Biological Conservation 144 (2011) 2112–2118

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Concerns regarding the scientific evidence informing impact risk assessment and management recommendations for invasive birds

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ARTICLE INFO

Article history:
Received 13 February 2011
Received in revised form 27 April 2011
Accepted 1 May 2011
Available online 25 May 2011

Keywords:
Invasive
Impact
Eradication
Conservation
Biodiversity
Ranking

ABSTRACT

Invasive species can be a major threat to biodiversity and economy. Given the large number of introduced invasive species and the limited resources available, a rigorous assessment of the potential impact of these species is of vital importance for prioritizing management programs. Often, general scoring systems in which certain criteria are used to assess the impact of an invader along several impact categories are applied to obtain a ranking of troublesome invaders. Likewise, Kumschick and Nentwig (2010) provided a first categorization of invasive bird impacts in Europe, and argued that several invasive birds should be eradicated because of the threat they pose to biodiversity.

This is surprising, as recent reviews suggest that there is little evidence that invasive birds strongly impact biodiversity. We therefore re-evaluated this risk assessment. We found that in the majority of cases, the evidence presented to support impact claims is weak, as they are generally not based on direct scientific research but on often anecdotal observations relating to small areas only. Moreover, even if all claims would materialize, this does not necessarily justify a call for eradication. Previous experiences with eradications have learnt that a feasibility study, encompassing all aspects of biological invasions (including public opinion and possible benefits of the invader) is critical for the achievement of any strategy against invasive species. This is essential, as ill-conceived calls for eradication could result in a public backlash, causing funding agencies and managers to shy away from the problems posed by invasive species.

1. Introduction

Invasive species are species that are not native to a certain ecosystem or region and whose introduction by humans causes economic and or environmental harm. Invasive species are currently recognized as a leading threat to biodiversity conservation and can incur large economic losses (Pimentel et al., 2005; Sala et al., 2000). These impacts led researchers and conservation practitioners towards studies aimed at a better understanding of species invasion processes (Byers et al., 2002), resulting in several practices and guidelines to manage both existing and potential invasion threats (Genovesi and Shine, 2003; Kolar and Lodge, 2001; McNeely et al., 2001). Since biological invasions proceed through arrival, establishment and spread phases (Cassey et al., 2004b; Duncan et al., 2003), they are best tackled by preventing the introduction of species that have a high chance to become invasive in the region to which they are transported (CBD, 2002).

Numerous studies have tried to answer the question of what makes a certain species a successful invader (Blackburn and Duncan, 2001a; Cassey et al., 2005; Kolar and Lodge, 2001), as this information could provide the basis for preventing the transport and introduction of certain species. However, no broadly applicable species-level characteristics of successful invasive species have been identified so far (Hayes and Barry, 2008). Moreover, even if it would be possible to reliably identify troublesome invaders; legal obstacles (e.g. free trade rules) could thwart efforts to exclude species (Simberloff, 2003). Species are also introduced unintentionally (e.g. insects in timber), and there could always be species slipping through the net (McAusland and Costello, 2004; Suarez et al., 2005). Thus, many species will have to be tackled once they are already established. In order to manage those non-native species that have established and become invasive, it is necessary to estimate the impact of these invaders (McNeely et al., 2001). Given restricted financial resources, species have to be ranked according to their overall (i.e. ecological, economic and social) impact for setting management priorities (Byers et al., 2002; Chornesky et al., 2005; Manchester and Bullock, 2000). Rigorous impact assessment is of vital importance to policy makers, and several recent papers (e.g. Benke et al., 2011; Larson et al., 2010; Thiele et al., 2010) have

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doi:10.1016/j.biocon.2011.05.001

highlighted the need for an improvement of the theoretical basis of the assessment of invasive species impacts. To date, most studies aimed at ranking invasive species according to their impact have applied a general scoring system in which certain criteria are used to assess the impact of an invader along a number of impact categories (Holt, 2006). Also, most invasive species risk assessments tend to focus solely on negative interactions while in fact, invasive species can also establish facilitative interactions with native species, potentially resulting in benefits for biological conservation efforts (Goodenough, 2010).

