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INVASION NOTE

Overestimation of establishment success of non-native birds in Hawaii and Britain

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Abstract The tens rules states that 10 % of all introduced species establish and about 10 % of those species become invasive. Several studies have failed to support the tens rule. However, these studies are beset by a general weakness: many unsuccessful invasions are never reported, and without these data tests of the tens rules are inadequate. Here, using data on the establishment success of non-native birds in Hawaii and Britain and comparing these data with those from a previous study, we show that lack of information about failed species introductions, and the tendency to report species that have become invasive more than those that have not, result in an overestimate of the establishment success and invasion rates of non-native species.

Keywords Birds · Exotic species · Invasion · Tens rule

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Introduction

In order to become invasive, a non-native species must pass through three stages: arriving in a new region, establishing a population, and spreading. Of the many species introduced accidentally or intentionally to new regions, the majority fail to establish and an even smaller proportion become invasive (Williamson and Brown 1986). In an attempt to quantify the probability of getting from initial introduction to invasion, Williamson and Brown (1986) formulated the tens rule, which states that about 10 % of all introduced species establish and about 10 % of established species become invasive, with limits between about 5 and 20 % at each step (Williamson 1993). However, the tens rule has no theoretical basis; it does not explain or predict. It is just a descriptive pattern.

Recent reviews have challenged the tens rule (Jeschke and Strayer 2005; Jeschke 2008). Jeschke and Strayer (2005) found that establishment success rates of freshwater fish, mammals, and birds native to Europe and introduced to North America, or vice versa, were almost 50 % in each direction, and almost 50 % of these species became invasive (see Figure 2 in Jeschke and Strayer 2005). Similarly, Jeschke (2008) reported that 79 and 50 % of introduced mammals and birds, respectively, established at the site of introduction and 63 % of the mammals and 34 % of the birds that established became invasive (see Figure 1 in Jeschke 2008).

One problem with such studies is that the data are inadequate to draw conclusions about the tens rule

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(Simberloff 1995; Rodriguez-Cabal et al. 2009), because failures are less likely to be recorded than successes. Although Jeschke and Strayer (2005) noted this problem and conceded that this can render some of their estimates of establishment success too high, Jeschke (2008) felt that the lack of knowledge of unsuccessful introduced species would not affect his conclusion. Rodriguez-Cabal et al. (2009) demurred, but Jeschke (2009), in reply, argued that his conclusion in 2008 was based on careful analysis of two taxa, mammals and birds, that are so well-studied that knowledge gaps are not debilitating. Here we examine the conclusions of Jeschke (2008, 2009) by analyzing data on the introduction of land birds in Hawaii and Britain, part of the same data analyzed by Jeschke (2008), and giving details of the best figures we have been able to obtain for introduction and establishment of non-native bird species in these archipelagos.

Materials and methods

We reviewed literature on the number of non-native bird species introduced and those that have established self-sustaining populations in the Hawaiian and Britain archipelagos. We considered a species as established when the population has persisted for at least 15 years. We did not include species for which it was known that only one individual was released. Then we compared our data to those of Jeschke (2008). Jeschke (2008) did not report data for Ni'iahu, Kaho'olawe and Hawai'i. Although data are available for these, we present data for only those Hawaiian islands reported by Jeschke (2008) in our tables; the full data are in the Appendix A: supplementary material.

