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PATTERNS OF SUCCESS AMONG INTRODUCED BIRDS IN THE HAWAIIAN ISLANDS

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Abstract. At least 140 species of 14 different orders of birds have been introduced to the six main Hawaiian Islands. The introduced species came from six continents and the introductions were carried out by a variety of agents including state and local governments, private citizens, and the acclimatization society known as the Hui Manu. The introductions mostly occurred during the early to mid-twentieth century. Most (79%) of the intentional introductions were of species from three orders: Galliformes, Columbiformes, and Passeriformes.

Introduction success rates were significantly greater for passeriforms than for either columbiforms or galliforms, although the reasons for this are unknown. In predicting the fate of future introductions, only the columbiforms showed an "all-or-none" pattern of introduction history. Successful species had larger native geographic ranges than did unsuccessful species, which supports the hypothesis that range size is correlated with the ability to adapt to a new environment. Finally, in a partial test of the introduction effort hypothesis we found that galliforms successfully introduced to the island of Hawai'i were introduced in significantly larger numbers than unsuccessful species.

Key Words: doves; game birds; introduced species; introduction effort; introduction success; native range size; perching birds; pigeons.

Numerous species of birds from six continents have been introduced to the Hawaiian Islands (Caum 1933, Berger 1981, Long 1981, Pratt et al. 1987). These species were introduced by a variety of groups for a variety of reasons. As noted by Berger (1981), the first avian introduction came with early Polynesians who brought the Red Junglefowl (*Gallus gallus*) for food. Since that time, a number of private citizens have brought species to Hawai'i (e.g., Caum 1933). Some of these introductions were made inadvertently as individual birds escaped captivity (e.g., Melodious Laughingthrush or Hwamei, *Garrulax canorus,* on O'ahu), whereas others were intentionally released for aesthetic reasons or even as an attempt at biological control (Caum 1933). There also have been intensive efforts both by private citizens (e.g., Lewin 1971) as well as state and county agencies (Schwartz and Schwartz 1949; Walker 1966, 1967) to establish populations of various game birds for recreational hunting. In the early to mid-twentieth century, the acclimatization society known as the Hui Manu actively introduced several species to various islands (Caum 1933, Berger 1981).

Regardless of their source, a central question in any study of introduced birds is "Why do some species succeed and others fail?" In several papers we and our colleagues have argued that competition has played an influential role in determining the outcomes of passerine species' introductions in Hawai'i (Moulton and Pimm 1983, 1986a, 1987; Moulton 1985, 1993; Mountainspring and Scott 1985; Moulton et al. 1990; Moulton and Lockwood 1992). These arguments are based on three main findings. First, introductions tend to be less successful when more species of introduced birds are already present (Moulton 1993; Moulton and Pimm 1983, 1986a). Second, there is a pattern of limiting similarity among congeneric pairs of introduced birds: differences in bill length are significantly greater in pairs that coexist than in pairs of species that were not able to coexist (Moulton 1985). And third, successful introduced passerines show a pattern of morphological overdispersion (Moulton and Pimm 1987, Moulton and Lockwood 1992); i.e., successful species are morphologically more different from each other than expected by chance.

Although these three patterns are consistent with predictions from competition theory, other explanations for patterns in introduction outcomes have been advanced. These include introduction history of a species (Simberloff and Boecklen 1991) and introduction effort (e.g., Pimm 1991, Veltman et al. 1996).

The idea that introduction history can predict future introduction outcomes is appealing in its simplicity. The concept comes from Simberloff and Boecklen (1991) who argued that whenever and wherever a given species is introduced, it tends to either always succeed or always fail. This leads to an "all-or-none" pattern in the distribution of birds introduced onto a series of islands: some species being successful on "all" the islands in the series and others being successful on "none" of the islands. If introduced birds actually follow this pattern, then predicting the outcome of future introductions would be greatly simplified. Moulton (1993) and Moulton and Sanderson (1997), however, argued that the all-or-none pattern reported by Simberloff and Boecklen (1991) for passerine birds was primarily an artifact of sample size.

Another factor that might influence the outcome of introductions is the effort invested in the introduction process. Griffith et al. (1989) found that introduction effort along with habitat quality were associated with introduction outcome. Similarly, Pimm (1991) studied introductions of seven game bird species (all of which had been successfully introduced somewhere in the world) in the western United States and found that there was a very high (360/424 = 85%) failure rate. Pimm's analysis indicated that the failure rate was particularly high when fewer than 75 individuals were released. More recently, studies of introduced birds in New Zealand (Veltman et al. 1996, Duncan 1997, Green 1997) have concluded that introduction effort is the most influential variable in determining which species succeed. In each of the three studies, the authors reported that successful species were introduced in larger numbers and more frequently than were unsuccessful species.

Several authors have reported a positive relationship between the size of the native geographic range of a species and its average abundance (e.g., Bock and Ricklefs 1983, Brown 1984). If widespread species tend to be ecologically more generalized than species with narrow distributions, we would predict that successful introduced species would tend to be those that have larger native ranges.

Many analyses of avian introduction success in Hawai'i have focused on passerine birds (e.g., Moulton and Pimm 1983, 1986a,b, 1987; Williams 1987, Moulton and Lockwood 1992), yet passerines represent fewer than half the total number of birds that have been introduced to the Hawaiian Islands (Berger 1981, Long 1981). Our objectives in this paper were to examine patterns of success for introduced species in Hawai'i across three taxonomic orders of birds: Galliformes, Columbiformes, and Passeriformes. Specifically, are the success rates of nonpasserine birds different from those of the passerines? Second, is an all-or-none pattern evident in the nonpasserine orders? Third, is native range size greater for successful introduced species than for unsuccessful introduced species in passerines and nonpasserines? And, fourth, does introduction effort play a role in determining the success of introduced birds in Hawai'i?