A recent paper (Kumschick and Nentwig, 2010) assessed the potential risk that invasive birds pose to the economy and biodiversity in Europe. Kumschick & Nentwig (2010, hereafter referred to as K&N) modified an existing impact scoring system for invasive mammals (Nentwig et al., 2009) to rank invasive birds in Europe. They found that birds, in comparison to mammals, generally have a lower impact in Europe, but that some bird species reach impact values as high as some of the worst mammal species. However, whereas these high-risk mammals are often targeted by eradication campaigns, high-risk birds are not. According to K&N, the current lack of invasive bird eradication campaigns is scientifically not justified at all, and they call for action against these invaders. The fact that some invasive birds score so high in the K&N assessment may be partly due to the fact that K&N consider a broad range of impacts, including criteria that are not always included in other studies (e.g. impacts on human social life). However, a second recent review that suggests that currently, there is only little evidence for strong negative impacts on biodiversity by invasive birds (Blackburn et al., 2009). The K&N paper caught our attention because they come to a different conclusion, as it was found that several invasive birds pose a high risk to the environment. K&N's results and their management conclusions motivated us to rerun their risk assessment procedure. This enabled us to assess the soundness of the methods used, and allowed assessment of whether the impacts reported, and the underlying evidence presented, are compelling enough to consider eradication campaigns. First, we introduce the K&N scoring system. Then, we proceed by carefully repeating their analysis to verify whether we arrive at a similar ranking of invasive species based on the recorded impacts in Europe. We specifically focus on the following two questions: Does the evidence present in the literature justify the claim that invasive birds can have an impact as severe as the worst invasive mammals? Should the worst ranking invasive birds be targeted by eradication campaigns? We close by highlighting recent methodological improvements in ecological risk assessment models and also discuss, in a more general way, the usefulness of eradication campaigns in dealing with the problems posed by invasive birds in comparison with several other management options such as control or mitigation.

2. Methods

K&N compiled a list of invasive bird species based on the European database of invasive birds that was generated in the framework of the DAISIE project (http://www.daisie.se/). They analysed the impact of invasive bird species that have self-sustaining populations in Europe, that were introduced before 1984 and that have their entire native range outside Europe. This yields a list of 26 bird species, and for those species the literature was surveyed to summarize the impacts they could have in Europe. Environmental impact was assessed using six subcategories corresponding to impact through competition, predation, hybridization, transmission of diseases, herbivory and impact on ecosystem functioning. Damage to the economy was categorized into six categories as well, corresponding to damage to agriculture, livestock, forestry, human health, infrastructure and human social life (Appendix A, Kumschick and Nentwig, 2010). Impact values for each category ranged from 0 to 5, where 0 means no impact known or detectable and 5 the highest impact possible. A detailed description of these categories can be found in Appendix A (which is an exact copy of the Appendix B of the K&N paper). K&N discriminated between the potential impact of a species, and its actual impact, whereby the actual impact was obtained by multiplying the species' potential impact scores with the percentage of European UTM 50×50 km squares where the species currently occurs. This procedure resulted in a ranking of invasive birds that is meant to inform management priorities. Note that we think this procedure is debatable, and we discuss its appropriateness and possible alternatives below.