Data

The data from the Hawaiian islands were collected from an exhaustive bibliography review of 71 years of the journal *Elepaio* from its first issue to the November 2010 issue (volume 70, number 8). Additional information on the Hawaiian archipelago was extracted from a recent review of the bird fauna of Hawaii by Pyle and Pyle (2009) (Appendix A in supplementary material). The only fully reliable list of British birds and their status is the British list maintained by the British Ornithologists' Union (BOU), reviewed annually, and available at http://www.bou.org.uk/thebritishlist/British-List-2010.pdf. It has six sections, categories, A–F. Category A is "Species recorded in an apparently natural state at least once since 1 January 1950," so it includes regular and irregular breeders, migrants and natural stragglers. Category C is introduced bird species with self-sustaining populations. The BOU requires much detailed evidence before accepting a population as self-sustaining. The detailed procedures used by the BOU before accepting a species as C (established) are fully described in Dudley (2005) and the papers he quotes. Category E is "introductions, human-assisted transportees or escapees from captivity" but "thought not to be self-sustaining". It is "provisional" and "not exhaustive." For invasion biologists, species in E are casual and most of those in C are established (naturalized). However, Category C has been split since 2005 into six subcategories (Dudley 2005). For our purpose, established introduced species are those in C1 (straight introductions), C2 (as C1 but also in A) and C4 (feral), totalling 18 allowing for double entries. Casual species are those in E but not also in A or C. Our count is 288 in E less 29 also in A or C, which gives 259 casuals.

Data were analyzed using a Chi-square test on the number of casual (introduced minus established) versus established species.

Results and discussion

We found that, of the seven islands analysed by Jeschke (2008), five have lower proportions of established birds than he reported, two of them significantly so, and two have higher proportions (Table 1). For the Hawaiian archipelago and Britain, the numbers of events recorded by Jeschke (2008) were too low, approximately by half for the Hawaiian archipelago and almost nine times smaller for Britain. These results show that his test of the tens rule is inadequate because the data he used are insufficient. For the Hawaiian archipelago he used Simberloff and Boecklen (1991) for O'ahu, Moloka'i, Lana'i and Mau'i, Case (1996) for Kauai, and Sol (2000) for the Hawaiian archipelago. For Britain, he used Case (1996), who in turn used three sources, Heinzel et al. (1972), Lever (1987), and Ridpath and Moreau (1966). Heinzel et al. (1972) is a field guide with a very short list of casuals and is not concerned with introduced status. Lever (1987) is a good natural history book but

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Table 1 Comparison between the number of introduced and established non-native birds, and the proportion of success, in the Hawaiian islands and Britain in this study and in Jeschke (2008)

	Our data			Jeschke (2008)				
	Introduced	Established	%	Introduced	Established	%	χ^2	*P*
Kaua'i								
Total	70	37	53	52	27	52	0.002	0.961
O'ahu								
Columbiformes and Passeriformes	64	28	44	53	31	58	2.272	0.132
Total	118	41	35					
Moloka'i								
Columbiformes and Passeriformes	23	20	87	18	16	89	0.035	0.851
Total	41	31	73					
Lana'i								
Columbiformes and Passeriformes	24	18	75	18	13	72	0.015	0.903
Total	41	30	73					
Mau'i								
Columbiformes and Passeriformes	30	22	73	28	18	64	0.554	0.457
Total	67	35	52					
Hawaiian archipelago								
Total	183	57	31	103	45	44	5.092	0.024*
Britain								
Total	277	18	6	30	9	30	18.639	<0.001*

Additionally, we added data on all non-native birds introduced into the Hawaiian islands (total). Significant *P* values are indicated by an asterisk

not systematic and scarcely treats casuals, while Ridpath and Moreau (1966) is on the birds of Tasmania. Jeschke (2008) also used Williamson and Brown (1996), though his figures are not those given there. Additionally, even though we used two of the most up-to-date and well-recorded data sets, these data sets are far from exhaustive. We believe that our proportions are still too high, because species that have spread from their introduction location would be more likely to be reported than those that have not, and any inaccuracy would thus be in the direction of overestimating the fraction of non-native species that became established. We also believe that our conclusions are also valid for mainland ecosystems. Moreover, Britain is a continental island and, for birds, behaves like a mainland system. Finally, from our results we can expect the bias to be higher for taxa for which information on introduction attempts is more incomplete.

In conclusion, that the tens rule frequently does not always hold is scarcely news. In Fig 2.2 in chapter 2 of Williamson (1996), 50 % of the points, including all the Hawaiian data points, are outside the 5–20 % limits that Williamson (1993) suggested as a rough rule, not generating precise descriptions (Williamson 1996, 2006). We still feel that the tens rule is a helpful concept that can be used as a point of reference.

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