**Application of the Environmental Impact Classification for Alien Taxa (EICAT) to a global assessment of alien bird impacts**

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**Abstract**

***Aim***

To apply the recently published EICAT protocol to an assessment of the magnitude of environmental impacts of alien bird species established worldwide.

***Location***

Global.

***Methods***

A review of published literature and online resources was undertaken to collate information on the reported environmental impacts of 415 bird species with self-sustaining alien populations worldwide. The resulting data were then categorised following the EICAT guidelines, and analysed using R.

***Results***

Environmental impact data were found for approximately 30% of species with alien populations. Most alien birds had low impacts, categorised as either Minimal Concern (**MC**) or Minor (**MN**). However, 44 bird species had moderate (**MO**) impacts or above, with five having massive (**MV**) impacts. Almost half of all impacts identified related to competition between alien birds and native species. Impact magnitudes were non-randomly distributed: Impacts due to predation tended to be more severe than for other impact mechanisms, and impacts on oceanic islands tended to be more severe than for other regions, but impacts associated with Psittaciform species tended to be less severe than for other alien bird orders. Approximately 35% of assessments were allocated a ‘low’ confidence rating.

***Main conclusions***

The EICAT protocol can be effectively applied to categorise and quantify the impacts of all alien species within an entire taxonomic class. The results demonstrate significant variation in both the type and severity of impacts generated by alien birds. However, we found no data regarding the environmental impacts of the great majority of alien bird species, and where impact data were available, our assessments were frequently allocated a ‘low’ confidence rating. Our work therefore identifies major data gaps that will help influence the direction of future invasive alien species impact research.

**Introduction**

It is widely recognised that alien taxa can have significant adverse environmental impacts (Simberloff, 2013a; European Commission, 2015a; Pagad *et al.*, 2015). In recognition of this, the Strategic Plan for Biodiversity 2011-2020 (https://www.cbd.int/sp/), developed under the Convention on Biological Diversity (CBD), includes a specific target to address their impacts. Aichi Target 9 states that by 2020, invasive alien species and their pathways should be identified and prioritised, and priority species should be controlled or eradicated (CBD, 2013). Similarly, in 2015, the European Union (EU) published new legislation in response to the potential threat associated with biological invasions across the region. Target 5 of the EU 2020 Biodiversity Strategy (<http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm>) requires the development of a list of invasive alien species of Union concern, to be drawn up and managed by Member States using risk assessments and scientific evidence (European Commission, 2015b).

However, the type and severity of the impacts associated with alien species varies greatly among taxa, and despite the regulatory requirements imposed by the CBD and the EU, there is much uncertainty regarding the mechanisms and processes that lead to successful invasions; the species which have (or are likely to have) the most damaging impacts; and the most appropriate courses of action to prioritise and manage alien invasions (Ricciardi *et al.*, 2013; Simberloff *et al.*, 2013b; Kumschick *et al.*, 2015a). This may in part be due to the fact that we do not have a standardised method by which to compare and contrast the impacts of alien species. In recognition of this problem, Blackburn *et al.* (2014) proposed a protocol to classify alien species according to the magnitude of their environmental impacts. This protocol was recently formalised as the Environmental Impact Classification for Alien Taxa (EICAT) with the provision of a framework and guidelines for implementation (Hawkins *et al.*, 2015). The principal aim of EICAT is to enable invasion biologists to identify variation in the magnitude and types of impacts associated with alien taxa, allowing clear comparisons to be made regarding their impacts across different regions and taxonomic groups (Hawkins *et al.*, 2015).

The EICAT protocol has been developed in consultation with the IUCN, and it is possible that it will be formally adopted as their mechanism for classifying the environmental impacts of alien species. If this happens, EICAT assessments for all known alien species worldwide should be completed and peer reviewed by 2020, in-line with the requirements stipulated under Aichi Target 9 and Target 5 of the EU 2020 Biodiversity Strategy. It is envisaged that EICAT will be used to develop a biodiversity indicator for invasive alien species impacts, and through on-going periodic assessments of impacts, will provide a mechanism to monitor changes in the impacts of invasive alien species, for example to determine the effectiveness of a management intervention in alleviating adverse impacts. A significant outcome arising from the application of EICAT will be a global stocktake of the broad range of impacts associated with alien taxa. Thus, the EICAT protocol will help to direct attention not only to the most damaging invasive alien species, but also to those species, taxa, locations or impact mechanisms for which we do not have sufficient information from which to make informed management decisions to mitigate the impacts of alien taxa.

A key next step in the development of the EICAT protocol is to apply it to a set of species with alien populations, in order to test how readily it can be applied, and to identify any aspects of the protocol that may need refinement. Thus, here we present one of the first applications of EICAT, with a global assessment of the environmental impacts of alien bird species. More than 400 bird species have established alien populations somewhere in the world (Dyer *et al.* in revision a), and some of these established populations have been shown to cause significant impacts to the environment (Long, 1981; Brochier *et al.*, 2010; Kumschick *et al*., 2015b). For example, on the Seychelles, the common myna (*Acridotheres tristis*) has been found to compete with, and subsequently affect the breeding success of the Seychelles magpie robin (*Copsychus sechellarum*) (Komdeur, 1995); in Sweden, the Canada goose (*Branta canadensis*) damages natural shoreline vegetation communities through intense grazing (Josefsson & Andersson, 2001); in France, the African sacred ibis (*Threskiornis aethiopicus*) predates upon eggs of the sandwich tern (*Thalasseus sandvicensis*) (Yesou & Clergeau, 2005); and in Spain, the ruddy duck (*Oxyura jamaicensis*) hybridises with the globally endangered white-headed duck (*Oxyura leucocephala*) (Muñoz-Fuentes *et al.*, 2007). We use data obtained from a thorough search and review of the available literature to quantify alien bird impacts under the EICAT protocol.

Our study follows two recent global assessments of the impacts of alien birds using different methodologies (Baker *et al.*, 2014; Martin-Albarracin *et al.*, 2015). These assessments identified impact data for a relatively small number of alien bird species (33 and 39, respectively), and concluded that there is a lack of data on the impacts of alien birds, particularly for less developed regions of the world (see also Pyšek *et al.*, 2008). Data availability has also been shown to vary with impact type and alien bird order. For example, Martin-Albarracin *et al.* (2015) found nearly 40% of data were for competition impacts, whilst a recent study comparing the impacts of alien birds in Europe and Australia (Evans *et al.*, 2014) found that orders with a strong association with human activity, particularly Passeriformes (perching birds), Anseriformes (ducks, geese and swans) and Galliformes (gamebirds), were amongst those with the most frequently reported impacts. We therefore expected to find little or no impact data for many alien bird species, and to find significant variation in the availability of data across regions, impact types, and taxa.

Notwithstanding the examples above, we expected to find that impacts associated with alien birds are relatively weak, particularly in comparison to other taxa such as mammals. Baker *et al.* (2014) concluded that there is little evidence for detrimental impacts generated by alien birds, and the low number of alien birds implicated in the extinction of native species (Bellard et *al.*, 2016) also suggests that their impacts are not particularly severe. However, previous studies suggest that impact severity varies with impact mechanism (Kumschick *et al.*, 2013; Evans *et al.*, 2014; Baker *et al.*, 2014; Martin-Albarracin *et al.*, 2015) and across alien bird orders. Kumschick & Nentwig (2010) examined the impacts of alien birds in Europe, and found Anseriformes and Psittaciformes (parrots) to generally be associated with more severe impacts, whilst Martin-Albarracin *et al.* (2015) found Anatidae (Anseriformes) to have the highest impacts globally. Thus, we expected to find variation in impact severity across different types of impact, and across bird orders, with Anseriformes amongst the most damaging. Impacts generated by invasive alien species may be particularly severe on oceanic islands (Pearson, 2009; CBD, 2015). Although to our knowledge no studies have been undertaken to determine whether this generalisation can be extended to alien birds, we expected to find variation in impact severity across geographic regions, with more severe impacts associated with islands.

Based on the evidence provided by past studies, we test whether the magnitude of alien bird impacts varies across impact mechanisms, and whether the magnitude, mechanisms and availability of data on alien bird impacts vary across alien bird orders. We further test whether the magnitude of alien bird impacts varies across biogeographic regions. We also test whether our confidence in the EICAT assessment for each alien bird species (as measured through the allocation of a confidence rating of ‘high’, ‘medium’ or ‘low’ for each assessment) varies with impact mechanism, impact magnitude and across bird orders. By determining the form and extent of such variations, we aim to improve our understanding of the nature of environmental impacts generated by alien birds, and to identify knowledge gaps so as better to prioritise future impact studies on this taxon. We conclude with some observations on the application of the EICAT protocol to real-world data on impacts.

**Methods**

***Data***

A list of 415 alien bird species with self-sustaining populations across the globe was extracted from the Global Avian Invasions Atlas (Dyer *et al.*, in revision a). GAVIA is a global database (incorporating data up to March 2014) that brings together information on global alien bird introductions (from sources including atlases, country species lists, peer-reviewed articles, websites and through correspondence with in-country experts) to provide the most comprehensive resource on the global distributions of alien bird species. Data extracted from the GAVIA database has recently been used to study the drivers of global alien bird species introductions (Dyer *et al.*, in revision a), and also to undertake a global analysis of the determinants of alien bird geographic range size (Dyer *et al.*, in revision b).

A review of published literature was then undertaken to collate information on the reported impacts of each of these species (for details on the method adopted for the literature review, see Supporting Data: Appendix S1). The environmental impacts of each alien bird species identified from the literature search were categorised into one of 12 impact mechanisms defined in the EICAT guidelines (Hawkins *et al.*, 2015) and summarised in Table 1. For each of the 12 mechanisms, a series of semi-quantitative scenarios were used to assign impacts to one of the following five categories, depending on their severity: in order of increasing severity, these are Minimal Concern (**MC**), Minor (**MN**), Moderate (**MO**), Major (**MR**) or Massive (**MV**). The scenarios reflect increases in the order of magnitude of the impacts associated with a species, as reflected in the level of biological organisation affected (a full description of the scenarios associated with each impact mechanism is presented in Hawkins *et al.* 2015). As an example, the most severe impacts associated with alien populations of the rose-ringed parakeet (*Psittacula krameri*) were for competition (impact mechanism 2 in Table 1): parakeets have been found to cause reductions in the size of populations of nuthatches (*Sitta europeae*) in Belgium, but with no evidence to show that these impacts have resulted in local population extinction or changes to the structure of communities (Strubbe & Matthysen 2007; Strubbe & Matthysen 2009). As such, recorded impacts match the semi-quantitative scenario relating to **MO** in the EICAT framework (Hawkins *et al.,* 2015).

Each species was assessed for its impact under all of the 12 mechanisms for which data were available. However, a species was assigned to an impact category in the EICAT scheme based on the evidence of its most severe impacts only. Thus, the rose-ringed parakeet would be assigned to **MO** on the basis of available evidence of its impacts in terms of competition, as this is the mechanism of its highest impact. Some species most severe impacts related to more than one impact mechanism: for example, the most severe impacts associated with the mute swan (*Cygnus olor*) were **MO**, for both competition and grazing/herbivory/browsing. In such cases, species were assigned to impact categories on the basis of all mechanisms ranked equally most severe (in this case of the mute swan, both impacts were assigned to **MO**).

To quantify uncertainty about the correct classification of the magnitude of the environmental impacts of any alien species, confidence ratings of ‘high’, ‘medium’ or ‘low’ were appended to each assessment, following the EICAT guidance (Hawkins *et al.*, 2015). For example, the impact data for the rose-ringed parakeet were published, peer reviewed and empirical. There were also several studies suggesting the same level of impact (**MO**). Consequently, a confidence rating of ‘high’ was allocated to the EICAT assessment for this species. Where there was evidence to suggest that a species had an alien population, but insufficient data was available to determine and classify any impacts of that species, it was assigned to the Data Deficient (**DD**) category.

As this represents the first comprehensive assessment of birds using the EICAT protocol, both the Maximum Recorded Impact and the Current Recorded Impact were assessed for each bird species with a known alien population. The Maximum Recorded Impact measures the greatest deleterious impacts associated with a species. The Current Recorded Impact reflects the existing impacts associated with a species. The current and maximum recorded impacts of a species with alien populations may differ, for example if management actions have been applied to mitigate species impacts. For example, rinderpest, a viral disease of ungulates, was introduced from Asia to southern Africa in cattle in the late 19th Century. It caused dramatic declines in the populations of native species including wildebeest (*Connochaetes spp.*) and buffalo (*Syncerus caffer*). Under the EICAT protocol, the Maximum Recorded Impact for rinderpest would therefore be Moderate (MO), as the virus caused declines in populations of native species. However, rinderpest has since been successfully eradicated globally. Under EICAT, the eradication of rinderpest would have initially resulted in its classification being reduced to Minimal Concern (**MC**), and upon official confirmation of its global eradication in 2011, its classification would have been updated to No Alien Population (**NA**) (Simberloff, 2013a).

***Analysis***

The actual and expected distributions of impact magnitudes and impact mechanisms across orders, and impact magnitudes across impact mechanisms, were all analysed using contingency tables tests (Chi-square Test of Independence, or where expected numbers were small (less than 5), Fisher’s Exact Test for Count Data (following McDonald (2014)). Low samples sizes in some of the categories of interest meant that we amalgamated categories for some analyses. Thus, impact categories were combined to produce two groups: ‘lower tier’ impacts, consisting of impacts classified as **MC** and **MN**, and ‘upper tier’ impacts, consisting of impacts classified as **MO**, **MR** and **MV**. We used the Wilcoxon Rank Sum test to compare the number of empirical data sources underlying ‘lower tier’ and ‘upper tier’ impact classifications, and underlying different confidence ratings. For analyses involving bird orders, five orders (Passeriformes, Psittaciformes, Galliformes, Anseriformes and Columbiformes (pigeons and doves)) were tested as separate groups, with the remaining orders combined to produce one group titled ‘other’. For analyses regarding regions, areas were defined by continent (Africa, Asia, Australasia, Europe, North (including Central) America, South America) with the islands of the Atlantic, Indian and Pacific oceans combined to form one category. All analyses were carried out using RStudio version 0.99.893 (R Core Team, 2015).

**Results**

The 415 bird species with alien populations derive from 26 orders. The majority of these species (363, or 87.5%) come from just five orders: Passeriformes (43.9% of the dataset), Psittaciformes (14.9%), Galliformes (13%), Anseriformes (8.9%) and Columbiformes (6.7%). The remaining 52 species are distributed across the other 21 orders. The distribution of assessments across mechanism, category and order is given in Supporting Data: Table S1. The full list of EICAT assessment results for individual species is provided in Supporting Data: Table S2.

