Focus

Avian invasions: from basic to applied research

Miquel Vall-llosera

Understanding the factors that influence an invasion process is essential for preventing, assessing and mitigating the environmental and economic impact of invasive species. Here, avian invasions are used as study models to investigate the factors that enable an introduced species to be a successful invader, and to assess whether this information can be used to predict future invasions. To answer these questions, firstly, an integrative approach was used that combined comparative analysis, observations and field experiments and, secondly, a risk-assessment protocol was developed for predicting how exotic species establish themselves. Successful avian invaders were found to be ecological generalists and to exhibit behavioural flexibility, and tended to prioritize future over current reproduction. Invasion success was also affected by the size of the founder population – especially if it was very small – and by certain characteristics (e.g. the biotic resistance of the native community) of the invaded location. Despite the relatively low number of factors considered, the risk assessments generated were able to predict with a high degree of accuracy the probability of success of invasive bird species in Europe and Australia. Therefore, this methodology could be used to develop prevention strategies aimed at mitigating the impact of invasive species. To avoid a future dominated by invasive species, these tools will only be fully effective if they are properly implemented as part of environmental management policies.

Key words: alien species, biological invasions, biotic resistance, behavioural flexibility, propagule pressure, risk assessment.

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The challenge of biological invasions

Alien species are those that have been introduced either intentionally or unintentionally by humans outside their natural range (IUCN 2000). Although humans have transported and traded plant and animal species for millennia, the frequency and extension of these artificial geographical expansions have increased in recent years as a result of the growing volume of international trade and tourism (Levine & D'Antonio 1999, Meyerson & Mooney 2007, Hulme 2009). Today, biological invasions are considered to be one of the most important changes occurring in the global environmental, and contribute to current biodiversity loss and biotic homogenization (McKinney & Lockwood 1999, Rosenzweig 2001, Zavaleta *et al.* 2001). The threats that biotic invasions pose to biodiversity and to ecosystem-level processes have direct economic consequences such as losses in crops, forests, fisheries, and grazing capacity, and indirect effects in terms of the costs of combating such invasions (Mack *et al.* 2000, Pimentel *et al.* 2005). Concern regarding the impact of biological invasions has prompted enormous interest in the understanding of the factors that influence these invasion processes. Such information is essential for preventing, evaluating and mitigating the impact of invasive species (Byers *et al.* 2002, Andersen *et al.* 2004).

The invasion paradox

Biological invasions are a challenging paradox for ecologists: why are invasive species, whose initial populations are generally small and genetically impoverished, able to thrive and sometimes even displace native species in environments to which they have had little time to adapt? Solving this paradox requires an understanding of two scientific problems (Sax & Brown 2000). Firstly, some species succeed in establishing themselves despite a very small founder population and, secondly, successful alien species not only become abundant and widespread but also often become dominant in new communities and displace native species. A way of understanding these two phenomena is to study the adaptations that allow species to overcome these constraints.

A first step in identifying the adaptations that allow a species to become a successful invader is to identify the main causes of the extinction of introduced populations. A typical route towards extinction in natural small populations is stochasticity, i.e. the quality of lacking any predictable order or plan. Stochastic processes or stochasticity in ecology refers to processes that respond to contingencies. Most human-driven introductions fail to establish self-sustaining populations (Long 1981, Lever 1987), the commonest explanation being that introduced species are normally only released in small numbers. Small, isolated founder populations are at great risk from extinction due to stochastic fluctuations in their abundances derived from non-predictable variability in demographic, genetic and/or environmental factors (Pimm 1989). Indeed, there is firm evidence to suggest that introductions that originate from larger population sizes are more likely to establish themselves successfully than those that derive from smaller populations (Lockwood *et al.* 2005, 2009). Nevertheless, there are many documented cases of introduction attempts that have ended in a failure despite an abundance of individuals of the introduced species (Long 1981, Lever 1987). On the other hand, some introduction attempts involving very few individuals have succeeded in establishing self-sustaining populations. Clearly, factors other than the initial number of invaders are critical in determining the fate of introductions.

