Combined effects of bird extinctions and introductions in oceanic islands: decreased functional diversity despite increased species richness

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Loss of island functional diversity

Abstract

Aim: We analyze the consequences of species extinctions and introductions on the functional diversity and composition of island bird assemblages. Specifically, we ask if introduced species have compensated the functional loss resulting from species extinctions.

Location: Seventy-four oceanic islands (>100 km^2) in the Atlantic, Pacific and Indian Oceans.

Time period: Late Holocene.

Major taxa studied: Terrestrial and freshwater bird species.

Methods: We compiled a species list per island (extinct and extant, native and introduced), and then compiled traits per species. We used single-trait analyses to assess the effects of past species extinctions and introductions on functional composition. Then, we used probabilistic hypervolumes in trait space to calculate functional richness and evenness of original versus present avifaunas of each island (and net change), and to estimate how functional unique are extinct and introduced species.

Results: The net effects of extinctions and introductions were: an increase in average species richness per island (alpha diversity), yet a decline in diversity across all islands (gamma diversity); an average increase in the prevalence of most functional traits, yet an average decline in functional richness and evenness, associated with the fact that extinct species were functionally more unique (when compared to extant natives) than introduced species.

Main conclusions: Introduced species are on average offsetting (and even surpassing) the losses of extinct species per island in terms of species richness, and they are increasing the prevalence of most functional traits. However, they are not compensating for the loss of functional richness due to extinctions. Current island bird assemblages are becoming functionally poorer, having lost unique species and being composed of functionally more redundant species. This is likely to have cascading repercussions on the functioning of island ecosystems. We highlight that taxonomic and functional biodiversity should be assessed simultaneously to understand the global impacts of human activities.

Keywords

Biotic homogenization, birds, compositional turnover, exotic species, extinctions, functional composition, functional diversity, introductions, oceanic islands, probabilistic hypervolume

1. Introduction

Human activities are profoundly changing the distribution of species worldwide at an alarming pace: the composition of communities is being altered both through the local or global disappearance of some species and the introduction and expansion of others (McKinney & Lockwood, 1999). Oceanic islands are among the most threatened ecosystems and their assemblages have been largely shaped by the history of human occupation: compared to continents, islands tend to have higher extinction rates by being more sensitive to habitat modification and biological invasion (Loehle & Eschenbach, 2011; Whittaker et al., 2017; Russell & Kueffer, 2019). Their discreteness, small size, simplified communities, unique biodiversity, and often recent human influence have transformed them into living laboratories remarkably useful to study the impacts of human activities and explore promising conservation strategies (Whittaker et al., 2017; Russell & Kueffer, 2019). In particular, birds have suffered a high proportion of extinctions on islands (Sax & Gaines, 2008), which affected mostly large, flightless and ground-nesting species with specialized diets (e.g. nectivores and insectivores; Boyer & Jetz, 2014). Consequently, on many islands, these non-random extinctions led to a disproportionate loss of functional diversity (Boyer, 2008; Boyer & Jetz, 2014; Sobral et al., 2016; Sayol et al., 2021), potentially causing a sharp decline in the variety of ecological functions provided by birds (e.g. Heinen et al., 2018) and ultimately affecting ecosystem functioning (Şekercioğlu et al., 2004; Sax & Gaines, 2008; Luck et al., 2012).

Although having been recently considered a fundamental question in ecology, conservation and island biogeography, it is yet unclear if introduced species can functionally replace the loss of natives (Patiño et al., 2017). Extinct and introduced bird species can have distinct functional roles, and therefore some functions once performed by extinct birds may have disappeared from some islands (Sobral et al., 2016). A recent study found that the loss of functional diversity through bird extinctions is not offset by the gain of functional diversity through bird introductions (Sayol et al., 2021). The authors showed that although introduced birds often equal or exceed the number of extinct birds, these appear to perform a narrower set of functional roles on oceanic islands. However, it remains uncertain how changes in functional diversity due to species extinctions and introductions translate into changes in function at the assemblage level. For example, while the decline in the diversity of morphological traits associated with resource use (e.g. beak size and shape) implies a loss of overall function, it is not clear if it means the loss of specific functions (e.g. pollination or insect predation) because of the complexity of mapping functions across the trait space (Pigot et al., 2020).

Functional diversity is usually measured using species traits, under the assumption that these correlate to the species function in the ecosystem (Cadotte et al., 2011). A simple but seldom used measurement of functional diversity change is to assess the changes in functional composition. These changes can be calculated as the difference between the species lost and gained for each individual trait, and measured as absolute changes for categorical (number of species belonging to each trait class – e.g. nectivore class of trait diet) and quantitative traits (average value of all species - e.g. body mass), or as relative changes for categorical traits alone (proportion of species belonging to each trait class; Boyer & Jetz, 2014; Mouillot et al., 2014). In the past two decades, a multitude of mathematical approaches have been developed to estimate and visualize the functional diversity of assemblages as a measure of trait variation or multivariate trait differences within an assemblage (Cadotte et al., 2011; Mammola et al., 2021). These often follow the Hutchinsonian niche concept, relying on the position of species or individuals within a multidimensional space. Among these, the convex hull hypervolume is one of the most used despite some important limitations, such as the assumption that the multidimensional space is homogenously occupied, making it extremely sensitive to outliers (Mammola & Cardoso, 2021; Mammola et al., 2021). To overcome this limitation, new methods have used probabilistic hypervolumes (Blonder et al., 2018), of which the most popular uses high-dimensional kernel density estimations to delineate the shape and volume of the multidimensional space (Carvalho & Cardoso 2020; Mammola & Cardoso, 2021). This density-based approach assumes a heterogeneous trait space, representing variations in point density within the multidimensional space and better reflecting the concept of niche by Hutchinson (Mammola et al., 2021). Point density is higher where more functionally similar species exist and are closer together within the multidimensional space. Thus, contrarily to other approaches where adding a species can only increase or maintain the occupied volume, in kernel density hypervolumes, adding a species may decrease the volume (i.e. functional richness), namely if the species is added to an area of the hypervolume already filled with other species (decreasing the average distance between points within the cloud).

Because many introduced birds are functionally redundant and most extinct birds were functionally unique (Sobral et al., 2016), many of the functional consequences of extinctions and introductions affect not only the overall volume and boundaries of the multidimensional space but also deeply reorganize its internal structure. Consequently, we expect that both functional richness and evenness will decrease in most oceanic islands following extinctions and introductions, and also that functional originality of extinct species will be higher than that of natives, whereas functional originality of introduced species will be lower. Moreover, as previously shown, both bird extinctions and introductions are non-random events (Boyer & Jetz, 2014), so we expect a severe decline, or even loss, of some important ecological functions provided by birds (e.g. seed dispersal; Heinen et al., 2018), which will most likely translate into drastic consequences for ecosystem functioning (e.g. regeneration of insular native forests; Şekercioğlu et al., 2004; Anderson et al., 2011).

Taking all this into account, our study aims to quantify the consequences of species extinctions and introductions on the functional diversity and composition of island bird assemblages. Focusing on 74 oceanic islands, we explore the changes in functional composition by analysing the species lost and gained in each individual trait, and calculate the changes in functional richness and evenness, as well as the functional originality of each species, using kernel density hypervolumes. Functional richness can show whether introductions compensate for the amount of functional richness lost following extinctions, whereas functional evenness can show how extinctions and introductions reshape the distribution of species within the multidimensional space. Functional originality of species can show how unique is the position of a species within the multidimensional space. We expect to provide new insights on the link between the changes in taxonomic and functional diversity by evaluating the changes of each individual trait after species extinctions and introductions. By studying the changes of each individual trait, we provide clues on which traits appear to promote extinctions or introductions, shedding a light on how ecosystem functions could be affected in the future. For example, the loss of nectivore species and their replacement by granivores (i.e. seed predators) can disrupt well-established mutualistic plant-animal interactions, particularly through reduced pollination and seed dispersal (Caves et al., 2013; Carpenter et al., 2020), drastically impairing the future of insular native forests (Şekercioğlu et al., 2004). With this functional perspective, we aim to gain valuable insights into the ecology of island bird assemblages and thus understand how to maintain their remaining functional diversity.

2. Methods

2.1. Island selection

We focused on the world's largest oceanic islands with more than 100 km^2, including single islands and also those belonging to archipelagos. From an initial list of 87 islands (Weigelt et al., 2015), we excluded 13 for which we were unable to obtain a species checklist or that do not have terrestrial or freshwater breeding bird species (see below and Table S1.1).

2.2. Bird species database

We compiled a list of known breeding bird species for each island, including extinct, extirpated and established introduced species, following the taxonomy used by Birdlife International (Handbook of the Birds of the World & BirdLife International, 2018). Given our focus on the temporal changes in species composition within islands, we also included island-level extirpations. For simplicity, we use the terms ‘extinction’ and ‘extinct’ for both global and local extinctions.

We excluded marine birds, non-breeding migrants, occasional breeders, vagrant and accidental species, and focus on regularly breeding terrestrial and freshwater species, since these are the most dependent on island resources and also have particularly high rates of extinction and introduction on oceanic islands (del Hoyo et al., 2014). To obtain a complete list of bird species for each island, we identified extant breeding species, including introduced species, from Avibase (Lepage, 2018), HBW Alive (del Hoyo et al., 2014), IUCN Red List of Threatened Species (IUCN, 2020; Fig. S3.1) and regional field guides (Table S2.2). In particular, for introductions, we also used the Global Avian Invasions Atlas (Dyer et al., 2017a) and specific literature (Table S3.3).

We considered as extinct the native species classified as Extinct and Extinct in the Wild in the *IUCN Red List of Threatened Species* (IUCN, 2020), and as Extinct or Extirpated in *Avibase* (Lepage, 2018). To improve the list of extinct species and capture extinctions prior to 1500 AD, we analysed specific literature (Hume, 2017; Paleobiology Database, 2018; Fig. S3.2), and thoroughly reviewed extinction records for each target island (Table S3.4). Species classified as Probably Extinct in the literature (especially in Hume, 2017) and Critically Endangered – Probably Extinct in the *IUCN Red List of Threatened Species* were carefully analysed and considered extinct only when the *IUCN Red List of Threatened Species* supported this claim. We only included extinct taxa if these had been identified to species level, which is often not possible from fossil or historical records. The final database comprised 759 species, including 214 extinct, 172 introduced and 445 extant natives (Table S1.1).

2.3. Bird species traits

For each species, we gathered information on body mass, foraging time, diet, foraging strata, volancy and habitat (Table S3.5). These traits are commonly used in studies evaluating bird functional diversity and summarising the effects of species on ecological processes and on responses of communities to environmental change (Boyer, 2008; Luck et al., 2012; Sobral et al., 2016; Sayol et al., 2021).

For extant species, our main source of information regarding average body mass, foraging time (‘diurnal’ or ‘nocturnal’), diet and foraging strata was the EltonTraits database (Wilman et al., 2014). For the 40 (out of 617) species missing from this database, we inferred traits from the closest species in the genus (Table S3.6). We treated average body mass both as a continuous variable, and as an ordinal trait, based on the 5-quantiles categories: 'very small', 'small', 'medium', 'large', and 'very large'. Regarding diet, we converted the information on the relative importance of each diet class in EltonTraits into six mutually exclusive binary classes: 'granivore', 'herbivore', 'frugivore', 'invertivore', 'carnivore', and 'omnivore'. In addition, to capture the unique nectar-feeding strategy, we created one binary class, 'nectivore', identifying all species dependent on nectar from Mohoidae, Meliphagidae, Trochilidae and Nectariniidae families. For foraging strata, we adapted the information on prevalence (i.e. time spent) from EltonTraits into seven binary classes: 'ground', 'understory', 'midhigh', 'canopy', 'aerial', 'water', and 'nonspecialized'. Information about flight ability (volancy) was extracted directly from Sayol et al. (2020). Information about habitat was obtained from the first level of classification of the IUCN Habitats Classification Scheme (IUCN, 2020), combined into 10 non-mutually exclusive binary classes: 'forest', 'savannah', 'shrubland', 'grassland', 'wetlands', 'desert', 'artificial aquatic habitats', 'marine habitats', 'artificial terrestrial habitats', and 'rocky and subterranean habitats'. The last three habitat classes combined IUCN habitat categories that had few and ecologically similar species, which we assumed to have similar responses to environmental variables.

For extinct bird species, we also used mostly *EltonTraits* to collect information on body mass, foraging time, diet and foraging strata (Wilman et al., 2014; Fig. S3.3). For missing species (96 out of 214) and traits, we explored additional references (Boyer, 2008; Sobral et al., 2016; Heinen et al., 2018; Crouch & Mason-Gamer, 2019; Case & Tarwater, 2020; IUCN, 2020; Sayol et al., 2020) (Fig. S3.3). Lastly, whenever information on a trait for a given species was still missing, we first attempted to derive it from descriptions of the species, or (if not possible) inferred it from the traits of the closest species in the genus (Appendix 4).

2.4. Data analysis

Data processing and statistical analyses were done in R (v.4.0.4; R Core Team, 2021).

2.4.1. Species compositional changes

We used species richness (alpha taxonomic diversity) to quantify the changes in species composition associated with bird species extinctions and introductions in each island. Then, we calculated: average loss, as the average number of extinctions per island; average gain, as the average number of introductions per island; and net change, as the difference between gains and losses (including 95% confidence intervals based on all 74 studied islands). We also calculated changes in the overall number of extinct and introduced species (gamma diversity), and the net change across all islands.

2.4.2. Effects of bird extinctions and introductions on functional composition

For each island and for each categorical trait (body mass, foraging time, diet, foraging strata, volancy and habitat), we assessed how extinctions and introductions affected functional composition, i.e. the prevalence of species associated with each trait class at the assemblage level. We did this by calculating, for each trait class in each island: 'loss', as the number of extinct species; 'gain', as the number of introduced species; and 'net change', as the difference between gain and loss. We then averaged results across islands, to obtain the average gain, loss and net change of species per island for each trait class, as well as the respective 95% confidence intervals. We calculated averages by considering only islands where the trait class was represented by at least one species, either extant or extinct. The average values were considered to be statistically significant if the 95% confidence interval did not comprise zero.

The calculations described above were done using both the absolute number of species gained and lost, and their percentages to account for differences in the number of species between island. Thus, for each island, we divided the number of species lost or gained associated with each trait class by the total number of species in the original avifauna (i.e. pre-extinctions, including extant native and extinct species, but not introduced species). This allowed us to verify if gain and loss were affected by island species richness.

For analysis of body mass as a continuous trait, we estimated, for each island, loss as the average body mass of extinct species, gain as the average body mass of introduced species, and net change as the difference between gain and loss. We then obtained average results and respective 95% confidence intervals by averaging losses, gains and net changes across islands.

To understand if extinct and introduced species are a random subset of all analysed species, we ran a series of null model analyses, each one based on 9,999 iterations. We used a null model approach for all traits (categorical and continuous) to ensure consistency. The null distributions were slightly skewed (i.e., non-normal), so we followed a non-parametric method to estimate the standardised effect size, using ses function in 'BAT' package (Mammola & Cardoso, 2021). We ran a separate null model for body mass and each of the six categorical traits, by randomly sampling the number of extinct species (*n* = 214) from a species pool considering extinct and extant bird species (*n* = 621), and the number of introduced species (*n* = 172) from a species pool considering introduced and extant bird species (*n* = 582), and calculated either the number of species in the different trait classes or the mean body mass of species in this sample. We recognize that the species pool used for introduced species only includes island bird species which is a limitation, however, we are simply trying to understand if there is a bias in introduced species and not if there is an introduction filter. As such, the extinct or introduced species pool allows us to test if the observed losses or gains, respectively, are different from what would be expected considering the extant species occurring on islands. For example, considering the categorical trait diet, if the standardised effect size for carnivore species is positive and statistically significant, it indicates that more carnivore species went extinct than would be expected considering the number of carnivore species across islands. Accordingly, the overall negative net change would be reflecting the proneness of carnivore birds to extinction.

2.4.3. Effects of bird extinctions and introductions on functional diversity

For each island, we analysed how bird species extinctions and introductions affected functional diversity, using three measures based on probabilistic hypervolumes: functional richness (alpha functional diversity), functional originality of species (i.e. uniqueness within the assemblage) and functional evenness (Fig. S3.4). To calculate these measures, we built a trait space from a matrix composed of all analysed species and 10 traits derived from those used in previous analyses (Table 1 - more details on trait selectivity can be found in Appendix 5).

(insert Table 1 here)

We computed the pairwise functional distances between each pair of species using the Gower dissimilarity index, giving the same weight to each trait (range: 0 – 0.887), and then calculated the contribution of each trait to the resulting distance matrix, using respectively dist.ktab and kdist.cor in 'ade4' package (Table S3.7; Dray & Dufour, 2007). We analysed the distance matrix through a principal coordinate analysis (PCoA) with the Cailliez correction for negative eigenvalues to extract orthogonal axes for the hypervolume delineations, using the pcoa function in the 'ape' package (Paradis et al., 2004). To construct the trait space, we retained the first eight PCoA axes, which cumulatively explained 81.3% of the total variation (Fig. S3.5).

The trait space was constructed using a Gaussian kernel density estimator with a 95% bandwidth (Blonder et al., 2018). These kernel density hypervolumes were approximated to a cloud of species-based stochastic points, which were positioned according to their traits in the multidimensional space. The 95% bandwidth means that hypervolumes represent 95% of this cloud density. The functional richness of the assemblage is estimated as the volume of the hypervolume delineated by the cloud of stochastic points (Fig. S3.4; Mammola et al., 2021). This approach assumes a heterogeneous trait space, representing variations in point density within the multidimensional space. Point density is higher where more functionally similar species exist and are closer together within the multidimensional space. Thus, adding a species may decrease functional richness, namely if the species is added to an area of the hypervolume already filled with other species, decreasing the average distance between points within the cloud.

Likewise to the taxonomic approach, we calculated the overall functional richness at two points in time: originally (i.e. including all native species, both extant and extinct); and presently (i.e. including extant native and introduced species) considering all islands (gamma diversity). For this purpose, we used the kernel.alpha function in the 'BAT' package (Cardoso et al., 2015; Mammola & Cardoso, 2021). The net change in functional richness was calculated as the difference between present and original functional richness. Then, we estimated the functional richness for each island, considering original and present avifaunas, using the kernel.alpha function in the 'BAT' package (Cardoso et al., 2015; Mammola & Cardoso, 2021). Also for each island, we calculated net change in functional richness as the difference between present and original functional richness.

Similarly, we evaluated the evenness of the total trait space for each island, considering original and present avifaunas, using kernel.evenness in 'BAT' package (Fig. S3.4; Mammola & Cardoso, 2021), and calculated net change as the difference between the two. Functional evenness of the assemblage is estimated as the overlap between the observed hypervolume and a theoretical, perfectly even hypervolume (Fig. S3.4). A high functional evenness indicates that the species are evenly distributed within the hypervolume. We then calculated average values of functional richness and evenness across islands, and respective 95% confidence intervals, for the original and the present avifaunas, and for the net change.

Finally, we evaluated the functional originality of each species (comparable to functional uniqueness) for each island, considering original and present avifaunas. Functional originality is the average dissimilarity between the species and a sample of random points within the boundaries of the hypervolume. Within each island, the sum of values across all species is equal to one. We estimated originality based on a 0.01 fraction of random points, using the kernel.originality function in the 'BAT' package (Fig. S3.4; Mammola & Cardoso, 2021). It is important to note that for each native species, we obtained two values of functional originality, one considering the original avifauna and another considering the present avifauna. For each island, we calculated the average functional originality of all extinct species and of all native species in the original avifauna, and the average functional originality of all introduced species and of all native species in the present avifauna. From these values, we estimated average values of originality for extinct and native species, and for introduced and native species across all islands, and respective 95% confidence intervals.

3. Results

Our database included 759 species in 2709 island populations, distributed across 74 oceanic islands (10 single islands and 64 belonging to 11 archipelagos; Table S1.1 and Fig. S3.6). Of these, 214 species and 280 populations were extinct, 172 species and 801 populations were introduced, and the remaining (445 species and 1628 populations) were extant natives. Some species were introduced to an island but native to another, or extinct from one island while extant on another.

3.1. Species compositional changes revealed by species richness

There was a net decrease in the total number of species (gamma diversity) across all islands, as there were more extinct than introduced species (Fig. S3.7). However, average species richness per island (alpha diversity) experienced a positive net change, since the average number of introduced species on each island was higher than the number of extinct species (Fig. S3.7 and S3.9, Table S3.8).

3.2. Effects of species compositional changes on functional composition

We found a positive average net change in the prevalence of 23 out of 34 trait classes (Fig. 1 and Table S3.9 and S3.10), meaning that, for each of those trait classes, the average number of introduced species per island associated with the trait class was higher than that of extinct species. Conversely, net change was negative for seven traits classes and non-significant for five. Qualitatively similar results were obtained when correcting for islands' species richness (using percentages of species gained and lost), with only three additional traits classes having a non-significant net change (nocturnal, invertivore and nectivore; Fig. S3.8). We thus focus on absolute numbers of introduced/extinct species.

(insert Figure 1 here)

We observed a positive net change across all classes of body mass (Fig. 1), meaning that more species were introduced than extinct in each size category. However, the average body mass of extinct species was higher than that of introduced species (natural log-transformed average body mass = 5.241g ± 0.284 > 4.513g ± 0.125, calculated across 52 and 73 islands, respectively), and there was a decrease in average body mass (-0.785 ± 0.348, calculated across 74 islands; Table S3.9).

We also found a positive net change in the prevalence of diurnal species, granivores, herbivores, invertivores, omnivores, volant species, ground, understory, nonspecialized foragers, and in species that occur in each habitat class, except marine habitats. In contrast, we found a negative net change in the prevalence of carnivores, nectivores, canopy foragers, weak flyers, and flightless species. The only introduced nocturnal bird species was the barn owl, *Tyto alba*, in all the Hawaiian Islands.

Within 4 out of 6 groups of traits, the class with the highest net change (very large body mass, diurnal foraging, ground foraging and volant species) had both the largest loss and the largest gain (Fig. 1), suggesting that these classes are, overall, the most susceptible to changes in species composition. In contrast, the class with the highest net change for both diet and habitat (granivore and occurring in artificial terrestrial habitats) had the greatest gain but not the greatest loss.

Introductions added on average more novel trait classes than those that had been lost by extinctions. Indeed, for 19 trait classes, introduced species added novel trait classes to between 1 and 18 islands (column "+" in Fig. 1), while extinctions removed 12 trait classes between 1 and 22 islands, (column "-" in Fig. 1). Weak flyers and flightless birds were particularly prone to extinction and have disappeared from almost all islands where they used to occur (weak flyers: 9/9 islands, flightless: 22/23 islands - only species, the Campbell teal *Anas nesiotis*, remains in Campbell Island).

3.3. Effects of species compositional changes on functional diversity

There was a net decrease in the overall functional richness (gamma diversity) considering all islands (before extinctions and introductions = 4.349×10^{-6} > after extinctions and introductions = 2.440×10^{-6}). Moreover, despite the net positive change in average species richness per island, we found a net negative change in average functional richness (Fig. 2a and S3.9, Table S3.8). The overall trends of taxonomic and functional richness only coincided (both decreasing or increasing) in 10 out of 74 islands (13.5% - Fig. S3.8). In 57 islands (77%), functional richness decreased despite increased species richness, while in three islands (Socorro, Floreana and San Cristóbal) there was an increase of functional richness despite a decrease in species richness (4.1%). Introduced species with traits mostly similar to extant natives were responsible for a reduced functional richness on 19 islands that had no extinctions.

(insert Figure 2 here)

The species compositional changes also led to a negative net change in average functional evenness per island, indicating that the original avifauna was, on average, more evenly distributed across the trait space than the present avifauna (Fig. 2b and S3.9).

Compared with extant native species, the average functional originality of extinct species was significantly higher, whereas that of introduced species did not differ significantly (Fig. 2c and S3.10), meaning that extinct species have a more unique position within the trait space than either extant natives or introduced species.

4. Discussion

4.1. Increase in local species richness despite net losses across islands

We found an increase in the average number of bird species per oceanic island (alpha diversity), even though overall species richness decreased across all islands (gamma diversity; Fig. S3.7). This apparent paradox reflects the fact that a smaller overall number of species were introduced, but to multiple islands (Blackburn et al., 2009; Dyer et al., 2017b), than those that went extinct, often endemic to single islands (Boyer, 2008; Boyer & Jetz, 2014). This turnover in community composition associated with extinctions and introductions is likely to increase the similarity between island bird assemblages (i.e., lowering beta diversity, promoting biotic homogenization; McKinney & Lockwood, 1999). These findings are in line with previous studies (e.g. Sobral et al., 2016; Sayol et al., 2021).

An incomplete knowledge of original island avifaunas creates uncertainty around these estimates of the magnitude of species compositional change. First, we are likely to underestimate the number of extinct species (Boehm & Cronk, 2021), given that new extinct species are still being described (e.g. Rheindt et al., 2020). Second, it is not always clear which species are native or introduced (Essl et al., 2018). It is important to keep in mind that these results are a snapshot in time; the number of introduced species is likely to continue to increase in many islands (Seebens et al., 2017). The total number of introductions may thus eventually surpass the total number of extinctions on islands.

4.2. Changes in species composition lead to changes in functional composition

We found evidence of significant changes in the ecological and morphological traits of island bird assemblages, consistent with previous studies (e.g. Sax & Gaines, 2008). The higher average island species richness was accompanied by an increased prevalence of most traits (Fig. 1 and Table S3.10).

Very large bird species were the most unstable populations in oceanic islands, having simultaneously the greatest number of extinct and introduced species than expected by chance (Table S3.10). Moreover, the average body mass of island bird assemblages decreased because the average body mass of extinct species was higher than that of introduced species. This finding provides further support that large species are particularly prone to extinction (Boyer, 2008; Fromm & Meiri, 2021).

Regarding diet classes, the largest positive net gains in prevalence were by far of granivores, followed by herbivores, omnivores and invertivores. There was no significant net change for frugivores, while for carnivores and nectivores the changes were negative. Similar trends have been described before, especially about the higher than expected number of granivore and herbivore introduced birds (Blackburn et al., 2009; Soares et al., 2021), and reflect a simplification of ecological networks; favouring lower positions in the trophic chain and unspecialized species, which are often better adapted to simplified anthropogenic landscapes, while hampering species that rely on more complex relationships, such as top positions in the trophic chain and nectarivory. These changes to island bird assemblages might disrupt well-established mutualistic plant-animal interactions and affect native plants, particularly through reduced pollination and seed dispersal (e.g. Caves et al., 2013; Carpenter et al., 2020). Herbivore birds introduced to islands that had no native browsers or grazers can greatly affect ecosystems, including by reducing food resources for pollinators and ultimately changing the phenotypic traits of plants related to pollination (e.g. flowering phenology, flower production, quantity and quality of nectar and pollen; Traveset & Richardson, 2006). Although having gained more species than lost, more herbivore species went extinct than expected, which corroborates recent studies that considered herbivore birds to be at high risk of extinction (Atwood et al., 2020). Conversely, carnivore birds have lost more species than expected by chance, having long been recognized as more extinct-prone due to their high diet specificity (Şekercioğlu et al., 2004). Their loss can have serious negative consequences to ecosystems (Şekercioğlu, 2006), such as the increase of undesirable species and disease outbreaks if predators and scavengers disappear, or the decline of guano and associated nutrients input if piscivores are loss (Şekercioğlu et al., 2004). Nectivore birds, which had a higher loss than expected, can also play a critical ecological role in the ecosystem, and their disappearance can have serious impacts on plant-bird mutualistic interactions, potentially impairing the future of insular native forests (Şekercioğlu et al., 2004; Boyer, 2008). This is particularly important in some island ecosystems that have few pollinators and many flowering plant species that depend exclusively on birds (Anderson et al., 2011).

Flightless and weak flying birds can have important and sometimes irreplaceable ecological roles in key ecosystem functions (Boyer & Jetz, 2014), such as seed dispersal, pollination and herbivory (e.g. Carpenter et al., 2020), but they have been completely eradicated from almost all islands (Sayol et al., 2020; Fromm & Meiri, 2021). This proneness to extinction was corroborated by their bigger loss than expected and is mostly a consequence of the high vulnerability to introduced mammalian predators, as most of these birds evolved in their absence (Milberg & Tyrberg, 1993; Russell & Kueffer, 2019). Competition with introduced mammals may also be important, as some of them occupy niches similar to those of flightless birds.

The prevalence of ground, understory, nonspecialized forager species and of species associated with all habitat classes (except marine) increased, while that the prevalence of canopy foragers decreased. Even though there was a clear net gain in the prevalence of forest species, even more than expected by chance, they were also the ones most subject to extinctions. The loss of forest-dependent birds is likely a direct consequence of the extreme anthropogenic deforestation that occurred on many oceanic islands (Pimm et al., 2006; Hume, 2017; Russell & Kueffer, 2019). In the Hawaiian Islands, for example, hunting and destruction of lowland forest by Polynesians extinguished many endemic forest birds, long before European arrival (Olson & James, 1982). Conversely, this replacement of island native forests by humanized habitats favoured the establishment of bird species that prefer open areas, which often have ground or unspecialized foraging strategies (Blackburn et al., 2009; Soares et al., 2021).

Overall, although islands have gained more bird species than they have lost, the functional composition of their avifaunas has changed markedly, potentially with important consequences to ecosystem functioning (e.g. Heinen et al., 2018).

4.3. More species but with common traits, resulting in decreased functional diversity

The combined effect of bird extinctions and introductions resulted in a higher average island species richness (Fig. S3.7) and an increased prevalence of most traits (Fig. 1). However, this decreased average island functional richness (Fig. 2a), indicating that introduced species tend to be functionally closer to remaining native species than what extinct species were, resulting in a more compact cloud of points in the multidimensional trait space. In a hypothetical island assemblage with two species of birds, one frugivore and one granivore, the extinction of the frugivore would decrease functional richness, whereas the introduction of several granivore species would increase the prevalence of this trait class, but not functional diversity. The net result of extinctions and introductions in such an island would be a functionally impoverished assemblage, despite the higher prevalence of granivores. Accordingly, we also observed a decrease of assemblage functional evenness (Fig. 2b) and found that, whereas extinct species were functionally more unique than those that persist, introduced species were by contrast functionally less unique (Fig. 2c). The non-random extinction and introduction of bird species was already known to impair the functional diversity of island bird assemblages (Boyer & Jetz, 2014), since introduced species do not compensate for the functional roles of extinct species (Sobral et al., 2016; Sayol et al., 2021). Moreover, the overall decrease in functional richness considering all islands also suggests that island bird assemblages might be becoming functionally homogenized (lower functional beta diversity). Recent studies have shown that the introduction of functionally similar species is promoting functional homogenization of native bird assemblages on oceanic archipelagos (Sobral et al., 2016; Sayol et al., 2021).