METHODS AND MATERIALS

We used Caum (1933), Schwartz and Schwartz (1949), Munro (1960), Walker (1966, 1967), Lewin (1971), Berger (1981), Long (1981), Lever (1987), and Pratt et al. (1987) to compile lists of nonindigenous birds introduced to the Hawaiian Islands. In compiling our lists we attempted to ascertain not only the current status of each species but also the date of first introduction. In our analyses we considered species to be successful if they were present on an island in 1990. We considered species to be unsuccessful if there were no recorded observations after 1990. Scientific names of 140 species introduced in the Hawaiian Islands are provided in Appendix 1. Scientific names of introduced species not included in our statistical analyses are provided in Appendix 2.

In order to determine success rates for the species in the different orders, we considered a species to be successful if it succeeded on any island, and unsuccessful only if it failed on every island on which it was released. By this approach, even if a species fails on all but one island, we believe that environmental conditions in the archipelago overall were potentially suitable for establishment and that perhaps differences in the mechanics of the release or interactions with other species might have occurred on islands where the species failed. We compared introduction success rates across orders with a chi-square test of equal proportions.

We used range maps in Long (1981) to estimate native range size for all introduced species, except *Garrulax caerulatus* and *Callipepla douglasii,* which were not included by Long. We used a grid method similar to the methods of Moulton and Pimm (1986b). We placed a small acetate grid over the native range map in Long (1981) and counted the number of squares that were intersected. Each square represented approximately 259,000 km^2. In earlier analyses of native range size of introduced passerines in Hawai'i (Moulton and Pimm 1986b), *Uraeginthus angolensis* and *U. cyanocephala* were omitted because of concern about the potential confusion with young *U. bengalus* in the field. However, we included all three *Uraeginthus* species in this analysis because Berger (1981) reported each was seen and identified in the wild.

We used Mann-Whitney tests for all our range size comparisons because data were not normally distributed. We compared native geographic range sizes of successful versus failed introductions, both within and across orders.

RESULTS

At least 140 species of nonindigenous birds from 14 orders have been released in the Hawaiian Islands (Table 1). Our results differ from earlier totals of 162 species (Long 1981) and 170 species (Berger 1981) for two reasons. First, those authors followed a somewhat different taxonomy. For example, Berger (1981) listed the Green Pheasant (*Phasianus versicolor*) as being a distinct species, whereas we followed Sibley and Monroe (1990) and treated it as being conspecific with the Ring-necked Pheasant (*Phasianus colchicus*). Second, at least among the passerines, we have excluded several species included by Long and Berger on grounds that simply too few individuals (i.e., < 5) were released. Simberloff and Boecklen (1991) list 14 of these species in their Appendix B, although based on Berger (1981) we included the two *Uraeginthus* species (*U. angolensis* and *U. cyanocephala*).

Although a great diversity of species has been released into the Hawaiian Islands, for the most

TABLE 1. SPECIES OF BIRDS INTRODUCED TO THE HAWAIIAN ISLANDS (CAUM 1933, BERGER 1981, LONG 1981)

Order	Number of species
Tinamiformes	1
Pelecaniformes	1
Ciconiiformes	3
Falconiformes	1
Galliformes	40
Turniformes	1
Gruiformes	1
Charadriiformes	2
Anseriformes	4
Columbiformes	18
Psittaciformes	14
Strigiformes	1
Apodiformes	1
Passeriformes	52

part three orders accounted for the bulk of the introductions. These are the game birds (Galliformes), pigeons and doves (Columbiformes), and perching birds (Passeriformes). These species represent 110 introductions (Appendices 3–5). Berger (1981) lists 14 species of a fourth order, Psittaciformes. However, according to Berger (1981), 13 of these species were accidental introductions. Moreover, Pratt et al. (1987) considered only one species of this order (*Psittacula krameri*) to be successful in Hawai'i. Thus, we restricted our tests to the three orders for which there was evidence for intentional introductions: Galliformes, Columbiformes, and Passeriformes.

HISTORICAL PERSPECTIVE

In order to develop a historical perspective on the phenomenon of introductions for the galliforms, columbiforms, and passeriforms, we categorized introductions by time period (Fig. 1). Historical peaks in the number of introductions were evident for each order.

For galliforms, the number of species' introductions increased steadily from 1901 until the early 1960s and then declined to zero. There has not been an introduction of a new species of galliform into the Hawaiian Islands since 1965 (*Francolinus adsperus*). For columbiforms, the peak occurred in the 1920s. Indeed, there have been only two introductions (*Zenaida asiatica* in 1961 and *Zenaida macroura* in 1962) of species from this order since 1960. The passeriforms also appear to show a decline in the number of introductions after the 1960s (Fig. 1). Closer inspection reveals an even sharper decline in the frequency of introductions, with only one new passerine species introduced since 1980 (*Estrilda astrild* in 1981). The remaining nine species were all present on other islands in the archipelago prior to 1975 and possibly arrived onto new islands via interisland colonization.

SUCCESS RATES

Success rates differed significantly among orders ($\chi^2 = 14.59$, df = 2, $P < 0.005$). Among

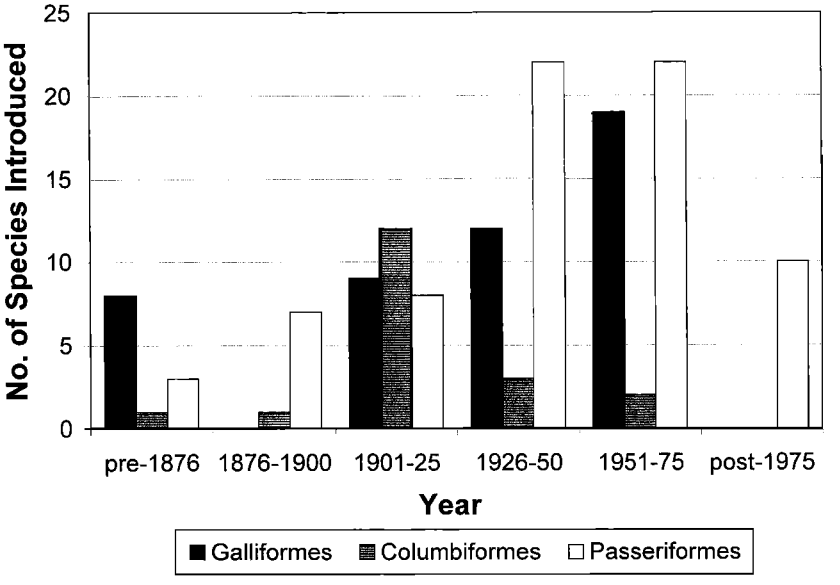

FIGURE 1. Chronology of species introductions to the Hawaiian Islands.