Adaptations for surviving the founder effect

Classical ecologic theory argues that establishment is facilitated by life histories that promote rapid population growth, thereby reducing the period during which the founder population is small and highly vulnerable to stochastic extinctions (Lewontin 1965, Pimm 1989, 1991). This is known as the 'population growth' hypothesis. Despite being rooted in classic demography (Pielou 1969), current empirical evidence for this hypothesis is inconclusive (Kolar & Lodge 2001, Blackburn *et al.* 2009). Nevertheless, this lack of firm support could be due to the small sample of species analyzed thus far.

Birds are an ideal model for studying biological invasions. Worldwide, over 400 species of birds have been introduced outside their native ranges, many of which have become invasive and now cause great ecological and economic damage (e.g. disease transmission, agricultural depredation and regional biodiversity extinction) in their new regions (Long 1981). Furthermore, a good global historical record of bird introductions exists (Long 1981, Lever 1987, 2005) and high-quality information on ecological and biological traits is available for most introduced bird species (Del Hoyo *et al.* 1992-2013). However, the information on over 2,500 introduction events in birds collated by Sol *et al.* (2012) provides little support for this hypothesis. Of the life history traits previously used to test this hypothesis, only clutch size has been associated with establishment success when controlling for both taxonomic and regional effects. Indeed, contrary to this prediction, species that lay larger clutches have been found to be the worst invaders.

A stricter test of the population growth hypothesis is whether or not establishment success is correlated with direct calculations of population growth rates. To conduct such a test, the maximum rate of population increase (R_{max}) of each introduced species was estimated by solving Cole's equation (Cole 1954). Despite its limitations, this approach reliably captures variation between species in population growth and is undoubtedly more accurate than the use of life history surrogates. Contrary to expectation, there was no evidence to suggest that the likelihood of establishment was related to R_{max} in birds. This unexpected finding may be due to the fact that the relationship between the size of the founder population and the probability of success is not linear. In fact, we found that above a threshold of 300 individuals, the release of more individuals could not be linked to any increase in establishment success (Sol *et al*. 2012). However, when we focused our attention only on those introductions that involved a small numbers of individuals, R_{max} did have a greater effect on establishment success. This result suggests that the role of demographic stochasticity is more relevant when the initial population is small.

The population growth hypothesis has been criticized for ignoring the fact that fast growth implies high survival costs. The resulting trade-off defines a 'fast-slow' continuum of life-history variation, ranging from species that invest more in reproduction than in survival, to those that invest more in survival. This has two consequences. Firstly, populations of fast-living species are more vulnerable to suffer dramatic stochastic population fluctuations and so their populations are more likely to fall below a threshold from which recovery is not possible. Secondly, fast-living species are unlikely to possess adaptations for surviving in novel environments. This hypothesis does not take into account the fact that, in order to invade successfully, species require adaptations that will enable them to both overcome the risk of extinction due to stochasticity and find a suitable ecological niche in the introduction site in which they can survive. One such adaptation is to have a large brain relative to body size. Large brain size is related to greater cognitive ability and the ability to develop new behavioural patterns (Lefebvre *et al*. 1997). Evidence exists that suggests that more flexible behaviour is related to greater invasive potential (Sol & Lefebvre 2000, Sol *et al*. 2002). Thus, having a large brain and being able to learn or innovate would seem to be very useful traits when identifying potential resources and dangers in a novel environment. It is unlikely that fast-living species possess this type of adaptations since the evolution of a relatively large brain requires a long process of development (Iwaniuk & Nelson 2003). Indeed, fast-living species have smaller brains and so lack this behavioural plasticity (Sol *et al*. 2012).

Although not totally invalidating the population growth hypothesis, this result does seem to suggest that the advantages of a fast-life strategy will only become evident when species are introduced in very low numbers and when the challenges posed by the novel environment do not substantially decrease the intrinsic rate of population growth. An example of this is when a degree of environmental matching exists between the regions of origin and introduction.