Impact data were obtained for 119 species from 14 orders (28.7% of alien bird species) (Figure 1). The same five orders that contain most alien bird species also include most of the species with recorded impacts (88.2%), with the remainder spread across a further nine orders. Data describing the most severe impacts of the 119 alien species (data used to allocate species’ impacts) were obtained from 311 sources, 72.5% of which were anecdotal, with the remainder being empirical. An average of 0.4 empirical data sources per alien bird species was found for those with ‘lower tier’ (**MC** and **MN**) impacts, versus 1.3 per alien bird species with ‘upper tier’ (**MO**, **MR** and **MV**) impacts (Wilcoxon Rank Sum Test; W = 1376.5, N = 102, *P* < 0.001).

No impact data were found for 296 species (71.3%), which were therefore categorised at Data Deficient (**DD**). No impact data were obtained for any of the species in 12 orders with alien populations, such that almost half of the 26 orders with aliens were entirely **DD**. Recorded impacts are non-randomly distributed across orders (2 = 20.6, df = 5, *P* = 0.001). This result arises primarily from fewer Passeriform species, and more Psittaciform species, with recorded impacts than expected (Supporting Data: Table S3).

For all 119 species with recorded impacts, the Maximum Recorded Impact was found to be the same as the Current Recorded Impact. For 23 species, the highest recorded impact was equally high for two or more impact mechanisms, resulting in a total of 146 impact mechanism allocations (Supporting Data: Table S1). The majority of these 146 impacts were categorised as ‘lower tier’ (**MC** or **MN**) (69.9%) (Figure 2). However, 44 species had ‘upper tier’ impacts, with five having massive (**MV**) impacts, resulting in native species’ population extinctions. Impact magnitudes are non-randomly distributed across orders (2 = 16.0, df = 5, *P* = 0.003), primarily because of fewer Psittaciform species with ‘upper tier’ (**MO**, **MR** and **MV**) impacts than expected (Supporting Data: Table S4).

Nearly half of all impact allocations were for competition (43.2%) (Figure 3), whilst no impacts were allocated for physical impacts on ecosystems, poisoning/toxicity or bio-fouling. Impact magnitudes are non-randomly distributed across impact mechanisms (2 = 13.6, df = 5, *P* = 0.018). In particular, more predation impacts are allocated to ‘upper tier’ (**MO**, **MR** and **MV**) categories than expected (Table 2).

Impact mechanisms are also non-randomly distributed across orders (2 = 116.2, df = 25, *P* < 0.001). There were more Psittaciform species than expected with competition impacts, more Anseriform species with hybridisation impacts, more Columbiform species with disease impacts, and more Galliform species with interaction impacts. There were also more species in ‘other’ orders with predation impacts than expected; these were Accipitriformes (hawks, eagles and allies), Coraciiformes (kingfishers, rollers, hornbills and allies), Cuculiformes (cuckoos), Falconiformes (falcons), Gruiformes (cranes and allies), Pelecaniformes (pelicans and allies) and Strigiformes (owls and allies), which together accounted for 42.3% of all predation impacts (Table 3).

The greatest number of impacts were recorded on oceanic islands (57 impact assignments, or 34%), primarily those of the Pacific (24.4%), particularly Hawaii (13.7% of all impact allocations). Continents with the most recorded impacts were North America (21.4%) and Australasia (17.3%). The fewest impacts were recorded in South America and Africa (3.6% each). Impact magnitudes were non-randomly distributed across regions (2 = 15.5, df = 4, *P* = 0.004). This result arises primarily from more ‘upper tier’ (**MO**, **MR** and **MV**) impacts on oceanic islands than expected, and fewer in North (and Central) America (Supporting Data: Table S5).

Impact assessments were allocated a ‘high’ confidence rating on 53 occasions (36.3%). A similar proportion were allocated a ‘low’ rating (51), whilst 42 were allocated a ‘medium’ rating. Confidence ratings were randomly distributed across impact mechanisms (2 = 19.3, df = 10, *P* = 0.065), although a relatively high proportion of assessments relating to disease transmission were allocated a ‘low’ confidence rating (Table 4a). Confidence ratings were non-randomly distributed across impact magnitudes (2 = 11.9, df = 2, *P* < 0.003), with more ‘upper tier’ (**MO**, **MR** and **MV**) impact assessments allocated a ‘high’ confidence rating than expected (Table 4b). Confidence ratings were also non-randomly distributed across orders (2 = 47.9, df = 10, *P* < 0.001), with more Galliform and Columbiform assessments allocated a ‘low’ confidence rating, than expected. ‘Medium’ confidence ratings tended to be over-represented amongst Psittaciformes (Supporting Data: Table S6).

An average of 2.7 empirical data sources were found for assessments allocated a ‘high’ confidence rating, 0.5 for those allocated a ‘medium’ confidence rating, and 0.4 for those allocated a ‘low’ confidence rating. More empirical data sources were found for ‘high’ confidence assessments than for ‘low’ (Wilcoxon Rank Sum Test; W = 2413.5, N = 102, *P* < 0.001) or ‘medium’ (W = 1986, N = 102, *P* < 0.001), while medium and low categories did not differ in this regard (W = 1050, N = 102, *P* = 0.77).

**Discussion**

Birds are one of the best-known and best-studied groups, yet to date there are no recorded environmental impacts for more than 70% of bird species with alien populations. This includes all the alien species in half of the 26 bird orders with aliens. The obvious exception to this general paucity of data is the Psittaciformes – parrot species tend to be noisy and conspicuous, and are relatively well studied (Supporting Data: Table S3). The absence of knowledge regarding alien bird impacts reflects the findings of other recent studies on the impacts of alien taxa (Roberts *et al.*, unpubl.; Baker *et al.*, 2014; Martin-Alberracin *et al.*, 2015; Kraus, 2015), and alien birds have even received proportionately lower levels of research effort in comparison to other taxonomic groups (Pyšek *et al.* 2008). Despite growth in the study of invasion biology (Richardson & Pyšek, 2008), impact is a topic that remains understudied.

There are at least two broad reasons why no environmental impact data exist for most alien bird species. First, some alien bird populations may be perceived to cause little or no environmental damage, and consequently their potential impacts are not studied. Lack of data here reflects a perceived (but perhaps real) lack of impact. This would fit with a recent synthesis of bias in invasion biology research (Pyšek *et al.*, 2008), which found a tendency for research to focus on species that were considered to have the most severe impacts – as would be expected in a climate of scarce research funding (see Joseph *et al.*, 2009). Whether such species actually have no environmental impacts, or their impacts have just not been noticed, is unknown.

Second, alien bird species may have clear (and perhaps high) impacts, but these impacts are unknown – in this case, a lack of data belies impact. This lack of knowledge may be because alien populations occur in remote locations where they go unnoticed or are not easily recorded or studied (e.g. tropical regions such as parts of Africa and South America). Consistent with this hypothesis, we found more data on alien bird impacts for invasions within more industrially developed regions of the world. At the continental scale, 53.6% of data on recorded impacts came from mainland North (and Central) America, Australia and Europe. For Asia, two-thirds of all impact records were for invasions to Singapore, Japan and Hong Kong, the three most highly ranked Asian economies in the Global Competitiveness Index (World Economic Forum, 2014). The fewest records were for Africa and South America. It is generally the case that comparatively less conservation research is being undertaken in these most biodiverse regions of the world (Wilson *et al.*, 2016).

Pyšek *et al.* (2008) also found a significant geographical bias regarding the locations of invasion biology studies, with oceanic islands (which play host to a large range of invasive alien species) being largely ignored in comparison with North America and continental Europe. Yet, we found that approximately 34% of recorded impacts were for invasions on islands of the Atlantic, Indian and Pacific oceans. This may be because islands are more susceptible to impacts associated with invasive alien species (Pearson, 2009; CBD, 2015; Harper & Bunbury, 2015), and the severity of their impacts has resulted in higher levels of research there. Our results support this suggestion, as we found impacts to be more severe on islands (see Supporting Data: Table S5). It may also be because approximately 65% of the islands identified in this study are territories of developed countries (e.g. Bermuda; Hawaii; Mariana Islands; Marquesas Islands; Tahiti).

As we had expected, the environmental impacts of alien bird species were generally low, with approximately 70% found to be either negligible, or without population-level impacts (Figure 2). If invasion research is biased towards species with more severe impacts (Pyšek *et al.*, 2008), this suggests that the majority of alien bird species have low environmental impacts, and lack of data simply reflects lack of impact. The same is true if alien bird species with impact data are a random sample of all alien bird species. Only if studies of alien birds were biased away from species with higher-level impacts would our analyses give a false impression of the levels of alien bird impacts. This is possible if alien birds have lower environmental impacts in areas that are better studied, such as Europe and North America, perhaps because the environments there are generally degraded by other processes (e.g. destruction of primary habitat). Ultimately, there is no way of knowing whether the few higher level impacts for alien bird species is absence of evidence or evidence of absence.

Nevertheless, 44 bird species did have ‘upper tier’ environmental impacts, with 35 negatively affecting populations of native species (**MO**), four affecting the composition of native communities (**MR**), and five resulting in species extinctions (**MV**). For example, on Lord Howe Island (Australia), the mallard (*Anas platyrhynchos*) hybridises with the Pacific black duck (*Anas superciliosa*), resulting in the local extirpation of this native species, and its replacement by mallard x Pacific black duck hybrids (Guay *et al.*, 2014). Despite current concerns regarding the need for eradication campaigns to address the impacts of invasive birds (Strubbe *et al.*, 2011), in the case of the mallard, management is considered warranted.

Four mechanisms accounted for almost 85% of alien bird environmental impacts: competition, predation, interaction with other alien species (which relates primarily to the spread of alien plants) and hybridisation (Supporting Data: Table S1). Almost 45% of all recorded impacts were associated with competition between alien birds and native species. The prevalence of competition may be because this mechanism is associated with frequent, daily interactions between species, when compared to other impact mechanisms (more species compete with others for food or habitat, than predate, hybridise or interact with other aliens to have impacts). However, competition is generally a relatively weak mechanism for population change. Competitive interactions can help drive the displacement of one species by another (e.g. the grey squirrel (*Sciurus carolinensis*) invasion of the UK, resulting in the widespread exclusion of the native red squirrel (*Sciurus vulgaris*); Gurnell *et al.*, 2004), but the process generally tends to be slow and subtle. Thus the competitive impacts of alien bird species tended to be low (Table 2). In contrast, predation tends to be a strong mechanism for population change, and predation by aliens has been associated with numerous native species extinctions (e.g. small Indian mongoose (*Herpestes auropunctatus*) predation of the barred-wing rail (*Nesoclopeus poecilopterus*) in Fiji; Hays & Conant, 2007). Thus, we found that predation by alien birds on native species tended to be associated with more severe impacts when compared to other impact mechanisms (Table 2).

Impact mechanisms were not distributed randomly across bird taxa with alien populations (Table 3). Thus, Psittaciformes were associated with competition impacts, Anseriformes with hybridisation impacts, Columbiformes with disease impacts, Galliformes with impacts generated by interactions with other alien species (primarily the spread of alien plants), and orders grouped together as ‘other’ with predation impacts. These patterns generally reflect the behaviour and life history of species from these orders within their native ranges. For example, Psittaciformes are often cavity-nesting species, and cavities tend to be the subject of competition, particularly by species unable to excavate their own (secondary cavity-nesters) (Newton, 1994; Grarock *et al.*, 2013). Anseriformes have long been associated with hybridisation, with more than 400 interspecies hybrid combinations recorded within the Anatidae – more than for any other bird family (Johnsgard, 1960). Orders associated with predation impacts include well-known avian predators, including Accipitriformes, Falconiformes and Strigiformes.

Impact magnitudes were also not distributed randomly across bird taxa with alien populations (Supporting Data: Table S4). Psittaciformes were associated with less severe impacts when compared to other orders of alien bird, reflecting the fact that parrots generally interact with other native species through competition. Alien parrots have often been introduced to areas with no native parrot species, which may further reduce opportunities for direct competition with species that have similar habitat and food preferences (e.g. rose-ringed parakeet (*Psittacula krameri*) establishment in the UK; Peck *et al.*, 2014). Almost 30% of impact assessments for alien parrots were for North America, which may explain why impacts on this continent were found to be less severe when compared to other continents (Supporting Data: Table S5). Conversely, Passeriformes and orders in the ‘other’ category tended to be associated with more severe environmental impacts (Supporting Data: Table S4). This is because nearly 30% of Passeriform impact assessments (primarily for corvids (crows and allies)), and over 65% of impact assessments for species within the ‘other’ category, related to predation impacts (Table 3), which were found to be more severe when compared to other impact mechanisms (Table 2).

Our results showed that in general, we have higher confidence in assessments associated with more severe impacts (Table 4b). This relationship may arise because severe impacts are more obvious, and therefore the data on impacts used to undertake the EICAT assessment are considered more robust. It may also be attributable to data availability, whereby alien bird species with severe impacts tend to be more frequently studied than those with minor impacts (Pyšek *et al.*, 2008). This was true here, as a significantly greater number of empirical data sources were available for species with ‘upper tier’ (**MO**, **MR** and **MV**) than ‘lower tier’ (**MC** and **MN**) impacts, and also for impacts assigned a ‘high’ confidence rating, compared to those allocated a ‘medium’ or ‘low’ confidence rating. Less confidence was placed in disease impact assessments when compared to assessments for other impact mechanisms (Table 4a). Disease assessments can be complex, with recent studies suggesting it is often difficult to prove whether an alien species is solely responsible for the transmission of a disease to native species (Tompkins & Jakob-Hoff, 2011; Blackburn & Ewen, 2016). Less confidence was also placed in Columbiform assessments when compared to other bird orders (Supporting Data: Table S6), probably because Columbiformes were generally associated with disease impacts (Table 3).

***Conclusions***

Our study represents one of the first large-scale applications of the EICAT protocol, demonstrating that it is a practical means to categorise and quantify the impacts of alien species for a complete taxonomic class. Overall, the impact assessment phase of the work took about 3 months, suggesting an average of < 1 day per species assessed. The actual time taken to assess a species obviously varied substantially, but was manageable even for data-rich species. On the whole, it was straightforward to assign impacts to mechanism, if harder to assign impacts to categories. The process did, however, highlight some gaps in the existing EICAT guidelines (Hawkins *et al.*, 2015), most notably in terms of limited guidance on the approach to adopt when searching for, and recording, impact data. Based on this assessment, we are developing search guidelines and a recording sheet for use during EICAT assessments, which will be made available under the formal EICAT protocol in future. In the mean time, it is recommended that literature reviews are carried out following the approach outlined in Supporting Data: Appendix S1.