Islands are well-known for their high levels of endemism, unique functional traits and peculiar evolutionary patterns (Whittaker et al., 2017; Russel & Kueffer, 2019). Unfortunately, this uniqueness also makes insular species prone to anthropogenic extinctions (Hume, 2017), and their functions more difficult to replace (Boyer & Jetz, 2014). Introduced species tend to have specific ecological niches and prefer human-modified landscapes (Lee et al., 2010; Soares et al., 2021), thus it should not come as a surprise that they do not compensate for the lost functional diversity. However, more species with similar traits to the native bird species are being introduced to islands as a result of new sources in the bird trade market (more Neotropical bird species; Dyer et al., 2017b). These novel introductions appear to be better functional substitutes of extinct species and, most likely, have a great potential to outcompete native species and further push these assemblages towards a functional collapse (Soares et al., 2021).

4.4. Preserving the original functional diversity

We showed that a gain of species does not necessarily imply a gain in functional diversity, illustrating why these two facets of biodiversity should be assessed simultaneously to understand the impacts of human activities on biodiversity and ecosystem functioning. This mismatch between taxonomic, functional and even phylogenetic diversity has been observed across multiple different taxa (Brum et al., 2017), and has challenged the use of taxonomic diversity as a surrogate of functional diversity (Devictor et al., 2010). Traditionally, global conservation efforts focused on protecting species or sites that have high species richness, inadvertently underrepresenting other facets of biodiversity, such as functional diversity (Cadotte & Tucker, 2018). The non-linear and often negative relationship, as in oceanic island birds, between taxonomic and functional diversity calls for the prioritized protection of functionally unique species to maintain functional diversity. Such a line of action is also key to ensure that functional redundancy is kept, since it allows preserving ecosystem functions under further, and unfortunate, species loss.

In order to maintain functional diversity, we must prevent further loss of native ecosystems because their functioning depends on complex and irreplaceable ecological interactions (Aslan et al., 2013; Carpenter et al., 2020; Carmona et al., 2021). We also must avoid new introductions, especially of species that might affect species that perform unique functional roles, either through predation (Milberg & Tyrberg, 1993; Sax & Gaines, 2008; Loehle & Eschenbach, 2011), competition (Soares et al. 2021), or the disruption of mutualistic interactions (Caves et al., 2013; Carpenter et al., 2020). Lastly, we need to protect native species, giving particular attention to those that have unique functional traits. Many insular bird species often have characteristics considered to be adaptations to island life, such as body size changes (gigantism and dwarfism), loss of predator avoidance, flightlessness and loss of dispersal powers, naïveté toward predators and diminished clutch size (Whittaker et al., 2017; Russell & Kueffer, 2019; Sayol et al., 2020). We found that some of these characteristics have already disappeared from most islands where the species used to occur (e.g. weak flyers and flightless birds), or have drastically decreased (e.g. carnivores, nectivores, very large-bodied birds, forest and canopy foragers, and birds occurring in forests). Protecting these species known to be unique to islands is key to preserve the original functional diversity of island bird assemblages.

Functionally unique species have recently been considered key for effective conservation because they represent distinct ecological strategies and often have a disproportionally high extinction risk (Griffin et al., 2020; Carmona et al., 2021). However, in order to preserve the global diversity of ecological strategies, conservation efforts have to integrate complementary metrics, such as functional richness and functional uniqueness at multiple scales (Cooke et al., 2020). Many shortcomings still impair this integration, notably the lack of traits and distribution data for most taxa. Our work provides a framework using a density-based approach that allows capturing changes in functional diversity that do not only affect the overall volume and boundaries of the multidimensional space but also its internal structure. This framework involves the estimation of three well-known indices, functional richness, functional evenness and species functional originality (comparable to functional uniqueness), which can be explored at multiple scales, and can be applied to other taxa and other drivers of biodiversity change.

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6. Data accessibility statement

All data supporting the results present in the paper are archived in figshare and should be available after the acceptance of the paper. This data includes the species per trait matrix and the sites per species matrix. The current link to figshare repository is the following: https://doi.org/10.6084/m9.figshare.16782697.v1

670 ## 7. Tables

671 **Table 1.** Description of the 10 traits used to build the trait space.

Trait	Type	Description
Diurnal	Dichotomous	Diurnal (1), nocturnal (0)
Nectivore	Dichotomous	Nectivore (1), non-nectivore (0)
Water forager[1]	Dichotomous	Yes (1), no (0)
Forest specialist	Dichotomous	Forest specialist (1), non-forest specialist (0)
Wetland specialist	Dichotomous	Wetland specialist (1), non-wetland specialist (0)
Diet	Nominal	Granivore, herbivore, frugivore, invertivore, carnivore, omnivore
Average body mass	Quantitative	Natural log-transformed body mass
Habitat specialization	Quantitative	Number of suitable habitats listed by IUCN
Volancy	Ordinal	Flightless (1), weak flyer (2), volant (3)
Terrestrial foraging strata[2]	Ordinal	Ground (1), understory (2), midhigh (3), nonspecialized (3.5), canopy (4), aerial (5)

672 **Note:** [1]Water forager and terrestrial foraging strata are not mutually exclusive, meaning that a species can be considered, 673 for example, both water forager (1) and ground (1), as with most Anatidae species. [2]We considered nonspecialized birds, 674 species that forage in most strata between ground and aerial, and thus attributed them the average value of 3.5.

8. Figures

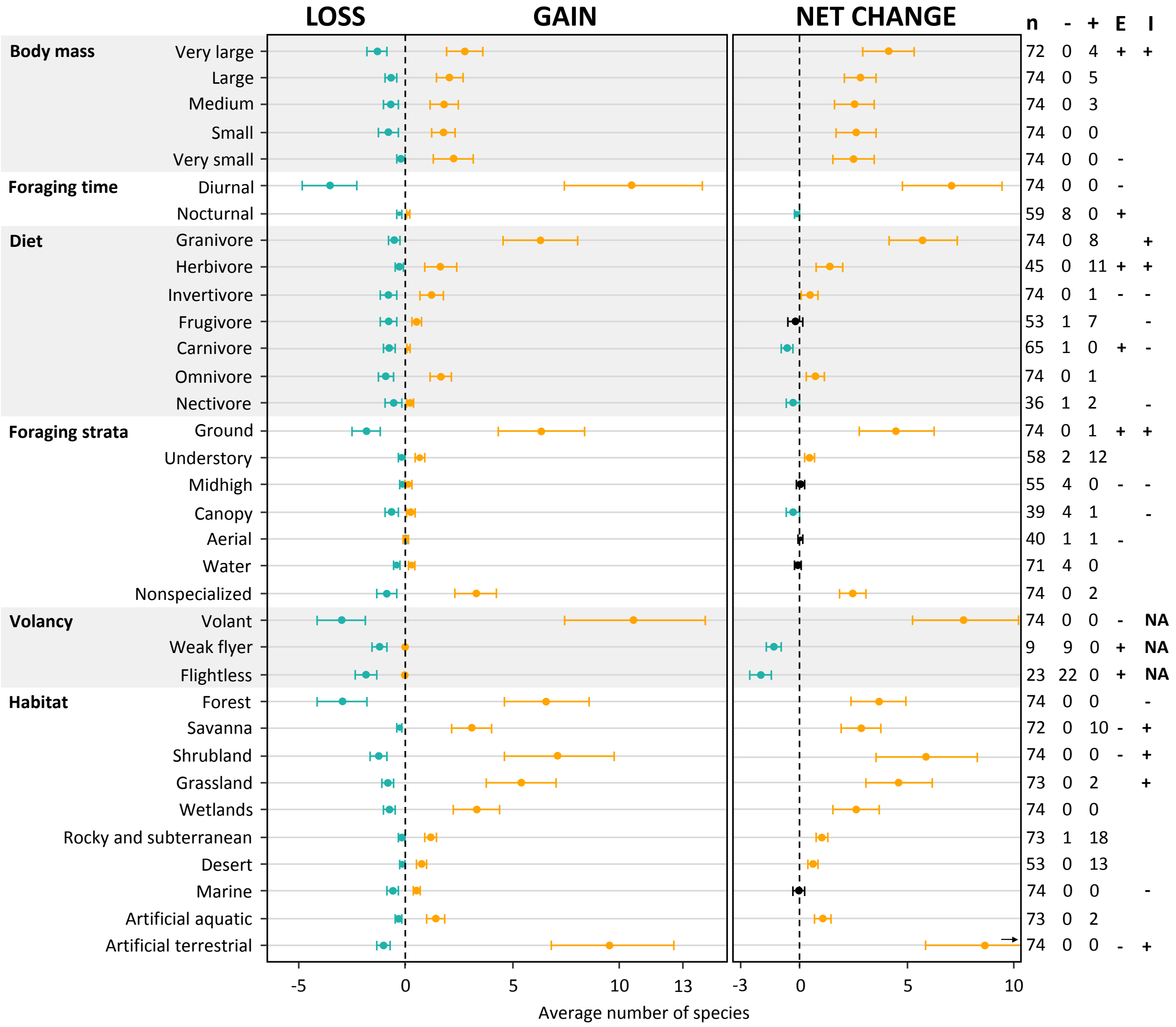

Figure 1. Effects of species compositional changes on island functional composition. For each trait class, we present the average number of species associated with the trait that were lost per island through extinctions (loss), gained through introductions (gain) and the difference between gain and loss (net change). Circles represent average values across islands, the horizontal bars the 95% confidence intervals. Non-significant values of net change (*p*-value > 0.05) are represented in black, whereas significant negative and positive values are represented in blue and yellow, respectively. Column 'n' represents the number of islands used in the calculations (i.e. with at least one species in the corresponding trait class), whereas columns '-' and '+' show respectively the number of islands that lost and gained species with a given trait. Columns 'E' and 'I' show only the significant results of the null models performed for each trait class for extinct and introduced species, respectively, where (+) and (-) indicate respectively if the standardized effect size was significantly larger or smaller than expected (NA shows that null models for volancy traits were not performed for introduced species). The arrow in the net change panel for the artificial terrestrial habitats indicates that the upper 95% confidence interval goes beyond the limits of the plot.

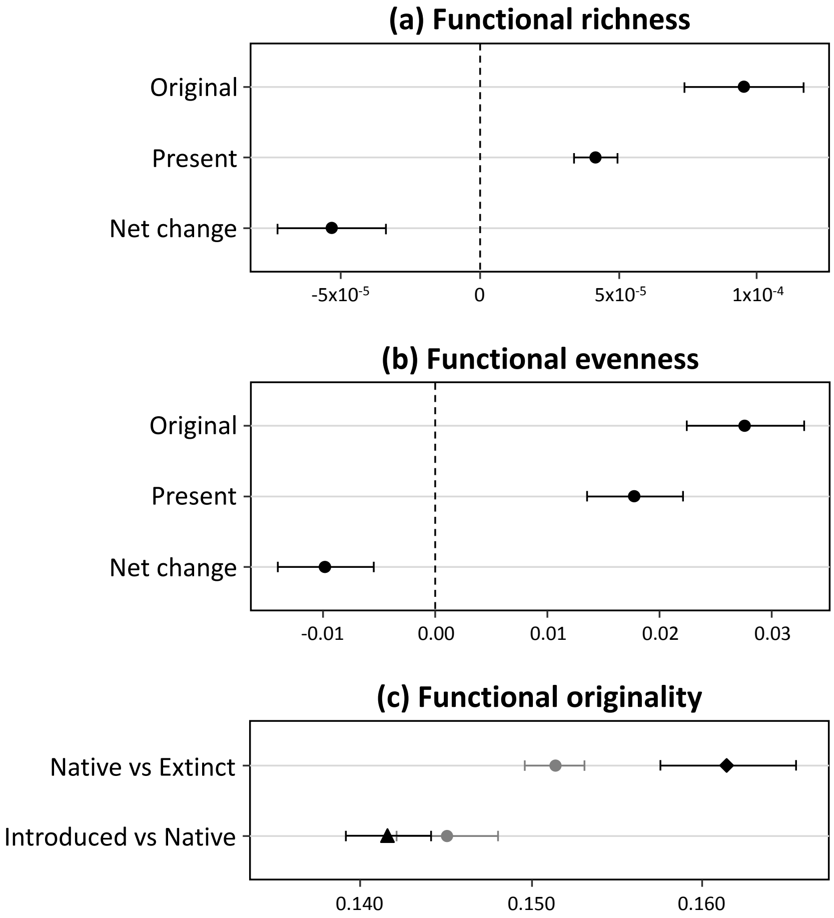

Figure 2. Effects of changes in the species composition of islands on three measures of functional diversity: (a) functional richness; (b) functional evenness; and (c) functional originality. Values presented are averages (circles) and 95% interval confidence estimates (horizontal bars) across islands. In (a) and (b), values correspond to the average volume of the trait space obtained from two probabilistic hypervolumes built for each of the 74 islands: one built with the species in original avifauna (extant native and extinct species), and another derived from the present avifauna (extant native and introduced species); net changes are the difference in volume between present and original: negative indicating a net loss in functional diversity; positive the opposite). In (c), we contrast the average functional originality of extant (circle) versus extinct (diamond) native species in the context of the original assemblages, and of introduced (triangle) versus extant native (circle) species in the context of the present assemblages. Average values were calculated, respectively, for the 52 islands with extinct species, the 73 with introduced species and the 74 with extant native species.

9. Supplementary material

Appendix 1:

Table S1.1 List of the 74 oceanic islands considered for analyses.

Appendix 2:

Table S2.2 List of the regional field guides used to curate the bird species database.

Appendix 3:

Table S3.3 Species that were reclassified as native or introduced in our database.

Table S3.4 List of references of scientific papers used to find extinct and extirpated bird species.

Table S3.5 Traits used to evaluate changes in functional composition.

Table S3.6 Extant bird species absent from the EltonTraits database and corresponding sister species.

Table S3.7 Contribution of each trait to the global distance matrix.

Table S3.8 Global change in island bird assemblages: total number of species, species richness and functional diversity metrics based on hypervolumes - functional richness, average functional originality and functional evenness.

Table S3.9 Average number of species belonging to each trait class and average body mass are represented for loss (extinct species), gain (introduced species) and net change (difference between gain and loss).

Table S3.10 Standard effective sizes and *p*-values from the null model analyses based on functional traits for extinct and introduced species.

Figure S3.1. Flow chart describing the decisions made to compile information on extant island bird species.

Figure S3.2 Flow chart describing the decisions made to compile information on extinct island bird species.

Figure S3.3 Flow chart describing the decisions made to compile information on the traits of the extinct species.

Figure S3.4 Graphical representation of (a) functional richness, (b) functional originality of each species and (c) functional evenness based on the probabilistic hypervolume approach (Adapted from Mammola & Cardoso, 2021).

Figure S3.5 Response variables projected as in PCA with scaling 1.

Figure S3.6 Location of all analysed islands that after bird extinctions and introductions had a positive net change in species richness, a negative net change and no net change.

Figure S.7 Total number of extinct and introduced species, and net change (introduced minus extinct) when considering (a) the total number of species across all islands and (b) the average number of species per island.

Figure S3.8 Effects of species compositional changes on island functional composition.

Figure S3.9 Net change values per island: species richness, functional richness and functional evenness.

Figure S3.10 Functional originality of extinct and extant native species in the original assemblage of each island, and of extant native and introduced species in the present assemblage of each island.

Appendix 4:

Traits of extinct bird species

Appendix 5:

Best combination of traits

Principal Component Analysis

Supporting information

Combined effects of bird extinctions and introductions in oceanic islands: decr

Appendix 1

reased functional diversity despite increased species richness

Table S1.1 List of the 74 oceanic islands considered for analyses. Country, archipelago (or single
of 759 species, and considering the original avifauna (extant native and extinct species) and the

Island	Archipelago	Country	Latitude	Longitude
Flores	Azores	Portugal	39.44195019	-31.20248975
Faial	Azores	Portugal	38.57821749	-28.70133237
Pico	Azores	Portugal	38.46947296	-28.33357296
São Jorge	Azores	Portugal	38.63723431	-28.02923616
Terceira	Azores	Portugal	38.72390111	-27.21229994
São Miguel	Azores	Portugal	37.79540002	-25.48189124
El Hierro	Canary Islands	Spain	27.7465263	-18.00662358
La Gomera	Canary Islands	Spain	28.11741094	-17.23260946
Lanzarote	Canary Islands	Spain	29.02447846	-13.64182499
La Palma	Canary Islands	Spain	28.68987985	-17.85832946
Fuerteventura	Canary Islands	Spain	28.40610644	-14.03648576
Gran Canaria	Canary Islands	Spain	27.95482144	-15.59319384
Tenerife	Canary Islands	Spain	28.29106238	-16.55631004
Sal	Cape Verde	Cape Verde	16.73722221	-22.93142337
Maio	Cape Verde	Cape Verde	15.21796274	-23.1606264
Boavista	Cape Verde	Cape Verde	16.09829585	-22.8139806
Fogo	Cape Verde	Cape Verde	14.92832644	-24.38432662
São Nicolau	Cape Verde	Cape Verde	16.598519	-24.25620288
Santo Antão	Cape Verde	Cape Verde	17.0565439	-25.17005504
São Vicente	Cape Verde	Cape Verde	16.84551987	-24.96781393
Santiago	Cape Verde	Cape Verde	15.08373553	-23.62480394
Santa Cruz	Galápagos	Ecuador	-0.627247533	-90.3584056
Fernandina	Galápagos Islands	Ecuador	-0.385734458	-91.51293684
Isabela	Galápagos Islands	Ecuador	-0.559292588	-91.18434395
Marchena	Galápagos Islands	Ecuador	0.332084997	-90.47574651
Santiago	Galápagos Islands	Ecuador	-0.266245407	-90.71254625
San Cristóbal	Galápagos Islands	Ecuador	-0.826798017	-89.43056011
Floreana	Galápagos Islands	Ecuador	-1.293602948	-90.43529129
Ni'ihau Island	Hawaiian Islands	United States	21.89664259	-160.1518306
Kaho'olawe Island	Hawaiian Islands	United States	20.54761153	-156.6093406
Lana'i Island	Hawaiian Islands	United States	20.83499455	-156.9270659
Moloka'i Island	Hawaiian Islands	United States	21.13317268	-157.0145176
Kaua'i Island	Hawaiian Islands	United States	22.05836307	-159.524241
Maui Island	Hawaiian Islands	United States	20.79041463	-156.336777
Hawai'i Island	Hawaiian Islands	United States	19.59808362	-155.518375
O'ahu Island	Hawaiian Islands	United States	21.45867443	-157.9733929
Tinian	Mariana Islands	Northern Mariar	15.01335054	145.6315661
Saipan	Mariana Islands	Northern Mariar	15.18912898	145.7539634
Guam	Mariana Islands	Guam	13.44353661	144.7770383
Ua Pou	Marquesas	French Polynesi	-9.39785707	-140.0739419
Nuku Hiva	Marquesas	French Polynesi	-8.866239028	-140.1393225
Hiva Oa	Marquesas	French Polynesi	-9.774777479	-139.0139219
Mauritius	Mascarene Islands	Mauritius	-20.28362628	57.57198448
La Réunion	Mascarene Islands	Reunion	-21.13334827	55.53268484
Anjouan	Mozambique Channel I	Comoros	-12.22216341	44.43643609

Mayotte	Mozambique Channel Is	Mayotte	-12.82399148	45.14392094
Grand Comore	Mozambique Channel Is	Comoros	-11.66258061	43.35420889
Príncipe	São Tomé and Príncipe	Sao Tome and Pr	1.615393603	7.397049246
São Tomé	São Tomé and Príncipe	Sao Tome and Pr	0.238989022	6.602256286
Socorro	Single Island	Mexico	18.7917511	-110.9750656
Niue	Single Island	Niue	-19.05241417	-169.858549
Christmas Island	Single Island	Christmas Island	-10.48534407	105.636553
Tutuila	Single Island	American Samoa	-14.30033425	-170.7176182
Madeira	Single Island	Portugal	32.74633725	-16.9991297
Macquarie Island	Single Island	Australia	-54.62840444	158.8639355
Campbell Island	Single Island	New Zealand	-52.54358975	169.162031
Saint Helena	Single Island	Saint Helena	-15.95940566	-5.708493692
Rodrigues	Single Island	Mauritius	-19.71670294	63.42134843
Guadalupe Island	Single Island	Mexico	29.03975791	-118.2851688
Bonaire	West Indies	Netherlands Ant	12.18452289	-68.28963405
Monserrat	West Indies	Montserrat	16.73945201	-62.18968496
Saint Kitts	West Indies	Saint Kitts and N	17.33922743	-62.76505946
Saint Lucia	West Indies	Saint Lucia	13.89843336	-60.96677353
Barbuda	West Indies	Antigua and Bar	17.63153076	-61.79337817
Antigua	West Indies	Antigua and Bar	17.07729257	-61.79838793
Grenada	West Indies	Grenada	12.11374768	-61.68377607
Dominica	West Indies	Dominica	15.43455158	-61.34998781
Saint Vincent	West Indies	Saint Vincent an	13.251309	-61.18897523
Maria Galante	West Indies	Guadeloupe	15.93211367	-61.26856868
Grand Cayman	West Indies	Cayman Islands	19.42527871	-80.87411884
Curaçao	West Indies	Netherlands Ant	12.19406424	-68.97262526
Barbados	West Indies	Barbados	13.17226216	-59.55638956
Saint Croix	West Indies	Virgin Islands, U.	17.73285959	-64.76845631
Martinique	West Indies	Martinique	14.65274682	-61.01811451

island), latitude and longitude were taken from Weigelt et al. (2015). Species richn
present avifauna (extant native and introduced species).

No. extinct	No. native	No. introduced	Species richness (original avifauna)
0	14	3	14
0	17	5	17
1	17	5	18
1	17	5	18
0	16	7	16
2	18	7	20
3	37	3	40
3	40	4	43
3	32	6	35
5	35	5	40
3	40	7	43
5	46	10	51
5	47	12	52
1	12	2	13
1	14	3	15
0	19	4	19
0	15	4	15
0	16	4	16
1	14	4	15
3	16	4	19
2	22	5	24
2	29	2	31
0	26	1	26
0	31	1	31
0	22	1	22
0	29	1	29
5	24	1	29
7	23	2	30
2	4	27	6
1	3	29	4
8	3	34	11
21	10	36	31
15	17	53	32
27	14	45	41
16	18	67	34
25	11	73	36
2	11	6	13
1	14	7	15
13	5	10	18
0	7	3	7
4	7	5	11
6	6	6	12
14	12	29	26
16	10	29	26
0	30	9	30

1	24	9	25
0	38	11	38
2	28	3	30
0	37	14	37
2	11	0	13
3	9	1	12
0	10	4	10
1	15	4	16
4	23	6	27
2	1	8	3
0	5	11	5
5	1	15	6
10	3	11	13
8	10	14	18
0	37	4	37
0	26	4	26
2	30	3	32
0	45	5	45
2	32	4	34
1	38	5	39
1	35	5	36
0	42	6	42
0	39	6	39
2	31	5	33
2	40	7	42
0	41	9	41
2	23	11	25
4	39	14	43
2	45	16	47

ess was calculated for each island from the final database with a total

Species richness (present avifauna)
17
22
22
22
23
25
40
44
38
40
47
56
59
14
17
23
19
20
18
20
27
31
27
32
23
30
25
25
31
32
37
46
70
59
85
84
17
21
15
10
12
12
41
39
39

33
49
31
51
11
10
14
19
29
9
16
16
14
24
41
30
33
50
36
43
40
48
45
36
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34
53
61

Supporting information

Combined effects of bird extinctions and introductions in oceanic islands: decr

Appendix 2

reased functional diversity despite increased species richness

Table S2.2 List of the regional fi

Island
Anjouan
Antigua
Barbados
Barbuda
Boavista
Bonaire
Campbell Island
Grand Cayman
Christmas Island
Curaçao
Dominica
El Hierro
Faial
Fernandina
Floreana
Flores
Fogo
Fuerteventura
Gran Canaria
Grand Comore
Grenada
Guadalupe Island
Guam
Hawai'i Island

Hiva Oa

Isabela

Kaho'olawe Island
Kaua'i Island

La Gomera

La Palma

La Réunion

Lana'i Island

Lanzarote

Macquarie Island

Madeira

Maio

Marchena

Maria Galante
Martinique
Maui Island

Mauritius

Mayotte
Moloka'i Island
Monserrat
Ni'ihau Island
Niue

Nuku Hiva

O'ahu Island

Pico

Príncipe

Rodrigues

Saint Croix

Saint Helena
Saint Kitts
Saint Lucia
Saint Vincent
Saipan
Sal
San Cristóbal
Santa Cruz
Santiago (Cape Verde)
Santiago (Galápagos)
Santo Antão
São Jorge
São Miguel
São Nicolau
São Tomé
São Vicente
Socorro
Tenerife
Terceira
Tinian
Tutuila
Ua Pou

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Supporting information

Combined effects of bird extinctions and introductions in oceanic islands: decreased functional diversity despite increased species richness

Appendix 3

Table S3.3 Species that were reclassified as native or introduced in our database. After a comprehensive bibliographic search, the status of 17 species was changed to introduced and one species to native.

Island	Family	Species	Dyer et al., (2017)	IUCN, (2020)	del Hoyo et al., (2014)	Reclassified status	Source
Bonaire	Icteridae	*Quiscalus lugubris*	-	Present (*Q. l. lugubris*)	-	Introduced	https://www.dutchcaribbeanspecies.org/linnaeus_ng/app/views/species/nsr_taxon.php?id=177295
Curaçao	Icteridae	*Quiscalus lugubris*	-	Present (*Q. l. lugubris*)	-	Introduced	
Kaho'olawe	Tytonidae	*Tyto alba*	-	-	Introduced (*T. alba pratincola*)	Introduced	http://hbs.bishopmuseum.org/birds/rlp-monograph
Lana'i	Columbidae	*Zenaida macroura*	-	-	Introduced	Introduced	
Lana'i	Tytonidae	*Tyto alba*	-	-	Introduced (*T. alba pratincola*)	Introduced	
Maui	Psittacidae	*Psittacula krameri*	-	-	Introduced	Introduced	
Mauritius	Ploceidae	*Foudia rubra*	Introduced	Native	Native	Native	*IUCN Red List of Threatened Species* and *HBW Alive*
Ni'ihau	Psittacidae	*Psittacula krameri*	-	-	Introduced	Introduced	http://hbs.bishopmuseum.org/birds/rlp-monograph
O'ahu	Phasianidae	*Pternistis erckelii*	-	-	Introduced	Introduced	
O'ahu	Phasianidae	*Pternistis erckelii*	-	Introduced	-	Introduced	
Príncipe	Columbidae	*Columba livia*	-	Absent	-	Introduced	https://bioone.org/journals/bulletin-of-the-british-ornithologists-club/volume-141/issue-2/bboc.v141i2.2021.a9/A-revised-bird-checklist-for-the-oceanic-islands-of-the/10.25226/bboc.v141i2.2021.a9.full
Saint Croix	Psittacidae	*Amazona ventralis*	-	Absent	-	Introduced	http://datazone.birdlife.org/species/factsheet/hispaniolan-amazon-amazona-ventralis/text
Saipan	Columbidae	*Streptopelia dusumieri*	-	-	Introduced	Introduced	http://www.gutenberg.org/files/42537/42537-h/42537-h.htm#Page_198
Saipan	Columbidae	*Streptopelia dusumieri*	-	Introduced	-	Introduced	
São Tomé	Ploceidae	*Euplectes hordeaceus*	-	-	Resident, perhaps introduced	Introduced	https://bioone.org/journals/bulletin-of-the-british-ornithologists-club/volume-

São Tomé	Columbidae	*Columba livia*	-	Absent	-	Introduced	141/issue-2/bboc.v141i2.2021.a9/A-revised-bird-checklist-for-the-oceanic-islands-of-the/10.25226/bboc.v141i2.2021.a9.full
Tinian	Columbidae	*Streptopelia dusumieri*	-	-	Introduced	Introduced	http://www.gutenberg.org/files/42537/42537-h/42537-h.htm#Page_198
Tinian	Columbidae	*Streptopelia dusumieri*	-	Introduced	-	Introduced	

Table S3.4 List of references of scientific papers used to find extinct and extirpated bird species.

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Table S3.5 Traits used to evaluate changes in functional composition.