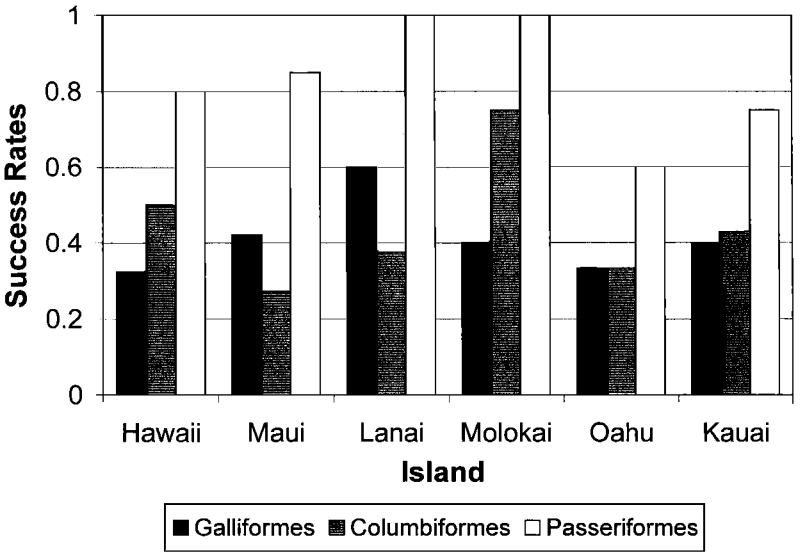

FIGURE 2. Success rates (number of successful introductions/total number of introductions) per order across the six main Hawaiian Islands.

passerines, 33 of 52 (64%) species have been successful on at least one island (Appendix 3). The success rates for galliform and columbiform species were not nearly so high. Only 12 of 40 (30%) introduced galliform species (Appendix 4) and 4 of 18 (22%) introduced columbiform species (Appendix 5) have been successful on at least one island.

Within islands the success rates also were variable (Fig. 2). For passerines, Moloka'i and Lāna'i shared the highest rates of success at 1.00 (13/13 for Moloka'i and 11/11 for Lāna'i). Lāna'i also had the highest success rate for galliforms (9/15, 0.60), whereas Moloka'i had the highest rate for columbiforms (3/4, 0.75; Fig. 2; Table 2). Although it is tempting to compare rates among islands across the different orders, results of any tests would be misleading because of the high potential for nonindependence. For example, with respect to passerines, only seven species were introduced to islands other than O'ahu (five to Kaua'i and two to Hawai'i). For galliforms, only O'ahu and Hawai'i have any unique species.

TABLE 2. SUCCESS RATES (NUMBER OF SUCCESSFUL INTRODUCTIONS/TOTAL NUMBER OF INTRODUCTIONS) PER ORDER ACROSS THE SIX MAIN HAWAIIAN ISLANDS

Island	Galliformes	Columbiformes	Passeriformes
Hawai'i	0.32	0.56	0.80
Maui	0.45	0.27	0.84
Lāna'i	0.53	0.43	1.00
Moloka'i	0.53	0.60	1.00
O'ahu	0.26	0.33	0.60
Kaua'i	0.40	0.375	0.75

ALL-OR-NONE PATTERNS

The hallmark of an all-or-none distributional pattern of introduced birds on islands would be presence of few, if any, mixed species. Mixed species are those that are successful on some islands and unsuccessul on others (Simberloff and Boecklen 1991). In principle, species released onto one island could show a mixed outcome if they spread to another island and then fail on one of the two islands. In practice this is very difficult to detect, because those species with the ability to spread to other islands could do so repeatedly giving the impression that they were established on the second island even if they were actually not able to survive there. This would be an example of what Brown and Kodric-Brown (1977) have termed a "rescue effect." With this in mind we believe that analyses for all-or-none patterns should be limited to those species that were physically introduced to more than one island.

In their analysis of introduced Hawaiian birds, Simberloff and Boecklen (1991) reported that among 19 introduced columbiform species, only one (*Pterocles exustus*) showed a mixed outcome, having succeeded on Hawai'i, and failed on Moloka'i and Kaua'i. However, Sibley and Monroe (1990) placed this species in the order Ciconiiformes. If this species is excluded, 18 columbiform species remain, 11 of which were

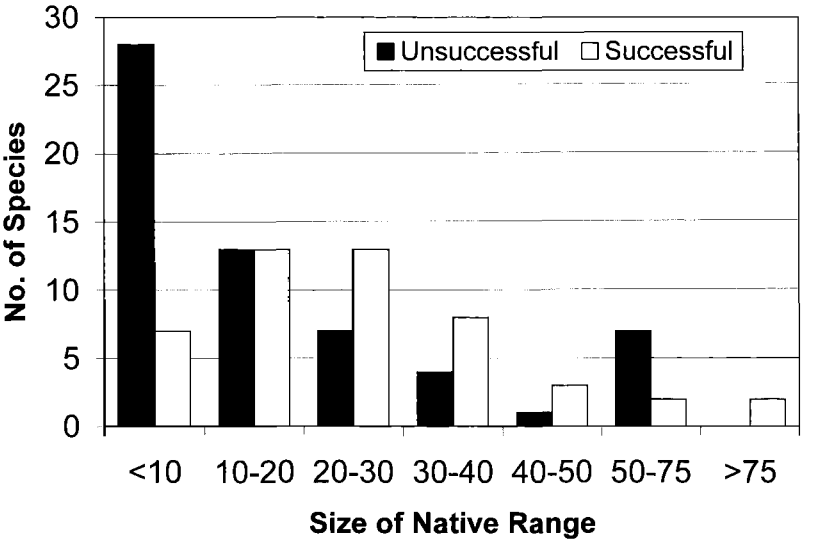

FIGURE 3. Size of native geographic range for unsuccessful versus successful introduced species. Range size measured in number of 259,000 km^2 map blocks (see Methods and Materials).

introduced onto more than one island. The observation of no mixed species out of eleven possible is evidence for an all-or-none pattern.