Another hypothesis linking life history variation to establishment success is the 'future returns' hypothesis. This hypothesis predicts that prioritizing future reproduction will facilitate responses to the inherent uncertainties of novel environments (Sol *et al*. 2012). Species that prioritize future reproduction tend to spread their reproductive efforts out over several attempts, thereby reducing the fitness costs implicit in losing, delaying or skipping a reproductive event (Bókony *et al*. 2009, Wilbur & Rudolf 2006). Prioritizing future over current reproduction will also tend to facilitate establishment success, and the species that do so are more likely to develop adaptations such as big brains that will buffer them against environmental risks and so reduce the likelihood that the population will die out (Legendre *et al*. 1999, Sæther *et al*. 2004, Sol 2007).

The future returns hypothesis is well supported by the above-mentioned compilation of data on avian invasions (Sol *et al*. 2012). Using the brood value, i.e. the relative fitness value of current reproduction relative to lifespan reproduction (Bókony *et al*. 2009), as an operational measure of the variation over a species' life history of reproduction prioritization, we found that species with low brood values were more likely to establish themselves in novel regions than those with high brood values. However, a low brood value can be achieved either by spreading the reproductive effort out over many breeding seasons or by breeding many times in just a few breeding seasons. There are thus two strategies that may help a species successfully establish itself (Figure 1). The first strategy is based on investing in survival and extending its lifespan.

