The role of life histories and population age structure in the invasion success of alien freshwater fish

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Project description

OVERVIEW

Alien species, those introduced outside their native range, can cause huge ecological and economic damage. With increasing global trade, the number of new alien species is growing rapidly. Thus, identifying which ones may establish and become invasive is an urgent global challenge. However, with no history of past invasion, it is hard to predict which new alien species will establish and threaten local biodiversity, and which ones will go naturally extinct. One way to predict the potential for invasion of recently introduced species and those at high risk of introduction, is to first identify what has promoted the establishment of species introduced in the past, and use this knowledge to predict the probability of success of potential future invaders. To this end, we need to address key questions in both basic and applied science.

Alien populations typically start small, yet some overcome the ecological, demographic and genetic barriers that lead small populations to extinction, and go on to establish and spread over large areas. Moreover, alien founder populations differ greatly in age structure from natural, stable populations, being often biased towards one age class. Recent demographic models propose that a population's age structure affects its response to natural disturbance and chance of long term persistence through transient population dynamics, but does so differently depending on the species' life history strategy (Gamelon *et al.* 2016). Thus, the probability of establishment in small alien populations should be strongly influenced by their age structure. This emerging idea is potentially key to explain the great variation in the establishment success of alien populations, but only one study in plants has tested it so far (Iles et al 2016). This project will investigate how the age structure and size of alien founder populations interact with species' life histories to determine the probability of establishment in alien freshwater fish populations across hundreds of species. Biological invasions have also an important human dimension, as alien species are either intentionally selected for introduction, or are able to hitchhike human transport network and overcome major geographical barriers to their natural dispersal. Thus, we need to identify the pathways of alien fish introduction into novel ranges and the species at risk of future release; this will allow us to make statistically informed predictions of invasion potential for future alien species based on their life histories, and across a range of possible founder population size and age structure.

Freshwater fish are among the most frequently introduced vertebrate species. Many of the already established fish populations now have major detrimental impacts on the native biodiversity and ecosystem services of the most vulnerable ecosystems on Earth – freshwater habitats. To date, over 500 freshwater fish species have been successfully introduced into non-native regions all over the world, some intentionally (e.g. for commercial fishery or sport fishing), others accidentally (e.g. through the pet trade). Many historical introductions are well recorded, including those that failed, and offer the opportunity to unravel the determinants of invasion success in freshwater fish. Unlike for terrestrial vertebrates, however, we know remarkably little about what makes some freshwater fish species more likely to establish in novel regions than others. Answering this question is essential if we are to predict the potential for invasion of new alien fish species with no prior history of introduction, and mitigate the impact of future and past invasions on vulnerable freshwater ecosystems.

Figure 1. Native to East Asia, the toupmouth gudgeon (*Pseudorasbora parva*) has been introduced to several locations in the U.K. and Europe through aquaculture, and is now established and rapidly spreading. This zooplanktivorous fish competes with native species, feeds on juveniles of valuable native fish species, and is a vector of diseases that harm both native and farmed fish. It is considered at least partly responsible for the extinction of many native species and is classed among the 100 worst alien species in Europe. (Photo from WikiMedia Commons).

OBJECTIVES

This project will:

1) build, from the peer reviewed and grey literature, the largest global scale database ever assembled on freshwater fish introductions, introduction pathways, and species life history traits;
2) test how species' life histories, founder population's age structure and size, interact and determine the probability of establishment of alien freshwater fish populations;
3) quantify how different pathways to introduction (e.g. angling, fisheries, pet trade) influence the probability of release in novel regions, and identify the species at high risk of future release in non-native regions;
4) derive statistically informed predictions of introduction and establishment success for freshwater fish species at risk of being released in novel environments, by combining outputs from objectives (2) and (3).

The project combines cutting edge phylogenetic comparative approaches and novel theoretical models of population transient dynamics to achieve these objectives. This research builds on recent publications on terrestrial vertebrate invasion success led by the Lead Supervisor, Dr Isabella Capellini, and supervisory team members (Capellini *et al.* 2015; Allen *et al.* 2017; Sol *et al.* 2012).

Figure 2. The brook trout (*Salvelinus fontinalis*) is a highly invasive freshwater fish, native to the eastern USA and Canada, that has been intentionally released in Europe and the U.K., and in Africa, Asia, Oceania and South America, for sport fishing and food production. It has spread to most of Europe and it is rapidly expanding. It competes with and predates on native fish, amphibians, zooplankton and invertebrates; it also alters nutrient cycles. It is considered one of the 100 worst alien species in Europe. (Photo from WikiMedia Commons).

TRAINING

The PhD student on this timely project will receive training in data collection and management to assemble the global scale database of freshwater fish introductions, introduction pathways and species life history characteristics. (S)He will be trained in cutting edge statistical methods (phylogenetic comparative approaches) in a Bayesian framework in R and in mathematical models of transient population dynamics, and will analyse the data using the University of Hull's High Performance Computer VIPER.

While working on important ecological questions and a global challenge, the student will gain a very valuable and rare set of interdisciplinary skills that will increase their employability, including statistical and mathematical modelling, multidisciplinarity, data management, numeracy, evaluating risk and uncertainty, as well as gaining in depth understanding of fundamental principles in ecology and freshwater science. The student will also have the opportunity to engage with stakeholders and attend events on alien freshwater species and hydroecology through a 3 months placement at Yorkshire Water.

Figure 3. The river Trent where alien populations of zander (*Sander lucioperca*), bitterling (*Rhodeus amarus*) and carp (*Cyprinus carpio*) have successfully established, as well as alien populations of several invertebrates (Nunn *et al.* 2007). (Photo: courtesy of Andrew Nunn).

RESEARCH ENVIRONMENT

The successful applicant will join Dr Isabella Capellini's research group in Evolutionary Comparative Ecology (University of Hull), which addresses an array of fundamental questions in ecology, from what 'makes' a successful invasive species, to how parental care evolves and to the evolution and ecology of sleep, using an array of cutting edge phylogenetic comparative approaches. The successful applicant will be exposed to a dynamic and diverse research environment within the University of Hull's Institute of Energy and Environment, the Ecology Research Group, and the Hull International Fisheries Institute.

The student will benefit from the training and collaboration with cosupervisor, Dr Jon Harvey (HIFI), a highly experienced fish ecologist regularly working with stakeholders to translate research into impact; and external cosupervisors, Professor Rob Freckleton (University of Sheffield) a leading ecologist with expertise in demographic modelling and phylogenetic comparative methods; and Dr Sally Street (Durham University), an anthropologist with interests in the human dimensions of biological invasions and in Bayesian modelling.

Figure 4. Native to China, the goldfish (*Carassius auratus*) has been released through the pet and ornamental trade all over the world, and has established numerous alien populations in the U.K. and Europe. This omnivorous fish is implicated in facilitating algal bloom and increasing water turbidity, as well as the decline of native fish species through predation. (Photo: courtesy of Andrew Nunn).

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