The biggest hindrance to the successful application of EICAT is the lack of impact data for most species. This problem is of course common to all evidence-based protocols. Unlike other recent studies (Baker *et al.* 2014; Martin-Albarracin *et al.* 2015), we used all available data to conduct assessments, from peer-reviewed papers in international scientific journals to unreviewed information lodged on websites. The quality of these data is likely to vary substantially, and we used EICAT confidence ratings to reflect any uncertainty regarding their robustness. We also used confidence ratings to reflect uncertainty related to the presence of additional factors that could adversely impact upon native species (primarily habitat loss and other alien species). For example, local population extinctions of the Cocos buff-banded rail (*Gallirallus philippensis andrewsi*) on the Cocos (Keeling) Islands (Australia) have been attributed to competition between this species and introduced junglefowl (*Gallus gallus* and *G. varius*). However, habitat modification and predation by introduced mammals are also believed to have contributed to the decline of the native rail (Reid & Hill, 2005). In such cases, it was often difficult to determine the level of impact attributable solely to the subject of the EICAT assessment.

Our use of the EICAT protocol to identify variation associated with the type and severity of impacts generated by alien birds sets the scene for further studies to test for causes of this variation, to improve our understanding of the factors that influence the mechanism and magnitude of impacts when species are introduced to novel locations. Obvious avenues for future investigation include whether or not certain life-history characteristics of alien birds (e.g. diet generalism, body mass, fecundity) are associated with more severe impacts, and more detailed exploration of spatial variation in impacts, and characteristics of the receiving environment that moderate them. Such studies have the potential to assist in predicting the potential impacts of species that do not yet have alien populations, and to inform recommendations for alien species management.

Nevertheless, our work demonstrates that there is still a long way to go to understand the impacts of even a well-studied group such as birds. We have no information on the environmental impacts of the great majority of bird species with alien populations. Further, even where impact data were available, assessments were frequently allocated a ‘low’ confidence rating. One of the potential benefits of the EICAT protocol is that it can be used to identify knowledge gaps and hopefully influence the direction of future invasive alien species research.

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**References**

Allin, C.C. & Husband, T.P. (2003) Mute Swan (Cygnus olor) Impact on Submerged Aquatic Vegetation and Macroinvertebrates in a Rhode Island Coastal Pond. *Northeastern Naturalist*, **10**, 305–318.

Baker, J., Harvey, K.J. & French, K. (2014) Threats from introduced birds to native birds. *Emu*, **114**, 1–12.

Barilani, M., Bernard-Laurent, A., Mucci, N., Tabarroni, C., Kark, S., Perez Garrido, J.A. & Randi, E. (2007) Hybridisation with introduced chukars (Alectoris chukar) threatens the gene pool integrity of native rock (A. graeca) and red-legged (A. rufa) partridge populations. *Biological Conservation*, **137**(1), 57–69.

Bellard C., Cassey P., & Blackburn, T.M. (2016) Alien species as a driver of recent extinctions. *Biology Letters*, **12**, 20150623.

Blackburn, T.M., Essl, F., Evans, T., Hulme, P.E., Jeschke, J.M., Kuhn, I., Kumschick, S., Markova, Z., Mrugala, A., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Ricciardi, A., Richardson, D.M., Sendek, A., Vila, M., Wilson, J.R.U., Winter, M., Genovesi, P. & Bacher, S. (2014) A Unified Classification of Alien Species Based on the Magnitude of their Environmental Impacts. *PLoS Biology*, **12**(5), e1001850.

Blackburn, T.M. & Ewen, J.G. (2016). Parasites as drivers and passengers of human-mediated biological invasions. *EcoHealth*, in press.

Brochier, B., Vangeluwe, D. & van den Berg, T. (2010) Alien invasive birds. *Scientific and Technical Review of the Office International des Epizooties*, **29**(2), 217–226.

Chimera, C.G. & Drake, D.R. (2010) Patterns of seed dispersal and dispersal failure in a Hawaiian dry forest having only introduced birds. *Biotropica*, **42**, 493–502.

Convention on Biological Diversity (CBD). (2013) *Aichi Biodiversity Targets.* [Online] Available from: http://www.cbd.int/sp/targets. (Accessed 8 September 2015).

Convention on Biological Diversity (CBD). (2015) *Island and invasive alien species.* [Online] Available from: https://www.cbd.int/island/invasive.shtml. (Accessed 17 December 2015).

Cruz, A., López-Ortiz, R., Ventosa-Febles, E.A., Wiley, J.W., Nakamura, T.K., Ramos-Alvarez, K.R. & Post, W. (2005) Ecology and management of shiny cowbirds (Molothrus bonariensis) and endangered yellow-shouldered blackbirds (Agelaius xanthomus) in Puerto Rico. *Ornithological Monographs*, **57**, 38–44.

Dyer, E., Cassey, P., Redding, D., Collen, B., Franks, V., Gaston, K.J., Jones, K.E., Kark, S., Orme., C.D.L. & Blackburn, T.M. (in revision a) The global distribution and drivers of alien bird species introduction and richness. *Nature Communications*.

Dyer, E., Franks, V., Cassey, P., Collen, B., Jones, K.E., Sekercioglu, C. & Blackburn, T.M. (in revision b) A global analysis of the determinants of alien geographic range size in birds. *Global Ecology and Biogeography*.

European Commission. (2015a) *Invasive Alien Species.* [Online]. Available from: http://ec.europa.eu/environment/nature/invasivealien/index\_en.htm. (Accessed 16 August 2015).

European Commission. (2015b) *Combat Invasive Alien Species.* [Online]. Available from: <http://ec.europa.eu/environment/nature/biodiversity/strategy/target5/index_en.htm>. (Accessed 20 April 2016).

Evans, T., Kumschick, S., Dyer, E. & Blackburn, T.M. (2014) Comparing determinants of alien bird impacts across two continents: implications for risk assessment and management. *Ecology and Evolution*, **4**(14), 2957–2967.

Fischer, J.R., Stallknecht, D.E., Page Luttrell, M., Dhondt, A.A. & Converse, K.A. Mycoplasmal Conjunctivitis in Wild Songbirds: The Spread of a New Contagious Disease in a Mobile Host Population. *Emerging Infectious Diseases*, **3**, 69–72.

Grarock, K., Lindenmayer, D.B., Wood, J.T. & Tidemann, C.R. (2013) Does Human-Induced Habitat Modification Influence the Impact of Introduced Species? A Case Study on Cavity-Nesting by the Introduced Common Myna (Acridotheres tristis)  
and Two Australian Native Parrots. *Environmental Management*, **52**, 958–970.

Guay, P-J., Taysom, A., Robinson, R. & Tracey, J.P. (2014) Hybridization between the mallard and native dabbling ducks: causes, consequences and management. *Pacific Conservation Biology*, **20**(1), 41–47.

Gurnell, J., Wauters, L.A., Lurz, P.W.W. & Tosi, G. (2004) Alien species and interspecific competition: effects of introduced eastern grey squirrels on red squirrel population dynamics. *Journal of Animal Ecology*, **73**, 26–35.

Harper, G.A. & Bunbury, N. (2015) Invasive rats on tropical islands: Their population biology and impacts on native species. *Global Ecology and Conservation*, **3**, 607–627.

Hawkins, C.L., Bacher, S., Essl, F., Hulme, P.E., Jeschke, J.M., Kühn, I., Kumschick, S., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Vilà, M., Wilson, J.R.U., Genovesi, P. & Blackburn, T.M. (2015) Framework and Guidelines for Implementing the Proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). *Diversity and Distributions*, **21**, 1360–1363.

Hays, W.S.T. & Conant, S. (2003) Male social activity in the small Indian mongoose Herpestes javanicus. *Acta Theriologica*, **48**, 485–494.

Johnsgard, P.A. (1960) *Hybridization in the Anatide and its Taxonomic Implications. Papers in Ornithology.* Paper 71. [Online] Available from: <http://digitalcommons.unl.edu/biosciornithology/71>. (Accessed 9 November 2015).

Joseph, L.N., Maloney, R.F. & Possingham, H.P. (2009) Optimal Allocation of Resources among Threatened Species: a Project Prioritization Protocol. *Conservation Biology*, **23**, 328–338.

Josefsson, M. & Andersson, B. (2001) The Environmental Consequences of Alien Species in the Swedish Lakes (Mälaren, Hjälmaren, Vänern and Vättern). *AMBIO*, **30**(8), 514–521.

Komdeur, J. (1995) Breeding of the Seychelles Magpie Robin (Copsychus sechellarum) and implications for its conservation. *Ibis*, **138**, 485–498.

Kraus, F. (2015) Impacts from Invasive Reptiles and Amphibians. *Annual Review of Ecology, Evolution, and Systematics*, **46**, 75–97.

Kumschick, S. & Nentwig, W. (2010) Some alien birds have as severe an impact as the most effectual alien mammals in Europe. *Biological Conservation*, **143**, 2757–2762.

Kumschick, S., Bacher, S. & Blackburn, T.M. (2013) What determines the impact of alien birds and mammals in Europe? *Biological Invasions*, **15**, 785–797.

Kumschick, S., Gaertner, M., Vilà, M., Essl, F., Jeschke, J.M., Pyšek, P., Ricciardi, A., Bacher, S., Blackburn, T.M., Dick, J.T.A., Evans, T., Hulme, P.E., Kühn, I., Mrugała, A., Pergl, J., Rabitsch, W., Richardson, D.M., Sendek, A. & Winter, M. (2015a) Ecological Impacts of Alien Species: Quantification, Scope, Caveats, and Recommendations. *BioScience*, **65**, 55–63.

Kumschick, S., Blackburn, T.M. & Richardson, D.M. (2015b) Managing alien bird species: Time to move beyond the “100 of the World's Worst” list. *Bird Conservation International,* in press. doi: http://dx.doi.org/10.1017/S0959270915000167

Long, J.L. (1981) *Introduced birds of the world. The worldwide history, distribution and influence of birds introduced to new environments.* David & Charles, London.

Madeiros, J. (2011) *Breeding Success and Status of Bermuda’s Longtail Population (White-tailed Tropicbird) (Phaethon lepturus catsbyii) at Ten Locations on Bermuda 2009 – 2011.* Department of Conservation Services, Bermuda Government.

Martin-Albarracin, V.L., Amico, G.C., Simberloff, D. & Nuñez, M.A. (2015) Impact of Non-Native Birds on Native Ecosystems: A Global Analysis. *PLoS ONE*, **10**(11), e0143070.

McDonald, J.H. (2014) *Handbook of Biological Statistics (3rd ed.).* Sparky House Publishing, Baltimore, Maryland.

Muñoz-Fuentes, V., Vilà, C., Green A.J., Negro, J.J. & Sorenson M.D. (2007) Hybridization between white-headed ducks and introduced ruddy ducks in Spain. *Molecular Ecology*, **16**, 629–638.

Newton, I. (1994) The role of nest sites in limiting the numbers of hole-nesting birds: A review. *Biological Conservation*, **70**(3), 265–276.

Pagad, S., Genovesi, P., Carnevali, L., Scalera, R. & Clout, M. (2015) IUCN SSC Invasive Species Specialist Group: invasive alien species information management supporting practitioners, policy makers and decision takers. *Management of Biological Invasions*, **6**(2), 127–135.

Pearson, D.E. (2009) *Biological Invasions on Oceanic Islands: Implications for Island Ecosystems and Avifauna.* Proceeding of the 3rd International Symposium on Migratory Birds Seabirds in Danger: Invasive Species and Conservation of Island Ecosystem. 25 September 2009, Mokpo, Korea. Rocky Mountain Research Station, USDA Forest Service, USA.

Peck, H.L., Pringle, H.E., Marshall, H.H., Owens, I.P.F. & Lord, A.M. (2014) Experimental evidence of impacts of an invasive parakeet on foraging behavior of native birds. *Behavioral Ecology*, **25**(3), 582–590.

Pyšek, P., Richardson, D.M., Pergl, J., Vojtech Jarošik, V., Sixtova, Z. & Weber, E. (2008) Geographical and taxonomic biases in invasion ecology. *Trends in Ecology and Evolution*, **23**, 237–244.

R Core Team. (2015) *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Rehfisch, M.M., Allan, J.R. & Austin, G.E. (2010) *The effect on the environment of Great Britain’s naturalized Greater Canada Branta canadensis and Egyptian Geese Alopochen aegyptiacus.* BOU Proceedings – The Impacts of Non-native Species.

Reid, J. & Hill, B. (2005) *Commonwealth of Australia. National Recovery Plan for the Buff Banded Rail (Cocos (Keeling) Islands). Gallirallus philippensis andrewsi.* Department of the Environment and Heritage, Canberra.

Ricciardi, A., Hoopes, M., Marchetti, M. & Lockwood, J. (2013) Progress toward understanding the ecological impacts of non-native species. *Ecological Monographs*, **83**, 263–282.

Richardson, D.M. & Pyšek, P. (2008) Fifty years of invasion ecology – the legacy of Charles Elton. *Diversity and Distributions*, **14**, 161–168.

Simberloff, D. (2013a) *Invasive Species: What Everyone Needs to Know.* Oxford University Press, Oxford.

Simberloff, D., Martin, J.L., Genovesi, P., Maris, V., Wardle, D., Aronson, J., Courchamp, F., Galil, B., Garcia-Berthou, E., Pascal, M., Pyšek, P., Sousa, R., Tabacchi, E. & Vila, M. (2013b) Impacts of biological invasions: what’s what and the way forward. *Trends in Ecology and Evolution*, **28**(1), 58–66.

Strubbe, D. & Matthysen, E. (2007) Invasive ring-necked parakeets (Psittacula krameri) in Belgium: Habitat selection and impact on native birds. *Ecography*, **30**, 578–588.

Strubbe, D. & Matthysen, E. (2009) Experimental evidence for nest-site competition between invasive ring-necked parakeets (Psittacula krameri) and native nuthatches (Sitta europaea). *Biological Conservation*, **142**, 1588–1594.

