we narrowed the results down to the 'Environmental Science/Ecology' subject area (as opposed to other unrelated areas such as 'Anatomy', 'Paleontology' or 'Physiology'). Here we assume that this filter will include most papers relating to invasion ecology, and exclude work on, for example, physiology. We acknowledge the limitations of this use of filters, as some papers may contain information relevant to ecosystem service effects which is not immediately obvious from the title and original aim of the study. This is a coarse measure; however it was the best compromise to reduce the number of papers and include only those with the highest possibility of containing relevant information.

## 3. Results

In total, the ISI Web of Knowledge provided 26,045 scientific papers on the 10 species investigated, the three fresh water species exhibiting notable coverage in comparison with the rest of the species (Fig. 1). After filters were applied, a total of 133 scientific papers and government/NGO reports were reviewed in order to summarise the effects that the top 10 invasive species have on ecosystem services (Table 1). The total number of papers available exceeded this; however a number of representative studies were chosen to cover all effects, with a particular focus on review papers. There were a number of species where it was notably difficult to obtain more than one or two relevant papers. *O. pes-caprae*, the terrestrial plant, and *Balanus improvisus*, the marine crustacean, were particularly information-poor (three and two information sources respectively, including the DAISIE factsheet). Of the 6248 papers relating to *D. polymorpha*, when the filter 'Environmental Sciences/Ecology' was applied, only 35% remained (Fig. 1). Similarly, only 10% of the work on *P. clarkii* (of total 7239 studies) fell into this category (Fig. 1). The other fresh water species, *S. fontinalis,* had a total of 7512 papers, with 24% falling into the environmental sciences category (Fig. 1). Amongst the terrestrial species, *O. pes-caprae* only produced 100 studies in total, and *B. canadensis* had the highest number, with 1,224, 57% of which related to environment/ecology (Fig. 1). For marine species the trend was comparatively low numbers of studies (maximum 889 for *U. pinnatifida*). In the case of the bay barnacle, *B. improvisus*, around 70% of the literature available does relate in some way to environmental science or ecology, but as we found, very few of these included information on ecosystem services impacts of invasions.

Information was categorized using the 11 Millennium Ecosystem Assessment effects on ecosystem services (Tables 1 and 2). Where there were sub-categories (for example competition and hybridization, within 'biological regulation of ecosystem services'), these were identified and described with sub-headings in the final table (Table 1). For some categories there were both positive and negative effects of a species, or in several cases only positive effects (e.g. *Codium fragile* and *Undaria pinnatifida* only had positive effects in the 'human health' category, with their anti-cancer properties). These were distinguished in Table 1, which contains the details of each category for which an effect was noted for each of the 10

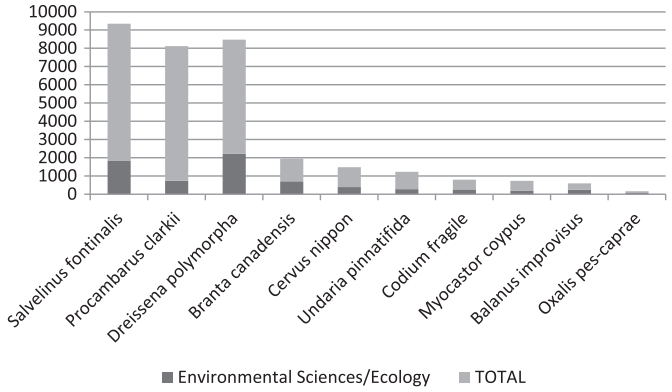


**Fig. 1.** Total number of articles retrieved from ISI web of knowledge when using the Latin name of 10 of the worst invasive species. In dark grey, studies in the category "environmental sciences and ecology".