Trait	Variable	Range/Classes	No. species	Source
Body mass	Continuous	2.61 – 22500g	759	Wilman et al., (2014)
	Categorical	Very small (<16.422g)	Very small (152)	Wilman et al., (2014)
		Small (16.422 - 37.240g)	Small (151)	
		Medium (37.240 - 98.544g)	Medium (153)	
		Large (98.544 - 327.370g)	Large (149)	
		Very large (>327.370g)	Very large (154)	
Foraging time	Categorical	Diurnal	Diurnal (734)	Wilman et al., (2014)
		Nocturnal	Nocturnal (25)	
Diet	Categorical	Granivore (> 50% seeds - class 'Seed')	Granivore (146)	Wilman et al., (2014)
		Herbivore (> 50% plants - class 'PlantO')	Herbivore (39)	
		Invertivore (> 50% invertebrates - class 'Invertebrate')	Invertivore (241)	
		Frugivore (> 50% fruits and/or nectar - class 'FruiNect')	Frugivore (104)	
		Carnivore (> 50% vertebrates, fish and/or carrion - class 'VertFishScav')	Carnivore (64)	
		Omnivore (< 50% in any of the other five classes)	Omnivore (165)	
Nectivore	Categorical	Nectivore (> 30% nectar, pollen, plant exudates, and gums - class 'Nect')	Nectivore (45)	Wilman et al., (2014)
		Non-nectivore (< 30% nectar, pollen, plant exudates, and gums - class 'Nect')	Non-nectivore (714)	
Foraging strata	Categorical	Ground (> 50% in 'ground')	Ground (314)	Wilman et al., (2014)
		Understory (> 50% in 'understory')	Understory (52)	
		Midhigh (> 50% in 'midhigh')	Midhigh (61)	
		Canopy (> 50% in 'canopy')	Canopy (51)	
		Aerial (> 50% in 'aerial')	Aerial (18)	
		Water (> 50% in summed prevalence in 'foraging below the water surface' and 'foraging on or just below the water surface')	Water (56)	
		Nonspecialized (otherwise)	Nonspecialized (207)	
Volancy	Categorical	Volant	Volant (711)	Sayol et al., (2020)
		Weak flyer	Weak flyer (9)	
		Flightless	Flightless (39)	
Habitat preferences	Categorical	Forest	Forest (591)	IUCN, (2020)
		Savannah	Savannah (131)	

	Shrubland	Shrubland (358)
	Grassland	Grassland (188)
	Wetlands	Wetlands (167)
	Rocky and subterranean habitats (IUCN categories ‘rocky areas’ and ‘caves & subterranean habitats’)	Rocky and subterranean habitats (37)
	Desert	Desert (27)
	Marine habitats (IUCN categories ‘marine neritic’, ‘marine oceanic’, ‘marine intertidal’, and ‘marine coastal/supratidal’)	Marine habitats (97)
	Artificial aquatic habitats	Artificial aquatic habitats (57)
	Artificial terrestrial habitats (IUCN categories ‘artificial – terrestrial’ and ‘introduced vegetation’)	Artificial terrestrial habitats (427)

Table S3.6 Extant bird species absent from the EltonTraits database and corresponding sister species.

Family	**Common name**	**Scientific name**	**Sister species**
Accipitridae	Variable Goshawk	*Accipiter hiogaster*	*Accipiter novaehollandiae*
Acrocephalidae	Saipan Reed-warbler	*Acrocephalus hiwae*	*Acrocephalus luscinius*
Acrocephalidae	Northern Marquesan Reed-warbler	*Acrocephalus percernis*	*Acrocephalus mendanae*
Caprimulgidae	Grey Nightjar	*Caprimulgus jotaka*	*Caprimulgus indicus*
Campephagidae	Comoro Cuckooshrike	*Coracina cucullata*	*Coracina cinerea*
Thraupidae	Grey Warbler-finch	*Certhidea fusca*	*Certhidea olivacea*
Monarchidae	Oahu Elepaio	*Chasiempis ibidis*	*Chasiempis sandwichensis*
Monarchidae	Kauai Elepaio	*Chasiempis sclateri*	*Chasiempis sandwichensis*
Nectariniidae	Grand Comoro Sunbird	*Cinnyris moebii*	*Cinnyris notatus*
Nectariniidae	Moheli Sunbird	*Cinnyris voeltzkowi*	*Cinnyris notatus*
Accipitridae	Northern Harrier	*Circus hudsonius*	*Circus cyaneus*
Picidae	Red-shafted Flicker	*Colaptes cafer*	*Colaptes auratus*
Psittacidae	Comoro Parrot	*Coracopsis sibilans*	*Coracopsis nigra*
Alcedinidae	Príncipe Kingfisher	*Corythornis nais*	*Corythornis leucogaster*
Alcedinidae	São Tomé Kingfisher	*Corythornis thomensis*	*Corythornis cristatus*
Vangidae	Comoro Blue Vanga	*Cyanolanius comorensis*	*Cyanolanius madagascarinus*
Fringillidae	Lesser Antillean Euphonia	*Euphonia flavifrons*	*Euphonia musica*
Ploceidae	Grand Comoro Fody	*Foudia consobrina*	*Foudia eminentissima*
Fringillidae	Gran Canaria Blue Chaffinch	*Fringilla polatzeki*	*Fringilla teydea*
Pycnonotidae	Moheli Bulbul	*Hypsipetes moheliensis*	*Hypsipetes parvirostris*
Fringillidae	Maui Akepa	*Loxops ochraceus*	*Loxops coccineus*
Motacillidae	Eastern Yellow Wagtail	*Motacilla tschutschensis*	*Motacilla alba*
Passerellidae	Sooty Fox-sparrow	*Passerella unalaschcensis*	*Passerella iliaca*
Passerellidae	Socorro Towhee	*Pipilo socorroensis*	*Pipilo maculatus*
Monarchidae	Ua Pou Monarch	*Pomarea mira*	*Pomarea mendozae*
Columbidae	Samoan Fruit-dove	*Ptilinopus fasciatus*	*Ptilinopus porphyraceus*
Tyrannidae	Little Vermilion Flycatcher	*Pyrocephalus nanus*	*Pyrocephalus rubinus*
Parulidae	Audubon's Warbler	*Setophaga auduboni*	*Setophaga coronata*
Parulidae	Socorro Parula	*Setophaga graysoni*	*Setophaga pitiayumi*
Columbidae	Philippine Collared-dove	*Streptopelia dusumieri*	*Streptopelia bitorquata*
Columbidae	Comoro Green-pigeon	*Treron griveaudi*	*Treron australis*
Turdidae	Eastern Red-legged Thrush	*Turdus ardosiaceus*	*Turdus plumbeus*
Turdidae	Dusky Thrush	*Turdus eunomus*	*Turdus naumanni*
Turdidae	Western Red-legged Thrush	*Turdus rubripes*	*Turdus plumbeus*
Turdidae	Príncipe Thrush	*Turdus xanthorhynchus*	*Turdus olivaceofuscus*
Zosteropidae	São Tomé White-eye	*Zosterops feae*	*Zosterops ficedulinus*
Zosteropidae	Kirk's White-eye	*Zosterops kirki*	*Zosterops maderaspatanus*

Zosteropidae	Mauritius Grey White-eye	*Zosterops mauritianus*	*Zosterops borbonicus*
Zosteropidae	Saipan White-eye	*Zosterops saypani*	*Zosterops conspicillatus*

Table S3.7 Contribution of each trait to the global distance matrix.

Trait	Contribution to distance matrix
Diet	0.516
Forest specialist	0.496
Volancy	0.394
Nectivore	0.364
Water forager	0.352
Terrestrial foraging strata	0.351
Body mass	0.278
Foraging time	0.273
Habitat specialization	0.270
Wetland specialist	0.267

Table S3.8 Global change in island bird assemblages: total number of species, species richness and functional diversity metrics based on hypervolumes - functional richness, average functional originality and functional evenness. The averages and respective 95% interval confidence estimates (parenthesis) are represented for the original (extant native and extinct species) and present avifaunas (extant native and introduced species). Net change was calculated as the difference between present and original avifaunas for each island. The last column shows the number of islands used to calculate original, present and net change.

	Original	**Present**	**Net change**	**No. islands**
Total number of species	214	172	-42	74;74;74
Species richness				74;74;74
Functional richness	9.53×10^{-5} (7.4×10^{-5}; 1.166×10^{-4})	4.16×10^{-5} (3.37×10^{-5}; 4.95×10^{-5})	-5.37×10^{-5} (-3.39×10^{-5}; -7.34×10^{-5})	74;74;74
Functional originality				
Extinct	0.162 (0.158; 0.166)	-	-	52;52;52
Introduced	-	0.142 (0.139; 0.144)	-	73;73;73
Native	0.151 (0.150; 0.153)	0.146 (0.142; 0.149)	-	74;74;74
Functional evenness	0.028 (0.023; 0.033)	0.018 (0.014; 0.022)	-0.010 (-0.014; -0.006)	74;74;74

Table S3.9 Average number of species belonging to each trait class and average body mass (and respective 95% confidence intervals in parenthesis), are represented for loss (extinct species), gain (introduced species) and net change (difference between gain and loss). Note that losses are always negative, whereas gains are always positive. Average results and respective 95% confidence intervals were obtained by averaging losses, gains and net change across islands. The last column shows the number of islands used to calculate loss, gain and net change.

Trait	Loss	Gain	Net change	No. island
Average body mass	-5.241 (-4.957; -5.526)	4.513 (4.388; 4.639)	-0.785 (-1.133; -0.437)	52;73;52
Body mass				
Very large	-1.351 (-1.842; -0.861)	2.811 (1.968; 3.653)	4.162 (2.945; 5.380)	72;72;72
Large	-0.716 (-1.002; -0.430)	2.108 (1.506; 2.710)	2.824 (2.103; 3.545)	74;74;74
Medium	-0.676 (-1.017; -0.335)	1.865 (1.194; 2.536)	2.541 (1.589; 3.492)	74;74;74
Small	-0.811 (-1.297; -0.325)	1.811 (1.256; 2.366)	2.622 (1.663; 3.580)	74;74;74
Very small	-0.236 (-0.396; -0.076)	2.292 (1.365; 3.219)	2.528 (1.559; 3.496)	74;74;74
Foraging time				
Diurnal	-3.554 (-4.840;-2.268)	10.716 (7.473; 13.959)	7.162 (4.831; 9.494)	74;74;74
Nocturnal	-0.288 (-0.417;-0.160)	0.136 (0.046; 0.226)	-0.153 (-0.288;-0.017)	59;59;59
Diet				
Granivore	-0.568 (-0.833;-0.302)	6.378 (4.604; 8.153)	5.811 (4.215; 7.407)	74;74;74
Herbivore	-0.311 (-0.531;-0.091)	1.689 (0.942; 2.435)	1.378 (0.762; 1.993)	45;45;45
Invertivore	-0.824 (-1.205;-0.444)	1.243 (0.677; 1.809)	0.419 (0.008; 0.830)	74:74;74
Frugivore	-0.811 (-1.227;-0.396)	0.547 (0.341; 0.753)	-0.264 (-0.615;0.087)	53;53;53
Carnivore	-0.769 (-1.012;-0.526)	0.154 (0.064; 0.244)	-0.615 (-0.858;-0.373)	65:65;65
Omnivore	-0.946 (-1.276;-0.616)	1.649 (1.149; 2.148)	0.703 (0.249; 1.156)	74;74;74
Nectivore	-0.556 (-0.955;-0.156)	0.222 (0.080; 0.365)	-0.333 (-0.636;-0.031)	36;36;36
Foraging strata				
Ground	-1.878 (-2.525;-1.232)	6.392 (4.347; 8.437)	4.514 (2.759; 6.268)	74;74;74
Understory	-0.224 (-0.380;-0.068)	0.672 (0.434; 0.911)	0.448 (0.227; 0.669)	58;58;58
Midhigh	-0.145 (-0.242;-0.049)	0.145 (0.014; 0.277)	0.000 (-0.165;0.165)	55;55;55
Canopy	-0.641 (-0.952;-0.330)	0.282 (0.117; 0.447)	-0.359 (-0.687;-0.031)	39;39;39
Aerial	-0.025	0.050	0.025	40;40;40

	(-0.076;0.026)	(-0.051;0.151)	(-0.089;0.139)	
Water	-0.408 (-0.576;-0.241)	0.296 (0.124; 0.467)	-0.113 (-0.298;0.073)	71;71;71
Nonspecialized	-0.878 (-1.340;-0.417)	3.338 (2.344; 4.331)	2.459 (1.823; 3.096)	74;74;74
Volancy				
Volant	-3.054 (-4.161;-1.947)	10.824 (14.129; 7.520)	7.770 (5.256; 10.285)	74;74;74
Weak flyer	-1.870 (-2.396;-1.343)	0.000 (0.000; 0.000)	-1.870 (-2.396;-1.343)	9;9;9
Flightless	-1.222 (-1.561;-0.883)	0.000 (0.000; 0.000)	-1.222 (-1.561;-0.883)	23;23;23
Habitat				
Forest	-2.973 (-4.134;-1.812)	6.649 (4.662; 8.636)	3.676 (2.401; 4.950)	74;74;74
Savannah	-0.278 (-0.391;-0.165)	3.111 (2.198; 4.024)	2.833 (1.896; 3.771)	72;72;72
Shrubland	-1.311 (-1.702;-0.920)	7.257 (4.698; 9.815)	5.946 (3.591; 8.301)	74;74;74
Grassland	-0.849 (-1.103;-0.595)	5.479 (3.855; 7.103)	4.630 (3.090; 6.170)	73;73;73
Wetlands	-0.770 (-1.032;-0.509)	3.378 (2.282; 4.474)	2.608 (1.536; 3.680)	74;74;74
Rocky and subterranean habitats	-0.192 (-0.313;-0.071)	1.219 (0.961; 1.478)	1.027 (0.726; 1.329)	73;73;73
Desert	-0.170 (-0.274;-0.065)	0.755 (0.526; 0.983)	0.585 (0.318; 0.852)	53;53;53
Marine	-0.635 (-0.900;-0.371)	0.541 (0.386; 0.695)	-0.095 (-0.358;0.169)	74;74;74
Artificial aquatic habitats	-0.370 (-0.518;-0.222)	1.452 (1.048; 1.856)	1.082 (0.686; 1.478)	73;73;73
Artificial terrestrial habitats	-1.027 (-1.348 -0.706)	9.730 (6.845; 12.615)	8.703 (5.855; 11.551)	74;74;74

Table S3.10 Standard effective sizes (SES) and *p*-values from the null model analyses based on functional traits for extinct and introduced species. As the test is two-sided, the statistical significance is indicated by *p*-value < 0.025 or *p*-value > 0.975. Null models for volancy were not performed for introduced species because all introduced birds were volant.

Trait	Extinct species		Introduced species	
	SES	*p*-value	SES	*p*-value
Average body mass	3.719	0.999	3.719	0.999
Body mass				
Very large	3.719	0.999	2.495	0.994
Large	0.936	0.825	0.830	0.797
Medium	-0.692	0.245	-1.271	0.102
Small	0.984	0.838	-0.117	0.454
Very small	-3.719	0.0001	-1.700	0.045
Foraging time				
Diurnal	-2.628	0.004	1.625	0.948
Nocturnal	2.620	0.996	-1.784	0.037
Diet				
Granivore	1.180	0.881	3.719	0.999
Herbivore	1.288	0.901	3.719	0.999
Invertivore	-3.615	0.0002	-3.719	0.0001
Frugivore	0.303	0.619	-3.719	0.0001
Carnivore	2.310	0.990	-3.615	0.0002
Omnivore	0.644	0.740	-0.487	0.313
Nectivore	0.125	0.550	-3.719	0.0001
Foraging strata				
Ground	3.719	0.999	3.719	0.999
Understory	-1.417	0.078	-1.064	0.144
Midhigh	-3.264	0.0006	-3.353	0.0004
Canopy	1.124	0.869	-2.445	0.007
Aerial	-2.770	0.003	-1.687	0.046
Water	-0.933	0.175	-1.480	0.069
Nonspecialized	-1.140	0.127	-0.775	0.219
Volancy				
Volant	-3.719	0.0001	-	-
Weak flyer	3.609	0.999	-	-
Flightless	3.719	0.999	-	-
Habitat				
Forest	0.922	0.822	-3.719	0.0001
Savannah	-3.720	0.0001	3.216	0.999
Shrubland	-3.719	0.0001	3.481	0.999
Grassland	-1.680	0.046	3.719	0.999
Wetlands	-0.834	0.202	1.598	0.945
Rocky and subterranean	-0.087	0.465	-1.088	0.138
Desert	-1.207	0.114	0.461	0.678
Marine	-1.121	0.131	-3.719	0.0001
Artificial aquatic	0.924	0.822	0.916	0.820
Artificial terrestrial	-3.719	0.0001	3.719	0.999

Figure S3.1. Flow chart describing the decisions made to compile information on extant island bird species.

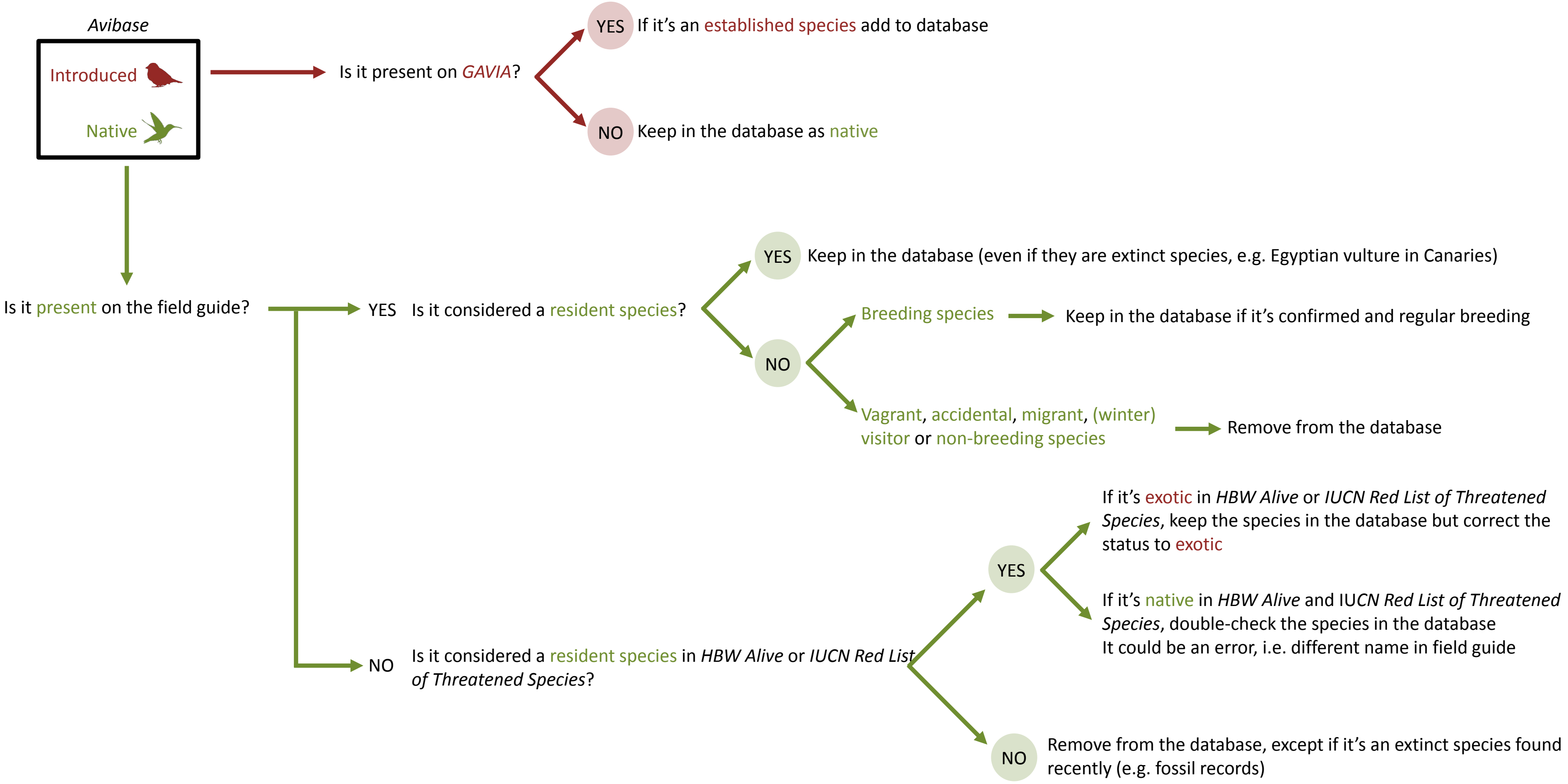

Figure S3.2 Flow chart describing the decisions made to compile information on extinct island bird species.

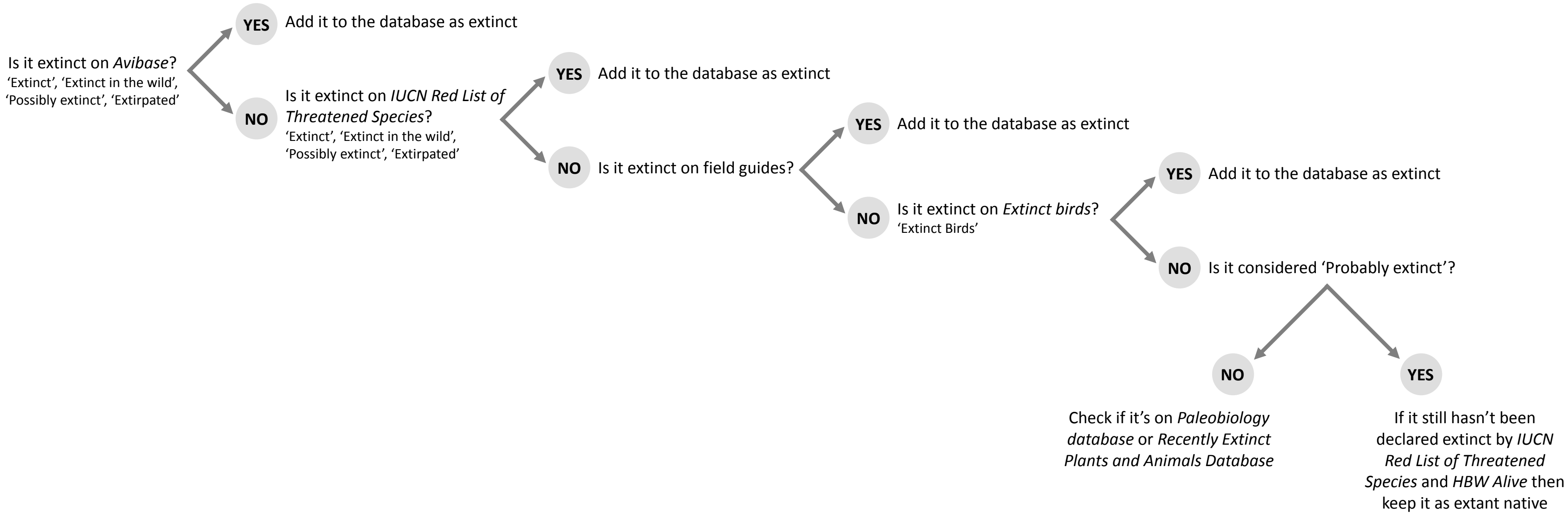

Figure S3.3 Flow chart describing the decisions made to compile information on the traits of the extinct species.

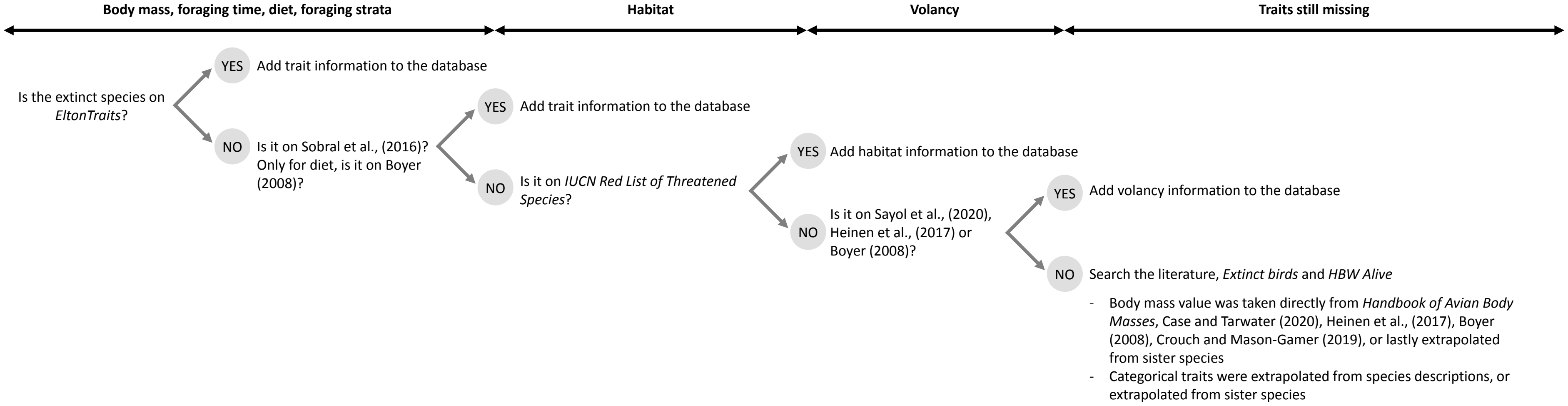

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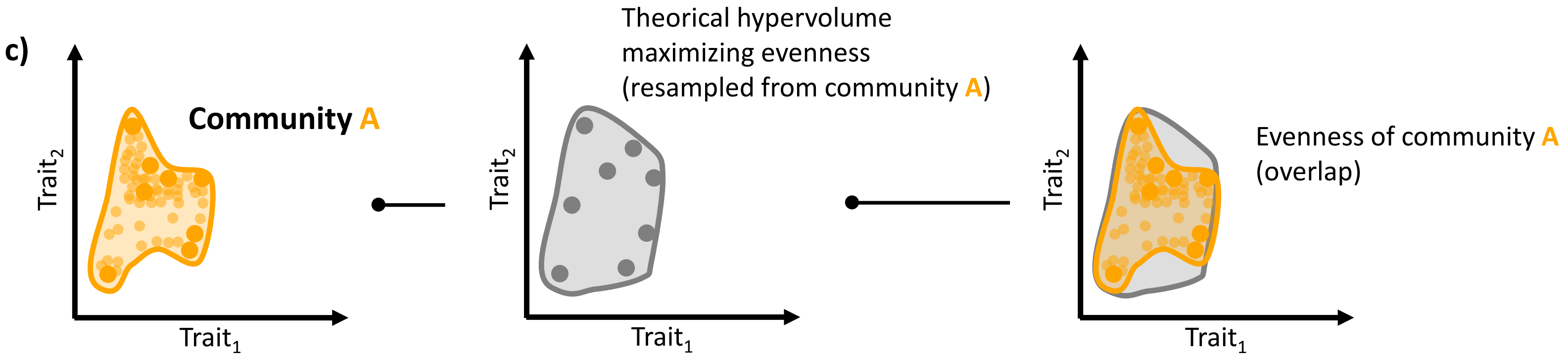
Figure S3.4 Graphical representation of (a) functional richness, (b) functional originality of each species and (c) functional evenness based on the probabilistic hypervolume approach (Adapted from Mammola & Cardoso, 2021).

Functional richness (probabilistic hypervolume)
The trait space can be constructed using kernel density hypervolumes, whereby it is approximated as a cloud of stochastic points sampled based on a set of observations (e.g. the traits of the species in the community)

Functional originality
Average distance between the observation (species) and a sample of stochastic points



Functional evenness
Regularity of functional elements distribution within the total trait space

Figure S3.5 Response variables projected as in PCA with scaling 1. The first forth orthogonal axes of the principal coordinate analysis (PCoA) with Cailliez correction are represented. Eight axes were retained and cumulatively explained 81.3% of the total variation (1st PCoA = 22.1%, 2nd PCoA = 36.9%, 3rd PCoA = 49.3%, 4th PCoA = 59.2%, 5th PCoA = 67.1%, 6th PCoA = 72.3%, 7th PCoA = 77%, 8th PCoA = 81.3%). The purpose of the different colours of the traits is only to improve the readability of plots.

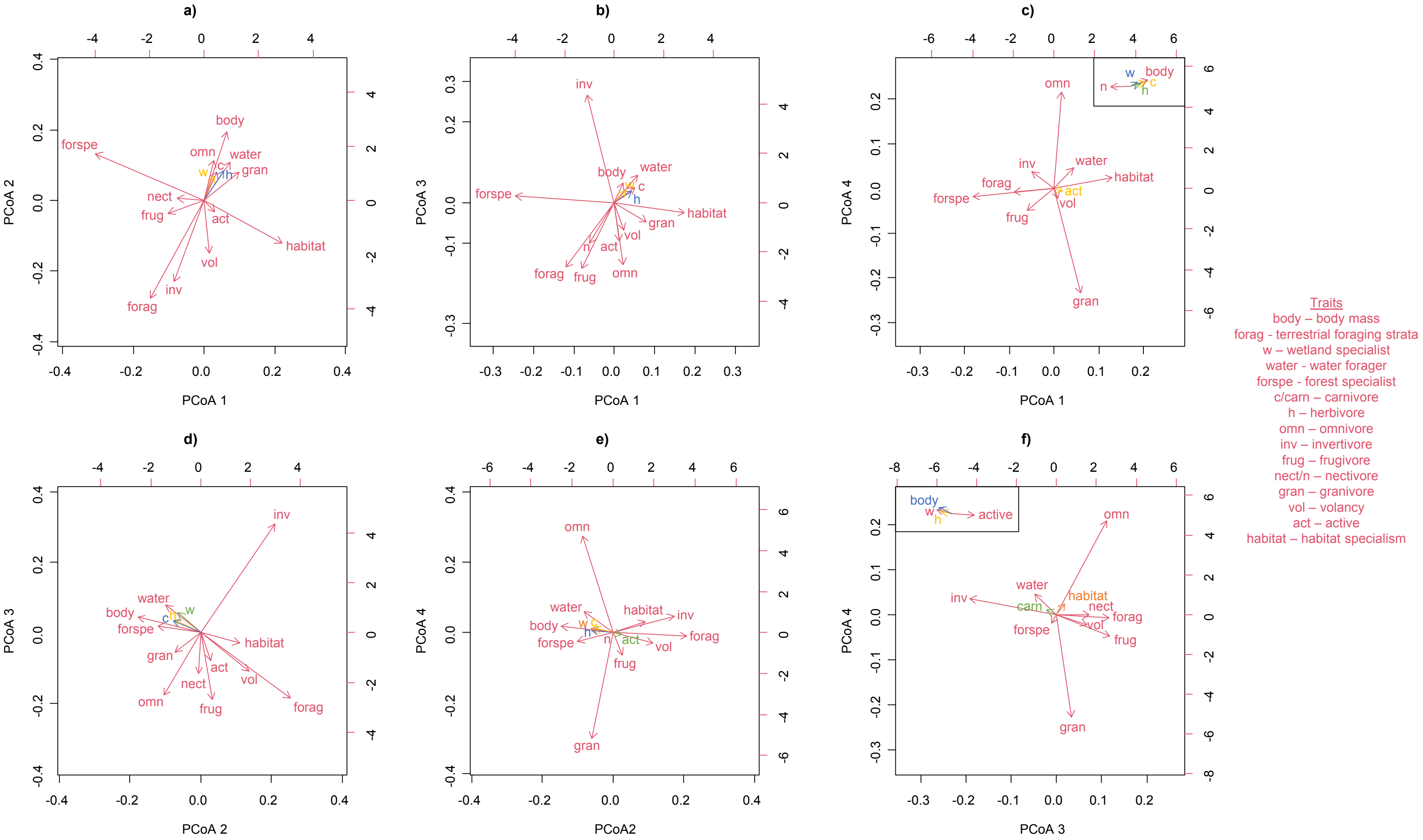


Figure S3.6 Location of all analysed islands that after bird extinctions and introductions had: a positive net change in species richness (n = 51; green); a negative net change (n = 5; red); and no net change (n = 22; black). The size of the dots represents the absolute value of net change in species richness per island.