Strubbe, D., Shwartz, A. & Chiron, F. (2011) Concerns regarding the scientific evidence informing impact risk assessment and management recommendations for invasive birds. *Biological Conservation*, **144**, 2112–2118.

Tassell, S. (2014) *The effect of the non-native superb lyrebird (Menura novaehollandiae) on Tasmanian forest ecosystems.* A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy. University of Tasmania.

Tompkins, D.M. & Jakob-Hoff, R. (2011) Native bird declines: don’t ignore disease. Letter to the Editor. *Biological Conservation*, **144**, 668–669.

Yesou, P. & Clergeau, P. (2005) Sacred Ibis: a new invasive species in Europe. *Birding World*, **18**(12), 517–526.

Wilson, K.A., Auerbach, N.A., Sam, K., Magini, A.G., Moss, A.S.L., Langhans, S.D. *et al.* (2016) Conservation Research Is Not Happening Where It Is Most Needed. *PLoS Biology*, **14**(3), e1002413.

World Economic Forum. (2014) *The Global Competitiveness Report 2014–2015: Full Data Edition.* Edited by Professor Klaus Schwab. Geneva.

**Supporting Information**

Additional Supporting Information may be found in the online version of this article:

**Appendix S1** {Insert short legend to online Appendix S1}

**Table S1** {Insert short legend to online Table S1}

**DATA ACCESSIBILITY**

{All topographic and environmental GIS layers, the habitat suitability model and BTM results generated for this study are available as raster grids from the Pangaea database: [http://doi.pangaea.de/10.1594/PANGAEA.808540.](http://doi.pangaea.de/10.1594/PANGAEA.808540)}

**Biosketch**

Thomas Evans is currently undertaking a PhD at University College London (UCL) having been awarded a studentship from the Natural Environment Research Council (NERC). His research focuses on the identification and management of impacts associated with invasive alien species.

Tim Blackburn is a Professor of Invasion Biology at University College London (UCL). His research is predominantly focused on understanding the processes driving human-mediated biological invasions, using birds as a model taxon.

Sabrina Kumschick’s research focuses on the impacts of alien species and the prioritisation of measures for their management. She aims to improve our ability to predict the level of risk posed by alien species, and to provide the evidence that enables more robust listings of harmful alien species.

**Tables**

Table 1: The 12 EICAT impact mechanisms used to categorise the impacts of alien species (Hawkins *et al.*, 2015), and alien bird impact examples.

| Impact mechanism | Description | Alien bird example | Impacted species / location | Reference |
| --- | --- | --- | --- | --- |
| (1) Competition | The alien taxon competes with native taxa for resources (e.g. food, water, space), leading to deleterious impact on native taxa. | Green junglefowl (*Gallus varius*) | Buff banded rail (*Gallirallus philippensis andrewsi*) – Cocos (Keeling) Islands (Australia) | Reid & Hill, 2005 |
| (2) Predation | The alien taxon predates on native taxa, either directly or indirectly (e.g. via mesopredator release), leading to deleterious impact on native taxa. | American crow (*Corvus brachyrhynchos*) | White-eyed tropicbird (*Phaethon lepturus catsbyii*) – Bermuda (British Overseas Territory) | Madeiros, 2011 |
| (3) Hybridisation | The alien taxon hybridises with native taxa, leading to deleterious impact on native taxa. | Chukar (*Alectoris chukar*) | Rock partridge (*Alectoris graeca*); red-legged partridge (*Alectoris rufa*) – France, Italy, Spain, Portugal | Barilani *et al.*, 2007 |
| (4) Transmission of disease to native species | The alien taxon transmits diseases to native taxa, leading to deleterious impact on native taxa. | House finch (*Carpodacus mexicanus*) | Various (song birds) – USA | Fischer *et al.*, 1997 |
| (5) Parasitism | The alien taxon parasitises native taxa, leading directly or indirectly (e.g. through apparent competition) to deleterious impact on native taxa. | Shiny cowbird (*Molothrus bonariensis*) | Yellow-shouldered blackbird (*Agelaius xanthomus*) – Puerto Rico | Cruz *et al.*, 2005 |
| (6) Poisoning/  toxicity | The alien taxon is toxic, or allergenic by ingestion, inhalation or contact to wildlife, or allelopathic to plants, leading to deleterious impact on native taxa. | No impacts identified |  |  |
| (7) Bio-fouling | Bio-fouling by the alien taxon leads to deleterious impact on native taxa. | No impacts identified |  |  |
| (8) Grazing/  herbivory/  browsing | Grazing, herbivory or browsing by the alien taxon leads to deleterious impact on native plant species. | Mute swan (*Cygnus olor*) | Various (submerged aquatic vegetation) – USA | Allin & Husband, 2003 |
| (9) Chemical impact on ecosystem | The alien taxon causes changes to the chemical biotope characteristics of the native environment; nutrient and/or water cycling; disturbance regimes; or natural succession, leading to deleterious impact on native taxa. | Egyptian goose (*Alopochen aegyptiaca*) | Various (eutrophication of waterbodies) – UK | Rehfisch *et al.*, 2010 |
| (10) Physical impact on ecosystem | The alien taxon causes changes to the physical biotope characteristics of the native environment; nutrient and/or water cycling; disturbance regimes; or natural succession, leading to deleterious impact on native taxa. | No impacts identified |  |  |
| (11) Structural impact on ecosystem | The alien taxon causes changes to the structural biotope characteristics of the native environment; nutrient and/or water cycling; disturbance regimes; or natural succession, leading to deleterious impact on native taxa. | Superb lyrebird (*Menura novaehollandiae*) | Various (forest floor communities including invertebrate assemblages) – Tasmania (Australia) | Tassell, 2014 |
| (12) Interaction with other alien species | The alien taxon interacts with other alien taxa, (e.g. through pollination, seed dispersal, habitat modification), facilitating deleterious impact on native species. These interactions may be included in other impact classes (e.g. predation, apparent competition) but would not have resulted in the particular level of impact without an interaction with other alien species. | Japanese white-eye (*Zosterops japonicus*) | Various (native plant communities) – Hawaii (USA) | Chimera & Drake, 2010 |

Table 2: Contingency table (Fisher’s Exact Test for Count Data) showing actual and expected numbers of impact allocations to ‘lower tier’ (**MC** and **MN**) and ‘upper tier’ (**MO**, **MR** and **MV**) impact categories for each impact mechanism. Expected values are displayed in italics. Individual X-squared values are displayed in (parentheses). Data for impact mechanisms (5) Parasitism, (9) Chemical impact on ecosystem and (11) Structural impact on ecosystem were removed from the dataset for the test, due to low sample size.

|  |  |  |  |
| --- | --- | --- | --- |
|  | No. of allocations to **MC** and **MN** impact category (‘lower tier’) | No. of allocations to **MO**, **MR** and **MV** impact category (‘upper tier’) | Total impact allocations |
| Competition | 49  *43.65*  (0.66) | 14  *19.35*  (1.48) | 63 |
| Predation | 11  *18.01*  (2.73) | 15  *7.99*  (6.16) | 26 |
| Interaction with other alien species | 16  *13.16*  (0.61) | 3  *5.84*  (1.38) | 19 |
| Hybridisation | 9  *10.39*  (0.19) | 6  *4.61*  (0.42) | 15 |
| Grazing/herbivory/browsing | 7  *6.93*  (0.00) | 3  *3.07*  (0.00) | 10 |
| Transmission of disease to native species | 5  *4.85*  (0.00) | 2  *2.15*  (0.01) | 7 |
| Total | 97 | 43 | 140 |

Table 3: Contingency table (Fisher’s Exact Test for Count Data) showing actual and expected numbers of impact allocations to each impact mechanism for each order. Expected values are displayed in italics. Individual X-squared values are displayed in (parentheses). Data for impact mechanisms (5) Parasitism, (9) Chemical impact on ecosystem and (11) Structural impact on ecosystem were removed from the dataset for the test, due to low sample size.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Competition | Predation | Interaction with other alien species | Hybridisation | Grazing/  herbivory/  browsing | Transmission of disease to native species |
| Passeriformes | 20  *20.70*  (0.02) | 13  *8.54*  (2.33) | 8  *6.24*  (0.49) | 1  *4.93*  (3.13) | 1  *3.29*  (1.59) | 3  *2.30*  (0.21) |
| Psittaciformes | 27  *14.40*  (11.02) | 1  *5.94*  (4.11) | 0  *4.34*  (4.34) | 1  *3.43*  (1.72) | 2  *2.29*  (0.04) | 1  *1.60*  (0.23) |
| Galliformes | 5  *7.65*  (0.92) | 1  *3.16*  (1.47) | 7  *2.31*  (9.55) | 3  *1.82*  (0.76) | 1  *1.21*  (0.04) | 0  *0.85*  (0.85) |
| Anseriformes | 5  *7.65*  (0.92) | 0  *3.16*  (3.16) | 0  *2.31*  (2.31) | 7  *1.82*  (14.72) | 5  *1.21*  (11.80) | 0  *0.85*  (0.85) |
| Columbiformes | 4  *4.95*  (0.18) | 0  *2.04*  (2.04) | 2  *1.49*  (0.17) | 2  *1.18*  (0.57) | 0  *0.79*  (0.79) | 3  *0.55*  (10.91) |
| Other | 2  *7.65*  (4.17) | 11  *3.16*  (19.48) | 2  *2.31*  (0.04) | 1  *1.82*  (0.37) | 1  *1.21*  (0.04) | 0  *0.85*  (0.85) |
|  | 63 | 26 | 19 | 15 | 10 | 7 |

Table 4: Contingency table showing actual and expected numbers of ‘low’, ‘medium’ and ‘high’ confidence assessments allocated to (a): each impact mechanism (Fisher’s Exact Test for Count Data); and (b): ‘lower tier’ (**MC** and **MN**) and ‘upper tier’ (**MO**, **MR** and **MV**) impact categories (Chi-square Test of Independence). Expected values are displayed in italics. Individual X-squared values are displayed in (parentheses). Data for impact mechanisms (5) Parasitism, (9) Chemical impact on ecosystem and (11) Structural impact on ecosystem were removed from the dataset for the test, due to low sample size (Table 4a only).

Table 4(a)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | No. of ‘low’ confidence assessments | No. of ‘medium’ confidence assessments | No. of ‘high’ confidence assessments | Total confidence assessment allocations |
| Competition | 21  *22.50*  (0.10) | 23  *17.55*  (1.69) | 19  *22.95*  (0.68) | 63 |
| Predation | 8  *9.29*  (0.18) | 8  *7.24*  (0.08) | 10  *9.47*  (0.03) | 26 |
| Interaction with other alien species | 10  *6.79*  (1.52) | 3  *5.29*  (0.99) | 6  *6.92*  (0.12) | 19 |
| Hybridisation | 3  *5.36*  (1.04) | 3  *4.18*  (0.33) | 9  *5.46*  (2.29) | 15 |
| Grazing/herbivory/  browsing | 2  *3.57*  (0.69) | 2  *2.79*  (0.22) | 6  *3.64*  (1.53) | 10 |
| Transmission of disease to native species | 6  *2.50*  (4.90) | 0  *1.95*  (1.95) | 1  *2.55*  (0.94) | 7 |
| Total | 50 | 39 | 51 | 140 |
| Table 4(b) |  |  |  |  |
| **MC** and **MN** impact categories (‘lower tier’) | 42  *35.63*  (1.14) | 32  *29.34*  (0.24) | 28  *37.03*  (2.20) | 102 |
| **MO**, **MR** and **MV** impact categories (‘upper tier’) | 9  *15.37*  (2.64) | 10  *12.66*  (0.56) | 25  *15.97*  (5.10) | 44 |
| Total | 51 | 42 | 53 | 146 |

**Figures**

Figure 1: The distribution across orders of alien bird species with impact data. Pas = Passeriformes; Psi = Psittaciformes; Ans = Anseriformes; Gal = Galliformes; Col = Columbiformes; Oth = Other orders.

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Figure 2: The number of impacts assigned to each impact category. A further 296 species were Data Deficient (**DD**). **MC** = Minimal Concern; **MN** = Minor; **MO** = Moderate; **MR** = Major; **MV** = Massive.

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Figure 3: The number of impacts assigned to each impact mechanism. Com = Competition; Pre = Predation; Int = Interaction with other alien species; Hyb = Hybridisation; Gra = Grazing/herbivory/browsing; Dis = Transmission of disease to native species; Che = Chemical impact on ecosystem; Par = Parasitism; Str = Structural impact on ecosystem.

Macintosh HD:Users:Tom:Desktop:Imp Mech.pdf

**Supporting Data: Appendix S1**

**EICAT Assessment – Alien Birds: Literature Search**

**Search protocol**

An exhaustive literature review was undertaken to identify sources of data describing the impacts of each alien bird species. Following an initial search using online databases (see below), a search for references listed in the articles/data sources found through the initial search was undertaken. This process was repeated to a point where no new sources of data were identified.

**Search terms**

Online searches were undertaken using the following search terms within a search string, in conjunction with the species scientific and common name: “introduced species”, “invasive species”, “invasive alien species”, “IAS”, “alien”, “non-native”, “non-indigenous”, “invasive bird”, “pest”, “feral” and “exotic”. Thus, the search string for the species Eurasian blackbird was (“introduced species” OR “invasive species” OR “invasive alien species” OR “IAS” OR “alien” OR “non-native” OR “non-indigenous” OR “invasive bird” OR “pest” OR “feral” OR “exotic”) AND (“Eurasian blackbird” OR “blackbird” OR “Turdus merula”).

**Data sources**

Databases searched included:

* Web of Science (<http://apps.webofknowledge.com/>).
* Google (<https://www.google.co.uk>).
* Google Scholar (<https://scholar.google.co.uk>).
* UCL Explore (<https://www.ucl.ac.uk/library/electronic-resources/about-explore>), which provides access to a range of online publication databases including JSTOR (<http://www.jstor.org>), Springer Link (<http://link.springer.com>), Wiley Online Library (<http://onlinelibrary.wiley.com>), Cambridge University Press (<http://www.cambridge.org>), Oxford University Press (<http://www.oxfordjournals.org/en/>), The Royal Society (<https://royalsociety.org/library/collections/journals/>) and ProQuest (<http://www.proquest.com/libraries/academic/databases/>).

Other online resources searched included the IUCN Red List of Threatened Species (<http://www.iucnredlist.org>), Delivering Alien Invasive Species Inventories for Europe (DASIE) (<http://www.europe-aliens.org>), CABI’s Invasive Species Compendium (<http://www.cabi.org/isc/>) and the Global Invasive Species Database (GISD) of the Invasive Species Specialist Group (ISSG) (<http://www.issg.org/database/welcome/>).