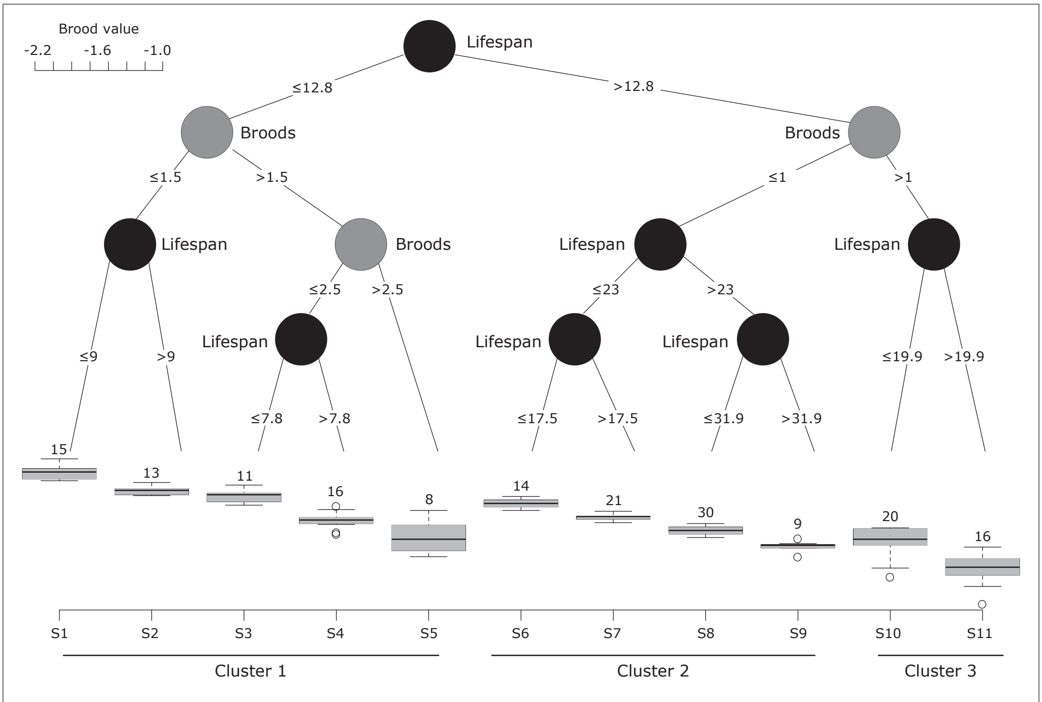

Figure 1. Tree regression describing brood value as a function of the number of broods per year (red circles) and the maximum lifespan (in years, blue circles). The tree regression recursively partitions data into sets that maximize the explained variance of the response variable (i.e. brood value) as a function of a set of predictors using the regression method. The graphs below show the median and percentiles of the brood value for each strategy (from S1 to S11). Differences in brood values between strategies are all significant at P < 0.05 except for the pairs S4-S7, S5-S10 and S9-S10. Adapted from Sol *et al.* 2012.
Arbre de regressió que descriu el valor de la niuada com una funció del nombre de postes per any (cercles vermells) i l'esperança màxima de vida (en anys, cercles blaus). L'arbre de regressió reparteix recursivament les dades en conjunts que maximitzen la variància explicada de la variable resposta (en aquest cas el valor de la niuada) en funció del conjunt de predictors fent servir mètodes de regressió. Els gràfics de la part inferior mostren la mediana i els percentils del valor de la niuada de cada estratègia (de S1 a S11). Totes les diferències entre estratègies en el valor de la niuada foren significatives a P > 0.05, excepte per a les parelles S4-S7, S5-S10 i S9-S10. Adaptat de Sol et al. *2012.*

Long-lived species can spread their reproduction efforts out over many breeding seasons – and hence be able to withstand the loss of a clutch in one season – or may postpone reproduction until conditions are more favourable; in these species the costs of reproductive failure due to stochastic factors are thus lower. Investing in lifespan enables a species to invest in adaptations such as larger brains, which will provide a buffer against ecological challenges and allow them to overcome the difficulties inherent in living in unfamiliar environments. The second strategy is based on investing in multiple reproduction events in the same season. This strategy could help compensate for the high juvenile and adult mortality rates that are to be expected in a species introduced into a new location. In conclusion, species with adaptations that reduce or offset mortality during the early stages of an invasion – either via long lifespans that ensure survival until environmental conditions permit successful reproduction or extended breeding seasons – are more likely to survive the founder event and successfully establish themselves in a new location.

Adaptations for finding an appropriate niche

In theory, an invader must possess adaptations that will enable it to locate a suitable ecological niche in the novel environment possessing appropriate resources and suitable climatic conditions (Shea & Chesson 2002). Nevertheless, even if it is appropriately adapted, a species may still fail to establish itself in face of competition with and/or predation by native species (Shea & Chesson 2002, Ives & Helmus 2011), a process known as 'biotic resistance' (Elton 1958). Consequently, we need to understand how invaders pinpoint appropriate ecological niches given resistance from the recipient community.

Many exotic species are successful in environments that have been altered by human activities and as a result harbour fewer competitors and/or enemies (Byers 2002, Crooks *et al*., 2011). This phenomenon suggests that the success of most invaders is linked to adaptations allowing them to occupy the empty ecological niches generated by human activities that most native species are incapable of taking advantage of (Sax & Brown 2000, Sol *et al*. 2012). Nevertheless, a number of species have had notable success in invading natural habitats; a well-known case is the successful establishment of several European passerines including Blackbird *Turdus merula*, Song Thrush *T. philomenos* and Dunnock *Prunella modularis* (to name but a few) in forests in New Zealand (Diamond & Veitch 1981, Williams, 2006, van Heezik *et al*. 2008). Ecological theory proposes two hypotheses that attempt to explain this situation: opportunism and competition. The opportunism hypothesis associates the success of invaders with their ability to identify resource opportunities that are little used by native species (Sher & Hyatt 1999, Davis *et al*. 2000, Shea & Chesson 2002); the competition hypothesis argues instead that successful invaders out-compete native species and thus displace them from their current niches (MacArthur & Levins 1967, Schoener 1983, Tilman 1994).