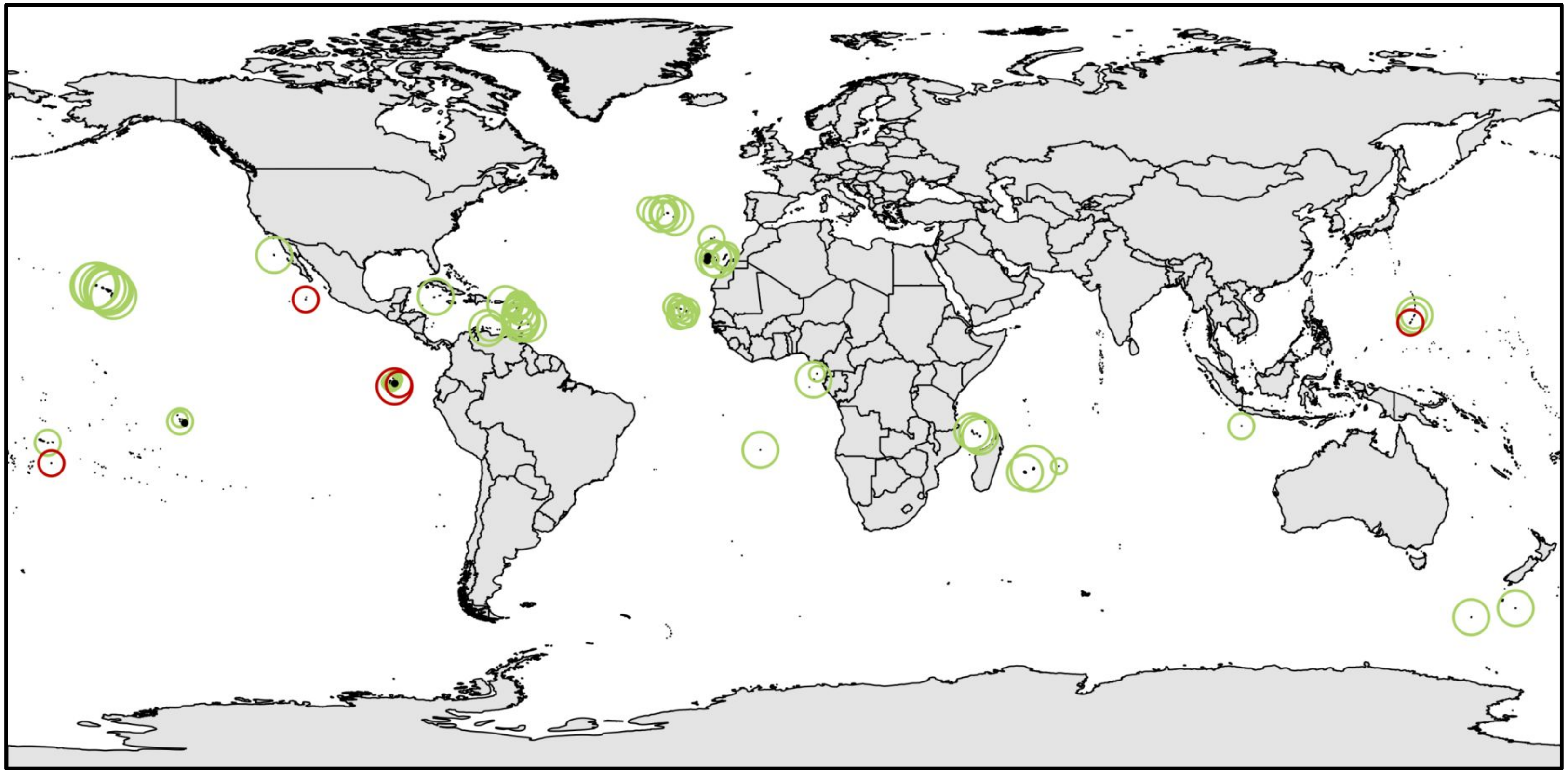


Figure S3.7 Total number of extinct and introduced species, and net change (introduced minus extinct) when considering (a) the total number of species across all islands and (b) the average number of species per island. In (b), the averages (circles) and 95% interval confidence estimates (horizontal bars) were obtained from values across each of the 74 islands. A negative net change indicates that the original avifauna tended to have a higher species richness than the present avifauna, whereas a positive net change indicates the opposite.

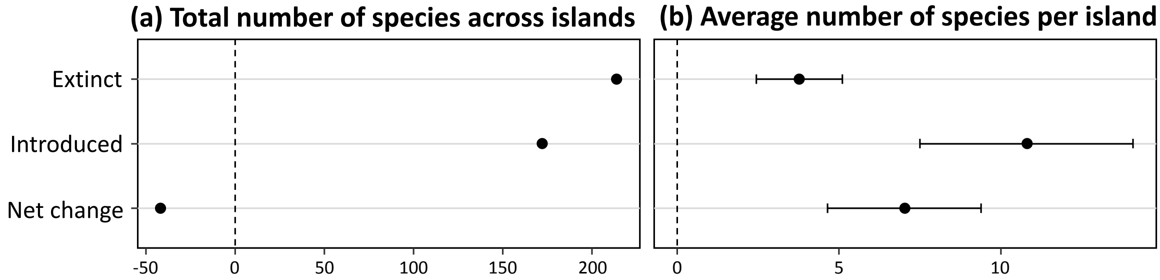


Figure S3.8 Effects of species compositional changes on island functional composition. For each trait class, it is presented the average percentage of species lost per island through extinctions (loss), gained through introductions (gain) and the difference between gain and loss (net change). The percentage of species equals to the number of species lost or gained belonging to each trait class divided by the total number of species in the original avifauna. Circles represent average values across all islands, the horizontal bars the 95% confidence intervals. Non-significant values of net change (p-value > 0.05) are represented in black.

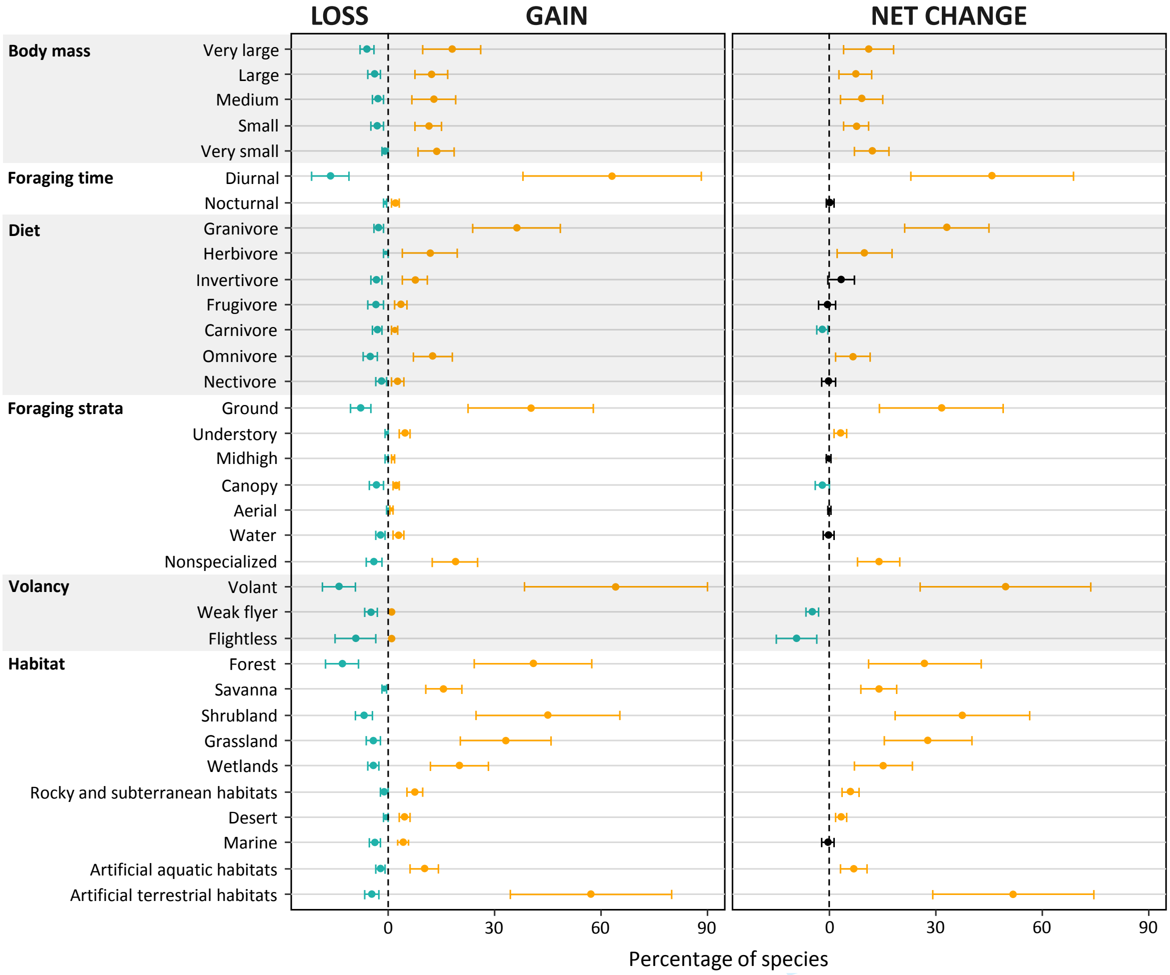


Figure S3.9 Net change values per island: species richness (65 positive values in yellow, 5 negative in blue, 4 null in black), functional richness (12 positive, 62 negative) and functional evenness (11 positive, 63 negative).

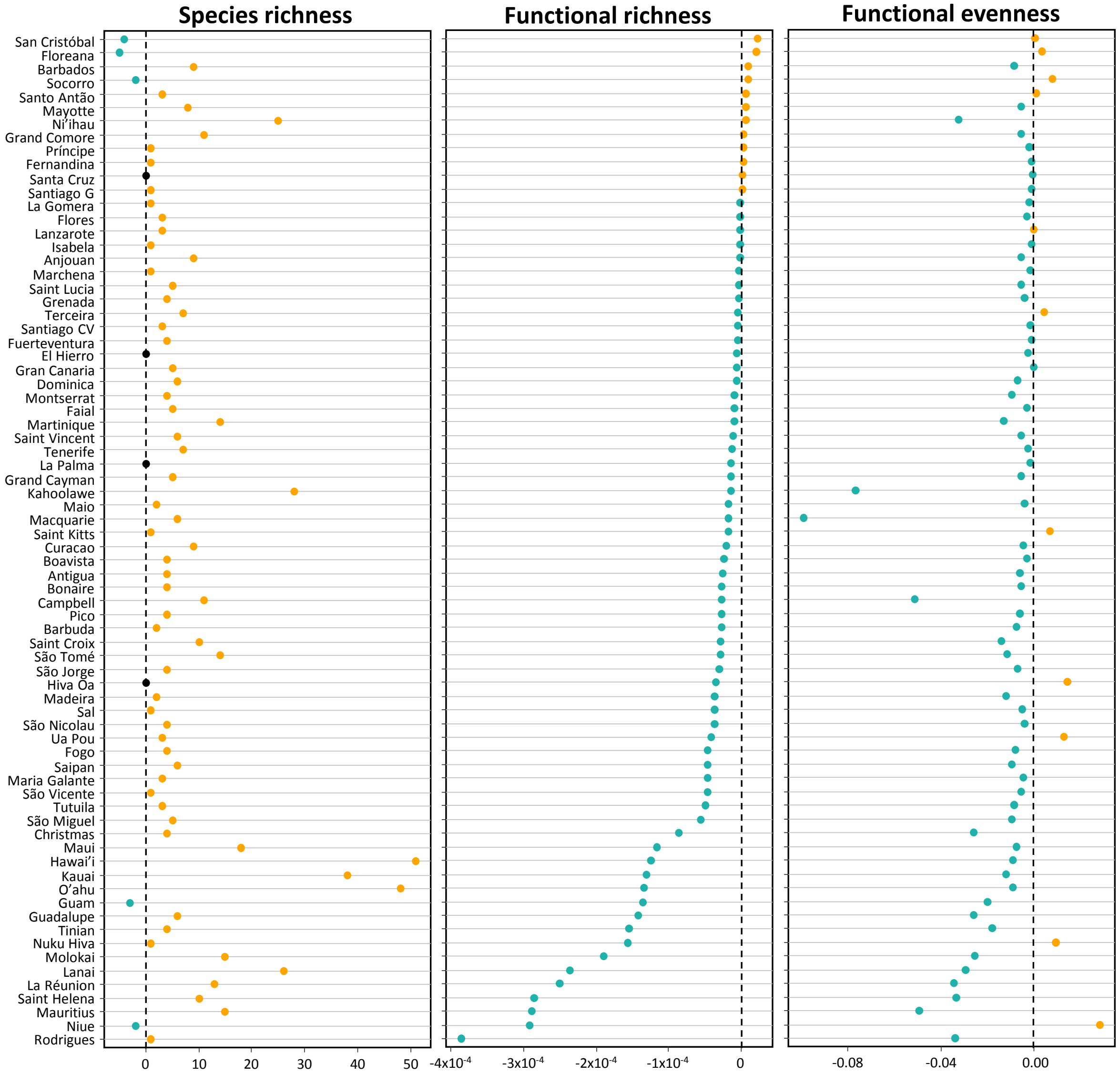
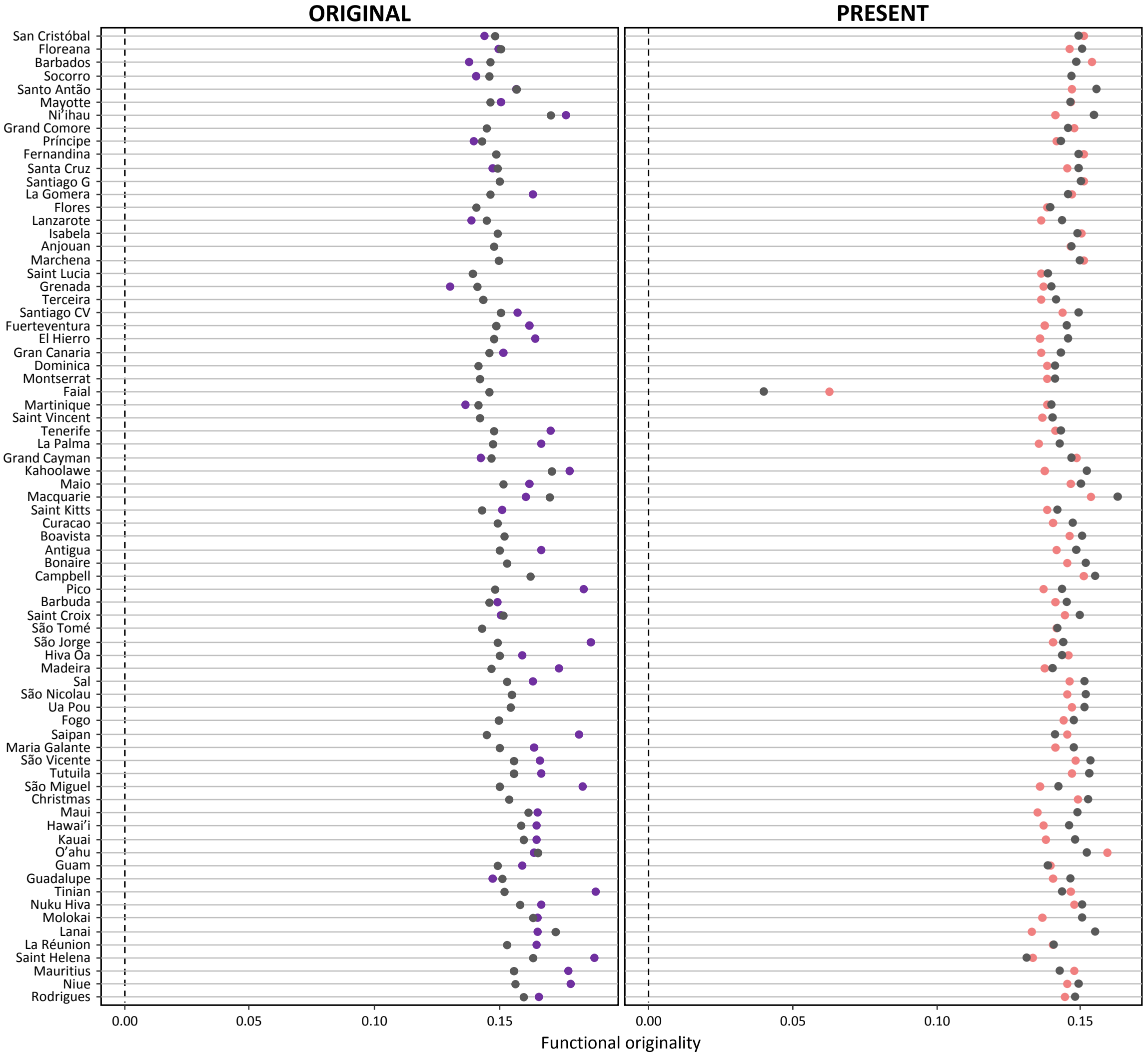


Figure S3.10 Functional originality of extinct (purple) and extant native (grey) species in the original assemblage of each island, and of extant native (grey) and introduced (pink) species in the present assemblage of each island.



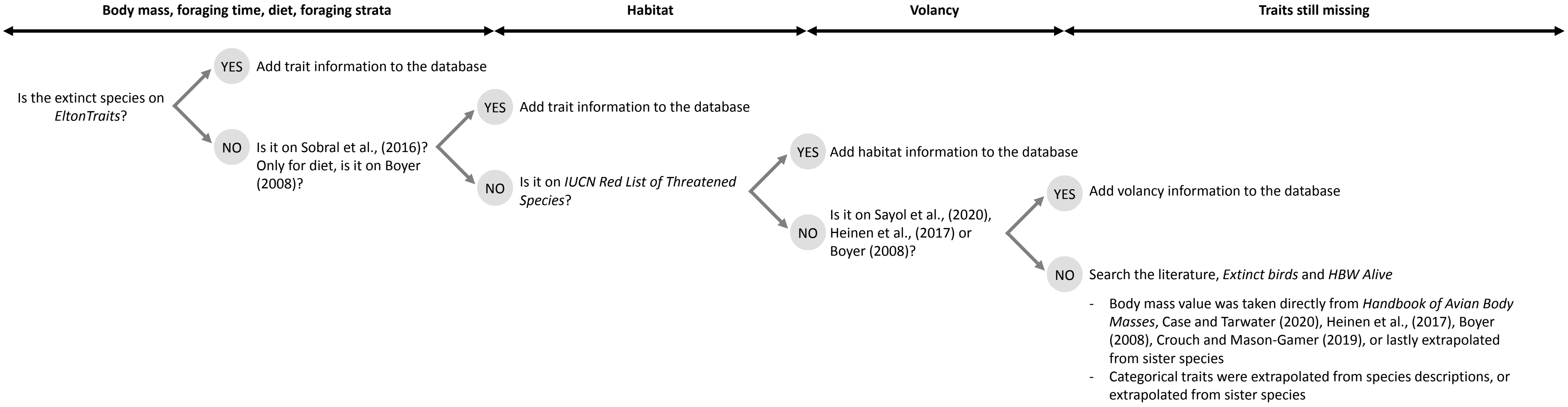
Supporting information

Combined effects of bird extinctions and introductions in oceanic islands: decreased functional diversity despite increased species richness

Appendix 4

Traits of extinct bird species

🟩 Green indicates no extrapolation since the information was available for that species in at least one of the analysed databases or the literature (e.g. a published body mass value). 🟨 Yellow indicates extrapolation by direct interpretation of descriptions or by taking information from the closest species in the genus.



- Body mass value was taken directly from *Handbook of Avian Body Masses*, Case and Tarwater (2020), Heinen et al., (2017), Boyer (2008), Crouch and Mason-Gamer (2019), or lastly extrapolated from sister species
- Categorical traits were extrapolated from species descriptions, or extrapolated from sister species

References: EltonTraits: Wilman, H., Belmaker, J., Simpson, J., de la Rosa, C., Rivadeneira, M. M., Jetz, W. (2014). EltonTraits 1.0: Species-level foraging attributes of the world's birds and mammals. *Ecology, 95*, 2027-2027. https://doi.org/10.1890/13-1917.1; Sobral et al., (2016): Sobral, F., Lees, A. C., Cianciaruso, M. V. (2016). Introductions do not compensate for functional and phylogenetic losses following extinctions in insular bird assemblages. *Ecology Letters*, *19*, 1091-1100. https://doi.org/10.1111/ele.12646; IUCN Red List of Threatened Species: IUCN (2020). The IUCN Red List of Threatened Species. Version 2020-3. Retrieved from https://www.iucnredlist.org; Sayol et al., (2020): Sayol, F., Steinbauer, M. J., Blackburn, T. M., Antonelli, A., Faurby, S. (2020). Anthropogenic extinctions conceal widespread evolution of flightlessness in birds. *Science Advances*, *6*, eabb6095. https://doi.org/10.1126/sciadv.abb6095; Extinct birds: Hume, J. P. (2017). *Extinct birds*, 2nd ed. Bloomsbury Natural History; HBW Alive: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A., Kirwan, G. (Eds) (2014). Handbook of the birds of the world alive. Lynx Edicions. Retrieved from https://www.hbw.com/; Handbook of Avian Body Masses: Dunning, J. B. J. (2017). *CRC Handbook of Avian Body Masses*, 2nd ed. Taylor & Francis Group; Case and Tarwater (2020): Case, S. B, Tarwater, C. E. (2020). Functional traits of avian frugivores have shifted following species extinction and introduction in the Hawaiian Islands. *Functional Ecology*, *34*, 2467-2476. https://doi.org/10.1111/1365-2435.13670; Heinen et al., (2018): Heinen, J. H., van Loon, E. E., Hansen, D. M., Kissling, W. D. (2018). Extinction-driven changes in frugivore communities on oceanic islands. *Ecography*, *41*, 1245-1255. https://doi.org/10.1111/ecog.03462; Boyer (2008): Boyer, A. G. (2008) Extinction patterns in the avifauna of the Hawaiian islands. *Diversity and Distributions*, *14*, 509-517. https://doi.org/10.1111/j.1472-4642.2007.00459.x; Crouch and Mason-Gamer (2019): Crouch, N. M. A., Mason-Gamer, R. (2019) Mass estimation of extinct taxa and phylogenetic hypotheses both influence analyses of character evolution in a large clade of birds (Telluraves). *Proceedings Royal Society B*, *286*, 20191745. http://dx.doi.org/10.1098/rspb.2019.1745

Myadestes woahensis		
Body mass	50	50g, following Case and Tarwater (2020). We choose this reference because it is a paper specifically focused on Hawaiian Islands and more recent than Heinen et al. (2017), who estimated a weight of 45.25g
Foraging time	Diurnal	We presumed diurnal, like its congenerics in Hawaii (*M. palmeri*, *M. myadestinus* and *M. lanaiensis*)
Diet	Frugivore	Classified here as frugivore, following Case and Tarwater (2020). Also: was classified as low frugivore by Heinen et al. (2017; i.e., up to 30% of fruit in diet). Its congenerics *M. palmeri*, *M. myadestinus* and *M. lanaiensis* are all classed as frugivores by Wilman et al. 2014 or Sobral et al. (2016)
Foraging strata	Canopy	We presume canopy, given that it is classified as arboreal by Case and Tarwater (2020) and its congenerics (=*M. palmeri*, *M. myadestinus* and *M. lanaiensis* are all classified as foraging in the canopy by Wilman et al. 2014 or Sobral et al. (2016)
Volancy	Volant	Volant following Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Vini sinotoi		
Body mass	39.875	39.875g, following Heinen et al. (2017)
Foraging time	Diurnal	We presume diurnal, given that all *Vini* species in Wilman et al. 2014 are diurnal
Diet	Frugivore	We presume frugivore, following the Heinen et al. (2017) who classified it as low frugivore (i.e., up to 30% of fruit in diet). Also: closest congeneric *Vini ultramarine* is classified as frugivore in Wilman et al. 2014
Foraging strata	Canopy	We presume canopy given that in Elton 1.0 *Vini ultramarine* is classified as foraging on the canopy (60%) and midhigh (40%)
Volancy	Volant	Following Heinen et al. (2017). Note however that it is classified as Unknown by Sayol et al. (2020)
Habitat	Forest, Artificial terrestrial habitats	We presume it used forest habitats, and could have also used artificial terrestrial habitats, , given that these are the dominant habitats used by Vini species (in 4 out of 5 species) and the congeneric *V. ultramarine* is classified as using these habitats in the IUCN Red List

Vini vidivici		
Body mass	39.875	39.875g, following Heinen et al. (2017)
Foraging time	Diurnal	We presume diurnal, given that all *Vini* species in Wilman et al. 2014 are diurnal
Diet	Frugivore	We presume frugivore, following the Heinen et al. (2017) who classified it as low frugivore (i.e., up to 30% of fruit in diet). Also: closest congeneric *Vini ultramarine* is classified as frugivore in Wilman et al. 2014

Foraging strata	Canopy	We presume canopy given that in Elton 1.0 *Vini ultramarine* is classified as foraging on the canopy (60%) and midhigh (40%)
Volancy	Volant	Following Heinen et al. (2017). Note however that it is classified as Unknown by Sayol et al. (2020)
Habitat	Forest, Artificial terrestrial habitats	We presume it used forest habitats, and could have also used artificial terrestrial habitats, , given that these are the dominant habitats used by Vini species (in 4 out of 5 species) and the congeneric *V. ultramarine* is classified as using these habitats in the IUCN Red List

Corvus viriosus		
Body mass	610.55	610.55g, following Heinen et al. (2017). We choose this reference because although Case and Tarwater (2020 - who estimated a weight of 671.80g) is a paper specifically focused on Hawaiian Islands and more recent than the first, we know from Hume (2017) that this species was smaller than C. impluviatus: - "Second large species of crow formerly occurred on Oahu, where it was sympatric with the Deep-billed Crow C. impluviatus". "Larger than the extant Hawaiian Crow C. hawaiiensis, and had a longer, straighter and shallower bill, and differed from C. impluviatus in the shape of the bill and characters of the post-cranial bones" Additional context on body size: - Olson and James (1991): Length of humerus = 73.4 +- 2.9; Length of femur = 60.4 +- 2.2
Foraging time	Diurnal	We presumed diurnal, as that is the case with all other species of the genus *Corvus* in Wilman et al. 2014
Diet	Frugivore	We presumed it was frugivore, following Case and Tarwater (2020). Also: classified as low frugivore by Heinen et al. (2017; i.e., "percentage of fruit in the diet up to 30%"). However, *C. hawaiiensis* is classified as omnivore in Elton 1.0
Foraging strata	Nonspecialized	Presumed nonspecialised given that congeneric *C. hawaiiensis*, *C. woodfordi* and *C. meeki* are classified as nonspecialized in Wilman et al. 2014. However, classified as arboreal by Case and Tarwater (2020).
Volancy	Volant	Considered volant following Heinen et al. (2017), even if it is classified as unknown by Sayol et al. (2020). Congeneric *C. hawaiiensis* is volant
Habitat	Forest, Shrubland, Artificial terrestrial habitats	We presume that it occurred in forest, shrubland and artificial terrestrial habitats by extrapolation from living *C. hawaiiensis* (classified as forest in the IUCN Red List) According to Hume (2017) bones were found in lowland, coastal sites, so it may have been a predominantly lowland species (Hume 2017). However, before human occupation these islands were densely forest down to the seashore (Hume 2017)

Corvus impluviatus		
Body mass	629.72	629.72g, following Heinen et al. (2017). We choose this reference because although Case and Tarwater (2020) is a more recent paper specifically focused on Hawaiian Islands, it estimated a weight lower than Corvus viriosus - 518.00g
Foraging time	Diurnal	We presumed diurnal, as that is the case with all other species of the genus *Corvus* in Wilman et al. 2014
Diet	Frugivore	Presumed frugivore following Case and Tarwater (2020). Also, classified as low frugivore by Heinen et al. (2017; "percentages of fruit in the diet up to 30%"). However, congenerics also endemic to Pacific Islands *C. hawaiiensis*, *C. woodfordi* and *C. meeki* are classified as omnivore in Wilman et al. 2014. Also, according to Hume (2017): "The bill is reminiscent of that of the White-billed Crow *C. woodfordi* from the Solomons, and of the Bougainville Crow *C. meeki*, but broader and deeper. These western Pacific corvids are forest inhabitants that feed on fruit and insects, and it is likely that the Deep-billed Crow had a similar ecology"
Foraging strata	Nonspecialized	Presumed nonspecialised given that congeneric *C. hawaiiensis*, *C. woodfordi* and *C. meeki* are classified as nonspecialized in Wilman et al. 2014. However, classified as arboreal by Case and Tarwater (2020)
Volancy	Volant	Presumed volant following Heinen et al. (2017). However: classified as unknown by Sayol et al. (2020). Congeneric *C. hawaiiensis* is volant
Habitat	Forest, Shrubland, Artificial terrestrial habitats	We presume that it occurred in forest, shrubland and artificial terrestrial habitats by extrapolation from living *C. hawaiiensis* (classified as forest in the IUCN Red List) According to Hume (2017) "This species would have been susceptible to forest destruction after the arrival of the Polynesians. Loss of habitat and Pacific Rat *Rattus exulans* predation are almost certainly the causes of its extinction"