In this paper, we focus on the five birds that rank high in the K&N scoring system and for which K&N argue that they should be the target for eradication campaigns: Canada goose (*Branta canadensis*), sacred ibis (*Threskiornis aethiopicus*), ruddy duck (*Oxyura jamaicensis*), ring-necked parakeet (*Psittacula krameri*) and monk parakeet (*Myiopsitta monachus*). We carefully reviewed the literature (presented in K&N) on these species and an assessment of the five species was conducted independently by each author (DS, AS and FC). First, we highlighted all relevant quotes in the referenced papers while assessing whether those quotes were based on research data, anecdotal/observational data or hypotheses only. Then, we assigned a score to each species and each impact category separately, summarized why we gave a certain impact score and how it differs compared with the scores given by K&N (Appendix B). Finally, we also noted whether positive effects were attributed to the invasive birds, an often ignored factor (reviewed in Bruno et al., 2005; Goodenough, 2010). These positive impacts are listed in Appendix B but are not further used in the impact re-assessment, as our focus here is to examine the strength of the evidence for negative interactions used by K&N to arrive at their conclusions. Since the impact assessments of the three of us did not differ strongly (Appendix B), we averaged them to allow a clear comparison with the K&N impact assessment (Appendix C). In several cases, we found that it was difficult to assign a certain score to a given category (either because the available evidence was ambiguous or because of difficulties in interpreting the categorization used, see Appendix B); we thus provided a range of scores (e.g. 2 to 3) for some categories. However, for our assessment and discussion we use only the results obtained by considering the most severe assessments (maximal scores), to present a more conservative comparison. Significant differences between K&N's ranking and ours were assessed using Wilcoxon signed-rank tests for pair-wise comparisons in SPSS 14.

3. Results

The assessment we compiled presents considerable differences compared to the assessment presented by K&N. Table 1 summarizes the two assessments for both potential environmental and

Table 1
Total potential environmental and economic impacts of five invasive birds in Europe according to Kumschick & Nentwig (2010; abbreviated as K&N) vs. our assessment (SSC). A higher score indicates a worse impact.

	Environmental impact		Economic impact	
	K&N	SSC	K&N	SSC
Canada goose	15	10	21	13.3
Ruddy duck	8	7	0	0
Sacred ibis	9	5.7	5	2.7
Ring-necked parakeet	4	2	11	5.7
Monk parakeet	1	0	6	3.3

economic impacts of invasive birds in Europe (Appendix C presents tables for both our minimum and maximum impact assessments). In the original K&N assessment, environmental impacts ranged from 1 to 15 while the economic impact varied between 0 and 21. In our assessment, impacts ranged from 0 to 10 for environmental impacts and from 0 to 13.3 for economic impacts. It is thus immediately clear that, even when using our most severe impact assessments, both for the economic and the environmental impact, our estimates are considerably lower than the K&N estimate, except for ruddy duck (Table 1). The Wilcoxon signed-rank tests indicate that the difference between K&N's ranking and ours was significant for environmental ($P = 0.042$) and nearly so for economic impacts ($P = 0.062$). The ranking of the bird species in terms of their potential impact is consistent in both assessments. The highest potential environmental impact is observed for Canada goose, followed by sacred ibis and ruddy duck while potential economic damage is greatest for Canada goose, followed by ring-necked and monk parakeet. The mechanisms leading to the greatest impacts on local biodiversity are also equal to the K&N assessment, namely competition and hybridization. Whereas K&N note that three bird species would rank among the 20 mammals with the highest impact, this is only the case for one species (Canada goose) in our ranking. K&N state that the Canada goose has a higher impact than all invasive mammals except the brown rat (*Rattus norvegicus*), although in our assessment, the Canada goose only ranks 12th compared to all mammals. When looking at the impact categories, we found that for the five species for which we reviewed the literature, impacts are, on average, distributed more or less equally among environment and economy whereas K&N report that birds have a two times higher impact on the environment compared to their economic impact.

4. Discussion

K&N Claim 1. "*Some alien birds have as severe an impact as the most effectual alien mammals in Europe*"