Key texts on avian invasions were used to guide the assessment process, including Long (1981), Lever (2005) and Blackburn *et al.* (2009).

**Reference documents**

Relevant data sources and articles were selected according to the information provided in the titles and abstracts, based on the search terms above, and the EICAT impact mechanisms and criteria. The following reference documents were used to collate data on alien bird impacts during the EICAT assessment:

ACIL Tasman, 2006. *Starlings in Western Australia: assessing the likely cost of an incursion.* Prepared for the Invasive Animals CRC. December 2006.

Ainley, D.G. et al., 2001. The Status and Population Trends of the Newell’s Shearwater on Kaua'i: Insights from Modeling. In: Evolution, Ecology, Conservation, and Management of Hawaiian Birds: A Vanishing Avifauna. Scott, J.M., Conant, S., & C. Van Riper, III. (Editors). *Studies in Avian Biology*, 22, pp.108–123.

Allendorf, F.W. et al., 2001. The problems with hybrids: Setting conservation guidelines. *Trends in Ecology and Evolution*, 16(11), pp.613–622.

Allin, C.C. & Husband, T.P., 2003. Mute Swan (Cygnus olor) Impact on Submerged Aquatic Vegetation and Macroinvertebrates in a Rhode Island Coastal Pond. *Northeastern Naturalist*, 10(3), pp.305–318.

Amano, H.E. & Eguchi, K., 2002. Foraging niches of introduced Red-billed Leiothrix and native species in Japan. *Ornithological Science*, 1(2), pp.123–131.

Amaral, A.J. et al., 2007. Detection of hybridization and species identification in domesticated and wild quails using genetic markers. *Folia Zoologica*, 56(3), pp.285–300.

Amidon, F.A., 2000. *Habitat relationships and life history of the Rota Bridled White-eye (Zosterops rotensis).* Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science, p.121.

Anamalia Life, 2014. *Common redpoll.* Online. Available from:

<http://animalialife.com/birds/common-redpoll.html>.

Andersen, L.W. & Kahlert, J., 2012. Genetic indications of translocated and stocked grey partridges (Perdix perdix): Does the indigenous Danish grey partridge still exist? *Biological Journal of the Linnean Society*, 105(3), pp.694–710.

Atlantic Flyway Council, 2003. *Atlantic Flyway Mute Swan Management Plan 2003-2013.* Prepared by the Snow Goose, Brant, and Swan Committee Atlantic Flyway Technical Section. Adopted by Atlantic Flyway Council July 2003.

Baker, J., Harvey, K.J. & French, K., 2014. Threats from introduced birds to native birds. *Emu*, 114(1), pp.1–12.

Banks, A.N. et al., 2008. *BTO Research Report No. 489. Review of the Status of Introduced Non-Native Waterbird Species in the Area of the African-Eurasian Waterbird Agreement: 2007 Update*.

Baratti, M. et al., 2004. Introgression of chukar genes into a reintroduced red-legged partridge (Alectoris rufa) population in central Italy. *Animal Genetics*, 36(1), pp.29–35.

Barilani, M. et al., 2005. Detecting hybridization in wild (Coturnix c. coturnix) and domesticated (Coturnix c. japonica) quail populations. *Biological Conservation*, 126, pp.445–455.

Barilani, M. et al., 2007. Hybridisation with introduced chukars (Alectoris chukar) threatens the gene pool integrity of native rock (A. graeca) and red-legged (A. rufa) partridge populations. *Biological Conservation*, 137(1), pp.57–69.

Bartuszevige, A.M. & Gorchov, D.L., 2006. Avian seed dispersal of an invasive shrub. *Biological Invasions*, 8(5), pp.1013–1022.

Bean, M.J., 2013. *Department of the Interior. Fish and Wildlife Service. 50 CFR Part 21. Migratory Bird Perite; Control Order for Introduced Migratory Bird Species in Hawaii*.

Beemster, N. & Klop, E., 2013. *Risk assessment of the Black swan (Cygnus atratus) in the Netherlands.* A&W-report 1978. Altenburg & Wymenga ecologisch onderzoek, Feanwâlden.

Behrouzi-Rad, B., 2010. Population Estimation and Breeding Biology of the House Crow Corvus splendens on Kharg Island, Persian Gulf. *Podoces*, 5(2), pp.87–94.

Bennett, W.A., 1990. Scale of Investigation and the Detection of Competition: An Example from the House Sparrow and House Finch Introductions in North America. *The American Naturalist*, 135(6), pp.725–747.

Bernews, 2013. *Birds threatening Bermuda longtail population.* Online.

Available from: http://bernews.com/2013/09/crows-threatening-bermudaslongtail-population/.

Bermuda Audubon Society, 2015. *American crow.* Online. Available from:

<http://www.audubon.bm/birding/bermuda-birds/114-american-crow>.

Bird Ecology Study Group, 2016. *Sub-species of Red-breasted Parakeet.* Online. Available from: <http://www.besgroup.org/2007/03/27/subspecies-of-red-breasted-parakeet/>.

BirdLife Australia, 2011. *Pest Bird Case Study: The Common Myna*. Online. Available from: http://www.birdsaustralia.com.au/documents/POL-PestBirdCase-CommonMyna.pdf.

BirdLife International, 2016. *Species factsheet: Ducula aurorae.* Online. Available from: http://www.birdlife.org/datazone/species/factsheet/22691668.

BirdLife International, 2016. *Species factsheet: Foudia flavicans.* Online. Available from: http://www.birdlife.org/datazone/speciesfactsheet.php?id=8578.

BirdLife International, 2016. *Species factsheet: Seychelles Fody.* Online. Available from: <http://www.birdlife.org/datazone/speciesfactsheet.php?id=8577>.

BirdLife International, 2016. *Species factsheet: Nesoenas picturatus.* Online. Available from: http://www.birdlife.org/datazone/species/factsheet/22690364

BirdLife International, 2016. *Species factsheet: Pterodroma cookii.* Online. Available from: http://www.birdlife.org/datazone/speciesfactsheet.php?id=3888.

BirdLife International, 2016. *Species factsheet: Ptilinopus mercierii.* Online. Available from: http://www.birdlife.org/datazone/species/factsheet/22691495.

Blackburn, T.M., Lockwood, J.L. & Cassey, P., 2009. *Avian Invasions. The Ecology and Evolution of Exotic Birds.* Oxford University Press. Oxford.

Blanvillain, C. et al., 2003. Impact of introduced birds on the recovery of the Tahiti Flycatcher (Pomarea nigra), a critically endangered forest bird of Tahiti. *Biological Conservation*, 109(2), pp.197–205.

Bonter, D.N., Zuckerberg, B. & Dickinson, J.L., 2010. Invasive birds in a novel landscape: Habitat associations and effects on established species. *Ecography*, 33(3), pp.494–502.

Braithwaite, L. & Miller, B., 1975. The Mallard, (Anas platyrhynchos), and Mallard-Black Duck, (Anas superciliosa rogersi), Hybridization. *Australian Wildlife Research*, 2, pp.47–61.

Butler, C.J., 2005. Feral Parrots in the Continental United States and United Kingdom: Past, Present, and Future. *Journal of Avian Medicine and Surgery*, 19(2), pp.142–149.

Byrd, G.V., Moriarty, D.I. & Brady, B.G., 1983. Breeding biology of Wedge-tailed Shearwaters at Kilauea Point, Hawaii. *The Condor*, 85, pp.292–296.

CABI, 2016. *Invasive Species Compendium.* Online. Available from: http://www.cabi.org/isc/.

Camp, R.J. et al., 2014. *Technical Report HCSU-048. Status of forest birds on Rota, Mariana Islands.*

Carleton, A.R. & Owre, O.T., 1975. The Red-Whiskered Bulbul in Florida: 1960-71. *The Auk*, 92(1), pp.40–57.

Cassey, P., 2001. *Comparative analyses of successful establishment among introduced land birds.* PhD Thesis. Australian School of Environmental Studies. Griffith University.

Cezilly, F. & Johnson, A.R., 1992. Exotic Flamingos in the Western Mediterranean Region: A Case for Concern? *Colonial Waterbirds*, 15(2), pp.261–263.

Chazara, O. et al., 2010. Evidence for introgressive hybridization of wild common quail (Coturnix coturnix) by domesticated Japanese quail (Coturnix japonica) in France. *Conservation Genetics*, 11(3), pp.1051–1062.

Chimera, C.G. & Drake, D.R., 2010. Patterns of seed dispersal and dispersal failure in a hawaiian dry forest having only introduced birds. *Biotropica*, 42(4), pp.493–502.

Clarke, G. & Meredith, A., 2014. *Nutrient contribution to lakes from Canada geese in the Upper Waitaki Canterbury Water Management Zone.* Environment Canterbury.

Clergeau, P. et al., 2010. New but nice? Do alien sacred ibises (Threskiornis aethiopicus) stabilize nesting colonies of native spoonbills (Platalea leucorodia) at Grand-Lieu Lake, France? *Oryx*, 44(04), pp.533–538.

Clergeau, P., Levesque, A. & Lorvelec, O., 2004. The precautionary principle and biological invasion: the case of the House Sparrow on the Lesser Antilles. *International Journal of Pest Management*, 50(2), pp.83–89.

Clergeau, P. & Yésou, P., 2006. Behavioural Flexibility and Numerous Potential Sources of Introduction for the Sacred Ibis: Causes of Concern in Western Europe? *Biological Invasions*, 8, pp.1381–1388.

Cole, F.R. et al., 1995. Conservation implications of introduced Game Birds in High-Elevation Hawaiian Shrubland. *Conservation Biology*, 9(2), pp.306–313.

Columbia University, 2003. *Introduced Species Summary Project. White-winged dove (Zenaida asiatica).* Online. Available from: <http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Zenaida_asiatica.html>.

Columbia University, 2003. *Introduced Species Summary Project. Monk Parakeet (Myiopsitta monachus).* Online. Available from: <http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Myiopsitta_monachus2.html>.

Connett, L. et al., 2013. Gizzard contents of the Smooth‐billed Ani Crotophaga ani in Santa Cruz, Galapagos Islands, Ecuador. *Galapagos Research*, 68.

Conroy, G., 2012. *Invasive Animals Cooperative Research Centre. Media release: World-first scientific evidence that Indian Mynas harm native Australian bird populations*.

Cosgrove, P., 2003. Mandarin Ducks and the potential consequences for Goldeneye. *Scottish Birds*, 24(1), pp.1–10.

Cosgrove, P.J., Maguire, C.M. & Kelly, J., 2008. *Ruddy Duck (Oxyura jamaicensis) Management Plan.* Prepared for NIEA and NPWS as part of Invasive Species Ireland.

Cottam, C. & Scheffer, T.H., 1935. *The Crested Myna, or Chinese Starling, in the Pacific Northwest.* Technical Bulletin No. 467, U.S. Dept. of Agriculture.

Coutts-Smith, A.J. et al., 2007. *The threat posed by pest animals to biodiversity in New South Wales*. Invasive Animals Cooperative Research Centre.

Cruz, A. et al., 2005. Ecology and management of shiny cowbirds (Molothrus bonariensis) and endangered yellow-shouldered blackbirds (Agelaius xanthomus) in Puerto Rico. *Orthological Monographs*, 57, pp.38–44.

Czajka, C., 2011. Resource Use by Non-Native Ring-Necked Parakeets (Psittacula krameri) and Native Starlings (Sturnus vulgaris) in Central Europe. *The Open Ornithology Journal*, 4(1), pp.17–22.

De Sousa, E. et al., 2008. Prevalence of Salmonella spp. Antibodies to Toxoplasma gondii, and Newcastle Disease Virus in Feral Pigeons (Columba livia) in the City of Jaboticabal, Brazil. *Journal of Zoo and Wildlife Medicine*, 41(4), pp.603–607.

Delivering Alien Invasive Species Inventories for Europe (DASIE), 2016. *Delivering Alien Invasive Species Inventories for Europe.* Online. Available from: http://www.europe-aliens.org/default.do.

Department of Agriculture and Food, 2010. *Animal Pest Alert: Barbary Dove.* Government of Western Australia.

Department of Agriculture and Food, 2010. *Animal Pest Alert: Canada Goose.* Government of Western Australia.

Department of Agriculture and Food, 2008. *Animal Pest Alert: Common Myna.* Government of Western Australia.

Department of Agriculture and Food, 2008. *Animal Pest Alert: House Crow.* Government of Western Australia.

Department of Agriculture and Food, 2007. *Animal Pest Alert: Indian Ringneck Parakeet.* Government of Western Australia.

Department of Agriculture and Food, 2010. *Animal Pest Alert: Red-whiskered Bulbul.* Government of Western Australia.

Department of Conservation Services, 2015. *Kiskadee (Pitangus sulphuratus).* Online. Available from: <http://www.conservation.bm/kiskadee/>.

Department of Conservation Services, 2015. *Bermuda cicada (Tibicen Bermudiana).* Online. Available from: <http://www.conservation.bm/bermuda-cicada/>.

Department of the Environment (Australia), 2016. *Ninox novaeseelandiae albaria — Southern Boobook (Lord Howe Island), Lord Howe Boobook Owl.* Online. Available from: <http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=26043>.

Department of Employment Economic Development and Innovation, 2010. *Pest Animal Risk Assessment: Blackbird (Turdus merula).* Biosecurity Queensland.

Department of Employment Economic Development and Innovation, 2010. *Pest Risk Assessment: Indian House Crow (Corvus splendens).* Biosecurity Queensland.

Department of Environment and Climate Change (NSW), 2007. *Lord Howe Island Biodiversity Management Plan.*

Department of Environment and Climate Change (NSW), 2007. *Terrestrial Vertebrate Fauna of the Greater Southern Sydney Region: Volume 2 Fauna of Conservation Concern & Priority Pest Species.* A joint project between the Sydney Catchment Authority and the Department of Environment and Climate Change (NSW) (DECC).

Department of Environment and Conservation, 2007. *Fauna Note No. 7: Laughing and Spotted Turtle-Doves.* Government of Western Australia.

Department of Environment and Conservation, undated. *Information for residents: Control of introduced corellas and lorikeets in the metropolitan area.* Government of Western Australia.

Department of Environment and Conservation, 2009. *Pest Notes: Corellas and other flocking cockatoos.* Government of Western Australia.