To assess the relative importance of these two hypotheses, the invasion of the forests in Collserola Natural Park (NE Spain, near Barcelona) by the Red-billed Leiothrix *Leiothrix lutea*, an Asian passerine, was used as a study case. The species offers a rare opportunity for studying such an invasion because the avian community in this natural park has been systematically monitored for 23 years and so information on bird abundance and richness is available from both before and after the irruption of this invasive species (Vall-llosera 2012).

According to the opportunism hypothesis, an invader should settle in habitats that offer little biotic resistance. An indirect measure of biotic resistance is the phylogenetic structure of the native community. Assuming that closely related species compete more fiercely than species belonging to distantly related taxa, an overdispersed phylogenetic distribution of species in the native community implies that closely related taxa with similar niche-use are being locally excluded. On the other hand, a neutral and clustered distribution of taxa indicates that habitat filtering predominates over competition in the organization of the avian community. In the case of Collserola, co-occurring native species in the habitats in which the Red-bellied Leiothrix has become established are often more closely related to each other than expected (Vall-llosera 2012). This finding indicates that competition plays only a marginal role in the organization of the avian community and so, aside from the adaptations made by the invader, other factors such as the composition of the native community in the introduction site will probably have a critical influence on the success of the invasion. In the Collserola Natural Park, the lack of competition between co-occurring species offers opportunities that the Red-bellied Leiothrix has taken advantage of to establish itself.

The invasion of Collserola by the Red-bellied Leiothrix provides further evidence for the opportunism hypothesis given that its foraging niche does not overlap entirely with that of the most abundant co-existing native species (e.g. Great Tit *Parus major*, Blue Tit *Cyanistes caeruleus* and Firecrest *Regulus ignicapilla*). The most important niche overlap was with the Blackcap *Sylvia atricapilla*. Nevertheless, even in this case, the Red-bellied Leiothrix exhibits particular behavioural traits such as monospecific flocking in winter and behaves opportunistically when foraging.

A comparison of relative brain size between this invasive bird and the native species present in Collserola reveals that the Red-bellied Leiothrix has a larger-than-expected brain for its body size and that its brain is also clearly larger than those of most co-occurring native species (Vall-llosera 2012). This result suggests that the Red-bellied Leiothrix possesses a greater capacity to adopt to novel feeding opportunities and to develop new foraging techniques, abilities that should lead to success in novel environments.

In an experiment, the apparition of novel trophic resources was simulated by installing birdfeeders in the field. Although the Red-bellied Leiothrix exploited this novel resource, they were not the first species to arrive and also used the feeders less often than predicted by its abundance (Vall-llosera 2012). However, they behaved remarkable differently from native species. They visited feeders continuously and in large flocks, and exhausted food supplies in just a few hours or days; by contrast, the food in the feeders visited only by native species lasted for almost a week. Thus, the foraging mode used by the Red-bellied Leiothrix was patently opportunistic.

Despite the large body of evidence for the opportunism hypothesis, competition could also play a role in the success of the Red-bellied Leiothrix in Collserola. Population trends of ecologically similar native species in invaded and non-invaded habitats by the Red-bellied Leiothrix may help us to understand how this invasive bird is impacting the population dynamics of the native community. However, we did not detect any decline of native species associated with the irruption of the Leiothrix. This is not to say that there was no competition but rather that this had little impact on population dynamics.

In conclusion, competition and opportunism should be seen as complementary explanations that, when combined, may contribute to a better understanding the success of exotic species in natural environments.

Assessing the risk of biological invasions

Only few adaptations in the invasive species such as ecological generalism, behavioural flexibility and investment in future reproduction are required to resolve the invasion paradox. In addition to these adaptations, the outcome of invasions is also affected by both the size of the founder population – above all, when it is very small – and characteristics such as the biotic resistance of the native community in the invasion site. Given the seemingly small number of factors that influence establishment success, an obvious question arises: is it possible to accurately predict the risk that a particular alien species will become successfully established in a new site? The ability to predict the success of invasions could represent an essential tool for mitigating the negative ecological, economic and health impact of invasive species since eradication and control strategies have hitherto proved very costly and ineffective (Mack *et al.* 2000, Myers 2003). Knowledge of the real risk posed by an invasive species in an introduction site would be very valuable in the development of strategies aimed at controlling the trade in exotic species, in the design of detection and prompt eradication strategies for particularly problematic species, and in the critical task of educating public opinion about the inherent problems of the ownership and release of certain alien species.