Gallicolumba nui		
Body mass	146.49	Following the estimated of 146.49g by Heinen et al. (2017)
Foraging time	Diurnal	We presumed diurnal, as that is the case with all other species of the genus *Gallicolumba* in Wilman et al. 2014
Diet	Frugivore	Following Heinen et al. (2017), who classified it as low frugivore ("percentages of fruit in the diet up to 30%"). Steadman (1997) considered it likely to be "ground frugivore/granivore"
Foraging strata	Ground	Presumed to feed on the ground based on Steadman (1997: "ground frugivore/granivore")
Volancy	Volant	Volant, following Heinen et al. (2017). However, classed as "unknown" by Sayol et al. (2020)
Habitat	Forest	Presumed to use forest based on the habitat of 7 Gallicolumba species in IUCN Red List

Branta hylobadistes		
Body mass	2617.6	Following the estimated of 2617.60g by Case and Tarwater (2020)
Foraging time	Diurnal	We presumed diurnal, as that is the case with all other species of the genus Branta in Wilman et al. 2014
Diet	Herbivore	Presumed herbivore (folivorous) based on congeneric *Branta sandvicensis* (granivore by Wilman et al. 2014 - 80% plants). Also, assumed to be frugivore on Case and Tarwater (2020): "For subfossil taxa, we evaluated the likelihood of frugivory by examining the diets of species in the same taxonomic family that are endemic to the Hawaiian Islands and are morphologically similar. For instance, some extinct species of Hawaiian waterfowl were large-bodied, terrestrial folivores (James & Burney, 1997; Olson & James, 1991), and while it is uncertain whether they consumed fruit, they are ecologically and morphologically similar to the frugivorous nēnē, an endemic Hawaiian goose, resulting in their inclusion."
Foraging strata	Ground	Presumed ground by Case and Tarwater (2020), and according to Hume (2017): "Being terrestrial and at best a poor flier". Also, congeneric *Branta sandvicensis* is ground by Wilman et al. 2014
Volancy	Weak flyer	Weak flyer, following Sayol et al. (2020)
Habitat	Shrubland, Grassland	Presumed to use forest shrubland and grassland on the habitat of *Branta sandvicensis* in IUCN Red List

Chelychelynechen quassus		
Body mass	6668.10	Following the estimated of 6668.10g by Case and Tarwater (2020)
Foraging time	Diurnal	We presumed diurnal, as that is the case with all other species of the genus Branta in Wilman et al. 2014 (which represent the closest group of goose)
Diet	Herbivore	Presumed herbivore based on Hume (2017): "Analogous to large terrestrial grazing mammals or giant tortoises on other islands, and cropped tough vegetation with its specialised jaws". Also, assumed frugivore by Case and Tarwater (2020)
Foraging strata	Ground	Presumed ground since it was flightless and analogous to large terrestrial grazing mammals or giant tortoises. Also, assumed ground by Case and Tarwater (2020)
Volancy	Flightless	Flightless following Sayol et al. (2020)
Habitat	Shrubland, Grassland	Presumed to use shrubland and grassland based on the habitat of *Branta sandvicensis* in IUCN Red List

Talpanas lippa		
Body mass	882	Estimated as the average of the interval published by Iwaniuk et al. 2009 – (692–1072g)
Foraging time	Nocturnal	Based on Hume (2017): "Presumably nocturnal"

Diet	Invertivore	Invertivore based on Hume (2017): "Used its broad, sensitive bill to forage for invertebrates on the forest floor"
Foraging strata	Ground	Based on Hume (2017): "forage for invertebrates on the forest floor"
Volancy	Flightless	Flightless following Sayol et al. (2020)
Habitat	Forest	Based on Hume (2017): "forage for invertebrates on the forest floor"

Ciridops tenax		
Body mass	41.70	Following the estimated of 41.70g by Case and Tarwater (2020). However, Hume (2017): "The Kaua'i Palmcreeper was a smaller bird than *C. anna* of Hawaii, with a narrower, longer bill and less robust legs, but still stouter than the other red-and-black Hawaiian finches"; and according to Pratt (2005): "Possibly somewhat smaller than 'Ula-'ai-hawane". Also, *C. anna* is 23.1g (Case and Tarwater 2020). Additional context on body size (James & Olson 1991): - *C. tenax* Femur length = 13.4 -+ 0.53 - *C. anna* Femur length = 14.8
Foraging time	Diurnal	Presumed diurnal based on *C. anna* (Sobral et al. 2016)
Diet	Invertivore	Presumed invertivore based on Pratt (2005): "One preserved stomach held only foliage insects (S. L. Olson in Scott et al. 1986), but nectar would have been difficult to detect". And *C. anna* is insectivore in Sobral et al. (2016). However, assumed frugivore by Case and Tarwater (2020)
Foraging strata	Canopy	We presumed as canopy based on congeneric closest *C. anna* in Sobral et al. (2016); also assumed arboreal by Case and Tarwater (2020)
Volancy	Volant	Presumed volant as *C. anna* and because it was supposed to forage on the canopy. However, classed as "unknown" by Sayol et al. (2020)
Habitat	Forest	Presumed to use forest based on the habitat of *C. anna* in IUCN Red List; and also based on Hume (2017): "The Kaua'i Palmcreeper disappeared before the arrival of Europeans, no doubt a victim of Polynesian habitat destruction and perhaps over-hunting for its feathers (which were probably red and black)"

Nesoenas duboisi		
Body mass	303	Following the estimated of 303g by Heinen et al. (2017)

Foraging time	Diurnal	Presumed diurnal based on *N. rodericanus* in Sobral et al. (2016) and two Nesoenas sp. in Wilman et al. 2014
Diet	Granivore	Presumed granivore as congeneric *Nesoenas mayeri* and *Nesoenas picturata* in Wilman et al. 2014, and *N. rodericanus* in Sobral et al. (2016)
Foraging strata	Ground	Presumed ground as congeneric *Nesoenas picturata* in Wilman et al. 2014, and*N. rodericanus* in Sobral et al. (2016)
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red list

Necropsittacus borbonicus		
Body mass	325	Following the estimated of 325g by Heinen et al. (2017)
Foraging time	Diurnal	Presumed diurnal based on closest congeneric *N. rodericanus* (Sobral et al. 2016)
Diet	Granivore	Presumed granivore based on closest congeneric *N. rodericanus* (Sobral et al. 2016)
Foraging strata	Understory	Presumed understory based on closest congeneric *N. rodericanus* (Sobral et al. 2016)
Volancy	Volant	Presumed volant based on closest congeneric *N. rodericanus* (Sayol et al. 2020)
Habitat	Forest	Presumed to use forest based on the habitat of *N. rodericanus* (IUCN Red List)

Ptaiochen pau		
Body mass	3261.70	Following the estimated of 3261.70g by Case and Tarwater (2020)
Foraging time	Diurnal	Presumed diurnal based on other Moa-nalos (*Thambetochen xanion* and *Thambetochen chauliodous*)
Diet	Herbivore	Presumed herbivore based on other Moa-nalos. However, assumed frugivore by Case and Tarwater (2020)
Foraging strata	Ground	Ground by Case and Tarwater (2020), and based on the fact that its flightless
Volancy	Flightless	Volant by Sayol et al. (2020)
Habitat	Forest	Presumed to use forest based on Hume (2017): “Restricted to a montane habitat, and lived sympatrically with *Thambetochen chauliodous* on Maui”, and Olson and James (1991): “*Ptaiochen pau* appears to have been restricted to higher elevations”

Thambetochen xanion		
Body mass	4064.30	Following the estimated of 4064.30g by Case and Tarwater (2020). According to Hume (2017): “This moa-nalo from Oahu was smaller and less robust than *T. chauliodous*, with a slightly longer, less decurved bill”
Foraging time	Diurnal	Presumed diurnal based on other Moa-nalos

Diet	Herbivore	Presumed herbivore based on Sorenson et al. (1999): “Adapted to browsing, largest herbivores”. However, assumed frugivore by Case and Tarwater (2020)
Foraging strata	Ground	Ground by Case and Tarwater (2020), and based on the fact that its flightless and adapted to browsing
Volancy	Flightless	Volant by Sayol et al. (2020)
Habitat	Forest, Shrublands	Presumed to use forest based on Hume (2017): “Seems to have been a lowland bird”, and Wikipedia regarding Moa-nalos: “they were folivorous, at least in dry shrub or mesic forest habitats eating particularly fronds from ferns”

Thambetochen chauliodous		
Body mass	6063.20	Following the estimated of 6063.20 by Case and Tarwater (2020). According to Olson and James (1991): “Differs from *T. xanion* in larger size, shorter, more decurved tip of rostrum, larger nostril, wider internarial bar and narrower lateral nasal bar”
Foraging time	Diurnal	Presumed diurnal based on other Moa-nalos
Diet	Herbivore	Presumed herbivore based on Hume (2017): “These birds were specialised for hindgut fermentation of plant fibres”, and Sorenson et al. (1999): “Adapted to browsing, largest herbivores”. However, assumed frugivore by Case and Tarwater (2020)
Foraging strata	Ground	Ground by Case and Tarwater (2020), and based on the fact that its flightless and adapted to browsing
Volancy	Flightless	Volant by Sayol et al. (2020)
Habitat	Forest, Shrublands	Presumed to use forest based on Hume (2017): “Seems to have been a lowland bird”, and Wikipedia regarding Moa-nalos: “they were folivorous, at least in dry shrub or mesic forest habitats eating particularly fronds from ferns”

Aidemedia chascax		
Body mass	23.1	Following the estimated of 23.1g by Boyer (2008)
Foraging time	Diurnal	Based on species behavioural descriptions
Diet	Invertivore	Insectivore by Boyer (2008); according to Olson and James (1991): “Describes the use of gaping by Sturnus vulgaris and various icterids to feed in such diverse substrates as flowers, fruit, grass, bark, and earth. It seems likely that Aidemedia fed similarly”

Foraging strata	Ground	Based on Hume (2017): “They habitually insert the bill into a substrate and spread their beak apart using strong muscular actions”
Volancy	Volant	Presumed volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest	Presumed to use forest based on all other other extinct Fringillidae species in Hawaiian islands

Aidemedia zanclops		
Body mass	21.3	Following the estimated of 23.1g by Boyer (2008)
Foraging time	Diurnal	Based on species behavioural descriptions
Diet	Invertivore	Insectivore by Boyer (2008); according to Olson and James (1991): “Describes the use of gaping by Sturnus vulgaris and various icterids to feed in such diverse substrates as flowers, fruit, grass, bark, and earth. It seems likely that Aidemedia fed similarly”
Foraging strata	Ground	Based on *A. chascax* behavioural description of “gaping birds”
Volancy	Volant	Presumed volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest	Presumed to use forest based on all other other extinct Fringillidae species in Hawaiian islands

Aidemedia lutetiae		
Body mass	18.8	Following the estimated of 18.8g by Boyer (2008)
Foraging time	Diurnal	Based on species behavioural descriptions
Diet	Invertivore	Insectivore by Boyer (2008); according to Olson and James (1991): “Describes the use of gaping by Sturnus vulgaris and various icterids to feed in such diverse substrates as flowers, fruit, grass, bark, and earth. It seems likely that Aidemedia fed similarly”
Foraging strata	Ground	Based on *A. chascax* behavioural description of “gaping birds”
Volancy	Volant	Presumed volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest	Presumed to use forest based on all other other extinct Fringillidae species in Hawaiian islands

Circus dossenus		
Body mass	441.4	Following the estimated of 441.4g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on Circus sp. (Wilman et al. 2014)
Diet	Carnivore	Presumed carnivore based on Hume (2017): “Bird-hunting specialist”, and all other Circus sp. (Wilman et al. 2014)

Foraging strata	Ground	Presumed carnivore based on Hume (2017): “Bird-hunting specialist, and could easily manoeuvre through thick forest to hunt, so it relied heavily on undisturbed forest and forest bird species”, and all other Circus sp. (Wilman et al. 2014)
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	Presumed to use forest based on Hume (2017): “Smaller than any known extant harrier and exhibited Accipiter-like short, broad wings, characteristics of a forest-inhabiting species”

Haliaeetus albicilla spp.		
Body mass	5767.5	Following the estimated of 5767.5g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on Haliaeetus sp. (Wilman et al. 2014)
Diet	Carnivore	Presumed carnivore by Boyer (2008)
Foraging strata	Nonspecialized	Presumed nonspecialized as congeneric *H. albicilla*
Volancy	Volant	Volant by Sayol et al. (2020) and (Boyer 2008)
Habitat	Forest, Grassland, Wetlands (inland), Marine, Artificial aquatic habitats, Artificial terrestrial habitats, Marine	Presumed to use Forest, Grassland, Wetlands (inland), Marine and Artificial aquatic habitats and Marine based on *H. albicilla* in IUCN Red List

Chloridops regiskongi		
Body mass	61.2	Following the estimated of 61.2g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on *C. kona* (Sobral et al. 2016)
Diet	Granivore	Granivore by Boyer (2008), and according the Hume (2017): “The great size of the bill alludes to its ecology and no doubt it was a granivore, crushing the hard seeds of trees and shrubs with its massive jaws”
Foraging strata	Nonspecialized	Presumed nonspecialized as congeneric *C. kona* (50% understory and 50% midhigh in Wilman et al. 2014)
Volancy	Volant	Presumed volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest	Presumed to use Forest based on behavioural descriptions on Hume (2017): “It occurred sympatrically on Oahu with the largest of the Chloridops, *C. regiskongi*, so presumably foraged in different types of forest or on a different-sized class of food”, and “If this species was endemic to the coastal dry forest, it would have

		disappeared rapidly after Polynesian habitat destruction, which was most severe in the lowlands". Also, *C. kona* occurs in Forest (IUCN Red List)

Chloridops wahi		
Body mass	31.2	Following the estimated of 31.2g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on *C. kona* (Sobral et al. 2016)
Diet	Granivore	Granivore by Boyer (2008), and according the Hume (2017): "May have fed on the hard seeds of Zanthoxylon"; and Pratt (2005): "Smaller and weaker bill implies feeding on seeds less difficult to crack than the hard dry fruits of naio on which Kona Grosbeak fed"
Foraging strata	Nonspecialized	Presumed nonspecialized as congeneric *C. kona* (50% understory and 50% midhigh in Wilman et al. 2014)
Volancy	Volant	Presumed volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest	Presumed to use forest based on behavioural descriptions on Hume (2017): "It occurred sympatrically on Oahu with the largest of the Chloridops, *C. regiskongi*, so presumably foraged in different types of forest or on a different-sized class of food". Also, *C. kona* occurs in Forest (IUCN Red List)

Telespiza persecutrix		
Body mass	22.8	Following the estimated of 22.8g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on two Telespiza in Wilman et al. 2014
Diet	Omnivore	We took a conservative approach and consider it omnivore as extant *Telespiza ultima* in Nihoa, although extant *Telespiza cantans* in Laysan is granivore (Wilman et al. 2014) and it was assumed granivore by Boyer (2008). Yet, according to Pigot et al. (2020) both *T. cantans* and *T. ultima* are omnivores
Foraging strata	Ground	Presumed ground as extant *Telespiza cantans* and *Telespiza ultima* (Wilman et al. 2014)
Volancy	Volant	Volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest, Shrubland, Grassland, Marine	Presumed to use forest, shrubland, grassland and marine based on congeneric sister species *Telespiza cantans* and *Telespiza ultima*, and extinct Telespiza ypsilon

Telespiza ypsilon* and *Telespiza aff. ypsilon		
Body mass	19.3	Following the estimated of 19.3g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on two Telespiza in Wilman et al. 2014

Diet	Omnivore	We took a conservative approach and consider it omnivore as extant *Telespiza ultima* in Nihoa, although extant *Telespiza cantans* in Laysan is granivore (Wilman et al. 2014) and it was assumed granivore by Boyer (2008). Yet, according to Pigot et al. (2020) both *T. cantans* and *T. ultima* are omnivores
Foraging strata	Ground	Presumed ground as extant *Telespiza cantans* and *Telespiza ultima* (Wilman et al. 2014)
Volancy	Volant	Volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest, Shrubland, Grassland, Marine	Presumed to use forest, shrubland, grassland and marine based on descriptions below: - Hume (2017): "This infers that the species was an adaptable one, and survived in the harsh, arid environment at coastal Ilio Point on Molokai" - Olson and James (1991): "The species was not restricted to extremely arid coastal habitats, however, as the specimens from Puu Naio Cave on Maui originated at about 305 m elevation in a region of more moderate climate" - Pratt (2005): "Abundance of bones indicates bird was common in arid lowland habitats, but also occurred in upland dry forest" And also according to *Telespiza cantans* and *Telespiza ultima* that are respectively shrubland and grassland, and shrubland and marine in IUCN Red List

Vangulifer mirandus		
Body mass	21.6g	Following the estimated of 21.6g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on species behavioural descriptions (Hume 2017)
Diet	Invertivore	Insectivore by Boyer (2008), and according to Hume (2017): "James & Olson (1991) comment that the bill seems too long and weak to crack seeds, too deep and broad to be used for probing in bark, and too blunt to be nectar-feeding apparatus. The ventral surface and lateral edges of the upper bill were richly supplied with blood vessels, which is a very unusual characteristic otherwise limited to kiwis. These presumably supplied sensory neurons, indicating that the bird had a sensitive bill that it used to detect food items", and to Pratt (2005): "The describers suggest that Vangulifer might have been a fly-catching honeycreeper, comparing it to todies and tyrant flycatchers, other birds that capture prey in aerial sallies"
Foraging strata	Nonspecialized	We took a conservative approach and consider it nonspecialized based on James & Olson (1991): "In several characters, *V. mirandus* is more similar to aerial insectivores than is *V. neophasis*. However, a curved bill would not be expected in a bird that fed exclusively by catching insects on the wing"
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	There is no information related to habitat, so we took a conservation approach and indicated forest since the species was insectivore and most endemic Fringillidae species occurred and still occur in the forest)

Vangulifer neophasis		
Body mass	24.1	Following the estimated of 24.1g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on species behavioural descriptions (Hume 2017)
Diet	Invertivore	Insectivore by Boyer (2008)
Foraging strata	Nonspecialized	We took a conservative approach and consider it nonspecialized based on Pratt (2005): "*V. neophasis* may be more closely related to Oreomystis and/or Paroreomyza than to *V. mirandus* (James 1998)"
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	There is no information related to habitat, so we took a conservation approach and indicated forest since the species was insectivore and most endemic Fringillidae species occurred and still occur in the forest). Also, proposed closest species like *Oreomystis bairdi*, *Paroreomyza flammea*, *Paroreomyza maculata* and *Paroreomyza montana* occur in forest (IUCN Red List)

Xestospiza conica		
Body mass	25	Following the estimated of 25g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on species behavioural descriptions (Hume 2017)
Diet	Granivore	Presumed granivore by Boyer (2008), and according to sister species *Chloridops regiskongi* which is also granivore, considering Pratts (2005): "H. James's (pers. comm.) most recent phylogenetic analysis fails to support the monophyly of Xestospiza and places this sp. as sister to *Chloridops regiskongi*, and in turn closely related to Rhodacanthis rather than to *X. fastigialis*"
Foraging strata	Nonspecialized	We took a conservative approach and consider it nonspecialized based on *Chloridops regiskongi* that is nonspecialized
Volancy	Volant	Volant by Boyer (2008), however unknown in Sayol et al. (2020)
Habitat	Forest	We took a conservative approach and consider it forest based on closest *Chloridops regiskongi* (IUCN Red List)

Xestospiza fastigialis		
Body mass	24.8	Following the estimated of 24.8g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on species behavioural descriptions (Hume 2017)
Diet	Granivore	Presumed granivore by Boyer (2008)

Foraging strata	Ground	Presumed to be ground as closest species *Melamprosops phaeosoma* (James 2004). Also, of 6 Molothrus in Wilman et al. 2014, 5 are ground foragers
Volancy	Volant	Volant by Boyer (2008), however unknown in Sayol et al. (2020)
Habitat	Forest	We took a conservative approach and consider it forest based on closest *Melamprosops phaeosoma* (IUCN Red List)

Porzana keplerorum		
Body mass	47	Following the estimated of 47g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal as all 13 Porzana sp. (Wilman et al. 2014)
Diet	Invertivore	Presume insectivore by Boyer (2008), and according to possible ancestor *P. pusilla* (Olson and James 1991) that has 70% of insects in their diet (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground based on being flightless, ground nester by Boyer (2008), and according to *P. pusilla* that is 50% water and 50% ground in Wilman et al. 2014
Volancy	Flightless	Flightless by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	We took a conservative approach and consider this species to occur in forest based on habitat of Zapornia species in Hawaiian Islands (*Zapornia sandwichensis*; IUCN Red List)

Porzana menehune		
Body mass	44,7	Following the estimated of 44.7g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal as all 13 Porzana sp. (Wilman et al. 2014)
Diet	Invertivore	Presume insectivore by Boyer (2008), and according to possible ancestor *P. pusilla* (Olson and James 1991) that has 70% of insects in their diet (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground based on being flightless, ground nester by Boyer (2008), and according to *P. pusilla* that is 50% water and 50% ground in Wilman et al. 2014
Volancy	Flightless	Flightless by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	We took a conservative approach and consider this species to occur in forest based on habitat of Zapornia species in Hawaiian Islands (*Zapornia sandwichensis*; IUCN Red List)

Porzana ralphorum		
Body mass	109.9	Following the estimated of 109.9g by Boyer (2008)

Foraging time	Diurnal	Presumed diurnal as all 13 Porzana sp. (Wilman et al. 2014)
Diet	Invertivore	Presume insectivore by Boyer (2008), and according to possible ancestor *P. pusilla* (Olson and James 1991) that has 70% of insects in their diet (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground based on being flightless, ground nester by Boyer (2008), and according to *P. pusilla* that is 50% water and 50% ground in Wilman et al. 2014
Volancy	Flightless	Flightless by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	We took a conservative approach and consider this species to occur in forest based on habitat of Zapornia species in Hawaiian Islands (*Zapornia sandwichensis*; IUCN Red List)

Porzana severnsi		
Body mass	100.5	Following the estimated of 100.5g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal as all 13 Porzana sp. (Wilman et al. 2014)
Diet	Invertivore	Presume insectivore by Boyer (2008), and according to possible ancestor *P. pusilla* (Olson and James 1991) that has 70% of insects in their diet (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground based on being flightless, ground nester by Boyer (2008), and according to *P. pusilla* that is 50% water and 50% ground in Wilman et al. 2014
Volancy	Flightless	Flightless by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	We took a conservative approach and consider this species to occur in forest based on habitat of Zapornia species in Hawaiian Islands (*Zapornia sandwichensis*; IUCN Red List)

Porzana ziegleri		
Body mass	48.4	Following the estimated of 48.4g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal as all 13 Porzana sp. (Wilman et al. 2014)
Diet	Invertivore	Presume insectivore by Boyer (2008), and according to possible ancestor *P. pusilla* (Olson and James 1991) that has 70% of insects in their diet (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground based on being flightless, ground nester by Boyer (2008), and according to *P. pusilla* that is 50% water and 50% ground in Wilman et al. 2014
Volancy	Flightless	Flightless by Sayol et al. (2020) and Boyer (2008)
Habitat	Forests	We took a conservative approach and consider this species to occur in forest based on habitat of Zapornia species in Hawaiian Islands (*Zapornia sandwichensis*; IUCN Red List)

Grallistrix auceps		
Body mass	735.1	Following the estimated of 735.1g by Boyer (2008)
Foraging time	Nocturnal	Presumed diurnal as all other species in Strigidae (Wilman et al. 2014)
Diet	Carnivore	Carnivore by Boyer (2008), and also Olson and James (1991): “Species of Grallistrix fed on birds”
Foraging strata	Ground	Presumed ground based on Hume (2017): “This suggests that the feet were incredibly strong, and that the owls probably dispatched their prey by crushing it. Parallel the skeletal proportions of forest-dwelling hawks of the genus Accipiter, which are specialist bird-predators”. Also, considered ground nester by Boyer (2008)
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	Presumed to occur in forest based on Hume (2017): “The Polynesians cleared the lowland forests and deprived the owls of food, and if the owls were roosting or nesting on the ground, the introduction of the Pacific Rat *Rattus exulans* may have been a major predator of eggs and chicks”

Grallistrix erdmani		
Body mass	595.9	Following the estimated of 595.9g by Boyer (2008)
Foraging time	Nocturnal	Presumed diurnal as all other species in Strigidae (Wilman et al. 2014)
Diet	Carnivore	Carnivore by Boyer (2008), and also Olson and James (1991): “Species of Grallistrix fed on birds”
Foraging strata	Ground	Presumed ground based on *Grallistrix auceps*, taking into account the foraging habits of Strix sp.; Also, considered ground nester by Boyer (2008)
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	Presumed to occur in forest based on Hume (2017): “Subfossil remains of this owl were found at altitudes ranging from 305m to 1,000m on the southern side of the Mount Haleakala crater. It is possible, therefore, that this species occupied varied habits and altitudes on pre-human Maui, much the same as the Laughing Owl *Ninox albifacies* did on New Zealand”, and behavioural descriptions of other extinct Grallistrix sp.

Grallistrix geleches		
Body mass	765.1	Following the estimated of 765.1g by Boyer (2008)
Foraging time	Nocturnal	Presumed diurnal as all other species in Strigidae (Wilman et al. 2014)
Diet	Carnivore	Carnivore by Boyer (2008), and also Olson and James (1991): “Species of Grallistrix fed on birds”
Foraging strata	Ground	Presumed ground based on Grallistrix auceps, taking into account the foraging habits of Strix sp.; Also, considered ground nester by Boyer (2008)
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)

Habitat	Forest, Marine	Presumed to occur in forest and marine based on Hume (2017): “Like Grallistrix orion, subfossil remains were found in coastal deposits, so they probably roosted or even nested in sand dunes or low dune vegetation”

Grallistrix orion		
Body mass	518	Following the estimated of 518g by Boyer (2008)
Foraging time	Nocturnal	Presumed diurnal as all other species in Strigidae (Wilman et al. 2014)
Diet	Carnivore	Carnivore by Boyer (2008), and also Olson and James (1991): “Species of Grallistrix fed on birds”
Foraging strata	Ground	Presumed ground based on Grallistrix auceps, taking into account the foraging habits of Strix sp.; Also, considered ground nester by Boyer (2008)
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest, marine	Presumed to occur in forest and marine based on Hume (2017): “Like *Grallistrix orion*, subfossil remains were found in coastal deposits, so they probably roosted or even nested in sand dunes or low dune vegetation. That roosting occurred at times on open sand dunes or in low dune vegetation”

Alectroenas payandeei		
Body mass	161.665	161.665g - we assumed a mean value between *A. nitidissima* (165.33g - Sobral et al. 2016) and *Alectroenas sganzini* (158g - Wilman et al. 2014), according to Hume (2017): “A single tarsometatarsus and a possible femur referable to the genus Alectroenas has shown that a species of blue pigeon once occurred on Rodrigues. It was larger than any of the extant Alectroenas species (*Alectroenas sganzini*), but smaller than its nearest relative, the Mauritius Blue Pigeon *A. nitidissima*” Additional context on body size: - Hume (2011): Tarsometatarsus mean length = 31.1 mm (*n*= 1); Tarsometatarsus mean length of A. *nitidissima* = 32.4 +- 1.25mm - Hume (2011): “Based on tarsometatarsus length, *A. payandeei* falls within the lower size range of *A. nitidissima*, but is more gracile in shaft width and depth, and particularly so at the proximal and distal ends. The new species was larger than surviving species of Alectroenas, suggests that in life it was approximately 28 cm in total length”
Foraging time	Diurnal	Presumed diurnal as congeneric species *Alectroenas nitidissimus* and *Alectroenas sganzini*
Diet	Omnivore	Presumed omnivore as closest congeneric species *Alectroenas nitidissimus* (Sobral et al. 2016)

Foraging strata	Canopy	Presumed canopy as closest congeneric species *Alectroenas nitidissimus* (Sobral et al. 2016 - 40% midhigh and 60% canopy)
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Allenia fusca atlantica		
Body mass	62.7	Considering that races vary primarily in size and in depth of colour of upperparts (HBW), we assumed the same weight as the thrush of St Lucia - 62.7g (CRC Handbook of Avian Body Masses) because Buden (1993) stated that this subspecies was very similar to St Lucia thrush. Also, *Allenia fusca* is 67.07g in Wilman et al. 2014
Foraging time	Diurnal	As *Allenia fusca* in Wilman et al. 2014
Diet	Omnivore	Presumed omnivore based on Hume (2017): "The diet comprised fruit, insects, and lizards, but it was also a predator of other birds' eggs and young"
Foraging strata	Nonspecialized	As *Allenia fusca* in Wilman et al. 2014
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest, Shrubland, Artificial terrestrial habitats	Presumed to occur in forest, shrubland and artificial terrestrial habitats as *Allenia fusca* (IUCN Red List); and considering Hume (2017): "It was supposedly restricted to dry coastal scrub and possibly mangroves on the island, but like other Scaly-Breasted Thrasher subspecies it probably occurred in a wide variety of habitats"

Branta rhuax		
Body mass	7545.6	Following the estimated of 7545.6 +- 425.2 g by Olson (2013)
Foraging time	Diurnal	Presumed diurnal as all other Branta sp. (Wilman et al. 2014)
Diet	Herbivore	Presumed herbivore as congeneric extant *Branta sandvicensis*
Foraging strata	Ground	Presumed ground as congeneric extant *Branta sandvicensisi* (Wilman et al. 2014), and because it was flightless
Volancy	Flightless	Flightless by Sayol et al. (2020)
Habitat	Shrubland, Grassland	Presumed to occur in shrubland and grassland as the congeneric extant *Branta sandvicensis* (IUCN Red List)

Chloris aurelioi		
Body mass	22.21	Following the estimated of 22.21 +- 2.73 g by Rando et al. (2010)