Department of Natural Resources Environment Arts and Sport, undated. *Fact Sheet: Spotted Turtle Doves.* Northern Territory Government.

Derégnaucourt, S., Guyomarc’h, J.C. & Spanò, S., 2005. Behavioural evidence of hybridization (Japanese x European) in domestic quail released as game birds. *Applied Animal Behaviour Science*, 94, pp.303–318.

Dhami, M.K. & Nagle, B., 2009. *Review of the Biology and Ecology of the Common Myna (Acridotheres tristis) and some implications for management of this invasive species.* Prepared for Pacific Invasives Initiative, The University of Auckland, Tamaki Campus, Private Bag 92019, Auckland 1.

Diamond, A.W., 2009. *Studies of Mascarene Island Birds.* Cambridge University Press.

Donaldson-Fortier, G. & Johnson, S., 2012. *WEC 256 - Florida’s Introduced Birds: Eurasian Collared-Dove (Streptopelia decaocto).* University of Florida, IFAS Extension.

Dyer, J. & Williams, M., 2010. An introduction most determined: Mallard (Anas platyrhynchos) to New Zealand. *Notornis*, 57(4), pp.178–195.

Eguchi, K. & Amano, H., 2004. Invasive Birds In Japan. *Global Environmental Research*, 8(1), pp.29–39.

Ellis, M.M. & Elphick, C.S., 2007. Using a stochastic model to examine the ecological, economic and ethical consequences of population control in a charismatic invasive species: Mute swans in North America. *Journal of Applied Ecology*, 44, 312-322.

Envioronment Canada, 2002. *Mute Swan: A Non-Native, Invasive Species In Canada*.

Environmental Health Services, undated. *Pest Fact 8: Indian Peafowl.* Townsville City Council.

Erftemeijer, P.L.A. & Seys, J., 1995. *Census of roosting Indian house crows (Corvus splendens) on Mombasa Island.*

Fanchette, R., 2012. *Invasive Alien Species: Threat to Biodiversity and Human Well-being. Seychelles Strategy, 2012.* IUCN Workshop, Mayotte, 23-27 January, 2012.

Fischer, J.R. et al., 1997. Mycoplasmal Conjunctivitis in Wild Songbirds: The Spread of a New Contagious Disease in a Mobile Host Population. *Emerging Infectious Diseases*, 3(1), pp.69–72.

Fisher, R.J. & Wiebe, K.L., 2006. Nest site attributes and temporal patterns of northern flicker nest loss: Effects of predation and competition. *Oecologia*, 147(4), pp.744–753.

Florida Fish and Wildlife Commission, 2015. *Nonnatives.* Online. Available

from: <http://myfwc.com/wildlifehabitats/nonnatives/>.

Foster, J.T. & Robinson, S.K., 2007. Introduced birds and the fate of Hawaiian rainforests. *Conservation Biology*, 21(5), pp.1248–1257.

Fowler, A.C., Eadie, J.M. & Engilis, A., 2009. Identification of endangered Hawaiian ducks (Anas wyvilliana), introduced North American mallards (A. platyrhynchos) and their hybrids using multilocus genotypes. *Conservation Genetics*, 10(6), pp.1747–1758.

Freed, L. & Cann, R., 2012. Increase of an introduced bird competitor in old-growth forest associated with restoration. *NeoBiota*, 13, pp.43–60.

Freed, L.A. & Cann, R.L., 2009. Negative Effects of an Introduced Bird Species on Growth and Survival in a Native Bird Community. *Current Biology*, 19(20), pp.1736–1740.

Freed, L.A., Cann, R.L. & Bodner, G.R., 2008. Incipient extinction of a major population of the Hawaii akepa owing to introduced species. *Evolutionary Ecology Research*, 10(7), pp.931–965.

Garnett, S.T., Szabo, J.K. & Dutson, G., 2011. *The Action Plan for Australian Birds 2010.* CSIRO Publishing. Melbourne.

Garrett, L.J.H. et al., 2007. Competition or co-existence of reintroduced, critically endangered Mauritius fodies and invasive Madagascar fodies in lowland Mauritius? *Biological Conservation*, 140(1-2), pp.19–28.

Gates, N. et al., *Bar-headed Goose. GB Non-native Species Secretariat.* Produced by RPS.

Gates, N. et al., *Egyptian Goose. GB Non-native Species Secretariat.* Produced by RPS.

GB Non-native Species Secretariat (NNSS), 2016. *Risk Assessments.* Online. Available from: http://www.nonnativespecies.org/index.cfm?sectionid=51.

Gillespie, G.D., 1985. Hybridization, Introgression, and Morphometric Differentiation between Mallard (Anas platyrhynchos) and Grey Duck (Anas superciliosa) in Otago, New Zealand. *The Auk*, 102(3), pp.459–469.

Gleadow, R.M., 1982. Invasion by Pittosporum undulatum of the Forests of Central Victoria. II. Dispersal, Germination and Establishment. *Australian Journal of Botany*, 30(2), pp.185–198.

Gottdenker, N.L. et al., 2005. Assessing the risks of introduced chickens and their pathogens to native birds in the Galápagos Archipelago. *Biological Conservation*, 126, pp.429–439.

Graham, A., 1996. *Towards an Integrated Management Approach for the Common Starling (Sturnus vulgaris) in South Australia.* MSc Thesis. University of Adelaide.

Grarock, K. et al., 2014. Are invasive species drivers of native species decline or passengers of habitat modification? A case study of the impact of the common myna (Acridotheres tristis) on Australian bird species. *Austral Ecology*, 39(1), pp.106–114.

Grarock, K. et al., 2013. Does Human-Induced Habitat Modification Influence the Impact of Introduced Species? A Case Study on Cavity-Nesting by the Introduced Common Myna (Acridotheres tristis) and Two Australian Native Parrots. *Environmental Management*, 52, pp.958–970.

Grarock, K. et al., 2012. Is it benign or is it a Pariah? Empirical evidence for the impact of the common Myna (Acridotheres tristis) on Australian birds. *PloS ONE*, 7(7), p.e40622.

Grundy, J.P.B., Franco, A.M.A. & Sullivan, M.J.P., 2014. Testing multiple pathways for impacts of the non-native Black-headed Weaver Ploceus melanocephalus on native birds in Iberia in the early phase of invasion. *Ibis*, 156, pp.355–365.

Guay, P.-J. et al., 2014. Hybridization between the Mallard and native dabbling ducks: causes, consequences and management. *Pacific Conservation Biology*, 20(1), pp.41–47.

Guillaume, G. et al., 2014. Effects of mute swans on wetlands: A synthesis. *Hydrobiologia*, 723(1), pp.195–204.

Gyimesi, A. & Lensink, R.O.B., 2012. Egyptian Goose Alopochen aegyptiaca: an introduced species spreading in and from the Netherlands. *Wildfowl*, 62, pp.126 – 143.

Hailey, A., 2011. *The Online Guide to the Animals of Trinidad and Tobago.* Online. Available from: https://sta.uwi.edu/fst/lifesciences/ogatt.asp.

Hardin, S. et al., 2011. Attempted eradication of Porphyrio porphyrio Linnaeus in the Florida Everglades. *Management of Biological Invasions*, 2, pp.47–55.

Harmon, W.M. et al., 1987. Trichomonas gallinae in columbiform birds from the Galapagos Islands. *Journal of wildlife diseases*, 23(3), pp.492–494.

Harper, M.J., McCarthy, M.A. & Van Der Ree, R., 2005. The use of nest boxes in urban natural vegetation remnants by vertebrate fauna. *Wildlife Research*, 32, pp.509–516.

Harrison, T., 1971. Easter Island: A last outpost. *Oryx*, 11, pp.2–3.

Heptonstall, R.E.A., 2010. *The Distribution and Abundance of Myna Birds (Acridotheres tristis) and Rimatara Lorikeets (Vini kuhlii) on Atiu, Cook Islands.* MSc Thesis. Submitted in accordance with the requirements for the degree of Masters of Science. Faculty of Biological Sciences. The University of Leeds.

Hernández-Brito, D., Luna, Á., et al., 2014. Alien rose-ringed parakeets (Psittacula krameri) attack black rats (Rattus rattus) sometimes resulting in death. *Hystrix, the Italian Journal of Mammalogy*, 25(2), pp.121–123.

Hernández-Brito, D., Carrete, M., et al., 2014. Crowding in the city: Losing and winning competitors of an invasive bird. *PLoS ONE*, 9(6).

Hill, R., 2002. *Recovery Plan for the Norfolk Island Green Parrot Cyanoramphus novaezelandiae cookii.* National Heritage Trust, Australia. Birds Australia.

Holt, R.D. et al., 2010. Disturbance of Lekking Lesser Prairie-Chickens (Tympanuchus pallidicinctus) by Ring-Necked Pheasants (Phasianus colchicus). *Western North American Naturalist*, 70(2), pp.241–244.

Holzapfel, C. et al., 2006. Colonisation of the Middle East by the invasive Common Myna Acridotheres tristis L., with special reference to Israel. *Sandgrouse*, 28(1), pp.44–51.

Horizons Regional Council, 2002. *Sulphur Crested Cockatoo (Kakatoe gelerita).*

House Finch Disease Survey, 2015. *House finch eye disease.* Online.

Available from: <http://www.birds.cornell.edu/hofi/hofifaqs.html>.

Hughes, B., Henderson, I. & Robertson, P., 2006. Conservation of the globally threatened white-headed duck, Oxyura leucocephala, in the face of hybridization with the North American ruddy duck, Oxyura jamaicensis: results of a control trial. *Acta Zoologica Sinica*, 52, pp.576–578.

Hume, J.P. & Walters, M., 2012. *Extinct Birds.* T & AD Poyser. London.

Ifran, N.R. & Fiorini, V.D., 2010. European Starling (Sturnus Vulgaris): Population Density and Interactions With Native Species in Buenos Aires Urban Parks. *Ornitologia Neotropical*, 21, pp.507–518.

Ingold, D.J., 1994. Influence of nest-site competition between European starlings and woodpeckers. *The Wilson Bulletin*, 106(2), pp.227–241.

Ingold, D.J., 1989. Nesting Phenology and Competition for Nest Sites among Red-Headed and Red-Bellied Woodpeckers and European Starlings. *The Auk*, 106(2), pp.209–217.

Ingold, D.J., 1998. The Influence of Starlings on Flicker Reproduction When Both Naturally Excavated Cavities and Artificial Nest Boxes Are Available. *The Wilson Bulletin*, 110(2), pp.218–225.

Innes, J. et al., 2012. Using five-minute bird counts to study magpie (Gymnorhina tibicen) impacts on other birds in New Zealand. *New Zealand Journal of Ecology*, 36(3).

Invasive Species In Belgium, 2015. *Alopochen aegyptiacus - Egyptian goose.* Online. Available from: http://ias.biodiversity.be/species/show/19.

Invasive Species of Japan, 2016. *Invasive Species of Japan.* Online. Available from: https://www.nies.go.jp/biodiversity/invasive/index\_en.html.

Invasive Species South Africa, 2015. *Saffron finch, Sicalis flaveola.* Online. Available from: <http://www.invasives.org.za/legislation/item/935-saffron-finch-sicalis-flaveola>.

Invasive Species Wiki, 2016. *Little Owl.* Online. Available from: http://invasive-species.wikia.com/wiki/Little\_Owl.

IUCN Invasive Species Specialist Group (ISSG), 2016. *The Global Invasive Species Database. Version 2015.1.* Online. Available from: http://www.iucngisd.org/gisd/.

IUCN Invasive Species Specialist Group (ISSG), undated. *Factsheet: Bubo virginianus.* Online. Available from: http://www.issg.org/pdf/inv\_of\_week/bubvir.pdf.

IUCN Invasive Species Specialist Group (ISSG), undated. *Factsheet: Dicrurus macrocercus.* Online. Available from: http://www.issg.org/pdf/inv\_of\_week/dicmac.pdf.

IUCN Invasive Species Specialist Group (ISSG), undated. *Factsheet: Pitangus sulphuratus.* Online. Available from: <http://www.issg.org/pdf/inv_of_week/pitsul.pdf>

IUCN Invasive Species Specialist Group (ISSG), 2007. *General Impacts of the House Crow (Corvus splendens).* Online. Available from: http://www.issg.org/database/species/impact\_info.asp?si=1199&fr=1&sts=&lang=EN.

Jackson, J.A. & Tate Jr, J., 1974. An Analysis of Nest Box Use by Purple Martins, House Sparrows, and Starlings in Eastern North America. *The Wilson Bulletin*, 86(4), pp.435–449.

Jansson, K. & Josefsson, M., 2008. *Invasive Alien Species Fact Sheet: Branta canadensis. Database of the North European and Baltic Network on Invasive Alien Species – NOBANIS.* Online. Available from: https://www.nobanis.org/globalassets/speciesinfo/b/branta-canadensis/branta\_canadensis.pdf.

Jaramillo, A. et al., 2008. The native and exotic avifauna of Easter Island: then and now. *Boletin Chileno de Ornitologia*, 14(1), pp.1–29.

Johnson, S.A. & Givens, W., 2012. *WEC 255 - Florida’s Introduced Birds: European Starling (Sturnus vulgaris).* University of Florida, IFAS Extension.

Johnson, S.A. & Hawk, M., 2012. *WEC 254 - Florida’s Introduced Birds: Muscovy Duck (Cairina moschata).* University of Florida, IFAS Extension.

Johnson, S.A. & Logue, S., 2012. *WEC 257 - Florida’s Introduced Birds: Monk Parakeet (Myiopsitta monachus).* University of Florida, IFAS Extension.

Johnson, S.A. & McGarrity, M., 2009. *WEC 270 - Florida’s Introduced Birds: Purple Swamphen (Porphyrio porphyrio).* University of Florida, IFAS Extension.

Johnson, S.A. & Sox, J., 2012. *WEC 253 - Florida’s Introduced Birds: House Finch (Carpodacus mexicanus).* University of Florida, IFAS Extension.

Johnson, S.A. & Violett, H., 2012. *WEC 260 - Florida’s Introduced Birds: House Sparrow (Passer domesticus).* University of Florida, IFAS Extension.

Josefsson, M. & Andersson, B., 2001. The Environmental Consequences of Alien Species in the Swedish Lakes Mälaren, Hjälmaren, Vänern and Vättern. *AMBIO*, 30(8), pp.514–521.

Kawakami, K. & Higuchi, H., 2003. Interspecific interactions between the native and introduced White-eyes in the Bonin Islands. *Ibis*, 145(4), pp.583–592.