Both for environmental and economic impacts, our assessment yields significantly lower risk scores than the assessment of K&N (except for the ruddy duck). This discrepancy is, in our view, caused by the fact that K&N overestimate the evidence for harm caused by invasive birds to environment and economy. A justification for all our assessments and a succinct discussion of why our opinion differs from that of K&N can be found in Appendix B (under the header 'Opinion'), but here we provide an example to illustrate our concerns. For the sacred ibis, K&N assigned a value of 5 to the predation impact category. According to their definition (see our Appendix A), this implies that sacred ibises are the driving force behind the 'decline of many species' and that they also prey on 'endemic or species listed as vulnerable, endangered or critically endangered by the IUCN', leading to 'local extinction' (Appendix A). These impact level descriptions are somewhat ambiguous. An impact score of 5 could mean that it is necessary to demonstrate the role of the sacred ibis as a driver of the (local) extinction of an endangered species, but can also be interpreted less stringent as just the fact that the ibises have been observed preying upon endangered species. In such cases, we have throughout our reassessment adopted the latter approach (i.e. more conservative regarding the K&N approach), and any observation of a sacred ibis depredating an endangered native species would lead us to a predation impact score of 5. However, the only two references provided to support this high impact score (Clergeau and Yésou, 2006; Yésou and Clergeau, 2005) mention that '...the cases outlined above are believed to have had no serious impact on the populations of the species [birds] preyed upon...' Moreover, all species thought to suffer from predation are designated as 'Least Concern' by the IUCN in Europe (BirdLifeInternational, 2008). Yésou and Clergeau (2005) mention the possibility that "...observed predation of Sacred Ibises on newts may have detrimental effects on discrete populations of these endangered amphibians.", but they do not provide any evidence or references for this claim. At least to our knowledge, there are no other publications that can justify an impact score of 5 and we argue that an impact score of 2 ("Predation on several abundant species, without large impact...''), or, when speculating, at most 3 ("Decline of one to several native species recognized") better fits the available evidence, even though such decline has not been found yet. On the other hand we share very similar concerns with K&N regarding the ruddy duck (Table 1). Evidence in the papers reviewed by K&N clearly reveals that ruddy ducks are the greatest threat to the survival of the white-headed duck (*Oxyura leucocephala*, listed as threatened by the IUCN), owing to the free hybridization between the two species (Green and Hughes, 1996) and we think therefore that the score is justified.

According to our assessment, invasive birds are a minor threat to economy and to the environment when compared to invasive mammals (Appendix C). This conforms to other research findings. Blackburn et al. (2009) reviewed the general literature on invasive birds and concluded that there is currently little evidence that invasive bird species strongly influence native species through competition or predation. Blackburn et al. (2009) also suggested that the effects of invasive birds may be more significant through their role as reservoir for diseases or via complex interactions (e.g. with plant invasions) leading to habitat modification. Both our and K&N's assessment do not lend support to these hypotheses, as competition and hybridization seem to be the larger threats. Shirley and Kark (2009) performed a literature review in order to verify whether certain species characteristics influence the propensity of birds to cause harm. Although they identified several traits that correlated with impact, it remains difficult to distinguish those species with large effects. Elucidating why some (groups of) species have more impact than others, and in which circumstances the impact is greatest will require more research (Parker et al., 1999; Shirley and Kark, 2009; Yokomizo et al., 2009). An important caveat here is that we based our estimates of the risk posed by invasive mammals on Nentwig et al. (2009), who used a scoring system similar to that of K&N. It cannot be excluded that this invasive mammal assessment is over-precautionary as well. However, mammals are responsible for the best documented ecological disturbances resulting from biological invasions, and it seems that the impacts of mammal invaders have been recorded in a less anecdotal manner than is the case for birds (e.g. Courchamp et al., 2003). When assuming that invasive mammals were scored appropriately, the reviews of bird and mammal risks suggest an interesting hypothesis for the differing impacts of both taxa. For birds, predation is only mentioned for one species (the sacred ibis) while 11 mammals are believed to prey upon native fauna (see Appendix B). Thus, predation is suspected to be far more common among invasive mammals than among birds (32.4% of invaders vs. 3.8%), possibly due to differences in the life-history characteristics of the set of bird and mammal species introduced (Blackburn and Duncan, 2001b; Cassey et al., 2004a). Sax et al. (2007) reviewed the ecological and evolutionary insights that can be drawn from studies of invasive species. They concluded that exotic competitors are unlikely to cause the complete extinction of species whereas most available evidence suggests that exotic predators and pathogens have disproportionately large roles in species extinctions. Gurevitch and Padilla (2004) noted that competition from invasive species is an important threat to plants, but that for animals, predation is far more important. It is currently unclear why this pattern emerges, but some authors have suggested that competition operates over longer time scales (Davis, 2003), and that the ultimate effects of competition from invasive species may only become clear over hundreds or even thousands of years (the socalled extinction debt, Malanson, 2008; Sax and Gaines, 2008). We hypothesize that the difference in the dominant modes of impact of birds (competition) vs. mammals (predation) may explain why mammals currently pose a greater threat to biodiversity, although more research along these lines is required to confirm the generality of this pattern, and the mechanisms behind it. For example, most of the literature on the predation effects of invasive mammals and birds has focused on impacts on other vertebrates, largely ignoring potential effects of insectivorous birds and mammals on native invertebrate communities.