Foraging time	Diurnal	Presumed diurnal as all other Carduelis sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore based on Hume (2017): "Differences in bill structure suggest that it occupied a different niche and had different food requirements. The longer bill in *C. aurelioi* suggests more versatile feeding habits than greenfinch species with robust and pyramidal bills, perhaps including a higher invertebrate component, similar to *F. coelebs*"; and also Rando et al. (2010): "Differences in beak morphology between *F. coelebs* and *C. aurelioi* suggest that both species mainly fed on different type of seeds within the laurel forest"
Foraging strata	Ground	Presumed ground based on Hume (2017): "Morphometrics obtained from the wing elements show that it was probably a weakly flying species, and the long tarsi, which were equivalent in size with those of the Trías Greenfinch *C. triasi*, indicate that it was a terrestrial species, perhaps foraging and nesting entirely on the ground"
Volancy	Flightless	Flightless by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on Rando et al. (2010): "Differences in beak morphology between *F. coelebs* and *C. aurelioi* suggest that both species mainly fed on different type of seeds within the laurel forest"

Colaptes auratus rufipileus		
Body mass	131.46	We assumed 131.46g (Wilman et al. 2014) since this subspecies of *Colaptes auratus* is only morphologically distinct (HBW)
Foraging time	Diurnal	Presumed diurnal because of HBW behavioural descriptions (HBW)
Diet	Invertebrate	Presumed invertivore as *Colaptes auratus* (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground based on *Colaptes auratus* (Wilman et al. 2014), and HBW behavioural descriptions: "Primarily on ground, in soil, especially anthills"
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest, Artificial terrestrial habitats	Presumed to occur in forest and artificial terrestrial habitats as *Colaptes auratus* (IUCN Red List), and also Hume (2017): "Apparently confined to the pine woods at the north end of the island"

Coturnix gomerae		
Body mass	126	Following the estimated of 126 ± 6g by Rando et al. (2019)
Foraging time	Diurnal	Presumed diurnal congeneric sympatric species *C. coturnix* and all other Coturnix sp. (Wilman et al. 2014)
Diet	Granivore	Presumed granivore as congeneric sympatric species *C. coturnix* (Wilman et al. 2014)

Foraging strata	Ground	Presumed ground all other Coturnix sp. (Wilman et al. 2014), and Hume (2017): “All extinct birds nested on the ground”
Volancy	Flightless	Flightless by Sayol et al. (2020)
Habitat	Grassland, Artificial terrestrial habitats	Presumed to occur in grasslands and artificial terrestrial habitats as congeneric sympatric species *C. coturnix* (IUCN Red List)

Coturnix lignorum		
Body mass	218	Following the estimated of 218 ± 17 g by Rando et al. (2019)
Foraging time	Diurnal	Presumed diurnal as congeneric sympatric species *C. coturnix* and all other Coturnix sp. (Wilman et al. 2014)
Diet	Granivore	Presumed granivore as congeneric species *C. coturnix* (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground all other Coturnix sp. (Wilman et al. 2014), and Rando et al. (2019): “Flightless ground dwellers”
Volancy	Flightless	Presumed flightless as suggested by Rando et al. (2019)
Habitat	Grasslands, Artificial terrestrial habitats	Presumed to occur in grasslands and artificial terrestrial habitats as congeneric sympatric species *C. coturnix* (IUCN Red List)

Cyanoramphus novaezelandiae erythrotis		
Body mass	90.22	We presumed the same body mass as *Cyanoramphus novaezelandiae* (Wilman et al. 2014), since Hume (2017): “27cm. Larger and paler than nominate *C. n. novaezelandiae*, and HBW: “*Cyanoramphus novaezelandiae* is 27 cm and 50–113 g”
Foraging time	Diurnal	Presumed diurnal as *Cyanoramphus novaezelandiae*
Diet	Granivore	Presumed granivore as *Cyanoramphus novaezelandiae* (Wilman et al. 2014 - 10% invertebrates, 30% fruits, 30% seeds, 30% plants); Although Taylor (1979): ““These parakeets were particularly common around the shore, where they fed on invertebrates from heaps of seaweed”, and Hume (2017): “They were particularly common on the shore, feeding on invertebrates living in heaps of seaweed and also on various seeds”
Foraging strata	Nonspecialized	Presumed nonspecialized as *Cyanoramphus novaezelandiae* (Wilman et al. 2014 - 20% ground, 40% understory, 40% midhigh)
Volancy	Volant	Presumed volant as *Cyanoramphus novaezelandiae* (Sayol et al. 2020)
Habitat	Shrubland, Grassland	Presumed to occur in forest, shrublands and artificial terrestrial habitats as *Cyanoramphus novaezelandiae* (IUCN Red List), but remove forest because “there are no trees on Macquarie Island, so the birds nested

		under bunches of tussock grass on the ground or in burrows" (Hume 2017); Also, Hume (2017): "Macquarie Island Parakeet inhabited the rather inhospitable, treeless, sub-Antarctic island of Macquarie"

Emberiza alcoveri		
Body mass	36.7	Following the estimated of 36.7g by Rando et al. (1999)
Foraging time	Diurnal	Presumed diurnal as all other Emberiza sp. (Wilman et al. 2014)
Diet	Granivore	Presumed granivore as most Emberiza sp. (Wilman et al. 2014), and Rando et al. (1999): "The species of the genus Emberiza are omnivorous. Their diet is based mainly on seeds and small invertebrates. The musculature of the bill suggests that it was capable of feeding on harder seeds than other members of the genus"
Foraging strata	Ground	Presumed ground based on Hume (2017): "Like those birds it was probably a terrestrial inhabitant of the forest floor"
Volancy	Flightless	Flightless by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on Hume (2017): "It may have been an inhabitant of the herb-rich understorey associated with the laurel forests"

Micrathene whitneyi graysoni		
Body mass	41	Following the estimated of 41 g by HBW considering 20 unsexed adults *M. w. whitneyi* in Arizona
Foraging time	Nocturnal	Presumed nocturnal as *Micrathene whitneyi* (HBW)
Diet	Invertivore	Presumed invertivore based on Jehl and Parkes (1982): "Both adequate nesting cavities and grasshoppers, small crabs (Grayson 1872) and other suitable food for this owl are abundant", and Hume (2017): "Like the other Elf Owl subspecies, they were insectivorous, foraging at night, dawn and dusk"
Foraging strata	Nonspecialized	Presumed nonspecialized based on *Micrathene whitneyi* (Wilman et al. 2014 - ground 40%, understory 40%, midhigh 20%)
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest, Savanna, Shrubland, Wetlands (inland)	Presumed to occur in forest, savanna, shrubland and wetlands (inland) as *Micrathene whitneyi* (IUCN Red List)

Nesoenas rodericanus		

Body mass	176.79	Taken directly from Sobral et al. (2016)
Foraging time	Diurnal	Taken directly from Sobral et al. (2016)
Diet	Granivore	Taken directly from Sobral et al. (2016)
Foraging strata	Ground	Taken directly from Sobral et al. (2016)
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest as closest extinct relative that inhabits La Reunion *N. duboisi*

Orthiospiza howarthi		
Body mass	46.62	Following the estimated of 46.62g in Heinen et al. (2018)
Foraging time	Diurnal	Presumed diurnal based on all other Fringillidae species of Hawaiian Islands
Diet	Frugivore	Presumed frugivore because it was classified as medium low frugivore by Heinen et al. (2017; i.e., between 40% to 60% of fruit in diet)
Foraging strata	Understory	Presumed understory following descriptions and closest phylogenetic species *Pyrrula erythaca* (James 2004)
Volancy	Volant	Volant by Heinen et al. (2018), although unknown by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest as other Fringillidae, and also based on Hume (2017): “It appears to have been one of the few montane endemics”

Otus frutuosoi		
Body mass	114	Following the estimated of 144±35 g (128.6–151.6) by Rando et al. (2013)
Foraging time	Nocturnal	Presumed nocturnal by behavioural descriptions and considering it’s an Otus sp.
Diet	Invertivore	Presumed invertivore based on del Hoyo et al. (1999): As in other small species of scops owls, the diet of *O. frutuosoi* was probably dominated by invertebrates; and Rando et al. (2013): “Due to the absence of rodents and reptiles in the island, small birds were the only vertebrates that could have formed part of its diet”
Foraging strata	Ground	Presumed ground based on Rando et al. (2013): “Overall, these results strongly suggest that *O. frutuosoi* had ground-dwelling habits”
Volancy	Weak	Weak flyer by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on Rando et al. (2013): “These data seem to indicate that *O. frutuosoi* may have inhabited the floor of laurel forest, an ecosystem that offered a variety of invertebrates (Oromí 1995) as food as well as protection from avian predators such as buzzards (*Buteo buteo*) that currently and in the past were present in the archipelago (Borges et al. 2010)”

Otus mauli		
Body mass	152	Following the estimated of c. 152 g (n = 1) by Rando et al. (2012)
Foraging time	Nocturnal	Presumed nocturnal by behavioural descriptions and considering it's an Otus sp.
Diet	Invertivore or Carnivore	Presumed invertivore based on Hume (2017): "Feeding on the abundant invertebrate life, and it may have taken reptiles and birds as well"
Foraging strata	Ground	Presumed ground based on Hume (2017): "Ground-dwelling inhabitant of the laurel forests; it probably also nested close to or on the ground", and the considering that *Otus scops* is ground (Wilman et al. 2014)
Volancy	Weak flyer	Weak flyer by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on Hume (2017): "Ground-dwelling inhabitant of the laurel forests"

Paroreomyza flammea		
Body mass	15	Following the estimated of 15g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal as other Paroreomyza sp. (Wilman et al. 2014)
Diet	Invertivore	Presumed invertivore by Boyer (2008), and also IUCN Red List: "This species was an insectivore, foraging in wet \`ohi\`a forests above 500 m"
Foraging strata	Midhigh	Presumed midhigh as other congeneric *Paroreomyza montana* and *Paroreomyza maculate* (Wilman et al. 2014); Also, Hume (2017): "The Kakawahie foraged on trunks and branches of the Koa Acacia koa, working both on the upper and underside of horizontal limbs, where they fed on insects. Very occasionally nectar was also taken"
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	Forest by IUCN Red List

Porphyrio caerulescens		
Body mass	2462.18	We assumed the same weight as *Porphyrio hochstetteri* (Wilman et al. 2014 - 2462.18g) considering that Hume (2017): "The Réunion Blue Gallinule was approximately the size of a South Island Takahe *Porphyrio hochstetteri*"
Foraging time	Diurnal	Presumed diurnal as other Porphyrio sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore based on Hume (2019): "It likely fed on vegetable matter and invertebrates, as do other Porphyrio"
Foraging strata	Ground	Presumed ground based on Hume (2017): "A great numbers of oiseaux bleus which nest amongst grasses and aquatic ferns" and that fact that was a weak flyer

Volancy	Weak flyer	Weak flyer by Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Ptilinopus mercierii		
Body mass	99.49	We assumed the same weight as *P. dupetithouarsii* (Wilman et al. 2014 - 99.49g)
Foraging time	Diurnal	Presumed diurnal as other Ptilinopus sp. (Wilman et al. 2014)
Diet	Frugivore	Presumed to be frugivore by HBW: “diet reported to be similar to that of *P. dupetithouarsii*, with which sometimes seen feeding together”, and Hume (2017): “The diet comprised fruits, vines and seeds”
Foraging strata	Canopy	Presumed to be canopy based on HBW: “A bird of the forest canopy; apparently more montane than the commoner, sympatric *P. dupetithouarsii*; found up to 1370m”; and also Hume (2017): “The habits of this subspecies are better documented than those of the Nuka Hiva race. It was described as arboreal, and more rapid and agile in flight than the White-capped Fruit Dove *Ptilinopus dupetithouarsii*”
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Rhodacanthis forfex		
Body mass	38	Following the estimated of 38g by Boyer (2008)
Foraging time	Diurnal	Presumed diurnal based on behavioural descriptions and other Fringillidae in Hawaiian Islands
Diet	Granivore	Granivore by Boyer (2008); but Hume (2017): “The bill was robust, with strong muscle attachments which presumably allowed the bird to slice into the tough, fibrous pods of Koa Acacia koa, which was the main food item of the koa finches on Hawaii. The habitat where the subfossil remains were found on Kaua’i contained a number of leguminous plants, including Kanaloa *Kanaloa kahoolawensis* and Koai’a *Acacia koaia*; these were probably utilised for food, with the birds also feeding on caterpillars and berries”
Foraging strata	Understory	Presumed understory as closest congeneric *Rhodacanthis flaviceps* and *Rhodacanthis palmeri* (Sobral et al. 2016)
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on Hume (2017): “The bill was robust, with strong muscle attachments which presumably allowed the bird to slice into the tough, fibrous pods of Koa Acacia koa, which was the main food item of the koa finches on Hawaii. The habitat where the subfossil remains were found on Kaua’i contained a number of leguminous plants, including Kanaloa *Kanaloa kahoolawensis* and Koai’a *Acacia koaia*; these were probably utilised for food, with the birds also feeding on caterpillars and berries”

Rhodacanthis litotes		
Body mass	28.2	Following the estimated of 38g by Boyer (2008); and also Hume (2017): “This was a smaller koa finch, approximately the size of *R. flaviceps*, but it differed in the structure of the bill, being more similar to the larger *R. palmeri* and *R. forfex*”
Foraging time	Diurnal	Presumed diurnal based on behavioural descriptions and other Fringillidae in Hawaiian Islands
Diet	Granivore	Granivore by Boyer (2008); but Hume (2017): “As in the case of *R. forfex* on Kaua’i, the habitat surrounding the fossil locality on Oahu comprised various legumes, but the Koa Acacia koa was comparatively scarce, suggesting that in the lowlands at least other leguminous plants were preferred”
Foraging strata	Understory	Presumed understory as closest congeneric *Rhodacanthis flaviceps* and *Rhodacanthis palmeri* (Sobral et al. 2016)
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on Hume (2017): “As in the case of *R. forfex* on Kaua’i, the habitat surrounding the fossil locality on Oahu comprised various legumes, but the Koa Acacia koa was comparatively scarce, suggesting that in the lowlands at least other leguminous plants were preferred”

Zosterops conspicillatus conspicillatus		
Body mass	9.2	We assumed a mean value of interval published on HBW for Guam (7.9–10.5g)
Foraging time	Diurnal	Presumed diurnal as *Zosterops conspicillatus* (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore as *Zosterops conspicillatus* (Wilman et al. 2014); also Jenkins (1983): “*Zosterops c. conspicillata* feeds primarily on insects… feeding only on insects gleaned from twigs or foliage; if fruits and seeds are taken, they probably comprise only a small portion of the diet”, and HBW: “Diet consisted of seeds, nectar, flowers and fruits of 22 vine, tree and herb species; also insects, small snails”
Foraging strata	Canopy	Presumed canipy based on Hume (2017): “The white-eye is primarily a canopy-feeder”
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest, Shrubland, Artificial terrestrial habitats	Presumed to occur in forest, shrubland and artificial terrestrial habitats as *Zosterops conspicillatus* (IUCN Red List)

Neochen barbadiana

Body mass	1250	We assumed the same weight as *Neochen jubata* (Wilman et al. 2014 - 1250g); and also Olson (1978): ""This included a new species of goose, *N. barbadiana*, related to the Orinoco Goose, *N. jubata*, of South America, thus rejecting another South American element in the avifauna of the Lesser Antilles"
Foraging time	Diurnal	Presumed diurnal as the only Neochen species, *Neochen jubata* (Wilman et al. 2014)
Diet	Herbivore	Presumed to be herbivore as *Neochen jubata* (Olson 1978), and also according to https://paleobiodb.org/classic/checkTaxonInfo?taxon_no=290688&is_real_user=1, and site fossilworks: "Volant herbivore"
Foraging strata	Ground	Presumed ground as congeneric extant *Neochen jubata* (Wilman et al. 2014 - ground 80%, water 20%)
Volancy	Volant	Presumed to be volant as *Neochen jubata* (Sayol et al. 2020); and also https://paleobiodb.org/classic/checkTaxonInfo?taxon_no=290688&is_real_user=1
Habitat	Forest, Savannah, Wetlands (Inland)	Presumed to occur in forest, savannah and wetlands (inland) as *Neochen jubata* (IUCN Red List)

Haematopus meadewaldoi		
Body mass	692	We assumed the same weight as *Haematopus moquini* (Wilman et al. 2014 - 692g), although it was apparently smaller HBW: "Differs from *H. moquini* in having shorter wings and longer bill" Additional context on body size: - HBW: H. meadewaldoi: "c. 43 cm. Differs from *H. moquini* in having shorter wings and longer bill", *H. moquini*: "42–45 cm; male 582–757g, female 646–800g" - Hume (2017): "40–45cm. Very similar to the African Black Oystercatcher *Haematopus moquini*, but with smaller wings, slenderer tarsi and a longer bill" - Hockey (1983): Tarsus length of *Haematopus moquini* = 56.1 + 2.1; Tarsus length of *Haematopus meadewaldoi* = 51.6
Foraging time	Diurnal	Presumed diurnal as all other Haematopus sp. (Wilman et al. 2014)
Diet	Invertebrate	Presumed invertivore based on Hume (2017): "It's diet was like that of other oystercatchers, comprising small molluscs and crustaceans" and "Unknown; probably mostly mussels and limpets. Likely prey species include limpets (*Patella candei, P. pipperata, P. cf. aspera*) and the mussel *Perna picta*; all of these species have been heavily exploited by man in E Canary Is. All oystercatchers attack different prey types using variety of techniques, e.g. hammering, prising, probing, stabbing"; Also, *Haematopus moquini* and all other Haematopus sp. are invertivores (Wilman et al. 2014)

Foraging strata	Ground	Presumed ground based on all other Haematopus sp. (Wilman et al. 2014), and IUCN Red List: “It inhabited the coastal zone where it foraged for invertebrates; its ecology was likely to have been typical of the genus”
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Marine	Marine Intertidal (IUCN Red List)

Icterus leucopteryx bairdi		
Body mass	36.9	Presumed weight of 36.9g as *Icterus leucopteryx* (Wilman et al. 2014), although it’s supposed to be smaller according to HBW: “This icterid, smaller and brighter yellow-green than nominate race, inhabited town gardens, as well as woodland”
Foraging time	Diurnal	Presumed diurnal as *I. leucopteryx* (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore as *I. leucopteryx* (Wilman et al. 2014 - 50% invertebrates, 30% fruits, 20% nectar)
Foraging strata	Midhigh	Presumed midhight as *I. leucopteryx* (Wilman et al. 2014), and Hume (2017): “hunting for food in the crowns of Coconut and Thrinax palm trees”
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest, Artificial terrestrial habitats	Presumed to occur in forest and artificial terrestrial habitats as *Icterus leucopteryx* (IUCN Red List)

Turdus ravidus		
Body mass	75.3	We assumed the same weight as *Turdus plumbeus* (Wilman et al. 2014 - 75.3g), because HBW: “The white-tipped tail, largely grayish plumage and red bare parts all suggest a close relationship with the Caribbean endemic Red-legged Thrush (*Turdus plumbeus*)” so apparently the only differences are related to coloration More information on closest species in HBW: “Among known species, the closest relative seems undoubtedly to be Red-legged Thrush, and among still living species the next closest relative should be White-chinned Thrush, *Turdus aurantius*”
Foraging time	Diurnal	Presumed to be diurnal as other Turdus sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed to be omnivore as *Turdus plumbeus* (Wilman et al. 2014) and also because HBW: “For food and most other life history topics no information is available. It can be assumed that it will have shared many (but not all) habits with its closest relative, the Red-legged Thrush (Turdus plumbeus)”
Foraging strata	Ground	Presumed to be ground as *Turdus plumbeus* (Wilman et al. 2014 - 60% ground, 20% midhigh and 20% canopy)

Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Myiagra freycineti		
Body mass	11.8	Following the estimated value of 11.8g by CRC book
Foraging time	Diurnal	Presumed to be diurnal as other Myiagra sp. (Wilman et al. 2014)
Diet	Invertivore	Presumed invertivore as Hume (2017): "skulking and foraging for insects in thick vegetation", and Jenkins (1983): "Myiagra freycineti is entirely insectivorous"
Foraging strata	Canopy	"but it tended to forage higher in the canopy" (Hume 2017)
Volancy	Volant	Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Hemignathus vorpalis		
Body mass	49.6	Following the estimated value of 49.6g by Boyer (2008)
Foraging time	Diurnal	Presumed to be diurnal as other Hemignathus sp. (Wilman et al. 2014)
Diet	Invertivore	Insectivore by Boyer (2008)
Foraging strata	Nonspecialized	Presumed nonspecialized as other congeneric species, *Hemignathus wilsoni* (=munroi) and *Hemignathus lucidus* (Wilman et al. 2014); and also, Hume (2017): "The 'akialoas and nukupu'us foraged by hammering and twisting off bark and lichens on trees, or probing into epiphytes, bark crevices or insect burrows" "James & Olson (2003) hypothesise that the bird might have been more terrestrial, probing into ground-level vegetation or using the long upper bill to move leaf litter, in the manner of the New Zealand Weka *Gallirallus australis* or Kiwi Apteryx sp."
Volancy	Volant	Volant by Sayol et al. (2020) and Boyer (2008)
Habitat	Forest	Presumed to occur in forest as other *Hemignathus* sp. (Wilman et al. 2014), and also James & Olson (2003): "There is no cause to reject the idea that *H. vorpalis* preferred forest habitat like its relatives"

Hemignathus upupirostris		
Body mass	28.5	Following the estimated value of 28.5g by Boyer (2008)
Foraging time	Diurnal	Presumed to be diurnal as other Hemignathus sp. (Wilman et al. 2014)

Diet	Invertivore	Insectivore by Boyer (2008); and also Hume (2017): "Very long, decurved bill, not modified for hammering as in the Nukupu'u *Hemignathus lucidus* or Akiapola'au *H. munroi*. Perhaps this bird did not predominantly feed on nectar as in other 'akialoas"
Foraging strata	Nonspecialized	Presumed nonspecialized as other congeneric species, *Hemignathus wilsoni* (=*munroi*) and *Hemignathus lucidus* (Wilman et al. 2014)
Volancy	Volant	Volant by Boyer (2008), although unknown by Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest as other *Hemignathus* sp. (Wilman et al. 2014), and also Hume (2017): "As the subfossil remains are known from coastal sites on Kaua'i and Oahu, the Hoopoe-billed 'Akialoa appears to have been a victim of Polynesian habitat alteration, which was much more severe in the lowlands"

Zapornia sandwichensis sandwichensis		
Body mass	35	Following the estimated value of 35g by Boyer (2008)
Foraging time	Diurnal	Presumed to be diurnal as other Zapornia sp. (Wilman et al. 2014)
Diet	Invertivore	Insectivore by Boyer (2008)
Foraging strata	Ground	Presumed ground since it was flightless and according to Hume (2017): "Its nest is made on the ground"
Volancy	Flightless	Volant by Sayol et al. (2020)
Habitat	Forest	IUCN Red List: "It inhabited clearings in upland forest."

Zapornia sandwichensis millsi		
Body mass	35	Following the estimated value of 35g by Boyer (2008)
Foraging time	Diurnal	Presumed to be diurnal as other Zapornia sp. (Wilman et al. 2014)
Diet	Invertivore	Insectivore by Boyer (2008)
Foraging strata	Ground	Presumed ground since it was flightless and according to Hume (2017): "Its nest is made on the ground"
Volancy	Flightless	Volant by Sayol et al. (2020)
Habitat	Forest	IUCN Red List: "It inhabited clearings in upland forest."

Akialoa lanaiensis		
Body mass	27.5	Following the estimated value of 27.5g by Boyer (2008)
Foraging time	Diurnal	Presumed to be diurnal as other Hemignathus sp. (Wilman et al. 2014)

Diet	Omnivore	Presumed omnivore based on HBW: “Arthropods (primarily beetle larvae and adults, spiders, and caterpillars) and nectar. Extent of nectar-foraging possibly varied during year, since some observers reported that 'akialoa fed extensively on nectar (Perkins 1903, Munro 1944a), while others reported little or no nectar-feeding (Wilson and Evans 1890, Henshaw 1902a)”; but also other information - Hume (2017): “Hunting for insects along the trunk and large limbs of a partly fallen Ohia” - Amante-Helweg et al. (2009): “Feeding on insects and nectar”
Foraging strata	Nonspecialized	Presumed nonspecialized as congeneric *Hemignathus wilsoni* (=*munroi*) and *Hemignathus lucidus* (Wilman et al. 2014); and also HBW: “These large Hawaiian honeycreepers foraged principally by creeping along tree trunks and large branches, probing for insects under moss and bark, and taking nectar from tubular flowers”
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Akialoa stejnegeri		
Body mass	34	Following the estimated value of 34g by Boyer (2008)
Foraging time	Diurnal	Presumed to be diurnal as other Hemignathus sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore based on Pratt (2005): “Actively hopped on short legs along lichen and moss-covered trunks and branches of trees, probing for invertebrates with the long bill deep into cracks and crevices, or into leaf bases of ‘ie‘ie and halapepe. Also took nectar from haha‘aiakamanu or other flowering lobelioids”
Foraging strata	Nonspecialized	Presumed nonspecialized as congeneric *Hemignathus wilsoni* (=*munroi*) and *Hemignathus lucidus* (Wilman et al. 2014)
Volancy	Volant	Volant by Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Alopochen kervazoi		
Body mass	1873	We presumed the same body mass as closest species *Alopochen aegyptiacus* (Wilman et al. 2014), since Hume (2017): “Analysis of subfossil remains collected by Kervazo in 1974 (Cowles 1994) clearly show that a derivative of the Egyptian Goose *Alopochen aegyptiacus*, closely related to the Mauritian species, once occurred on Réunion Island. Nothing more can be said about them other than that they differed from Egyptian Goose by having more robust leg bones and a shorter, deeper bill.” (Hume 2017) Additional context on body size:

		– *kervazoi* total length humerus = 126.0mm; *A. kervazoi* total length femur = 69.0mm (Mourer-Chauviré et al. 1999) – *aegyptiacus* total length humerus = 134.10 (11); *A. aegyptiacus* total length femur = 71.04 (11) (Mourer-Chauviré et al. 1999)
Foraging time	Diurnal	Presumed diurnal as all other Anatidae (Wilman et al. 2014)
Diet	Herbivore	Presumed granivore as closest species *Alopochen aegyptiacus* (Wilman et al. 2014 - 10% invertebrates, 90% plants)
Foraging strata	Ground	Presumed ground as closest species *Alopochen aegyptiacus* (Wilman et al. 2014 - 30% water and 70% ground)
Volancy	Volant	Volant in Sayol et al. (2020)
Habitat	Wetlands	Wetlands by IUCN Red List

Alopochen mauritiana		
Body mass	1683.97	We presumed the same body mass as *Branta leucopsis* (Wilman et al. 2014), since Newton and Gadow (1893): "Another part of this bird consists of the somewhat incomplete left half of the pelvis; it agrees in size with that of *Bernicla brenta*, consequently by inference with Sarcidiomis, measuring 70 mm"
Foraging time	Diurnal	Presumed diurnal as all other Anatidae (Wilman et al. 2014)
Diet	Herbivore	Presumed herbivore as closest species *Alopochen aegyptiacus* (Wilman et al. 2014 - 10% invertebrates, 90% plants), and also based on Hume and Winters (2015): "Geese are also here in abundance. They are a little larger than ducks, very tame and stupid, seldom in the water, eating grass, sometimes 40 or 50 or even a 100 together"
Foraging strata	Ground	Presumed ground as closest species *Alopochen aegyptiacus* (Wilman et al. 2014 - 30% water and 70% ground)
Volancy	Volant	Volant in Sayol et al. (2020)
Habitat	Wetlands	Wetlands by IUCN Red List

Pyrocephalus dubius		
Body mass	14.4	Presumed weight of 14.4g as *P. rubinus* (Wilman et al. 2014) since this species was thought to have been subspecies of *P. rubinus*; although it's supposed to be smaller according to Carmi et al. (2016): "In addition, nearly all classifications have considered *P. r. dubius* of San Cristóbal Island to be distinct from other Galápagos populations based mainly on its smaller size"

Foraging time	Diurnal	Presumed diurnal as the other tyrant-flycatchers Tyrannidae (Wilman et al. 2014)
Diet	Invertivore	Presumed invertivore as other tyrant-flycatchers Tyrannidae (Wilman et al. 2014)
Foraging strata	Nonspecialized	Presumed nonspecialized as closest congeneric species, the extant Galápagos Vermilion Flycatcher *P. nanus*, and the Vermillion Flycatcher *P. rubinus* (Wilman et al. 2014)
Volancy	Volant	Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Amazona martinicana		
Body mass	327.37	Presumed the same body mass as *Amazona arausiaca* (Wilman et al. 2014) since it was only known from Labat's brief description in 1742 and was mistaken with it. Also, Hume (2017): "Rothschild (1905b) identified the Dominican bird as the Red-necked Amazon *Amazona arausiaca*", and HBW: "Sometimes considered conspecific with extant *A. imperialis* and †*A. violacea*. Not known from any material remains, but said to be similar to extant *A. arausiaca* of nearby Dominica"
Foraging time	Diurnal	Presumed diurnal as all other Amazona sp. (Wilman et al. 2014)
Diet	Frugivore	Presumed frugivore as extant conspecific *Amazona amazonica* (Wilman et al. 2014)
Foraging strata	Midhigh	Presumed midhigh since it was mistaken by extant conspecific *Amazona arausiaca* (Wilman et al. 2014 - 20% understory, 50% midhigh and 30% canopy).
Volancy	Volant	Volant in Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List. Also, Juniper & Parr (1998): "This bird survives on the island in mountain forest, although at lower altitudes than those inhabited by the Imperial Amazon *A. imperialis*"

Anas theodori		
Body mass	668.85	Presumed that body mass was equal to the mean value of between *A. bernieri* and *A. melleri*, based on Hume (2017): "It was larger than its closest relative on Madagascar, the Madagascar Teal *A. bernieri*, and smaller than the other Madagascan Anas, Meller's Duck *A. melleri*". Body mass of *A. melleri* is 959.22g, and of *A. bernieri* is 378.48g (Wilman et al. 2014). Also, HBW: "Closest living relative formerly reckoned to be *A. melleri*, but now thought to be *A. bernieri*" Note: We also estimated body mass of *Anas theodori* using Field et al. (2013) equation of humerus length, obtaining. The estimated body of *Anas theodori* was 463.,78g (length of coracoid = 42mm; length of humerus = 70-78mm; length of metatarsus = 42mm; REFS)., However, when applying the same equation to

		estimate the body size of whereas *Anas melleri* (length of humerus = 89mm; Newton and Gadow 1893) we obtained a value of was 679.58g, about 70% of the 959.22g in Elton 1.0 (Wilman et al. 2014). If one assumes that the true body size of *A. theodori* is also 70% of what is obtained through the equation, we would get a value of 662.54g, very similar to the result used as the mean between *A. berneri* and *A. melleri*
Foraging time	Diurnal	Presumed diurnal as all other Anatidae (Wilman et al. 2014)
Diet	Herbivore	Presumed herbivore like closest relatives *A. melleri* and *A. bernieri* (both 50% plants) (Wilman et al. 2014)
Foraging strata	Water	Presumed water like closest relatives *A. melleri* (80% water, 20% ground) and *A. bernieri* (100% water) (Wilman et al. 2014)
Volancy	Volant	Volant in Sayol et al. (2020)
Habitat	Wetlands	Wetlands by IUCN Red List