Among the Galliformes, 23 species were released onto two or more islands. At least seven of 23 (30%) have had mixed outcomes: *Callipepla californica, C. gambelii, Alectoris chukar, Coturnix japonica, Gallus gallus, Pavo cristatus, Meleagris gallopavo* (Appendix 4). Thus, there is not an all-or-none pattern among the introduced game birds.

Moulton and Sanderson (1997) and Moulton (1993) argued that mixed species tended to be those introduced onto more islands. With this in mind we compared the median numbers of islands of introduction for always unsuccessful, always successful, and mixed species. Medians differed significantly (H = 8.95, P = 0.012), with the highest median recorded for mixed species (6.0), and medians of 3.0 for always unsuccessful species and 6.0 for always successful species. As a further test we combined species that were always successful with those that were always unsuccessful and compared the combined median with that of the mixed species. These medians also differed significantly (H = 5.23, P = 0.022).

TABLE 3. RESULTS OF NATIVE RANGE SIZE COMPARISONS BETWEEN SUCCESSFUL (S) AND UNSUCCESSFUL (F) INTRODUCED SPECIES (MEAN NUMBER OF 259,000 KM^2 GRID SQUARES)

Order	S	F	P
Galliformes	22.2	16.6	0.099
Columbiformes	36.1	23.3	0.123
Passeriformes	33.0	17.5	0.015

RANGE SIZE

We estimated native range size for 108 introduced species. Range size was significantly larger in successful species than in unsuccessful species (approximate $\chi^2 = 10.95$, df = 1, $P < 0.001$; Fig. 3; Table 3). Within orders, range size differences were significant for passerines (P = 0.015) and marginally significant in game birds (P = 0.099). However median range size did not differ significantly between successful and unsuccessful columbiforms (P = 0.123). In all three orders, the successful species had larger median native range sizes than did unsuccessful species.

INTRODUCTION EFFORT

Data are available for only a partial test of the influence of introduction effort on introduction success. Lewin (1971) provided numbers of individuals released for 26 Galliformes on the island of Hawai'i (Table 4). Most of the data were derived from private releases by the owners of the Pu'u Wa'awa'a Ranch, but in some instances data from releases made by state agencies were included. We excluded *Coturnix japonica* because it already was successful, apparently having colonized the island from Maui and/or Lāna'i (Schwartz and Schwartz 1949), and there were no further releases by the state or the owners of the ranch. The median number of individuals introduced was 179 for successful galliform species (N = 9) and 14 for unsuccessful galliform species (N = 17). Medians

TABLE 4. NUMBER OF INDIVIDUALS OF SPECIES OF GAME BIRDS, PIGEONS, AND DOVES RELEASED ON HAWAI'I (LEWIN 1971)

Species	Number released	Status
Colinus virginianus[a]	108	F
Oreortyx pictus	88	F
Callipepla squamata	14	F
Callipepla californica	412	S
Callipepla gambelii	546	F
Callipepla douglasii	113	F
Ammoperdix griseogularis	20	F
Cyrtonyx montezumae	8	F
Alectoris chukar	110	S
Alectoris barbara	104	F
Francolinus francolinus	226	S
Francolinus pintadeanus	10	F
Francolinus pondicerianus	214	S
Francolinus adsperus	4	F
Francolinus icterorhynchus	9	F
Francolinus clappertoni	10	F
Francolinus erckelii	179	S
Francolinus leucoscepus	27	F
Coturnix chinensis	8	F
Bambusicola thoracica	12	F
Lophura leucomelanos	67	S
Gallus sonneratii	14	F
Phasianus colchicus	244	S
Syrmaticus reevesii	180	F
Pavo cristatus	2	S
Meleagris gallopavo	115	S
Zenaida macroura	168	S
Zenaida asiatica	40	F
Streptopelia risoria (= decaocto?)	11	F
Streptopelia chinensis	8	S
Geopelia striata	18	S

[a] See Appendix 1 for common names.

were significantly different in a Kruskal-Wallis test ($H = 5.25$, $P = 0.02$).

Data for the columbiforms appear to be equally compelling, although we have not tested this group since there were just seven species introduced and two of these already were established on Hawai'i at the time of the introductions by the Pu'u Wa'awa'a Ranch (Lewin 1971).

DISCUSSION

The introduction process in the Hawaiian Islands has been highly nonrandom with respect to phylogeny. Thus 10 of the 14 orders are represented by five or fewer species. The three orders that are represented by more species are those that have been the focus of intentional introductions. Thus, most galliforms were likely introduced to enhance prospects for recreational hunting, and most columbiforms were introduced for recreational hunting or for aesthetic reasons. Passerines were introduced for a variety of reasons, including biological control and aesthetic reasons, as well as accidental releases of cage birds.

The phenomenon of avian introductions, at least for the three orders we have focused on here, appears to be historical, with most introduction efforts having come to a close. There have been no columbiform or galliform introductions to the Hawaiian Islands in more than 30 years. Moreover, no new passerine species have been introduced to the islands since 1981. This is not to say that there will not be future introductions from these, or other, taxa. Indeed, there have been recent sightings of various parrot species since 1990. For example, Pyle (1994) reported that 10 to 15 Nanday Parakeets (*Nandayus nenday*) were seen on the island of Hawai'i.

In terms of success rates, we found that passerine species had a significantly higher overall success rate than either of the nonpasserine orders. The reasons for this are unclear, but the pattern is highly significant. It is possible to explain some of this result via the propagule size hypothesis. We found a significant relationship between propagule size (i.e., introduction effort) and the success rates of galliforms introduced to the island of Hawai'i. Caum (1933) also noted that several columbiform species apparently were introduced in very small numbers. However, it remains to be shown that passerines were systematically released in larger numbers.