Above, we have followed the K&N scoring system, but while reviewing the literature, we noted that there is only a limited number of publications on the impacts of invasive birds and in the majority of cases, the evidence presented is weak (Appendix B). Most reports on the impact of invasive birds are not based on direct research but on often anecdotal observations. These observational data mostly relate to small areas only and it is not clear if and how consequences at the population level can be estimated (see Appendix B, header 'relevant quotes'). This is not only true for invasive birds (Bauer and Woog, 2011), as Thiele et al. (2010) found that most studies addressing the impact of invasive species apply methods that are unreliable to quantify impact and do not allow for a comparison of different invasive species. More generally, Lawler et al. (2006) conducted a review of the general conservation science literature over the last 20 years and found that, despite the fact that invasive species rank among the most pervasive threats to biodiversity (Sala et al., 2000), they are poorly studied in comparison with other threats such as habitat loss and climate change. K&N, in their introduction, recognize that for many invasive birds 'little more than their presence has been recorded (Temple, 1992)' but then, in our view, they downplay our generally poor understanding of the impacts caused by invasive birds. Given the lack of well-designed studies, it is in fact very difficult to reliably rank invasive birds according to their potential for harm.

Over the last years, several authors have discussed the theoretical underpinnings of potential risk assessments of invasive species and have proposed frameworks to evaluate the potential and current impacts of invaders (Benke et al., 2011; Parker et al., 1999; Thiele et al., 2010; Yokomizo et al., 2009). These frameworks depart from the scoring system developed by K&N in several ways, and although it is not our goal to review these frameworks here, the main points can be summarized as follows (based on Thiele et al., 2010). First, when quantifying regional impacts, one has to keep in mind that not all impacted ecosystem traits are spatially additive. For example, while the number of individuals of a native species lost to an invader can be summed up over several invaded sites to obtain the regional total, other impacts such as impacts on trophic interactions (e.g. food web connections) cannot (Thiele et al., 2010). The K&N scoring system, however, does not discriminate between spatially additive and non-additive impacts. This is troublesome, as, for example, the sacred ibis is assigned a score of 5 for predation, implying that it is believed to cause 'changes in the food web' through predation (Appendix A). In order to obtain a measure of the actual sacred ibis impacts, K&N multiply its impact scores with a measure of invaded range size. We find it difficult to grasp the exact meaning of the multiplication of a range size and a change in food web structure measured at a given locality.