Aphanapteryx bonasia		
Body mass	1150	We estimated a mean value of 1150g considering Livezey (2003) that "estimated a body mass of 1.3 kg in the male and around 1 kg for the female."
Foraging time	Diurnal	Presumed diurnal based on behavioural descriptions (Hume 2017)
Diet	Omnivore	Presumed omnivore based on Hume (2017): "Pretorius's account confirms that the rails were feeding on invertebrates amongst leaf litter, and Hachisuka (1953) surmised that as the tip of the bill was very sharp and strong, it probably fed by crushing molluscs and other shells, rather like an oystercatcher. The rails were probably opportunist omnivores"
Foraging strata	Ground	Presumed ground as it was observed foraging on the ground for food (Hume 2017; see above). Also, all other rails of neighbouring islands are ground foragers (Wilman et al. 2014)
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Erythromachus leguati		
Body mass	500	Following the (coarse) estimate by Hume (2019): "Erythromachus presumably exhibited marked size sexual dimorphism (Fig. 24), with the males being presumably bigger than females, as in other Rallidae (Ripley 1977; Livezey 2003), and may have had a body mass exceeding 500 g (Livezey 2003)."
Foraging time	Diurnal	Presumed diurnal based on behavioural descriptions (Hume 2017)
Diet	Omnivore	Presumed omnivore based on Hume (2017): "They generally feed on the eggs of the land tortoises, which they find in the ground, which makes them so fat that they often have difficulty in running", and Hume

		(2019): “According to Tafforet’s (1725–26) account Erythromachus was an opportunist predator, as it clearly took advantage of the breeding season of terrestrial tortoises to feed on the eggs, and perhaps hatchling young. But at other times of the year probably fed on terrestrial snails and other invertebrates, as well as scavenging seabird breeding colonies”
Foraging strata	Ground	Presumed ground based on Hume (2019): “More likely nesting deep in the forested valleys or in the mountainous hills of the interior, constructing nests well concealed in ground vegetation, as do many other flightless rails”. Also, all other rails of neighbouring islands are ground foragers (Wilman et al. 2014)
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest	Forest by IUCN Red List

Dryolimnas augusti		
Body mass	325	We estimated a mean value of 325g following the (coarse) estimate by Hume (2019): “Being slightly larger than *D. chekei*, it may have reached 35–38 cm in length, with a body mass of up to 300–350 g.”. Also, Hume (2017): “The Réunion Rail was a large, robust bird, much larger than White-throated Rail *Dryolimnas cuvieri*, with particularly robust legs.” (*Dryolimnas cuvieri* weights 182.38g; Wilman et al. 2014)
Foraging time	Diurnal	Presumed diurnal, as its only extant congeneric *Dryolimnas cuvieri*
Diet	Invertivore	Presumed invertivore as its extant congeneric *Dryolimnas cuvieri*, and based on Hume (2019): “On Aldabra, *Dryolimnas* feeds on a wide range of animal matter, including insects and other invertebrates in litter, marine and terrestrial molluscs, catching small, or scavenging large, land crabs, and consumes flies, maggots and eggs associated with giant tortoise carcasses (Penny & Diamond 1971; Safford & Hawkins 2013). Mauritius once harboured high densities of giant tortoises and land crabs, and a diverse terrestrial gastropod fauna (…), so Cheke’s Wood Rail almost certainly had a similar feeding niche, and may have also taken advantage of seasonal breeding sites of giant tortoises and invertebrates associated with seabird colonies.”
Foraging strata	Ground	Presumed ground given behavioural descriptions that it ate a wide diversity of terrestrial animal matter (Hume 2019; *Dryolimnas cuvieri*: 50% ground and 50% water, Wilman et al. 2014)
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest, Shrubland, Wetlands, Marine, Artificial aquatic habitats	We presumed it would use today (if extant) the same as its extant congeneric (closest relative) *Dryolimnas cuvieri* (IUCN Red List). Also Hume (2019): “suggests that it was an inhabitant of forests. It is also likely that it was restricted to lowland forests, because Dubois specifically mentioned the oiseaux bleu […] as the only montane rallid. *D. augusti* probably had the same habits as *D. chekei* on Mauritius, nesting in dense vegetation deep in forest”

Dryolimnas chekei		
Body mass	300	Following the (coarse) estimate by Hume (2019): "The endemic, flightless *Dryolimnas* of Mauritius and Réunion were larger and heavier than recent *Dryolimnas*, possibly reaching 35+ cm in length and weighing up to 300 g, or even heavier."
Foraging time	Diurnal	Presumed diurnal as its only extant congeneric *Dryolimnas cuvieri*
Diet	Invertivore	Presumed invertivore as its extant congeneric *Dryolimnas cuvieri*, and based on Hume (2019): "On Aldabra, Dryolimnas feeds on a wide range of animal matter, including insects and other invertebrates in litter, marine and terrestrial molluscs, catching small, or scavenging large, land crabs, and consumes flies, maggots and eggs associated with giant tortoise carcasses (Penny & Diamond 1971; Safford & Hawkins 2013). Mauritius once harboured high densities of giant tortoises and land crabs, and a diverse terrestrial gastropod fauna (…), so Cheke's Wood Rail almost certainly had a similar feeding niche, and may have also taken advantage of seasonal breeding sites of giant tortoises and invertebrates associated with seabird colonies."
Foraging strata	Ground	Presumed ground given behavioural descriptions that it ate a wide diversity of terrestrial animal matter (Hume 2019; *Dryolimnas cuvieri*: 50% ground and 50% water, Wilman et al. 2014)
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest, Shrubland, Wetlands (inland), Artificial aquatic habitats, Marine	We presumed it would use today (if extant) the same habitats as its extant congeneric (closest relative) *Dryolimnas cuvieri* (IUCN Red List)

Fulica newtonii		
Body mass	1200	Following the (coarse) estimate by Hume (2019): "From my comparison with other similar-sized species, it measured around 35 cm in total length and may have had a body mass of up to 1.2 kg"
Foraging time	Diurnal	Presumed diurnal as all other *Fulica* sp. (Wilman et al. 2014)
Diet	Granivore	Presumed granivore as *Fulica atra* (Wilman et al. 2014: 30% seeds, 30% plants, and 10% in four other classes); and also given Hume (2019): "The Mascarene Coot probably had similar habits to *F. atra* (see Taylor & van Perlo 1998), nesting in aquatic vegetation alongside water, and feeding on vegetable matter, aquatic seeds and invertebrates."

Foraging strata	Water	Presumed water as *Fulica atra* (Wilman et al. 2014); and also given Hume (2019): "The Mascarene Coot probably had similar habits to *F. atra* (see Taylor & van Perlo 1998), nesting in aquatic vegetation alongside water, and feeding on vegetable matter, aquatic seeds and invertebrates."
Volancy	Volant	Sayol et al. (2020)
Habitat	Wetlands (inland)	Wetlands by IUCN Red List

Hypotaenidia pendiculentus		
Body mass	205.92	Presumed the same weight as its closest congeneric *Hypotaenidia philippensi* (Wilman et al. 2014; to which it closely resembled and from which it probably descended), although it was said to be slightly smaller by Kirchman & Steadman (2006): "A medium-sized rail, slightly smaller than *Gallirallus philippensis*, and with disproportionately shorter wing elements"
Foraging time	Diurnal	Presumed diurnal as all other *Gallirallus* sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore as its closest congeneric *Hypotaenidia philippensi*. Moreover, extinct congeneric *Hypotaenidia owstoni* from the neighbouring island of Guam is also omnivore (Wilman et al. 2014)
Foraging strata	Ground	Presumed ground as extinct congeneric *Hypotaenidia owstoni* from the neighbouring island of Guam (Wilman et al. 2014). The habits of the closest congeneric *Hypotaenidia philippensi* were probably different because it is volant
Volancy	Weak flyer	Sayol et al. (2020)
Habitat	Forest, Shrubland, Grassland, Wetlands (inland), Rocky areas, Marine, Artificial terrestrial habitats, Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats as its extant congeneric *Hypotaenidia philippensi* (IUCN Red List)

Gallirallus huiatua		
Body mass	205.92	Presumed the same weight as *Hypotaenidia philippensi* (Wilman et al. 2014), based on Hume (2017): "The Niue Rail was a medium-sized flightless rail, about the size of volant Buff-banded Rail *Hypotaenidia philippensis*"

Foraging time	Diurnal	Presumed diurnal as all other *Gallirallus* sp. (Wilman et al. 2014)
Diet	Omnivore	Nothing is known so we presumed it was omnivore as *Hypotaenidia philippensi*, and considering that 7 out of 10 Gallirallus in Wilman et al. (2014) are omnivore
Foraging strata	Ground	Following, Steadman et al. (2020), who presented it as a ground-dwelling species. Moreover, 9 out of the 10 *Gallirallus* sp. in Wilman et al. 2014 are ground foragers
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest, Shrubland, Grassland, Wetlands (inland), Rocky areas, Marine, Artificial terrestrial habitats, Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats as *Hypotaenidia philippensi* (IUCN Red List)

Gallirallus epulare		
Body mass	205.92	Presumed the same weight as closest species *Hypotaenidia philippensi* (Wilman et al. 2014), although it was smaller (tarsometatarsus: shaft width = 3.5 in both *Gallirallus epulare* and *Hypotaenidia philippensi*), and also Kirchman and Steadman (2007): "This was a small, flightless rail, with reduced wing elements and corresponding robust leg elements"
Foraging time	Diurnal	Presumed diurnal as all other *Gallirallus* sp. (Wilman et al. 2014)
Diet	Omnivore	Nothing is known so we presumed it was omnivore as closest species *Hypotaenidia philippensi* (Wilman et al. 2014)
Foraging strata	Ground	Following, Steadman et al. (2020) who presented it as a ground-dwelling species. Moreover, 9 out of the 10 *Gallirallus* sp. in Wilman et al. 2014 are ground foragers
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest, Shrubland, Grassland, Wetlands (inland), Rocky areas, Marine, Artificial terrestrial habitats, Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats as *Hypotaenidia philippensi* (IUCN Red List)

Rallus lowei		
Body mass	110.67	Presumed the same body mass as Water Rail *Rallus aquaticus*, despite evidences suggest it was probably smaller: "All of these extinct Madeiran and Azorean rails were derived from Water Rail *Rallus aquaticus*, but differed in their smaller size, reduced wings, and shorter, but more robust limbs… The flightless Madeira Rail was the largest and heaviest of the Macaronesian rails, being overall smaller and stouter than Water Rail, but with more reduced wings – the humerus was around 24% shorter" (Hume 2017)
Foraging time	Diurnal	Presumed diurnal as all other *Rallus* sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore as Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 7 different classes all with less than 20%)
Foraging strata	Water	Presumed mainly water forager as its ancestor Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 50% water, 40% ground, 10% understory)
Volancy	Flightless	Sayol et al. (2020)
Habitat	Grassland, Wetlands (inland), Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats as its ancestor Water Rail *Rallus aquaticus* (IUCN Red List)

Rallus montivagorum		
Body mass	110.67	Presumed the same body mass as Water Rail *Rallus aquaticus*, despite evidences suggest it was probably smaller: "All of these extinct Madeiran and Azorean rails were derived from Water Rail *Rallus aquaticus*, but differed in their smaller size, reduced wings, and shorter, but more robust limbs" in Hume (2017), and Alcover et al. (2015) that states it was slightly smaller with a reduced sternum and much shortened tarsometatarsus
Foraging time	Diurnal	Presumed diurnal as all other *Rallus* sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore as Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 7 different classes all with less than 20%).
Foraging strata	Water	Presumed mainly water forager as its ancestor Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 50% water, 40% ground, 10% understory)
Volancy	Weak flyer	Sayol et al. (2020).

Habitat	Grassland, Wetlands (inland), Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats as its ancestor Water Rail *Rallus aquaticus* (IUCN Red List)

Rallus nanus		
Body mass	110.67	Presumed the same body mass as Water Rail *Rallus aquaticus*, despite evidences suggest it was probably smaller in Hume (2017): "This was the smallest of all Macaronesian rails, and the wings were relatively more reduced than in other Azorean rails, with a corresponding reduction of the keel (Alcover et al. 2015)"
Foraging time	Diurnal	Presumed diurnal as all other Rallus sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore as Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 7 different classes all with less than 20%)
Foraging strata	Water	Presumed mainly water forager as its ancestor Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 50% water, 40% ground, 10% understory). Although, according to Hume (2017): "The bill was elongate and slightly decurved, and Alcover et al. suggest that it was used to probe in soft soil, mosses and deep leaf litter, as hypothesised for other long-billed, flightless rails"
Volancy	Flightless	Sayol et al. (2020)
Habitat	Grassland, Wetlands (inland), Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats as its ancestor Water Rail *Rallus aquaticus* (IUCN Red List)

Rallus carvaoensis		
Body mass	110.67	Presumed the same body mass as Water Rail *Rallus aquaticus*, despite evidences suggest it was probably smaller in Hume (2017): "was a small, flightless species with extremely reduced wings and short, robust limbs; the bill was more curved than in Water Rail *Rallus aquaticus* (Alcover et al. 2015)"
Foraging time	Diurnal	Presumed diurnal as all other *Rallus* sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore as Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 7 different classes all with less than 20%)
Foraging strata	Water	Presumed mainly water forager as its ancestor Water Rail *Rallus aquaticus* (Wilman et al. 2014 – 50% water, 40% ground, 10% understory)
Volancy	Flightless	Sayol et al. (2020)

Habitat	Grassland, Wetlands (inland), Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats Presumed to occur in grasslands, wetlands, artificial aquatic habitats as its ancestor Water Rail Rallus aquaticus (IUCN Red List)

Ara autochthones		
Body mass	861.99	We estimated a mean value of 861.99g considering two congeneric species that were said to be similar in size by Olson and Maíz Lopez (2008): "*Ara autochthones* is distinct in being intermediate between these two clusters. Only *Ara glaucogularis* and *Anodorhynchus leari* (and presumably the very closely related *A. glaucus*, which may be only sub-specifically distinct (Alvarenga 2007)) are similar in size." (*Anodorhynchus leari* weights 939.99g and *Ara glaucogularis* 783.99g; Wilman et al. 2014)
Foraging time	Diurnal	Presumed diurnal as all other *Ara* sp. (Wilman et al. 2014)
Diet	Frugivore	Presumed frugivore based on behavioural descriptions of West Indian macaws (not necessarily *A. autochthones* though) found in Wiley and Kirwan (2013): "Oviedo y Valdés (1535: Libro Septimo, Capitulo ii: lxxii) reported West Indian macaws fed on manchineel *Hippomane mancinella*, which is common in the West Indies but is a powerful caustic poison to man and other animals. Du Tertre (1654: 296) said West Indian macaws fed 'on seeds and several fruits of trees, but mainly on the apples of the manchineel.'" Also: all 5 species of *Ara* in Wilman et al. (2014) are frugivore
Foraging strata	Canopy	Presumed canopy based on the description of macaws in Dominica (likely close relatives) by Wiley and Kirwan (2013): "In Dominica, Atwood (1791: 29) said macaws gathered atop the highest trees, where they 'feed on the berries in great numbers together.'"
Volancy	Volant	Presumed volant as all other *Ara* sp. (8 species) in Sayol et al. (2020) are considered volant, including the extinct congeneric island species, *Ara tricolor* (even though in Sayol et al. 2020 *A. autochthones* is classified as 'unknown'). Also, behavioural descriptions in Wiley and Kirwan (2013) said the West Indian macaws were volant: "du Tertre (1654: 294) said 'Their voice is loud and piercing, and they always cry when flying'." (although these were not necessarily *A. autochthones*)
Habitat	Forest	Presumed to have occurred in forest as its congeneric extinct island species, Cuban Macaw *Ara tricolor* (IUCN Red List). All other macaws (*Ara* sp.) are continental and occur in forests (as well as in other habitats)

Ara guadeloupensis

Body mass	1015	Presumed the same weight as *A. macao* (Wilman et al. 2014), based on Gala and Lenoble (2015): "Size information available in Father Du Tertre writings (Du Tertre 1667) led Clark (1905) to conclude that the Lesser Antilles Macaw would have been slightly smaller than *A. macao*"
Foraging time	Diurnal	Presumed diurnal as all other Ara sp. (Wilman et al. 2014)
Diet	Frugivore	Presumed frugivore based on behavioural descriptions of West Indian macaws (not necessarily *A. autochthones* though) found in Wiley and Kirwan (2013): "Oviedo y Valdés (1535: Libro Septimo, Capitulo ii: lxxii) reported West Indian macaws fed on manchineel *Hippomane mancinella*, which is common in the West Indies but is a powerful caustic poison to man and other animals. Du Tertre (1654: 296) said West Indian macaws fed 'on seeds and several fruits of trees, but mainly on the apples of the manchineel.'" Also: all 5 species of *Ara* in Elton 1.0 are frugivore
Foraging strata	Canopy	Presumed canopy based on the description of macaws in Dominica by Wiley and Kirwan (2013): "In Dominica, Atwood (1791: 29) said macaws gathered atop the highest trees, where they 'feed on the berries in great numbers together.'"
Volancy	Volant	Presumed volant as all other *Ara* sp. (8 species) in Sayol et al. (2020) are considered volant, including the extinct congeneric island species, *Ara tricolor* (even though in Sayol et al. 2020 *A. autochthones* is classified as 'unknown'). Also, behavioural descriptions in Wiley and Kirwan (2013) said the West Indian macaws were volant: "du Tertre (1654: 294) said 'Their voice is loud and piercing, and they always cry when flying." (although these were not necessarily *A. autochthones*)
Habitat	Forest	Presumed to have occurred in forest as its congeneric extinct island species, Cuban Macaw *Ara tricolor* (IUCN Red List). All other macaws (*Ara* sp.) are continental and occur in forests (as well as in other habitats)

Carduelis triasi		
Body mass	26	Presumed the same weight as closest sister species *Carduelis chloris* (Wilman et al. 2014), although it's known to have been larger (Alcover and Florit 1987)
Foraging time	Diurnal	Presumed diurnal as all other *Carduelis* sp. (Wilman et al. 2014)
Diet	Granivore	Presumed granivore based on Hume (2017): "It had a large, robust bill and probably fed on large seeds."
Foraging strata	Ground	Presumed ground since it was flightless. Also, according to Rando et al. (2010): "*Carduelis triasi* probably mainly inhabited and fed on the laurel forest floor"
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest, based on Rando et al. (2010): "*Carduelis triasi* probably mainly inhabited and fed on the laurel forest floor"

Columba thiriouxi		
Body mass	176.79	Presumed the same weight as *Nesoenas picturata* (Wilman et al. 2014), based on Hume (2017): "*Columba thiriouxi* was approximately the same size as *N. picturata* and *N. cicur*, i.e. 28cm in total length"
Foraging time	Diurnal	Presumed diurnal as all other *Columba* sp. (Wilman et al. 2014)
Diet	Frugivore	Presumed frugivore based on Hume (2017): "so it probably fed on seeds and fruit in the forest canopy" and because they feed predominantly in the canopy
Foraging strata	Canopy	Presumed canopy based on Hume (2017): "It had a short, robust tarsometatarsus, indicative of an arboreal species, so it probably fed on seeds and fruit in the forest canopy"
Volancy	Volant	Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest, based on IUCN Red List: "A small arboreal pigeon"

Nesoenas cicur		
Body mass	176.79	Presumed the same weight as *N. picturata* (Wilman et al. 2014), based on Hume (2017): "*Columba thiriouxi* was approximately the same size as *N. picturata* and *N. cicur*, i.e. 28cm in total length", and also "The Mauritian Turtle Dove is distinct from nominate *N. picturata*, both in morphology, having comparatively more robust pelvic elements, and in behaviour, based on inferences made from early accounts."
Foraging time	Diurnal	Presumed diurnal as other *Nesoenas* sp. in Wilman et al. (2014), and as *N. rodericanus* according to Sobral et al. (2016)
Diet	Granivore	Presumed granivore as its congeneric *Nesoenas mayeri* and *Nesoenas picturata* in Wilman et al. (2014), and as *N. rodericanus* according to Sobral et al. (2016)
Foraging strata	Ground	Presumed ground, as its congeneric *Nesoenas picturata* (Wilman et al. 2014), and given behavioural descriptions from Hume (2011): "*N. cicur* nested close to the ground", and Hume and Walters (2012): "Little is known, but it was probably more terrestrial than *N. picturatus*" *N. rodericanus* is also classified as ground dwelling in Sobral et al. (2016)
Volancy	Volant	Sayol et al. (2020)
Habitat	Forest, Artificial terrestrial habitats	We presumed it would use today (if extant) the same habitats as its closest congenerics, *N. mayeri* and *N. picturatus* (IUCN Red List). Also, Hume (2011): "It is difficult to ascertain why *N. cicur* became extinct so early, however, whereas *Alectroenas nitidissima* survived to more recent times and *N. mayeri* still exists. The montane ranges of *A. nitidissima* and *N. mayeri* may have provided refuge. *Nesoenas picturata* is

		more common in the lowlands where it occurs even on high islands, e.g. Comoros (Louette 1988). Therefore, if *N. cicur* also prefered lowland habitat, this may have made it more susceptible to introduced predators and human persecution. Ducros (1725) stated that 'tourterelles' were found on Mauritius in infinite numbers (he may have been referring to all Mauritius columbids) and could still be caught by hand. *Nesoenas cicur* must have disappeared shortly after."

Corvus pumilus		
Body mass	395.43	We estimated a mean body mass value of 395.43 considering *C. leucognaphalus* (501.86g – Wilman et al. 2014; a species it was once sympatric with on Puerto Rico) and *C. palmarum* (289g – Wilman et al. 2014), based on Wetmore (1937): "One of the principal characters in distinguishing *Corvus pumilis* has been size, the ulna being distinctly smaller than that of *C. leucognaphalus* and slightly larger than that of *C. palmarum*"; Almost nothing is known about this species (only an ulna was found)
Foraging time	Diurnal	Presumed diurnal as other Corvus sp. in Wilman et al. (2014)
Diet	Omnivore	Even though nothing is known about its diet, we assume omnivorous as its congenerics *C. leucognaphalus* and *C. palmarum* (Wilman et al. 2014). However, according to Hume (2017): "The endemic Puerto Rican Crow may have occupied a different niche [than those two species], perhaps having a different-shaped bill and favouring lowland habitats"
Foraging strata	Nonspecialized	Even though nothing is known about foraging habits, we assume nonspecialized as its congenerics *C. leucognaphalus* and *C. palmarum* (Wilman et al. 2014)
Volancy	Volant	Presumed volant as all *Corvus* sp. in Sayol et al. (2020), although it is classified as 'unknown' by that author
Habitat	Forest	We presumed it occurred in forest as the White-necked Crow *Corvus leucognaphalus* (a species it was once sympatric with on Puerto Rico; IUCN Red List)

Cryptopsar ischyrhynchus		
Body mass	69.2	We assumed the same weight as *Fregilupus varius* (Wilman et al. 2014), although we know it was smaller based on Hume (2014): "It was the smallest of the Mascarene sturnids, being approximately 260 mm in total length" (*Necropsar rodericanus* is 91.67g – Wilman et al. 2014)
Foraging time	Diurnal	Presumed diurnal based as all other Sturnidae in Wilman et al. (2014)
Diet	Carnivore	Presumed carnivore based on Hume (2017): "It had a bill similar in structure to that of the Eurasian Starling *Sturnus vulgaris*, which inserts its bill into soft substrates and forces it open to reveal food items. Like the Rodrigues Starling *Necropsar rodericanus*, the Mauritian bird was predominantly carnivorous, possibly

		feeding on small geckos, skinks and invertebrates, raiding the nests of forest birds, and seasonally scavenging among turtle, tortoise and seabird breeding colonies”
Foraging strata	Ground	Presumed ground foraging based on Hume (2017): “The Mauritius Starling occurred in the semi-dry evergreen forests of the island, and probably nested in tree hollows. It was a powerful gaping species, and probably foraged on the ground”
Volancy	Volant	Presumed volant as the other two starlings of Rodrigues *Necropsar rodericanus* and La Reunion *Fregilupus varius*. Also, if it “probably nested in tree hollows” it was surely volant
Habitat	Forest	Presumed to occur in forest based on Hume (2017): “The Mauritius Starling occurred in the semi-dry evergreen forests of the island, and probably nested in tree hollows. It was a powerful gaping species, and probably foraged on the ground”

Dysmoropelia dekarchiskos		
Body mass	368.515	The relationships of Dysmoropelia are obscure and almost nothing is known, being the only species of its genus. We assumed the average weight between *Columba junioniae* and *Leucosarcia melanoleuca* based on Olson (1975): “The tarsometatarsus is quite large and is as wide or wider than in such large pigeons as *Columba junioniae* and *Leucosarcia melanoleuca* – (308.46 and 428.57, respectively, in Wilman et al. 2014)
Foraging time	Diurnal	Presumed diurnal, as all Columbidae found in Wilman et al. (2014)
Diet	Granivore	Presumed granivore, as 3 of 4 turtle doves found on Wilman et al. (2014)
Foraging strata	Ground	Presumed to be a ground species, since it was presumed flightless, and was probably related to turtle doves as suggested by Rowland et al. (1999) and also Ashmole and Ashmole (2000): “St Helena Pigeon was closest to the Streptopelia turtle doves, which are adept colonisers of remote oceanic islands and archipelagos.” Also, Hume (2017): “The bird was almost certainly terrestrial and would have nested on the ground. Nothing else is known about it.”
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest as other extinct birds of Saint Helena, since this island was covered by forests before colonization: “When discovered in 1502, much of it was thickly forested in the highlands, with more open forests and grasslands in the lowlands, but systematic destruction of the habitat began soon after human colonisation (Ashmole & Ashmole 2000).”; Also, based on other turtle-doves, whose dominant habitat is forest (5 of 6 - IUCN Red List)

Nannococcyx psix

Body mass	18.6	Presumed the minimum weight considering all African *Chrysococcyx* emerald cuckoos in Wilman et al. (2014) (minimum = 18.6g, average = 25.11g, maximum = 37.7g), since Hume (2017) described that: “The St Helena Dwarf Cuckoo was a diminutive species, considerably smaller than the African *Chrysococcyx* emerald cuckoos, a genus from which it may have been derived (Olson 1975b).”; Almost nothing is known about this species (only a right humerus was found)
Foraging time	Diurnal	Presumed diurnal as all other African *Chrysococcyx* emerald cuckoos (Wilman et al. 2014)
Diet	Invertivore	Presumed invertivore as all other African *Chrysococcyx* emerald cuckoos (Wilman et al. 2014)
Foraging strata	Canopy	Nothing is none but we presumed it was a canopy forager as it is the dominant class of African *Chrysococcyx* emerald cuckoos in Wilman et al. (2014)
Volancy	Volant	Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on Hume (2017): “It was probably a forest bird”

Atlantisia podarces		
Body mass	875.72	Presumed the same weight as *Gallirallus australis* based on Hume (2017): “The St Helena Rail was one of the largest rails and was comparable in size to a New Zealand Weka *Gallirallus australis*, only more slender”
Foraging time	Diurnal	Presumed diurnal as all other Rallidae in Wilman et al. (2014)
Diet	Carnivore	Presumed invertivore, like the closely related Inaccessible Island Rail *Atlantisia rogersi*, and also based on Hume (2017): “It probably foraged among the island’s abundant seabird colonies for food, feeding on their eggs and chicks, but it may also have predated the island’s abundant snail and invertebrate fauna”
Foraging strata	Ground	Presumed to forage on the ground given that it was flightless (Sayol et al. 2020) and also based on Hume (2017): “It probably foraged among the island’s abundant seabird colonies for food, feeding on their eggs and chicks, but it may also have predated the island’s abundant snail and invertebrate fauna”
Volancy	Flightless	Sayol et al. (2020)
Habitat	Forest, grasslands	Presumed to occur in forests and grasslands based on what is known about Saint Helena at the time it was discovered: “When discovered in 1502, much of it was thickly forested in the highlands, with more open forests and grasslands in the lowlands, but systematic destruction of the habitat began soon after human colonisation (Ashmole & Ashmole 2000).”