Previous studies have suggested that it is indeed possible to execute reliable risk-assessment protocols using just a few variables (Kolar & Lodge 2002, Sol 2007). A database of documented bird introductions from around the globe (see above) has been used to develop a global risk-assessment protocol for the establishment of introduced birds (Vall-llosera & Sol 2009). Four predictors are significantly related to the establishment success of an introduced species: 1) the size of the initial introduced population, calculated as the number of individuals released during the introduction event; 2) ecological generalism, calculated as the number of different habitats in which it lives in its native range; 3) behavioural flexibility, calculated as the relative size of its brain; and 4) the location where the species is introduced (defined as land, continental island or oceanic island) (Figure 2). According to these mathematical models, the invasive species that are most likely to establish themselves successfully are (i) habitat generalists, (ii) those introduced in large numbers, (iii) those with larger brains and (iv) those introduced onto oceanic islands. We also developed a predictive model that organizes these predictors of establishment success in terms of their relative importance (Vall-llosera & Sol 2009). We found that habitat specialists were the least likely to become established, while birds with flexible behaviour and generalist species were the most likely to succeed. In addition, generalist species with small brains introduced in high numbers were more likely to establish themselves than species introduced in low numbers.

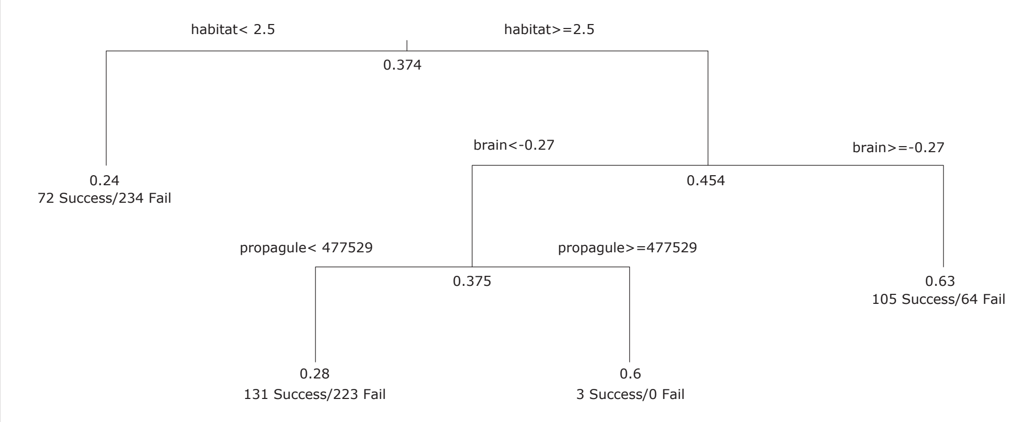

Figure 2. Tree regression describing the factors related to establishment success in bird introductions. The partitioning variable and its value are presented adjacent to each split, and the predicted probability of establishment is shown beneath each split. The number of known successful and failed introduction events categorized into each node is given below. Abbreviations: habitat (habitat generalism), brain (relative brain size) and propagule (initial number of individuals). The vertical lengths are proportional to the deviance explained by each split. Adapted from Vall-llosera & Sol 2009.
Arbre de regressió que descriu els factors relacionats amb l'èxit d'establiment en introduccions d'aus. La variable que reparteix les dades i el punt de tall en la mateixa es mostren al costat de cada divisió. També, sota cada divisió, s'indica la probabilitat predita d'establiment. El nombre conegut de fenòmens d'introducció categoritzats com exitosos o fallits en cada node es donen al final de cada branca. Les abreviacions són: hàbitat *(generalització d'hàbitat),* brain *(mida relativa del cervell) i* propagule *(nombre inicial d'individus). Les longituds verticals són proporcionals a la desviació explicada a cada divisió. Adaptat de Vall-llosera & Sol 2009.*