Second, the impact of an invader may correlate in a nonlinear way with its abundance and invader abundance can co-vary with environmental variation. Thus, both invader abundance and impact can vary across habitats. K&N, however, do not include information on invader abundance in their risk assessment because these data are only rarely available. This is certainly true, but the implications of not taking abundance into account are not discussed in the K&N paper. For example, the impact of Canada geese on ''human social life'' is estimated by K&N to have a value of 5. This corresponds to ''Pollution of water bodies used for public recreation, which leads to eutrophication and algal blooms, complete loss of recreational value of a habitat or a landscape"(Appendix A). However, multiplying this estimate with the invaded range size is problematic since Canada geese often reach their highest densities in (sub)urban areas (Rehfisch et al., 2002). Problems such as eutrophication will thus be highest in these habitats and potentially non-existent elsewhere. When extrapolating this impact, K&N implicitly assume that goose abundance and impact will be comparable throughout the whole invaded range. This is unlikely to be true, as in Europe, Canada geese nowadays occur in a variety of non-urban landscapes, albeit often at a lower density (Kirby and Sjoberg, 1997). Ignoring the relationships between abundance, impact and habitat carries the risk of misrepresenting the threat posed by an invader (Hauser and McCarthy, 2009). Thus, the policy recommendations that should be drawn from our evaluation of the K&N risk assessment are twofold. First, there is an urgent need for more empirical research on the autecology of invasive species and their interactions with native communities at a local scale. Second, future impact assessments should take the relationships between distribution, abundance and impact on different ecosystem traits into account. Ignoring these issues may lead to assessments that are of little value for both scientific investigations and setting management priorities, not only for invasive birds or mammals but for any group of invasive species.

Claim 2. ''*Birds are mostly excluded from eradication programmes so far. This is scientifically not justified at all*''

K&N argued that birds can have as severe an impact as the most effectual invasive mammals, and that therefore, they should also be targeted by eradication programmes. As shown above and explained in Appendix B, when critically interpreting the available evidence, birds (with the possible exception of the Canada goose) rank considerably lower than most mammals. One could thus conclude that managers in Europe make the right choice when focusing their resources on the eradication of invasive mammals, rather than birds. However, more importantly, even when birds would rank as high as K&N argue, they jump to a rash conclusion when calling for the eradication of these birds.

When prevention fails, and established populations of a (potentially) invasive species are discovered, policy organisations, such as the Convention on Biological Diversity (CBD, 2002) and the European Strategy on Invasive Alien Species (Genovesi and Shine, 2003), indeed consider eradication as the preferred management option. Eradication of harmful invasive species can potentially revert any impacts and restore the ecosystem to its previous state or at least set it along more acceptable trajectories (Fukami et al., 2006). Eradication has the advantage that often, it does not require the complex knowledge and ongoing commitment needed to efficiently implement sustained control or mitigation strategies (Choquenot and Parkes, 2001; Simberloff, 1999, 2003). In Europe, Genovesi (2005) reports at least 37 successfully completed eradication programs, resulting in the recovery of native species (e.g. removal of rats (*Rattus norvegicus*) from Mediterranean islands has lead to the recovery of several colonial nesting seabirds, Martin 2002 in Genovesi, 2005).

However, eradication efforts can be counterproductive if they are not feasible. In the worst case scenario, a failed eradication campaign can lead to the abandonment of the problem when a properly planned, sustained control campaign might have addressed the problem (Parkes and Panetta, 2009). Several authors have tried to set criteria to assess the feasibility of an eradication program (e.g. Cacho et al., 2006; Panetta and Lawes, 2005). In summary, for an eradication to be feasible, it has to be (technically and logistically) possible to remove all individuals from the wild. Also, there cannot be immigration from new sources, which implies that new introductions should be prevented. This also means that it may be necessary to coordinate eradication activities among invaded countries in order to prevent re-invasion from non-controlled areas. Furthermore, there must not be any net adverse effects (Parkes and Panetta, 2009). Adverse effects can arise, for example, when removing one pest leads to the increase of another one, as has happened on Macquarie Island. There, the removal of invasive cats (*Felis catus*) caused a substantial increase in rabbit (*Oryctolagus cuniculus)* numbers, which in its turn caused rapid and drastic landscape-wide ecosystem changes (Bergstrom et al., 2009a,b; Dowding et al., 2009). It is important to note that a feasibility assessment should also take into account the public opinion (Bremner and Park, 2007), as there already is a long list of eradication programs that failed due to public opposition (Bertolino and Genovesi, 2003; Genovesi, 2005). Finally, often only the costs of an invasion are tabulated and possible beneficial effects of an invader are ignored. When such benefits are included in the assessment, it is not always clear whether eradication is the preferred management option compared to only regulating populations at a reasonable level to conserve valuable goods and services provided by the presence of some invasive species (Ceia et al., 2011; Perrings, 2005; Witt, 2010). For example, in South Africa, the shrub mesquite (*Prosopis juliflora*) has invaded much of the semi-arid Nama region and the succulent karoo biomes, and it has major ecological effects in these habitats (Pasiecznik et al., 2001). However, in the arid regions, it is highly valued because it is a more reliable source of fuel and fibre than most native species (Matthews and Brand, 2004; Perrings, 2005). Other invasive species eradication campaigns that have been carried out so far indicate that feasibility planning is a crucial part of any eradication attempt, and that each case has its own unique mix of issues that have to be considered and managed (Panetta and Timmins, 2004). Thus, merely ranking high in a risk assessment falls short of meeting the scientific and societal requirements for initiating an eradication campaign.