Kawakami, K., Mizusawa, L. & Higuchi, H., 2009. Re-established mutualism in a seed-dispersal system consisting of native and introduced birds and plants on the Bonin Islands, Japan. *Ecological Research*, 24(4), pp.741–748.

Kerpez, T.A. & Smith, N.S., 1990. Competition between European Starlings and Native Woodpeckers for Nest Cavities in Saguaros. *The Auk*, 107(2), pp.367–375.

Kestenholz, M., Heer, L. & Kelller, V., 2005. Etablierte Neozoen in der europäischen Vogelwelt – eine Übersicht. *Der Ornithologische Beobachter*, 102, pp.153–180.

Khaleghizadeh, A., 2004. On the diet and population of the Alexandrine parakeet, Psittacula eupatria, in the urban environment of Tehran, Iran. *Zoology in the Middle East*, 32, pp.27–32.

Kirkpatrick, W. & Woolnough, A., 2007. *Pestnote 253: Common Starling.* Department of Agriculture and Food. Government of Western Australia.

Koenig, W.D., 2003. European Starlings and Their Effect on Native Cavity-Nesting Birds. *Conservation Biology*, 17(4), pp.1134–1140.

Komdeur, J., 1990. Breeding of the Seychelles Magpie Robin Copsychus sechellarum and implications for its conservation. *Ibis*, 138(3), pp.485–498.

Kumschick, S. & Nentwig, W., 2010. Some alien birds have as severe an impact as the most effectual alien mammals in Europe. *Biological Conservation*, 143(11), pp.2757–2762.

Kwok, H.-K., 2009. Foraging ecology of insectivorous birds in a mixed forest of Hong Kong. *Acta Ecologica Sinica*, 29(6), pp.341–346.

Latitude 42, 2011a. *Pest Risk Assessment: Chukar partridge (Alectoris chukar).* Latitude 42 Environmental Consultants Pty Ltd. Hobart, Tasmania.

Latitude 42, 2011b. *Pest Risk Assessment: Indian ringneck parrot (Psittacula krameri)*. Latitude 42 Environmental Consultants Pty Ltd. Hobart, Tasmania.

Lemaire, A. & van Kleunen, A., 2014. *A risk assessment of Mandarin Duck (Aix Galericulata) in the Netherlands. Sovon-report 2014/15.* Sovon Dutch Centre for Field Ornithology, Nijmegen.

Leven, M.R. & Corlett, R.T., 2004. Invasive Birds in Hong Kong, China. *Ornithological Science*, 3, pp.43–55.

Lever, C., 2005. *Naturalized birds of the world.* A&C Black Publishers Ltd. London.

Lever, C., 2009. *The naturalized animals of Britain and Ireland. Mammals, birds, reptiles, amphibians and fish.* New Holland Publishers (UK) Ltd. London.

Li, S.H. et al., 2010. Genetic introgression between an introduced babbler, the Chinese hwamei Leucodioptron c. canorum, and the endemic Taiwan hwamei L. taewanus: A multiple marker systems analysis. *Journal of Avian Biology*, 41(1), pp.64–73.

Linnebjerg, J.F. et al., 2010. Diet composition of the invasive red-whiskered bulbul Pycnonotus jocosus in Mauritius. *Journal of Tropical Ecology*, 26(03), p.347.

Linnebjerg, J.F., Hansen, D.M. & Olesen, J.M., 2009. Gut passage effect of the introduced red-whiskered bulbul (Pycnonotus jocosus) on germination of invasive plant species in Mauritius. *Austral Ecology*, 34(3), pp.272–277.

Lok, A.F.S.L., Tey, B.S. & Subaraj, R., 2009. Barbets of Singapore Part 1: Megalaima lineata hodgsoni Bonaparte, the Lineated Barbet, Singapore’s only exotic species. *Nature in Singapore*, 2, pp.39–45.

Long, J.L., 1981. *Introduced birds of the world.* The worldwide history, distribution and influence of birds introduced to new environments. David & Charles. London.

Los Angeles Times, 1991. *Question of How Wild Parrots Flew the Coop Is Up*

*in the Air.* Online. Available from: http://articles.latimes.com/1991-04

09/news/mn-205\_1\_wild-parrots.

Lowe, K.A., Taylor, C.E. & Major, R.E., 2011. Do Common Mynas significantly compete with native birds in urban environments? *Journal of Ornithology*, 152(4), pp.909–921.

MacGregor-Fors, I. et al., 2009. Relationship between the presence of House Sparrows (Passer domesticus) and Neotropical bird community structure and diversity. *Biological Invasions*, 12, pp.87–96.

Madeiros, J., 2011. *Breeding Success and Status of Bermuda’s Longtail Population (White-tailed Tropicbird) (Phaethon lepturus catsbyii) at Ten Locations on Bermuda 2009 – 2011.* Terrestrial Conservation Division, Department of Conservation Services, Bermuda Government.

Mandon-Dalger, I. et al., 2004. Relationships between alien plants and an alien bird species on Reunion Island. *Journal of Tropical Ecology*, 20(6), pp.635–642.

Marchant, J., 2012. *Black Swan, Cygnus atratus.* GB Non-native species secretariat.

Marion, L., 2013. Is the Sacred ibis a real threat to biodiversity? Long-term study of its diet in non-native areas compared to native areas. *Comptes Rendus Biologies*, 336(4), pp.207–220.

Markula, A., Hannan-Jones, M. & Csurhes, S., 2009. *Pest animal risk assessment: Indian myna (Acridotheres tristis).* Biosecurity Queensland. Queensland Primary Industries and Fisheries.

Marples, B.J., 1942. A Study of the Little Owl, Athene noctua, in New Zealand. *Transactions and Proceedings of the Royal Society of New Zealand*, pp.237–252.

Martin-Albarracin, V.L. et al., 2015. Impact of Non-Native Birds on Native Ecosystems: A Global Analysis. *Plos One*, 10(11), p.e0143070.

Massam, M., 2000. *Farmnote 117/99: Sparrows.* Department of Agriculture. Government of Western Australia.

Mathys, B. a. & Lockwood, J.L., 2009. Rapid evolution of great kiskadees on Bermuda: An assessment of the ability of the Island rule to predict the direction of contemporary evolution in exotic vertebrates. *Journal of Biogeography*, 36, pp.2204–2211.

Matthews, C.E. & Cummo, E., 1999. All wrapped up in Kudzu and other ecological disasters. *The American Biology Teacher*, 61(1), pp.42–46.

Maui Forest Bird Recovery Project, 2015. *Non-Native Birds.* Online. Available

from: <http://www.mauiforestbirds.org/articles/28>.

McLaughlan, C., Gallardo, B. & Aldridge, D.C., 2014. How complete is our knowledge of the ecosystem services impacts of Europe’s top 10 invasive species? *Acta Oecologica*, 54, pp.119–130.

Melo, C., 2007. Pitangus sulphuratus. *Ecologia*, 35(4), pp.1–2.

Menchetti, M. & Mori, E., 2014. Worldwide impact of alien parrots (Aves Psittaciformes) on native biodiversity and environment: a review. *Ethology Ecology & Evolution*, 26(2-3), pp.172–194.

Michigan Department of Natural Resources, undated. *Mute Swans - Invading Michigan’s Waters. A growing threat to native animals, habitat and humans.*

Mitchell, S.F. & Wass, R.T., 1996. Grazing by black swans (Cygnus atratus latham), physical factors, and the growth and loss of aquatic vegetation in a shallow lake. *Aquatic Botany*, 55(3), pp.205–215.

Morgan, D., Waas, J.R. & Innes, J., 2006. Do territorial and non-breeding Australian Magpies Gymnorhina tibicen influence the local movements of rural birds in New Zealand? *Ibis*, 148(2), pp.330–342.

Morgan, D., Waas, J.R. & Innes, J., 2005. Magpie interactions with other birds in New Zealand: Results from a literature review and public survey. *Notornis*, 52(2), pp.61–74.

Morgan, D., Waas, J.R. & Innes, J., 2006. The relative importance of Australian magpies (Gymnorhina tibicen) as nest predators of rural birds in New Zealand. *New Zealand Journal of Zoology*, 33(1), pp.17–29.

Morgan, D.K.J. et al., 2012. Native bird abundance after Australian magpie (Gymnorhina tibicen) removal from localised areas of high resource availability. *New Zealand Journal of Ecology*, 36(3).

Morton, E.S., Stutchbury, B.J.M. & Piper, W.H., 2004. Cooperative breeding in the Tropical Mockingbird (Mimus gilvus) in the Panama Canal zone. *Ornitologia Neotropical*, 15(3), pp.417–421.

Mountainspring, S. & Scott, J.M., 1985. Interspecific Competition Among Hawaiian Forest Birds. *Ecological Monographs*, 55(2), pp.219–239.

Muller, W., 2008. *Hybridisation, and the Conservation of the Grey Duck in New Zealand.* PhD Thesis. University of Canterbury.

Muñoz-Fuentes, V. et al., 2007. Hybridization between white-headed ducks and introduced ruddy ducks in Spain. *Molecular Ecology*, 16, pp.629–638.

Munoz, A.-R. & Real, R., 2006. Assessing the potential range expansion of the exotic monk parakeet in Spain. Diversity and Distributions, 12, pp.656–665.

National University of Singapore (Bird Ecology Study Group), 2015. *Whistling*

*ducks and hybrid ducklings.* Online. Available from:

<http://www.besgroup.org/2012/07/15/whistling-ducks-and-hybrid-ducklings-2/>.

Navas, J.R., 2002. Las aves exoticas introducidas y naturalizadas en la Argentina. *Revista del Museo Argentino de Ciencias Naturales*, 4(2), pp.191–202.

Neo, M.L., 2012. A review of three alien parrots in Singapore. *Nature in Singapore*, 5, pp.241–248.

Newson, S.E. et al., 2011. Evaluating the population-level impact of an invasive species, Ring-necked Parakeet Psittacula krameri, on native avifauna. *Ibis*, 153, pp.509–516.

New Zealand Birds Online, 2015. Online. Available from: http://www.nzbirdsonline.org.nz/.

Nyari, A., Ryall, C. & Townsend Peterson, A., 2006. Global invasive potential of the house crow Corvus splendens based on ecological niche modelling. *Journal of Avian Biology*, 37, pp.306–311.

Orchan, Y. et al., 2013. The complex interaction network among multiple invasive bird species in a cavity-nesting community. *Biological Invasions*, 15(2), pp.429–445.

Ortega, C.R., Cruz, A. & Mermoz, M.E., 2005. Issues and Controversies of Cowbird (Molothrus spp.) Management. *Ornithological Monographs*, 57, pp.6–15.

Panayides, P., Guerrini, M. & Barbanera, F., 2011. Conservation genetics and management of the Chukar Partridge (Alectoris chukar) in Cyprus and the Middle East. *Sandgrouse*, 33, pp.34–43.

Parks and Wildlife Commission NT, 2015. *Minor Pest – Barbary Dove.* Online. Available from: <http://www.parksandwildlife.nt.gov.au/wildlife/exotic/barbary#.Vo0Z4ZOLTR1>.

Paton, D.C. et al., 1988. Avian Vectors of the Seeds of the European Olive Olea Europea. *South Australian Ornithologist*, 30, pp.158–159.

Paton, J.B. & Barrington, D., 1985. The Barbary Dove in South Australia. *South Australian Ornithologist*, 29, pp.193–194.

Peacock, D.S., van Rensburg, B.J. & Robinson, M.P., 2007. The distribution and spread of the invasive alien common myna, Acridotheres tristis L. (Aves: Sturnidae), in southern Africa. *South African Journal of Science*, 103, pp.465–473.

Peck, H.L. et al., 2014. Experimental evidence of impacts of an invasive parakeet on foraging behavior of native birds. *Behavioral Ecology*, 25(3), pp.582–590.

Pell, A. & Tidemann, C., 1997. The impact of two exotic hollow-nesting birds on two native parrots in savannah and woodland in eastern Australia. *Biological Conservation*, (79), pp.145–153.

Perrott, J., 2010. *Breeding biology of laughing kookaburra (Dacelo novaeguinea) in New Zealand.* Unitec Research Committee.

Petrie, S.A. & Francis, C.M., 2003. Rapid increase in the lower Great Lakes population of feral mute swans: a review and a recommendation. *Wildlife Society Bulletin*, 31(2), pp.407–416.

Pfennigwerth, S., 2008. *Feral animals of Tasmania: how you can help control the State’s worst pest animal species.* Threatened Species Network. WWF Australia.

Phillips, R.B. et al., 2012. Eradication of rock pigeons, Columba livia, from the Galápagos Islands. *Biological Conservation*, 147, pp.264–269.

Phillips, R.B., Snell, H.L. & Vargas, H., 2003. Feral Rock Doves in the Galápagos Islands: Biological and Economic Threats. *Noticias de Galapagos*, 192(62), pp.6–11.

Poling, T.D. & Hayslette, S.E., 2006. Dietary Overlap and Foraging Competition between Mourning Doves and Eurasian Collared-Doves. *The Journal of Wildlife Management*, 70(4), pp.998–1004.

Porter, R.E.R., 1979. Food of the rook (Corvus frugilegus L.) in Hawke’s Bay, New Zealand. *New Zealand Journal of Zoology*, 6(2), pp.329–337.

Porter, R.E.R., Clapperton, B.K. & Coleman, J.D., 2008. Distribution, abundance and control of the rook (Corvus frugilegus L.) in Hawke’s Bay, New Zealand, 1969–2006. *Journal of the Royal Society of New Zealand*, 38(1), pp.25–36.

Pranty, B. et al., 2005. Discovery, Origin, and Current Distribution of the Purple Swamphen (Porphyrio Porphyrio) in Florida. *Florida Field Naturalist*, 28(1), pp.1–40.

Puigcerver, M., Vinyoles, D. & Rodríguez-Teijeiro, J.D., 2007. Does restocking with Japanese quail or hybrids affect native populations of common quail Coturnix coturnix? *Biological Conservation*, 136(4), pp.628–635.

Rajan, P. & Pramod, P., 2013. Introduced birds of the Andaman & Nicobar Islands, India. *Indian Birds*, 8(3), pp.71–72.

Randler, C., 2004. Aggressive interactions in Swan Geese Anser cygnoides and their hybrids. *Acta Ornithologica*, 39(2), pp.147–153(7).