Therefore, just a few predictors can accurately predict the outcome of new introductions. In fact, mathematical models are able to predict with precision the outcome (success or failure) of bird introductions in Europe and Australia (over 80% of correctly classified outcomes) using only the four variables described above. These models predicted the outcome of introductions more accurately and with less necessary information than previous protocols for risk assessment, which were based on complex tests that classified species into different risk groups according to the scores obtained (e.g. Bomford, 2008). Although it is impossible to predict with absolute certainty the results of a particular introduction, situations in which the invasion risk is high can at least be identified and consequently the taking of preventive measures can be strongly recommended (Vall-llosera & Sol 2009).

Assessment of invasive alien species in Catalonia

The goal of any risk assessment is to assist the decision-making processes in management strategies by identifying what fraction of introduced non-native species have a high risk of becoming established and could have an impact on the new region (Pheloung *et al.* 1999, Kolar & Lodge 2002, Bomford 2003, 2008). Previous studies have shown that risk-assessment protocols can be beneficial when used to filter out harmful invasive species (Keller *et al.* 2007). However, they also show that these methodologies are unfortunately very difficult – and even at times impossible – to apply (Fowler *et al.* 2007, Smith *et al.* 2008, Justo-Hanani *et al.* 2010). However, if they are to be fully effective, prevention protocols must be implemented as part of invasive species management plans or, otherwise, the efforts invested in mitigating biological invasions may prove to be fruitless (Fowler *et al.* 2007, Smith *et al.* 2008).

Thus, the above-described risk assessment was used to classify the exotic species present in Catalonia into different risk categories according to their probability of establishment and their classification on the list of species included in Spanish law on invasive species (Vall-llosera 2012). The Catalan list of exotic bird species includes 158 species (GAE-SEO/Birdlife, 2006), six of which are already established (Common Pheasant *Phasianus colchicus*, Feral Pigeon *Columba livia*, Monk Parakeet *Myopsitta monachus*, Rose-ringed Parakeet *Psittacula krameri*, Red-billed Leiothrix and Common Waxbill *Estrilda astrild*); the remaining species cannot yet be considered as established. Three species have arrived in Catalonia after having become established in neighbouring countries (Canada Goose *Branta canadensis*, Mandarin Duck *Aix galericulata* and Ruddy Duck *Oxyura jamaicensis*); six exotic species have bred in the wild but without as yet establishing stable populations; finally, 125 species have been recorded only occasionally in the wild.

The risk assessment classified 49 species (31%) in a high-risk category of establishment, i.e. species that have over a 60% of probability of establishment, of which three are indeed already established. The remaining 46 were classified either as introduced but not established or observed only occasionally in the wild (AERC, 2001). Likewise, there are nine species (5.7%) in the medium-risk category, with an establishment probability of almost 50%. Finally, there are 100 species (63.3%) classified with a probability of establishment of less than 30%. Of this latter group, only one species is already established, two arrive regularly from neighbouring countries, 13 breed occasionally and 82 are only observed sporadically. Therefore, this risk assessment was able to identify reasonably well the species with the greatest potential for establishing themselves despite the small sample of studied species.

The law that lists and catalogues invasive alien species in Spain names 75 species of exotic birds, of which 11 are considered to be invasive and 64 are relegated to a category of potentially invasive species. Of these 75 species, 58 are present in Catalonia and were evaluated using this risk-assessment protocol. Interestingly, Spanish law fails to include all the potentially invasive species in Catalonia and only 17 out of the 49 species placed in the high-risk group are present on the official list. Therefore, the remaining 32 high-risk species are not legally recognized as potentially invasive.