The simplest potential predictor of the outcome of species' introductions is introduction history (Simberloff and Boecklen 1991). If introduction history alone were an adequate predictor of introduction outcomes we should have detected clear all-or-none patterns within the orders we analyzed. Moulton (1993) and Moulton and Sanderson (1997) argued that the all-or-none patterns reported for passerines introduced to the Hawaiian Islands and elsewhere may be due to sampling artifact. When we extended the analysis here to include the columbiforms and galliforms, only the columbiforms show any evidence for such a pattern. Thus, we found little evidence to support the notion that introduction history is an adequate predictor of future introduction outcomes.

Our analyses suggested that one consistent predictor of introduction success was size of native geographic range. In all three orders we observed that successfully introduced species had larger native ranges than unsuccessful species. These results are consistent with the hypothesis that species with larger ranges are ecologically more generalized (Brown 1984) and hence better able to adapt to a new environment.

In a partial test of the introduction effort hypothesis, we found that galliforms introduced successfully to Hawai'i were introduced in larger numbers than were unsuccessful species. However, it should be noted that some species were successful with initial releases of as few as two individuals; e.g., a single pair of Peafowl (*Pavo cristatus*) released on the Pu'u Wa'awa'a Ranch in 1909 led to the successful establishment of the

species on Hawai'i (Lewin 1971). Also, for 6 of the 15 unsuccessful species, >85 individuals were released (*Colinus virginianus, Callipepla douglasii, Callipepla gambelii, Syrmaticus reevesii, Oreotyx pictus, Alectoris barbara*; Table 4). We do not know if successful game birds on islands other than Hawai'i were introduced in higher numbers than were unsuccessful species. Because data are lacking for passeriform and columbiform species, a thorough test of the introduction effort hypothesis was not possible.

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APPENDIX 1. SCIENTIFIC AND COMMON NAMES OF 142 SPECIES INTRODUCED TO THE HAWAIIAN ISLANDS (NOMENCLATURE FOLLOWS SIBLEY AND MONROE 1990)

Scientific name	Common name
Acridotheres tristis	Common Myna
Agapornis roseicapillis	Rosy-faced Lovebird
Alauda arvensis	Skylark
Alectoris barbara	Barbary Partridge
Alectoris chukar	Chukar
Amandava amandava	Red Avadavat
Amazona ochrocephala	Yellow-crowned Parrot
Amazona viridigenalis	Red-crowned Parrot
Ammoperdix griseogularis	See-see Partridge
Anas discors	Blue-winged Teal
Anas platyrhynchos	Mallard
Ara macao	Scarlet Macaw
Bambusicola thoracica	Chinese Bamboo-Partridge
Brotegeris jugularis	Orange-chinned Parakeet
Bubulcus ibis	Cattle Egret
Cacatua galerita	Sulphur-crested Cockatoo
Cacatua moluccensis	Salmon-crested Cockatoo
Callipepla californica	California Quail
Callipepla douglasii	Elegant Quail
Callipepla gambelii	Gambel's Quail
Callipepla squamata	Scaled Quail
Caloenas nicobarica	Nicobar Pigeon
Cardinalis cardinalis	Northern Cardinal
Carpodacus mexicanus	House Finch
Cettia diphone	Japanese Bush-Warbler
Chalcophaps indica	Emerald Dove
Chrysolophus amherstiae	Lady Amherst Pheasant
Chrysolophus pictus	Golden Pheasant
Colinus virginianus	Northern Bobwhite
Collocalia vanikorensis	Uniform Swiftlet
Columba livia	Rock Pigeon
Copsychus malabaricus	White-rumped Shama
Copsychus saularis	Oriental Magpie-Robin
Coturnix chinensis	Blue-breasted Quail
Coturnix japonica	Japanese Quail
Coturnix pectoralis	Stubble Quail
Crax rubra	Great Currasow
Cyanoptila cyanomelana	Blue-and-White Flycatcher
Cygnus olor	Mute Swan
Cyrtonyx montezumae	Montezuma Quail
Eclectus roratus	Eclectus Parrot
Eolophus roseicapilla	Galah
Erithacus akahige	Japanese Robin
Erithacus komadori	Ryukyu Robin
Estrilda astrild	Common Waxbill
Estrilda caerulescens	Lavendar Waxbill
Estrilda melpoda	Orange-cheeked Waxbill

APPENDIX 1. CONTINUED.

Scientific name	Common name
Estrilda troglodytes	Black-rumped Waxbill
Falco (rusticolus ?)	Gyrfalcon?
Francolinus adsperus	Red-billed Francolin
Francolinus clappertoni	Clapperton's Francolin
Francolinus erckelii	Erckel's Francolin
Francolinus francolinus	Black Francolin
Francolinus icterorhynchus	Heuglin's Francolin
Francolinus leucosepus	Yellow-necked Spurfowl
Francolinus pintadeanus	Chinese Francolin
Francolinus pondicerianus	Grey Francolin
Gallicolumba luzonica	Luzon Bleeding-Heart
Gallus gallus	Red Junglefowl
Gallus sonneratii	Grey Junglefowl
Garrulax albogularis	White-throated Laughingthrush
Garrulax caerulatus	Grey-sided Laughingthrush
Garrulax canorus	Hwamei
Garrulax chinensis	Black-throated Laughingthrush
Garrulax pectoralis	Greater Necklaced Laughingthrush
Geopelia cuneata	Diamond Dove
Geopelia humeralis	Bar-shouldered Dove
Geopelia striata	Zebra Dove
Geophaps lophotes	Crested Pigeon
Geophaps plumifera	Spinifex Pigeon
Geophaps smithii	Partridge Pigeon
Geotrygon montana	Ruddy Quail-Dove
Gracula religiosa	Hill Myna
Grallina cyanoleuca	Magpie-Lark
Lagonosticta senegala	Red-billed Firefinch
Larus novaehollandiae	Silver Gull
Larus occidentalis	Western Gull
Leiothrix lutea	Red-billed Leiothrix
Leptotila verreauxi	White-tipped Dove
Leucosarcia melanoleuca	Wonga Pigeon
Lonchura cantans	African Silverbill
Lonchura malacca	Black-headed Munia
Lonchura oryzivora	Java Sparrow
Lonchura punctulata	Scaly-breasted Munia
Lophura leucomelanos	Kalij Pheasant
Lophura nycthemera	Silver Pheasant
Melanocorypha mongolica	Mongolian Lark
Meleagris gallopavo	Wild Turkey
Melopsittacus undulatus	Budgerigar
Mimus polyglottos	Northern Mockingbird
Myiopsitta monachus	Monk Parakeet
Nandayus nenday	Nanday Parakeet
Neochen jubata	Orinoco Goose
Nothoprocta perdicaria	Chilean Tinamou
Numida meleagris	Helmeted Guineafowl
Oreortyx pictus	Mountain Quail
Ortalis cinereiceps	Grey-headed Chachalaca
Paroaria capitata	Yellow-billed Cardinal
Paroaria coronata	Red-crested Cardinal
Paroaria dominicana	Red-cowled Cardinal
Parus varius	Varied Tit
Passer domesticus	House Sparrow
Passerina ciris	Painted Bunting
Passerina cyanea	Indigo Bunting
Passerina leclancherii	Orange-breasted Bunting
Pavo cristatus	Common Peafowl
Penelope purpurascens	Crested Guan
Perdix perdix	Grey Partridge
Phalacrocorax carbo	Great Cormorant
Phaps chalcoptera	Common Bronzewing
Phasianus colchicus	Ring-necked Pheasant
Phoenicopterus ruber	Greater Flamingo