Although our knowledge on the ecology and impact on invasive birds is poor, the K&N impact scoring system justifies some concerns about avian invaders. It could be argued that for the highest ranking birds, it would be prudent to conduct a feasibility study to identify the most cost-effective way to manage the risks they may pose. For example, in the US, monk parakeets cause widespread damage to power structures by constructing their communal stick nests on utility poles (Avery et al., 2001). Pruett-Jones et al. (2007) conducted a population viability analysis to examine the effectiveness of several management options. They found that the effort needed to reduce the rate of population growth, which is a critical condition for achieving eradication, was too large to be practical. They concluded that it would probably be more cost-effective to focus efforts on the removal of problematic nests rather than attempting large-scale population control. Moreover, Burger and Gochfeld (2009) reported that in US cities, monk parakeets are often favourably looked upon by the public. They even suggested that these parakeets have significant positive effects, as they "are attractive birds that provide wonderful viewing opportunities for urban dwellers that have few other opportunities to observe 'wild' birds courting and breeding." Of course, these findings are not necessarily applicable to Europe, where both the harm done by the parakeets, their population dynamics and public opinion may differ. However, similar studies should be conducted for the invasive birds in Europe to identify the most appropriate management policies.

We close by mentioning that we are not opposed to eradication campaigns *per se* and do not believe that only 'perfect' ecological knowledge can justify management actions, but we find it important to uphold a reasonable relation between the quality of the data and the proposed management decisions. Considering invasive birds as an asset for conservation in urban areas, as Burger and Gochfeld (2009) do, may lead to a slippery slope. However, risk assessments based largely on hypotheses or on anecdotal observations are likely to lead to conclusions and management recommendations that are circumstantial at best. Moreover, accepting this kind of information as 'proof' in a scientific risk assessment may induce a process that could be described as 'data laundering', whereby other authors may use the results of the risk assessments to guide their own research or conclusions, without being aware of the often poor underlying evidence. In this paper, we have focused on the invasive bird risk assessment of K&N, but our critic that the evidence for impacts of invasive species is often anecdotal, speculative or based upon limited field observations holds more generally and is in fact not new (e.g. see Bauer and Woog, 2011; Didham et al., 2005; Gurevitch and Padilla, 2004). Moreover, Sutherland et al. (2004) noted that much of current practices in conservation biology are based upon anecdote and myth rather than upon the systematic appraisal of evidence, and we join their call for a greater scientific rigour in assessing conservation threats. When dealing with biological invasions, we are convinced that it is critically important to conduct well-designed feasibility studies that take all aspect of biological invasions into account. When research data on the potential impact of invasive birds is lacking, hypotheses or anecdotal observations may be used as they can present the only information available. But this should be recognized, mentioned and thoroughly discussed before drawing management conclusions in general or calling for eradication campaigns in particular. This is important as ill-conceived calls for eradication of invasive, but often popular and charismatic vertebrates, could result in a public backlash, causing funding agencies and managers to shy away from the problems posed by invasive species.

Acknowledgements

We thank Anne-Caroline Prevot-Julliard, Romain Julliard, Sander Jacobs and three anonymous reviewers for comments on earlier drafts of the manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2011.05.001.

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