Rehfisch, M.M., Allan, J.R. & Austin, G.E., 2010. *The effect on the environment of Great Britain’s naturalized Greater Canada Branta canadensis and Egyptian Geese Alopochen aegyptiacus.*

Reid, J. & Hill, B., 2005. *Commonwealth of Australia. National Recovery Plan for the Buff Banded Rail (Cocos (Keeling) Islands). Gallirallus philippensis andrewsi.* Department of the Environment and Heritage, Canberra.

Reynolds, M.H. et al., 2003. Evidence of change in a low-elevation forest bird community of Hawai’i since 1979. *Bird Conservation International*, 13(3), pp.175–187.

Rhymer, J.M., 2006. S33-4 Extinction by hybridization and introgression in anatine ducks. *Acta Zoologica Sinica*, 52, pp.583–585.

Rhymer, J.M. & Simberloff, D., 1996. Extinction by Hybridization and Introgression. *Annual Review of Ecology and Systematics*, 27, pp.83–109.

Rhymer, J.M., Williams, M.J. & Braun, M.J., 1994. Mitochondrial analysis of gene flow between New Zealand mallards (Anas platyrhynyhos) and Grey ducks (A.superciliosa). *The Auk*, 111(4), pp.970–978.

Ripper III, C. van et al., 1986. The Epizootiology and Ecological Significance of Malaria in Hawaiian Land Birds. *Ecological Monographs*, 56(4), pp.327–344.

Roberts, P., 1988. Introduced birds on Assumption Island - a threat to Aldabra. *Oryx*, 22(1), pp.15–17.

Robertson, P.A. et al., 2015. Towards the European eradication of the North American ruddy duck. *Biological Invasions*, 17, pp.9–12.

Runde, D.E., Pitt, W.C. & Foster, J.T., 2007. Population ecology and some potential impacts of emerging populations of exotic parrots. *Managing Vertebrate Invasive Species. Paper 42.*, pp.338–360.

Ryall, C., 2003. Notes on ecology and behaviour of House Crows at Hoek van Holland. *Dutch Birding*, 25, pp.167–171.

Ryall, C., 1992. Predation and harassment of native bird species by the Indian House Crow Corvus splendens, in Mombasa, Kenya. *Scopus*, 16, pp.1–8.

Samuel, M.D. et al., 2011. The dynamics, transmission, and population impacts of avian malaria in native hawaiian birds: A modeling approach. *Ecological Applications*, 21(8), pp.2960–2973.

Sanchez, M.I., Green, A.J. & Dolz, J.C., 2010. The diets of the White-headed Duck Oxyura leucocephala, Ruddy Duck O. jamaicensis and their hybrids from Spain. *Bird Study*, 47(3), pp.275–284.

Sanders, M.D. & Maloney, R.F., 2002. Causes of mortality at nests of ground-nesting birds in the Upper Waitaki Basin, South Island, New Zealand: A 5-year video study. *Biological Conservation*, 106(2), pp.225–236.

Dos Santos, V.M. et al., 2012. Is black swan grazing a threat to seagrass? Indications from an observational study in New Zealand. *Aquatic Botany*, 100, pp.41–50.

Scientific Advisory Committee, 2012. *Flora and Fauna Guarantee - Scientific Advisory Committee. Final recommendation on a nomination for listing. Nomination No. 827: Competition with native fauna by the Common Myna (Sturnus tristis) (Potentially Threatening Process).* Government of Australia.

Seitre, R. & Seitre, J., 1992. Causes of land-bird extinctions in French Polynesia. *Oryx*, 26(04), pp.215 – 222.

Shine, C., Reaser, J.K., & Guiterrez, A.T., 2003. Invasive Alien Species in the Austral-Pacific Region. National Reports & Directory of Resources. Global Invasive Species Programme, Cape Town, South Africa.

Simberloff, D., 2013. *Invasive species. What everyone needs to know.* Oxford University Press. Oxford.

Simberloff, D. & Holle, B. Von, 1999. Positive interactions of nonindigenous species: invasional meltdown? *Biological Invasions*, pp.21–32.

Singapore Birds, 2015. *Waterfowls.* Online. Available from:

http://singaporebirds.blogspot.co.uk/2012/05/order-anseriformes-family

anatidae.html.

Smith, G.C., Henderson, I.S. & Robertson, P.A., 2005. A model of ruddy duck Oxyura jamaicensis eradication for the UK. *Journal of Applied Ecology*, 42(3), pp.546–555.

Sol, D. et al., 1997. Habitat Selection by the Monk Parakeet during Colonization of a New Area in Spain. *The Condor*, 99(1), pp.39–46.

The Southland Times, 2016. *Predatory weka DOC enemy No 1 on island.* Online. Available from: <http://www.stuff.co.nz/southland-times/news/558740/Predatory-weka-DOC-enemy-No-1-on-island>.

Spotswood, E.N., Meyer, J.Y. & Bartolome, J.W., 2012. An invasive tree alters the structure of seed dispersal networks between birds and plants in French Polynesia. *Journal of Biogeography*, 39(11), pp.2007–2020.

Spotswood, E.N., Meyer, J.Y. & Bartolome, J.W., 2013. Preference for an invasive fruit trumps fruit abundance in selection by an introduced bird in the Society Islands, French Polynesia. *Biological Invasions*, 15(10), pp.2147–2156.

Stafford, L., 2010. *Mallard Strategy for South Africa.* Prepared by Louise Stafford, C.A.P.E. Invasive Species Coordinator. City of Cape Town,

Strubbe, D. & Matthysen, E., 2007. Invasive ring-necked parakeets Psittacula krameri in Belgium: Habitat selection and impact on native birds. *Ecography*, 30, pp.578–588.

Strubbe, D. & Matthysen, E., 2009. Predicting the potential distribution of invasive ring-necked parakeets Psittacula krameri in northern Belgium using an ecological niche modelling approach. *Biological Invasions*, 11(3), pp.497–513.

Strubbe, D. & Matthysen, E., 2010. The invasion of ring-necked parakeet (Psittacula krameri) in Europe and Belgium: mechanisms and consequences for native biota. In: *Science Facing Aliens. Proceedings of a Scientific Meeting on Invasive Alien Species held in Brussels, May 11th, 2009. Belgian Biodiversity Platform.*

Strubbe, D., Matthysen, E. & Graham, C.H., 2010. Assessing the potential impact of invasive ring-necked parakeets Psittacula krameri on native nuthatches Sitta europeae in Belgium. *Journal of Applied Ecology*, 47, pp.549–557.

Styche, A., 2000. *Distribution and behavioural ecology of the sulphur-crested cockatoo (Cacatua galerita L.) in New Zealand.* PhD Thesis. Victoria University of Wellington.

Suliman, A.S., Meier, G.G. & Haverson, P.J., 2011. Eradication of the house crow from Socotra Island, Yemen. In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. *Island invasives: eradication and management.* IUCN, Gland, Switzerland.

Sulivan, M.J.P., Grundy, J. & Franco, A.M.A., 2014. Report from a BOU-funded project. Assessing the impacts of the non-native Black-headed Weaver on native Acrocephalus warblers. *Ibis*, 156, pp.231–232.

T. R. New, 2010. *Beetles in Conservation*. Wiley-Blackwell. London.

Tassell, S., 2014. *The effect of the non‐native superb lyrebird (Menura novaehollandiae) on Tasmanian forest ecosystems.* A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy. University of Tasmania.

Tatu, K.S. et al., 2007. Mute Swans’ Impact on Submerged Aquatic Vegetation in Chesapeake Bay. *Journal of Wildlife Management*, 71(5), pp.1431–1439.

Taylor, A.K., Mazzotti, F.J. & Casler, M.L., 2004. *Parrots and Parakeets in Florida.* University of Florida, IFAS Extension.

Taysom, A., Johnson, J. & Guay, P.-J., 2014. Establishing a genetic system to distinguish between domestic Mallards, Pacific Black Ducks and their hybrids. *Conservation Genetics Resources*, 6, pp.197–199.

The Chesapeake Bay Mute Swan Working Group, 2004. *Mute Swan (Cygnus olor) in the Chesapeake Bay: A Bay-Wide Management Plan.* Prepared by The Chesapeake Bay Mute Swan Working Group. Chaired by Julie A. Thompson. United States Fish and Wildlife Service, Chesapeake Bay Field Office.

Thibault, J.C. et al., 2002. Understanding the decline and extinction of monarchs (Aves) in Polynesian Islands. *Biological Conservation*, 108(2), pp.161–174.

Thomas, A.C.W., 2013. *Little owl.* In Miskelly, C.M. (Ed.) New Zealand Birds

Online. Online. Available from: [www.nzbirdsonline.org.nz](http://www.nzbirdsonline.org.nz/).

Threatened Species Scientific Committee, *Advice to the Minister for the Environment and Heritage from the Threatened Species Scientific Committee (TSSC) on Amendments to the list of Threatened Species under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*. *Placostylus bivaricosus (Lord Howe Placostylus, Lord Howe Flax Snail).*

Threatened Species Scientific Committee, 2010. *Tyto novaehollandiae castanops (Tasmanian Masked Owl) Listing Advice.* Australian Government. Online. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/83821-listing-advice.pdf.

Tidemann, C., 2005. Indian Mynas - Can the problems be controlled? In *Urban Animal Management Conference Proceedings 2005*. The Australian National University, pp. 55–57.

Tidemann, C.R., *Mitigation of the impact of mynas on biodiversity and public amenity.* The Australian National University. School of Resources, Environment & Society.

Tompkins, D.M. et al., 2000. The role of shared parasites in the exclusion of wildlife hosts: Heterakis gallinarum in the ring-necked pheasant and the grey partridge. *Journal of Animal Ecology*, 69(5), pp.829–840.

Tracey, J. et al., 2007. *Managing Bird Damage to Fruit and Other Horticultural Crops.* Bureau of Rural Sciences, Canberra. Australian Government.

Tracey, J., Lukins, B. & Haselden, C., 2008. *Lord Howe Island ducks: abundance, impacts and management options.* A report to the World Heritage Unit, Lord Howe Island Board. January 2008. Invasive Animals Cooperative Research Centre, Canberra.

Tracey, J.P., Lukins, B.S. & Haselden, C., 2008. Hybridisation between mallard (Anas platyrhynchos) and grey duck (A. superciliosa) on Lord Howe Island and management options. *Notornis*, 55, pp.1–7.

Troetschler, R.G., 1976. Acorn woodpecker breeding strategy as affected by starling nest-hole competition. *The Condor*, 78(2), pp.151–165.

U.S. Fish and Wildlife Service, 2006. *Revised Recovery Plan for Hawaiian Forest Birds.* Portland, Oregon.

Uyehara, K.J., Engilis, A.J. & Reynolds, M., 2007. *Hawaiian Duck’s future threatened by feral mallards.* *USGS Fact Sheet 2007-3047.* UC Davis, University of California.

VanderWerf, E.A., 2012. *Hawaiian Bird Conservation Action Plan.* Pacific Rim Conservation, Honolulu, HI.

Waikato Regional Council., 2015. *Canada goose (Branta canadensis maxima).* Biosecurity Series - Animal Factsheet.

Weitzel, N.H., 1998. Nest-site competition between the European Starling and native breeding birds in northwestern Nevada. *The Condor*, 90, pp.515–517.

Wikelski, M. et al., 2004. Galápagos Birds and Diseases: Invasive Pathogens as Threats for Island Species. *Journal of Applied Microbiology*, 9(1).

Wilcox, C., 2009. *Tropical Island Invaders: Swamp Harrier (Circus approximans) Behavior and Seabird Predatioin on Moorea, French Polynesia*. University of California - Berkeley.

Wild Parrots of New York, 2015. *Facts About Wild Parrots.* Online. Available

from: http://www.wildparrotsny.com/index/breedfacts.html.

Williams, C.L. et al., 2005. A comparison of hybridization between mottled ducks (Anas fulvigula) and mallards (A-Platyrhynchos) in Florida and South Carolina using microsatellite DNA analysis. *Conservation Genetics*, 6(3), pp.445–453.

Williams, G., 2011. *100 Alien Invaders - Animals and Plants that are Changing Our World.* Bradt Travel Guides Ltd. Chalfont St Peter.

Williams, M. & Basse, B., 2006. Indigenous gray ducks, Anas superciliosa, and introduced mallards, A. platyrhynchos, in New Zealand: processes and outcome of a deliberate encounter. *Acta Zoologica Sinica*, 52(Supplement), pp.579–582.

Williams, P.A., 2006. The role of blackbirds (Turdus merula) in weed invasion in New Zealand. *New Zealand Journal of Ecology*, 30(2), pp.285–291.

Williams, P.A. & Karl, B.J., 1996. Fleshy fruits of indigenous and adventive plants in the diet of birds in forest remnants, Nelson, New Zealand. *New Zealand Journal of Ecology*, 20(2), pp.127–145.

Wingspan, 2015. *Little Owl.* Online. Available from:

http://www.wingspan.co.nz/introduced\_bird\_of\_prey\_new\_zealand\_little

owl.html.

Wittenberg, R., 2005. *Invasive alien species in Switzerland. An inventory of alien species and their threat to biodiversity and economy in Switzerland.* CABI Bioscience Switzerland Centre report to the Swiss Agency for Environment, Forests and Landscape.

Woo, E., 2008. *The Role of Plant-Bird Interactions in the Invasion of Juniperus bermudiana in Hawaii: Integrating Experiments, Behavior, and Models.* A Dissertation Presented by Eliza Woo to The Graduate School in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Ecology and Evolution. Stony Brook University.

Woodworth, B.L., 1997. Brood parasitism, nest predation, and season-long reproductive success of a tropical island endemic. *Condor*, 99(3), p.605.

Wootton, J.T., 1987. Interspecific competition between introduced house finch populations and two associated passerine species. *Oecologia*, 71(3), pp.325–331.

Wotton, D.M. & McAlpine, K.G., 2015. Seed dispersal of fleshy-fruited environmental weeds in New Zealand. *New Zealand Journal of Ecology*, 39(2), pp.155–169.

Wu, J.X., Delparte, D.M. & Hart, P.J., 2014. Movement patterns of a native and non-native frugivore in hawaii and implications for seed dispersal. *Biotropica*, 46(2), pp.175–182.

Yesou, P. & Clergeau, P., 2005. Sacred Ibis: a new invasive species in Europe. *Birding World*, 18(12), pp.517–526.

Yong, D.L. & Owyong, A., 2012. *Summary Report: Parrot Count 2012 (Singapore).* Nature Society (Singapore) and International Ornithological Union (IOU).