APPENDIX 1. CONTINUED.

Scientific name	Common name
Platycercus adscitus	Pale-headed Rosella
Porphyrio porphyrio	Purple Swamphen
Psittacula krameri	Rose-ringed Parakeet
Pterocles exustus	Chestnut-bellied Sandgrouse
Pycnonotus cafer	Red-vented Bulbul
Pycnonotus jocosus	Red-whiskered Bulbul
Rhipidura leucophrys	Willie-Wagtail
Rollulus rouloul	Crested Partridge
Serinus leucopygius	White-rumped Seedeater
Serinus mozambicus	Yellow-fronted Canary
Sicalis flaveola	Saffron Finch
Streptopelia chinensis	Spotted Dove
Streptopelia decaocto	Eurasian Collared-Dove
Sturnella loyca	Long-tailed Meadowlark
Sturnella neglecta	Western Meadowlark
Syrmaticus reevesii	Reeve's Pheasant
Syrmaticus soemmerringii	Copper Pheasant
Tiaris olivacea	Yellow-faced Grassquit
Turnix varia	Painted Buttonquail
Tympanuchis cupido	Greater Prairie Chicken
Tympanuchus phasianellus	Sharp-tailed Grouse
Tyto alba	Barn Owl
Uraeginthus angolensis	Blue-breasted Cordonbleu
Uraeginthus bengalus	Red-cheeked Cordonbleu
Uraeginthus cyanocephala	Blue-capped Cordonbleu
Urocissa erythrorhyncha	Red-billed Blue Magpie
Vidua macroura	Pin-tailed Wydah
Zenaida asiatica	White-winged Dove
Zenaida macroura	Mourning Dove
Zosterops japonicus	Japanese White-Eye

APPENDIX 2. LIST OF 31 SPECIES FROM 11 ORDERS NOT INCLUDED IN STATISTICAL ANALYSES. WITHIN EACH CELL, THE FIRST LINE INDICATES DATE OF FIRST INTRODUCTION (OR FIRST REFERENCE TO INTRODUCTION) AND STATUS (S = SUCCESSFUL; F = FAILED); THE SECOND LINE INDICATES MODE OF INTRODUCTION (1 = PRIVATE; 2 = STATE OR COUNTY AGENCY; 3 = UNKNOWN, INCLUDES ESCAPE FROM CAPTIVITY; 4 = POLYNESIANS; 5 = HUI MANU); AND THE THIRD LINE INDICATES REFERENCE

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Nothoprocta perdicaria				1966 F 2 1		
Phalacrocorax carbo						1890s F 1 1
Phoenicopterus ruber		1929 F 1 1				
Bubulcus ibis	1959 S 1 7	1959 S 1 7	1959 S 1 7	1959 S 1 7	1959 S 1 7	1959 S 1 7
Pterocles exustus		1961 F 2 5,11		1961 S 2 5,11	1961 F 2 5,11	
Falco (rusticolus?)[a]				1929 F 1 1		

APPENDIX 2. CONTINUED.

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Turnix varia			1922 F 2 1		1922 F 2 1	
Poyphyrio porphyrio	1933 F 3 1			1928 F 2 1		
Larus novaehollandiae	1924 F 3 1					
Larus occidentalis	1933 F 3 1		1933 F 3 1			
Cygnus olor				1920 F 1 1		
Neochen jubata	1922 F 2 1					
Anas platyrhynchos[b]				1955 S 1 6		
Anas discors[c]	1932 F 2 1					
Tyto alba	1959 S 2 7	1959 S 2 7	1959 S 2 7	1958 S 2 7	1959 S 2 7,11	
Collocalia vanikorensis	1962 S 2 7					
Brotegeris jugularis	1933 F 3 1					
Cacatua galerita	1933 F 3 1					
Cacatua roseicapilla	1933 F 3 1					
Cacatua moluccensis	1981 F 3 7					
Ara macao	1933 F 3 1					
Melopsittachus undulatus	1933 F 3 1					
Psittacula krameri	1933 S 3 1,7	1981 S 3 7,10		1981 S 3 7,10		
Nandayus nenday	1981 F 3 7			1981 U 3 13		
Myiopsitta monachus	1970 F 3 7					
Amazona viridigenalis	1971 U 3 7					

APPENDIX 2. CONTINUED.

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Amazona ochrocephala	1969 F 3 7					
Eclectus roratus	1981 F 3 7					
Agapornis roseicapillis	1973 F 3 7					
Platycercus adscitus			1877 F 1 1			
Urocissa erythrorhyncha	1966 F 1 7					

References: 1 = Caum 1933; 2 = Schwartz and Schwartz 1949; 3 = Munro 1960; 4 = Walker 1966; 5 = Walker 1967; 6 = Lewin 1971; 7 = Berger 1981; 8 = Moulton and Pimm 1983; 9 = Scott et al. 1986; 10 = Pratt et al. 1987; 11 = Simberloff and Boecklen 1991; 12 = Moulton 1993; 13 = Pyle 1994; 14 = Wunz 1992.