This assessment reveals that the Spanish legal framework excludes a significant number of potentially dangerous species from the list of species whose importation should be halted (Vall-llosera 2012). The failure to correctly identify potentially invasive species renders any management strategy designed to combat them ineffective and thus generates serious concerns about the ability in the near future of the current legal framework to mitigate the problem of biological invasions. Scientific research has demonstrated that it is able to generate tools that can be deployed in the tasks of improving environment quality. The final step is to persuade stakeholders to put these tools into practice as active policies. Although political decisions may be derived from a variety of legitimate arguments (including the social and economic impact of the trade in exotic species), environmental management plans cannot ignore scientific criteria if we are to prevent our native avian communities from becoming dominated by invasive species.

Resum

Aus invasores: de la recerca bàsica a l'aplicada

Comprendre els factors que influeixen en els processos biològics d'invasió és fonamental per prevenir, avaluar i mitigar els greus impactes ambientals i econòmics causats per les espècies invasores. Fent servir com a model d'estudi les invasions protagonitzades per aus, s'ha investigat, primer, quins factors fan que una espècie introduïda tingui èxit en la invasió, i segon, si aquesta informació es pot fer servir per prevenir futures invasions. Per resoldre aquestes qüestions, s'ha fet servir un enfocament integratiu, combinant anàlisis comparatives, observacions i experiments de camp, i a continuació s'ha desenvolupat un protocol d'anàlisi de riscos per a l'establiment d'espècies exòtiques. Els ocells bons invasors es caracteritzen per ser ecològicament generalistes, flexibles en el comportament i tendeixen a prioritzar la reproducció futura respecte l'actual. A aquests factors cal afegir que l'èxit en la invasió també està afectat per la mida de la població fundadora, especialment si aquesta és molt petita, i per característiques de l'entorn on es produeix la invasió, com ara la resistència de la comunitat nativa. Encara que són pocs factors, les anàlisis de riscos generats són capaços de predir la probabilitat d'èxit de l'establiment de les aus a Europa i Austràlia amb una precisió molt alta. Així doncs, aquesta metodologia es podria fer servir per produir eines útils per orientar les estratègies de prevenció destinades a mitigar l'impacte d'espècies invasores; tot i que per ser del tot efectives cal que aquestes eines siguin realment implementades en les polítiques de gestió ambiental, si es vol evitar un futur dominat per espècies invasores.

Resumen

Aves invasoras: de la investigación básica a la aplicada

Comprender los factores que influyen en los procesos biológicos invasivos es fundamental para prevenir, evaluar y mitigar los graves impactos ambientales y económicos causados por las especies invasoras. Utilizando como modelo de estudio las invasiones protagonizadas por aves, se han investigado, primero, qué factores hacen que una especie introducida tenga éxito en la invasión, y segundo, si esta información se puede utilizar para prevenir futuras invasiones. Para resolver estas preguntas, se ha utilizado un enfoque integrativo, combinando análisis comparativos, observaciones y experimentos de campo, y a continuación se ha desarrollado un protocolo de análisis de riesgos para el establecimiento de especies exóticas. Las aves más exitosas en sus invasiones se caracterizan por ser ecológicamente generalistas, flexibles en el comportamiento y tienden a priorizar la reproducción futura respecto a la actual. A estos factores hay que añadir que el éxito en la invasión también está afectado por el tamaño de la población fundadora, especialmente si ésta es muy pequeña, y por características del entorno en el que se da la invasión, como por ejemplo la resistencia de la comunidad nativa. Aunque son pocos factores, los análisis de riesgos generados son capaces de predecir la probabilidad de éxito del establecimiento de las aves en Europa y Australia con una precisión muy alta. Por tanto, esta metodología se podría utilizar para generar herramientas capaces de orientar las estrategias de prevención destinadas a mitigar el impacto de especies invasoras. No obstante, para ser del todo efectivas, es necesario que estas herramientas sean realmente implementadas en las políticas de gestión ambiental, si se quiere evitar un futuro dominado por especies invasoras.

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