[a] Caum (1933) listed *F. rusticolus* only as a tentative identification.

[b] May have interbred with natural migrants, as well as feral individuals.

[c] Species identity uncertain. Caum (1933) stated the species is *Querquedula discors* (Blue-winged Teal, *Anas discors*); however, he also reported that the individuals came from Australia where the Blue-winged Teal does not occur.

APPENDIX 3. INTRODUCED PASSERINES ON SIX MAIN HAWAIIAN ISLANDS (SEE APPENDIX 2 FOR EXPLANATION OF TERMS)

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Acridotheres tristis	1872 S 1 12	1883 S 3 8	1883 S 3 8	1883 S 3 8	1883 S 3 8	1883 S 3 8
Alauda arvensis	1867 S 3 12	1870 F 1 1,8	1886 S 3 8	1902 S 3 8	1917 S 3 8	1917 S 3 8
Amandava amandava	1900 S 3 12		1987 S 3 11	1987 S 3 11		
Cardinalis cardinalis	1929 S 3,5 1,8	1929 S 1 1,8	1949 S 3 8	1929 S 2 1	1951 S 3 8	1957 S 3 8
Carpodacus mexicanus	1870 S 3 12	1886 S 3 8	1886 S 3 8	1886 S 3 8	1886 S 3 8	1886 S 3 8
Cettia diphone	1929 S 1,2 1	1988 S 3 11	1980 S 3 11		1979 S 3 11	1980 S 3 11
Copsychus malabaricus	1939 S 5 11	1931 S 1 1				
Copsychus saularis	1932 F 5 1	1922 S 1 1,12				
Cyanoptila cyanomelana	1929 F 2,5 1,8			1937 F 5 8		
Erithacus akahige	1929 F 2 1					
Erithacus komadori	1931 F 3 8					
Estrilda astrild	1981 S 3 12					

APPENDIX 3. CONTINUED.

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Estrilda caerulescens	1965 S 3 12			1978 S 3 11		
Estrilda melpoda	1965 S 3 12		1989 S 3 MPM			
Estrilda troglodytes	1965 F 3 12			1975 S 3 11		
Garrulax albogularis		1919 F 1 1				
Garrulax caerulatus	1947 S 3 8					
Garrulax canorus	1900 S 3 1,8	1918 S 1 1,8	1902 S 1 1,8	1909 S 1 1,8	1909 S 1 1,8	
Garrulax chinensis		1931 F 1 1				
Garrulax pectoralis		1962 S 3 11				
Gracula religiosa	1960 S 3 11					
Grallina cyanoleuca	1922 F 2 1			1922 F 2 1		
Lagonosticta senegala	1965 F 3 11					
Leiothrix lutea	1928 S 2 1	1918 S 1 1	1928 S 2 1	1928 S 2 1	1928 S 2 1	
Lonchura cantans	1984 S 3 11	1984 S 3 11	1978 S 3 11	1972 S 3 11	1981 S 3 11	1979 S 3 11
Lonchura malacca	1936 S 3 8	1976 S 3 11				
Lonchura oryzivora	1964 S 3 12	1983 S 3 11	1986 S 3 11	1981 S 3 11		
Lonchura punctulata	1883 S 3 8,12	1883 S 3 8	1883 S 3 8	1883 S 3 8	1883 S 3 8	1883 S 3 8
Melanocorypha mongolica		1914 F 1 8				
Mimus polyglottos	1931 S 5 1,8	1946 S 3 8	1933 S 5 1,8	1959 S 3 8	1951 S 3 8	1970 S 3 11
Paroaria capitata				1973 S 3 11		
Paroaria coronata	1928 S 1,5 1,11	1928 S 3 8,11	1960 S 3 11	1976 S 3 11	1963 S 3 11	1976 S 3 11

APPENDIX 3. CONTINUED.

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Paroaria dominicana	1931 F 5 1					
Parus varius	1928 F 2 1,8	1890 F 1 1,8	1928 F 2 1,8	1928 F 2 1,8		
Passer domesticus	1871 S 3 1,8	1917 S 3 8	1917 S 3 8	1917 S 3 8	1917 S 3 8	1917 S 3 8
Passerina ciris				1937 F 5 8		
Passerina cyanea	1934 F 3 8			1937 F 5 8		
Passerina leclancherii	1941 F 5 8		1941 F 5 8,11			
Pycnonotus cafer	1966 S 3 11					
Pycnonotus jocosus	1965 S 3 11					
Rhipidura leucophrys	1926 F 2 1,8					
Serinus leucopygius	1965 F 3 11					
Serinus mozambicus	1964 S 3 11			1977 S 1 11		
Sicalis flaveola	1965 S 3 11			1966 S 3 11		
Sturnella loyca		1931 F 1 1				
Sturnella neglecta	1931 F 2 8	1931 S 1 1,11	1934 F 3 3			
Tiaris olivacea	1974 S 3 11					
Uraeginthus angolensis	1965 F 3 7					
Uraeginthus bengalus	1965 F 3 11			1973 S 3 11		
Uraeginthus cyanocephala	1969 F 3 12					
Vidua macroura	1962 F 3 12					
Zosterops japonicus	1929 S 2,5 1,11	1929 S 5 1,11	1938 S 3 8	1937 S 5 8	1938 S 3 8	1938 S 3 8

APPENDIX 4. INTRODUCED GAME BIRDS ON THE SIX MAIN HAWAIIAN ISLANDS (SEE APPENDIX 2 FOR EXPLAINATION OF TERMS)

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Crax rubra				1928 F 2 1		
Penelope purpurascens				1928 F 2 1		
Ortalis cinereiceps				1928 F 2 1		
Numida meleagris	1928 F 1 1,10	1874 F 1 1,10	1928 F 1 1,10	1928 F 1 1,10	1908 F 1 1,10	1914 F 1 1,10
Colinus virginianus	1906 F 2 1,4	1906 F 2 1,4	1906 F 2 1,4	1906 F 1 4	1906 F 2 1,4	1906 F 2 1,4
Oreortyx pictus		1929 F 2 1		1929 F 2 1		
Callipepla squamata				1961 F 2 6		
Callipepla californica	1855 F 3 1,10	1855 S 3 1,10	1855 S 3 1,10	1855 S 3 1,10	1855 S 3 1,10	1855 S 3 1,10
Callipepla gambelii	1958 F 2 4,10	1958 F 2 4,10	1958 F 2 4,10	1958 S 1,2 6,10		1958 S 2 4,10
Callipepla douglasii				1959 F 1 6		
Tympanuchus cupido	1895[a] F 1 1	1933[a,b] F 1 1				
Tympanuchus phasianellus				1932 F 2 1		
Cyrtonyx montezumae				1961 F 1 6		
Ammoperdix griseogularis				1959 F 1 6		
Alectoris chukar	1923 F 2 1,10	1957 S 2 4,10	1957 S 2 4,10	1949 S 2 5,10	1923 S 3 4,10	1923 S 3 4,10
Alectoris barbara			1961 F 2 4,10	1959 F 1,2 4,6	1961 F 2 4,10	1959 F 2 4,10
Francolinus francolinus		1959 S 2 9	1959 S 2 9	1959 S 1,2 6	1959 S 2 9	
Francolinus pintadeanus				1962 F 1 6		
Francolinus pondicerianus	1958 S 2 4,5,10	1958 S 2 4,5,10	1958 S 2 4,5,10	1959 S 1 6	1958 S 2 4,5,10	1958 S 2 5
Francolinus adsperus				1965 F 1 6		
Francolinus icterorhynchus				1961 F 1 6		

APPENDIX 4. CONTINUED.

Species	O'ahu	Kaua'i	Maui	Hawai'i	Moloka'i	Lāna'i
Francolinus clappertoni				1961 F 1 6		
Francolinus erckelii	1957 S 2 5,10	1957 S 2 5,10	1957 S 2 5,10	1958 S 1,2 6	1957 S 2 5,10	1957 S 2 5,10
Francolinus leucosepus				1959 F 2 6		
Perdix perdix		1910 F 1 1	1926 F 1 1	1929 F 2 1		
Coturnix chinensis	1922 F 2 1	1910 F 1 1	1922 F 2 1	1922 F 2 1	1922 F 2 1	
Coturnix pectoralis			1922 F 2 3			1922 F 2 3
Coturnix japonica	1921 F 3 2,10	1921 S 3 2,10	1921 S 2 1,10	1921 S 3 2,10	1921 S 3 2,10	1921 S 2 1,10
Rollulus rouloul	1924 F 2 1					
Bambusicola thoracica			1959 F 2 4,5,10	1961 F 1 6		
Lophura leucomelanos				1962 S 1 6,10		
Lophura nycthemera	1932 F 2 1	1870 F 1 1				
Gallus gallus	PH[c] S 4 2,10	PH S 4 2,10	PH F 4 2,10	PH F 4 2,10	PH F 4 2,10	PH F 4 2,10
Gallus sonnerati				1962 F 1 6		
Phasianus colchicus	1865 S 1 1,10	1865 S 1 1,10	1865 S 1 1,10	1865 S 1 1,10	1865 S 1 1,10	1865 S 1 1,10
Syrmaticus reevesii	1960 F 2 4,10	1960 F 2 4,10	1960 F 2 4,10	1959 F 1 6	1960 F 2 4,10	1960 F 2 4,10
Syrmaticus soemmerringii	1907 F 2 1	1907 F 2 1	1907 F 2 1			
Chrysolophus pictus	1932 F 2 1	1870 F 1 1				
Chrysolophus amherstiae	1932 F 2 1					
Pavo cristatus	1860 S 1 1,10	1860 F 1 1,10	1860 S 1 1,10	1928 S 1 1,10	1860 F 1 1,10	1860 F 1 1,10
Meleagris gallopavo	1815 F 1 1,10	1815 F 1 1,10	1815 S 1 1,10	1815 S 1 1,10	1815 S 1 1,14	1815 S 1 1,10

[a] May have been *Tympanuchus phasianellus* (Caum 1933).
[b] Based on "indefinite reports" (Caum 1933).
[c] Prehistoric introduction.

APPENDIX 5. INTRODUCED COLUMBIDS ON SIX MAIN HAWAIIAN ISLANDS (SEE APPENDIX 2 FOR EXPLANATION OF TERMS)

Species	O'ahu	Kaua'i	Moloka'i	Hawai'i	Moloka'i	Lāna'i
Caloenas nicobarica		1928 F 2 1	1922 F 2 1			
Chalcophaps indica	1924 F 2 1					
Columba livia	1796 S 3 1	1796 S 3 1	1796 S 3 1	1796 S 3 1	1796 S 3 1	1796 S 3 1
Gallicolumba luzonica		1929 F 1 1				
Geopelia cuneata	1928 F 2 1		1929 F 2 1			
Geopelia humeralis	1992 F 2 1	1922 F 1 1	1928 F 2 1			
Geopelia striata	1922 S 2 1	1922 S 2 1	1922 S 2 1	1922 S 2 1	1922 S 2 1	1922 S 2 1
Geophaps lophotes	1922 F 2 1			1922 F 2 1	1922 F 2 1	1922 F 2 1
Geophaps plumifera			1922 F 2 1			1922 F 2 1
Geophaps smithii			1992 F 2 1			1922 F 2 1
Geotrygon montana			1933 F 3 3			
Leptotila verreauxi			1933 F 3 3			
Leucosarcia melanoleuca			1922 F 2 1			1922 F 2 1
Phaps chalcoptera	1922 F 2 1					
Streptopelia chinensis	1879 S 3 1	1890 S 3 8	1890 S 3 8	1890 S 3 8	1890 S 3 8	1890 S 3 8
Streptopelia decaocto	1928 F 1 1	1920 F 1 1		1928 F 2 1		
Zenaida asiatica				1961 F 2 6		
Zenaida macroura				1962 S 1 9		