Zapornia astrictocarpus		
Body mass	35.4	Presumed the same weight as possible ancestor species *Z. pusilla* (35.4g – Wilman et al. 2014), based on Hume (2017): “Both *Z. palmeri* and *Z. astrictocarpus* had equally reduced wing elements, while the latter

		had less robust pelvis and leg elements. More importantly, *Z. astrictocarpus* had evolved a peculiar proximally fused carpometacarpus (wrist bone), unique among rallids, the purpose of which is unclear.”
Foraging time	Diurnal	Presumed diurnal as all other Rallidae in Wilman et al. (2014)
Diet	Carnivore	Presumed invertivore as possible ancestor *Z. pusilla*, and based on Hume (2017): “The crake was sympatric with the much larger St Helena Rail *Atlantisia podarces* (see p. 115), and may have similarly utilised seabird colonies for food (Ashmole & Ashmole 2000), perhaps feeding on regurgitated fish remains or small insects associated with decaying bird corpses”
Foraging strata	Ground	Presumed to forage on the ground given that it was flightless (Sayol et al. 2020), and also based on Hume (2017): “The crake was sympatric with the much larger St Helena Rail *Atlantisia podarces* […], and may have similarly utilised seabird colonies for food (Ashmole & Ashmole 2000), perhaps feeding on regurgitated fish remains or small insects associated with decaying bird corpses”
Volancy	Flightless	Sayol et al. (2020)
Habitat	Grassland, Wetlands (inland), Marine, Artificial aquatic habitats	We presumed it would use today (if extant) the same habitats as those of its presumed ancestor *Z. pusilla* (IUCN Red List)

Falco duboisi		
Body mass	183.21	Presumed the same weight as *Falco tinnunculus* (183.21g – Wilman et al. 2014) according to Cowles (1994): “A small falcon about the size of a kestrel, *Falco tinnunculus*, but with longer and more robust legs, and differing as follows”, and Hume (2017): “This kestrel differed from the extant Mauritius Kestrel *Falco punctatus* in being larger, and without the short, rounded wings typical of insular forest falcons, so it may have derived from a different ancestor” (*Falco punctatus* is 167.41g - Wilman et al. 2014)
Foraging time	Diurnal	Presumed diurnal as all other Falco sp. (Wilman et al. 2014)
Diet	Carnivore	Presumed carnivore based on Dubois (1674): “The second ones [Réunion Kestrel] are named yellow-feet, with the size and shape of falcons. They do harm to the fowls of the inhabitants and the game of the island.”
Foraging strata	Nonspecialized	Presumed nonspecialized as closest congeneric *Falco punctatus* of Mauritius (Wilman et al. 2014 - 20% ground, 20% understory, 40% midhigh, 10% canopy, 10% aerial)
Volancy	Volant	Sayol et al. (2020)
Habitat	Shruland	Shrubland by IUCN Red List

Hypsipetes cowlesi		
Body mass	65.145	We assumed the average value of *H. borbonicus* and *H. olivaceus* (respectively, 55.3g and 74.99 – Wilman et al. 2014) based on Hume (2015): “However, the size differences are much less striking when comparing the skeleton. Apart from the coracoid, humerus and ulna in *H. borbonicus* and the mandible and tarsometatarsus in *H. olivaceus*, *H. cowlesi* is approximately equal in skeletal element size (see Table 1), and therefore would have been approximately the same size as the other large Mascarene bulbuls in life at 22–24 cm in total length.” Also, *H. olivaceus* is 25–27 cm, and *H. borbonicus* is c. 22 cm (HBW)
Foraging time	Diurnal	Presumed diurnal as all other Hypsipetes sp. (Wilman et al. 2014)
Diet	Omnivore	Presumed omnivore based on Hume (2015): “The surviving Mascarene bulbuls are almost entirely arboreal, rarely obtaining food from the ground (Cheke 1987), and they generally forage in evergreen forest on fruits, insects and small vertebrates, especially Phelsuma geckos. Rodrigues once harboured a diverse geckonid fauna, including (…). Some of these would have provided abundant and suitable prey items for the Rodrigues bulbul. On Mauritius and Réunion, bulbuls take fruits from many species of forest trees, palms and shrubs, but they are especially fond of the fleshy fruit of the forest tree, fandamane (…). Fandamane was once an abundant component of Rodrigues forests”
Foraging strata	Midhigh	Presumed midhigh as *H. borbonicus* and based on behavioural descriptions (above) by Hume (2015). Also, *H. olivaceus* is *nonspecialized* (Wilman et al. 2014 - 20% *ground*, 40% *understory*, 40% *midhigh*)
Volancy	Volant	Presumed volant as *H. borbonicus* and *H. olivaceus*, and considering foraging strategy (Wilman et al. 2014)
Habitat	Forest	Presumed to occur in forest as the other closest congeneric species, *H. borbonicus* and *H. olivaceus* Also, Hume (2017): “Similar threats may have eliminated the Rodrigues Bulbul during the 17th or early 18th centuries, a time that saw the almost complete clearance of native forest; these factors would have been exacerbated by the island’s small size and lack of mountain refugia”

Loxioides kikuchi		
Body mass	37.84	Presumed the same weight as *L. bailleui* although it was probably larger based on James and Olson (2006): “Maxilla similar in general shape to that of *L. bailleui*, from which it differs in larger size” Also, only a maxilla is known and these two species are the only ones of their genus
Foraging time	Diurnal	Presumed diurnal based on behavioural descriptions and closest species *L. bailleui* (Wilman et al. 2014)
Diet	Granivore	Presumed granivore based on James & Olson (2006): “which also differed from *L. bailleui* in lacking a hooked bill, meant the birds fed on different food items and thus could coexist in similar habitats”
Foraging strata	Ground	Presumed ground as closest sister species *L. bailleui* (Wilman et al. 2014)

Volancy	Volant	Sayol et al. (2020)
Habitat	Forest	Presumed to occur on forest based on Hume (2017): “The drastic changes caused by farming in the dry, lowland forests on Kaua’i, which intensified after settlement by Europeans, was probably the reason for this bird’s extinction.”

Threskiornis solitarius		
Body mass	1794.89	We assumed the weight of the heaviest Threskiornis species (*Threskiornis molucca* weights 1794.89g in Wilman et al. 2014) based on Mourer-Chauviré et al. (1999): “The ibis of Reunion was probably much heavier than the living members of the genus Threskiornis” Considering that although it was closely related to the Sacred Ibis *T. aethiopicus* of Africa or Straw-Necked Ibis *T. spinicollis* of Australia, “the Reunion Ibis must have been of comparable size but was much heavier” (Mourer-Chauviré et al. 1999)
Foraging time	Diurnal	Presumed diurnal as all other Threskiornis sp. (Wilman et al. 2014)
Diet	Invertivore	Presumed invertivore based on Feuilley (1705): “Their food is only worms and filth, taken on or in the soil”
Foraging strata	Ground	Presumed ground based on diet and behavioural descriptions found in Hume (2017): “This bird is caught by running after it, since it flies only very little” Also, 3 of 5 Threskiornis sp. in Wilman et al. (2014) are ground foragers (>50%), whereas the other 2 are exactly 50% ground
Volancy	Volant	Sayol et al. (2020)
Habitat	Wetlands	Wetlands by IUCN Red List

Nycticorax duboisi		
Body mass	1014	We assumed the biggest weight published amongst *N. nycticorax* (278-1100g in HBW and 810g in Wilman et al. 2014) and *N. caledonicus* (550-1014g in HBW and 856g in Wilman et al. 2014), based on Mourer-chauviré et al. (1999): “The remains of *N. duboisi* are larger than the largest individuals of *N. nycticorax* or N. caledonicus in the USNM collection” Also, very little is known about this species (only an incomplete tibiotarsus was found (HBW)
Foraging time	Diurnal	Presumed diurnal as other two species of Nycticorax sp. in Wilman et al. 2014
Diet	Carnivore	Presumed carnivore as other two species of Nycticorax sp. in Wilman et al. 2014, and behavioural descriptions in Dubois (1674): “They live on fish.”
Foraging strata	Water	Presumed water since they ate fish. Also, *Nycticorax caledonicus* is water forager (>50% water) and

		Nycticorax nycticorax has exactly 50% on water (Wilman et al. 2014)
Volancy	Volant	Sayol et al. (2020)
Habitat	Wetlands	Wetlands by IUCN Red List

Nycticorax megacephalus		
Body mass	833	Presumed the mean of the genus Nycticorax sp. composed of *N. nycticorax* (810g – Wilman et al. 2014) and *N. caledonicus* (856g – Wilman et al. 2014)
Foraging time	Diurnal	Presumed diurnal as other two species of Nycticorax sp. in Wilman et al. 2014
Diet	Carnivore	Presumed carnivore since Leguat said that the Rodrigues Night Heron readily fed on the endemic Phelsuma day-geckos (Hume 2017)
Foraging strata	Water	Presumed water since they inhabit wetlands, but also following the other two Nycticorax sp. (Wilman et al. 2014)
Volancy	Volant	Sayol et al. (2020)
Habitat	Wetlands	Wetlands by IUCN Red List

Nycticorax mauritianus		
Body mass	833	Presumed the mean of the genus Nycticorax sp. composed of *N. nycticorax* (810g – Wilman et al. 2014) and *N. caledonicus* (856g – Wilman et al. 2014), based on Hume (2017): "This species was closely related to the Rodrigues Night Heron *N. megacephala*, but was less robust in the leg elements"
Foraging time	Diurnal	Presumed diurnal as other two species of Nycticorax sp. in Wilman et al. 2014
Diet	Carnivore	Presumed carnivore based other extant and extinct Nycticorax sp. (Wilman et al. 2014)
Foraging strata	Water	Presumed water since they inhabit wetlands, but also following the other two Nycticorax sp. (Wilman et al. 2014)
Volancy	Weak flyer	Sayol et al. (2020)
Habitat	Wetlands	Wetlands by IUCN Red List

Nycticorax kalavikai		
Body mass	856	Presumed the same weight as closest extant relative *N. caledonicus* (Wilman et al. 2014), based on Steadman et al. (2000): "*N. nycticorax* and *N. caledonicus* are similar osteologically, and are more similar to *N. kalavikai* in having a narrower bill than in *N. violacea*. Because it shares more characters with *N. kalavikai*

		than with other species, *N. caledonicus* is probably the closest living relative of *N. kalavikai*, as might be suspected on geographical grounds.”
Foraging time	Diurnal	Presumed diurnal as other two species of Nycticorax sp. in Wilman et al. 2014
Diet	Carnivore	Presumed carnivore based on Hume (2017): “Nothing is known about this species but Steadman et al. (2000) suggest that the Niue Night Heron may have fed on the abundant crabs present on Niue, much as the extinct Bermuda Night Heron *Nyctanassa carcinocatactes* (see p. 83) did on Bermuda (Olson & Wingate 2006)”
Foraging strata	Water	Presumed water as other Nycticorax sp. (Wilman et al. 2014)
Volancy	Volant	Presumed volant as other Nycticorax sp. (Sayol et al. 2020), and also Steadman et al. (2000): “Unlike the Polynesian forms, two of the three Mascarene species had relatively small wings and may have been flightless”
Habitat	Wetlands	Presumed to occur in wetlands as other Nycticorax sp. (IUCN Red List)

	Tyto noeli	
Body mass	520.975	Presumed the same as the average weight of *Tyto alba pratincola* in HBW, based on the rank presented in Steadman and Hilgartner (1999): “The West Indian species of Tyto can be arranged into a size progression from smallest to largest as follows: (1) *T. glaucops*; (2) *T. cavatica*; (3) *T. [alba?] nigrescens*, *T. [alba?] insularis*; (4) *T. alba furcata*, *T. alba pratincola*, T. sp (Barbuda); (5) *T. noeli*; (6) *T. neddi* (…)”, and also Suárez and Olson (2014): “The only species of giant barn owl named so far from the Lesser Antilles is *Tyto neddi* (…). That species was described as being slightly larger than *T. noeli* from Cuba and smaller than *T. ostologa* from Hispaniola.”; Hume (2017): “The smallest and least robust of the West Indian Tyto species, and exhibited pronounced sexual dimorphism”
Foraging time	Nocturnal	Presumed nocturnal as all other Tyto sp. (Wilman et al. 2014)
Diet	Carnivore	Presumed carnivore based on Hume (2017): “*T. noeli* ate large rodents and insectivores”, “held populations of hutias and giant rice rats, its principal food source”
Foraging strata	Ground	Presumed ground as 12 of 13 Tyto sp. (Wilman et al. 2014)
Volancy	Volant	Sayol et al. (2020)
Habitat	Forest	Presumed to occur in forest based on what we know about this island, since there is no other Tyto sp. or similar species occurring in the island of Barbuda Hume (2017): “Largest range, occurring in Cuba, Jamaica and Barbuda. It was sympatric with *T. pollens* and *T. cravesae* on Cuba”

Supporting information

Combined effects of bird extinctions and introductions in oceanic islands: decreased functional diversity despite increased species richness

Appendix 5

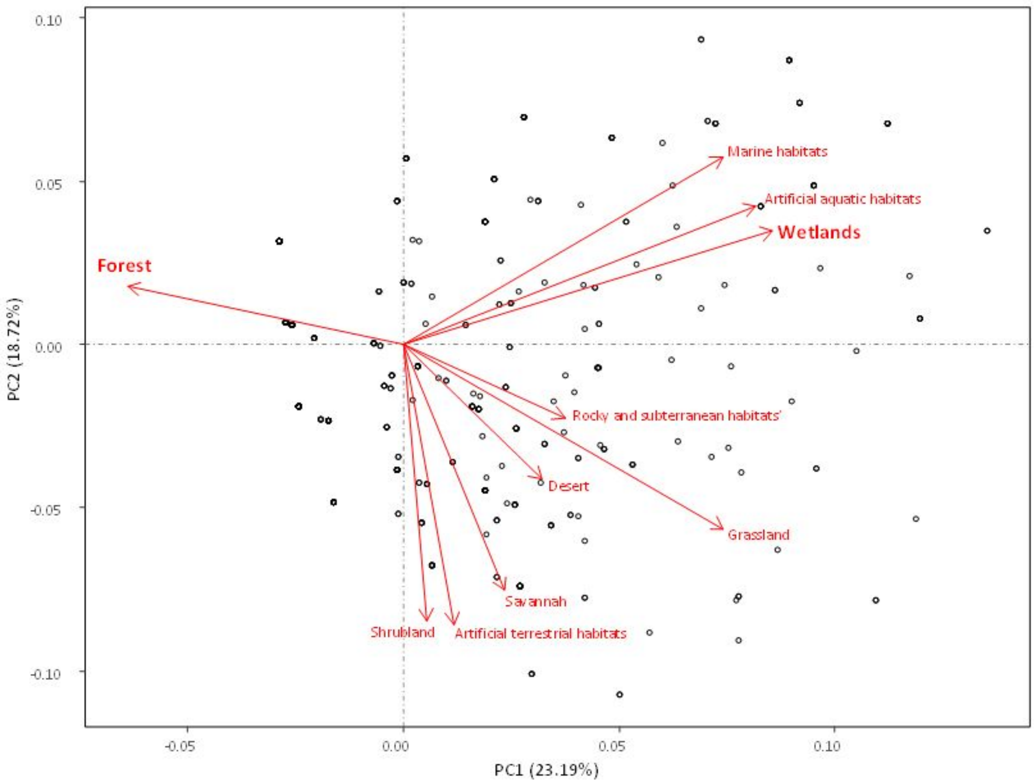
Best combination of traits

To identify the best combination of traits used to build the trait space and construct hypervolumes, we evaluated five different combinations of traits that varied according to the habitat trait alone. We chose the combination that minimized the number of axes needed to retain a minimum of 80% of the total variation in the PCoA (used as axes in hypervolume delineation), and maximized the range of the functional distance matrix computed with all 759 species (proxy for niche differentiation). The best compromise was the combination of the ten traits listed in Table 1 in the manuscript (combination highlighted in grey in the table below).

Combination of traits		No. of axes to retain a minimum of 80% of the total variation in PCoA	Range of the functional distance matrix
Dichotomous: diurnal, nectivore, water forager Nominal: diet Quantitative: average body mass Ordinal: volancy, terrestrial foraging strata	Binary: habitat (as a multichoice nominal variable)	12	0 - 0.949
	Quantitative: habitat specialization	7	0 - 0.867
	Quantitative: habitat specialization Dichotomous: forest specialist, wetland specialist	8	0 - 0.887
	Quantitative: habitat specialization, first two PCA axes (PCA considering all habitat classes*)	8	0 - 0.830
	Quantitative: habitat specialization, first two PCA axes (PCA considering all habitat classes*) Dichotomous: forest specialist, wetland specialist	9	0 - 0.851

Principal Component Analysis

We performed a Principal Component Analysis (PCA) using all ten habitat classes: ‘forest’; ‘savannah’; ‘shrubland’; ‘grassland’; ‘wetlands’; ‘desert’; ‘artificial aquatic habitats’; ‘marine habitats’; ‘artificial terrestrial habitats’. We found that the first PCA axis explained 23.2% of total variation and represented the gradient from forest to wetland species (se figure below). The second PCA axis explained 18.7% of the total variation. The first and second axes were used as quantitative traits in the analysis above.



EDITOR'S COMMENTS TO AUTHORS

Editor: Pigot, Alex L.

Comments to the Author:

I would like the thank the authors for their very detailed responses to the referee’s comments and for making the extensive revisions to their manuscript. As you will see both the referees are positive about the changes which I agree have improved the analysis and clarity of the text. They have, however, made a number of further suggestions that the authors should address. In addition to the referee’s comments, I feel that the Introduction still requires further work to make the novelty, aims and hypotheses of the study clear. Below I have provided some detailed comments on this, as well as some minor comments on other parts of the text. I think if the authors can address these remaining issues, then this will make for a very nice paper.

Response: Thank you very much for all your comments and suggestions, which we believe have greatly improved the manuscript. We have addressed all major and minor comments individually.

L60 I don’t think the following sentence accurately identifies the limitation of previous studies or the knowledge gap.

“However, it remains uncertain how species extinctions and introductions translate into functional changes at the assemblage level, largely due to the difficulty in linking taxonomic and functional diversity.”

The Sayol et a study looked at changes in functional diversity (not just taxonomic diversity), so isn’t the challenge to link changes in the FD of traits to changes in function? I completely agree that linking changes in FD and function is a major challenge. This provides a very strong rational for looking at functional composition, but this point needs to be made more precisely, perhaps using an example to hammer home the point to readers e.g. something like ‘while a decline in the diversity of morphological traits associated with resource use (e.g. beak size and shape) implies a loss of overall function, what it means for the loss of specific functions (e.g. pollination or insect predation) is not clear because of the complex mapping of functions across trait space’. If you will please forgive the self-citation, I think the paper we published looking at how different diets and foraging niches map on to morphospace in birds (Pigot et al 2020 Macroevolutionary convergence connects morphological form to ecological function in birds, Nature Ecology and evolution) could be useful here, although other studies looking at morphology-ecology relationships could also/instead be used as the authors see fit.

Response: We agree with the editor and have changed the text accordingly, adding the suggested reference: “However, it remains uncertain how changes in functional diversity due to species extinctions and introductions translate into changes in function at the assemblage level. For example, while the decline in the diversity of morphological traits associated with resource use (e.g. beak size and shape) implies a loss of overall function, it is not clear if it means the loss of specific functions (e.g. pollination or insect predation) because of the complexity of mapping functions across the trait space (Pigot et al., 2020).” (lines 60 to 65).

L65 I feel the description of functional composition could be further clarified as to me the use of the term ‘trait’ here feels a little awkward and inconsistent.

“These changes can be calculated as the difference between the species lost and gained for each individual trait, and measured as absolute (e.g. the number of species belonging to a certain trait) or relative changes (e.g. the proportion of species belonging to a certain trait; Boyer & Jetz, 2014)”

For example, ‘the number of species belonging to a certain trait’ would not make sense if we are dealing with a continuous quantitative trait. For categorical traits, the phrasing is also confusing. For example, I would say that ‘nectivory’ is not in itself a trait but is instead a trait category/class, with ‘diet’ being the trait. This is all semantics but I think this reflects the key issue that the authors need to be clearer in what they mean by traits and flesh out their argument with examples. This issue is present throughout the text with ‘trait’ and ‘trait classes’ used in different places (e.g. L309) to refer to the same thing, so I suggest the authors clarify/align terminology throughout.

The following paper is an example of one that looks at occupation of trait categories that may be useful to refer to here.

David Mouillot, et al Functional over-redundancy in fish faunas. Proceedings of the National Academy of Sciences Sep 2014, 111 (38) 13757 13762; DOI:10.1073/pnas.1317625111

Response: We agree that the term ‘trait’ is imprecise at times. Therefore, we checked the terms ‘trait’ and ‘trait class’ throughout the manuscript and altered a few sections to align the terminology (adding the suggested reference):

- “These changes can be calculated as the difference between the species lost and gained for each individual trait, and measured as absolute changes for categorical (number of species belonging to each trait class – e.g. nectivore class of trait diet) and quantitative traits (average value of all species - e.g. body mass), or as relative changes for categorical traits alone (proportion of species belonging to each trait class; Boyer & Jetz, 2014; Mouillot et al., 2014).” (lines 68 to 73).
- “We ran a separate null model for body mass and each of the six categorical traits, by randomly sampling the number of extinct species (*n* = 214) from a species pool considering extinct and extant bird species (*n* = 621), and the number of introduced species (*n* = 172) from a species pool considering introduced and extant bird species (*n* = 582), and calculated either the number of species in the different trait classes or the mean body mass of species in this sample”. (lines 211 to 216).
- “We found a positive average net change in the prevalence of 23 out of 34 trait classes (Fig. 1 and Table S3.9 and S3.10), meaning that, for each of those trait classes, the average number of introduced species per island associated with the trait class was higher than that of extinct species. Conversely, net change was negative for seven trait classes and non-significant for five. Qualitatively similar results were obtained when correcting for islands’ species richness (using percentages of species gained and lost), with only three additional trait classes having a non-significant net change (nocturnal, invertivore and nectivore; Fig. S3.8).” (lines 291 to 297).
- “Introductions added on average more novel trait classes than those that had been lost by extinctions. Indeed, for 19 trait classes, introduced species added novel trait classes to between 1 and 18 islands (column “+” in Fig. 1), while extinctions removed 12 trait classes between 1 and 22 islands, (column “-” in Fig. 1).” (lines 315 to 318).
- “Lastly, we need to protect native species, giving particular attention to those that have unique functional traits. Many insular bird species often have characteristics considered to

> be adaptations to island life, such as body size changes (gigantism and dwarfism), loss of predator avoidance, flightlessness and loss of dispersal powers, naïveté toward predators and diminished clutch size (Whittaker et al., 2017; Russell & Kueffer, 2019; Sayol et al., 2020). We found that some of these characteristics have already disappeared from most islands where the species used to occur (e.g. weak flyers and flightless birds), or have drastically decreased (e.g. carnivores, nectivores, very large-bodied birds, forest and canopy foragers, and birds occurring in forest).” (lines 466 to 473).

L82 Suggest replacing ‘with the same intensity’ with ‘to the same density’

Response: This sentence was removed following another comment.

One comment I made in the previous review was to query the authors statement that adding new species to the functional trait space could in theory result in a lower functional richness. I have to admit that I’m a little confused, as this contradicts the Sayol et al 2021 paper, which states that ‘Because the occupied volume necessarily increases as new species are added (unless the added species is morphologically identical to an existing species)’. The authors response and statements in the main text (e.g. L92 “Consequently, this representation of trait space allows a better evaluation of the effects of extinctions and introductions on island bird functional diversity.”) implies that the method they use to quantify the volume of functional trait space is different from Sayol et al 2021, but is this correct? Both studies are based on n-dimensional hypervolumes using the R Hypervolume package, right? This is relevant because it would determine whether it is necessary to standardise for richness. It is also important for the framing in the introduction – a large section (L73-93) is devoted to explaining why n-dimensional hypervolumes based on point densities are preferable to convex hulls, but this is less relevant to highlight if the approach has already been employed by Sayol et al 2021. Instead, it would make more sense to focus on those aspects of the study that are novel (e.g. looking at functional composition, evenness and originality rather than just functional richness).

Response: Yes, we used exactly the same approach as Sayol et al. (2021) – the n-dimensional hypervolumes - so both analyses have the same strengths and weaknesses in functional space representation. However, this representation allows for a decrease in richness when adding species, as the cloud of random points surrounding observations can shift towards overrepresented functional trait combinations. We have created the code below to demonstrate this: the addition of species similar to those already in the community may lead to the concentration of the kernel cloud around this part of the functional space and, consequently, to the decrease in functional richness.

comm1 – community containing only native species

comm2 - the same community (comm1) but after the introduction of five (functionally redundant) species (and no extinctions)

```
library(BAT) # import BAT package

comm1 = c(1,1,1,1,1,0,0,0,0,0) # community 1

comm2 = c(1,1,1,1,1,1,1,1,1,1) # community 2

comm = rbind(comm1, comm2) # aggregate communities – ‘sites x species’ matrix

wing = beak = c(1,2,3,4,5,3,3,3,3,3) # create traits – wing and beak
```

```
trait = cbind(wing, beak) # aggregate traits – 'trait x species' matrix
hyper = kernel.build(comm, trait) # build functional space (hypervolumes) of each community
plot(hyper) # plot functional space
alpha(comm) # calculate species richness
kernel.alpha(hyper) # calculate functional richness
```

Note that the kernel.build function is based on the hypervolume R package (https://rdrr.io/cran/BAT/man/kernel.build.html).

To clarify that we used the same approach as Sayol et al., (2021), we removed both the sentence ("Consequently, this representation of trait space allows a better evaluation of the effects of extinctions and introductions on island bird functional diversity."), and the reference (line 92).

Moreover, we followed the editor's suggestion and reduced the large section (previous lines 73 to 93) devoted to explaining the advantages of the n-dimensional hypervolumes over the convex hulls:

- "This density-based approach assumes a heterogeneous trait space, representing variations in point density within the multidimensional space and better reflecting the concept of niche by Hutchinson (Mammola et al., 2021). Point density is higher where more functionally similar species exist and are closer together within the multidimensional space. Thus, contrarily to other approaches where adding a species can only increase or maintain the occupied volume, in kernel density hypervolumes, adding a species may decrease the volume (i.e. functional richness), namely if the species is added to an area of the hypervolume already filled with other species (decreasing the average distance between points within the cloud)." (lines 83 to 91).

Lastly, we believe to have highlighted the novelty aspects of the study, such as functional composition, evenness and originality, by including specific hypotheses, as suggested below, and the following text:

- "We expect to provide new insights on the link between the changes in taxonomic and functional diversity by evaluating the changes of each individual trait after species extinctions and introductions. By studying the changes of each individual trait, we should be able to provide clues on which traits appear to promote extinctions or introductions, shedding new light on how ecosystem functions could be affected in the future. For example, the loss of nectivore species and their replacement by granivores (i.e. seed predators) can disrupt well-established mutualistic plant-animal interactions, particularly through reduced pollination and seed dispersal (Caves et al., 2013; Carpenter et al., 2020), drastically impairing the future of insular native forests (Şekercioğlu et al., 2004). With this functional perspective, we aim to gain valuable insights into the ecology of island bird assemblages and thus understand how to maintain their remaining functional diversity." (lines 111 to 121).

I feel the set up of the paper in the Introduction still needs improvement. While it describes the statistical approach for quantifying functional diversity and the different diversity metrics, the biological insights these will provide are not clear as no hypothesis are stated. I think adding specific hypothesis will help make the aims of the paper more tangible, rather than simply 'this representation of trait space allows a better evaluation of the effects of extinctions and introductions on island bird functional diversity' (L92) which feels a little vague and exploratory.

Response: Following the editor's suggestion, we added specific hypotheses to make the aims of the study more concrete and real:

- "Because many introduced birds are functionally redundant and most extinct birds were functionally unique (Sobral et al., 2016), many of the functional consequences of extinctions and introductions affect not only the overall volume and boundaries of the multidimensional space but also deeply reorganize its internal structure. Consequently, we expect that both functional richness and evenness will decrease in most oceanic islands following extinctions and introductions, and also that functional originality of extinct species will be higher than that of natives, whereas functional originality of introduced species will be lower. Moreover, as previously shown, both bird extinctions and introductions are non-random events (Boyer & Jetz, 2014), so we expect a severe decline, or even loss, of some important ecological functions provided by birds (e.g. seed dispersal; Heinen et al., 2018), which will most likely translate into drastic consequences for ecosystem functioning (e.g. regeneration of insular native forests; Şekercioğlu et al., 2004; Anderson et al., 2011)." (lines 95 to 102).

I think the null model is a good addition. I wonder, however, what the rationale is for applying this to only changes in functional composition and not functional diversity?

Response: Our goal was to study the increase or decrease of functional diversity, even if this was caused by the respective increase or decrease of taxonomic diversity (that is independent of the changes in taxonomic diversity). As such, we did not intend to disentangle functional and taxonomic diversity, and thus we have not performed null models for functional richness.

L316 Not clear to me what these numbers are.

Response: We clarified this by adding the following text: "(before extinctions and introductions = 4.349×10^{-6} > after extinctions and introductions = 2.440×10^{-6})" (line 334).

REVIEWER COMMENTS TO AUTHOR

Referee: 1

Comments to the Author

The modifications the authors made to this paper really benefited to the clarity and relevance of the study. I appreciate to see that all the comments have been addressed or discussed at best. Specifically, the introduction is now much clearer in the question and the lack this study fills. I understand why the sensitivity of obtained results to trait selection is not of upmost relevance here, and I better understand why some choices have been made (e.g. trait selection for building the functional space). This is a very nice study, and it is most likely that it will be highly cited! Thanks for those improvements, and I only suggest minor text modifications in the comments below.

Response: Thank you very much for all your suggestions, which have greatly improved the manuscript. We have addressed all comments below.

Introduction

The introduction is complete and highlight clearly how this study is valuable. Maybe work on the formulation of the 3 sentences L104-109 to avoid the repetition of “we hope” but the aim of the work is well exposed.

Response: We apologize because we did not notice the constant repetition. However, two of these sentences were removed after following a suggestion from another reviewer, so we only replaced ‘hope’ in the next sentence: “With this functional perspective, we aim to gain valuable insights into the ecology of island bird assemblages and thus understand how to maintain their remaining functional diversity.” (lines 119 to 121).

Methods

L206. Is “ses” a function in ‘BAT’ package? If yes specify.

Response: Yes, we have changed accordingly: “using ses function in ‘BAT’ package” (line 218).

L213. The null model on species traits gives new perspectives on the functional changes and is really welcome. However, the last sentence that should clarify what the model aims to verify is not clear and need more details.

Response: To improve clarity, we rewrote this sentence, adding further details and an example: “As such, the extinct or introduced species pool allows us to test if the observed losses or gains, respectively, are different from what would be expected considering the extant species occurring on islands. For example, considering the categorical trait diet, if the standardised effect size for carnivore species is positive and statistically significant, it indicates that more carnivore species went extinct than would be expected considering the number of carnivore species across islands. Accordingly, the overall negative net change would be reflecting the proneness of carnivore birds to extinction.” (lines 226 to 232).

L256. This paragraph on the gamma functional richness is not logically placed within the text. Maybe to locate between the alpha functional richness (before the evenness) and combine in one section the evenness and originality since they are both at the island level.

Response: We agree and have changed this accordingly: "Likewise to the taxonomic approach, we calculated the overall functional richness at two points in time: originally (i.e. including all native species, both extant and extinct); and presently (i.e. including extant native and introduced species) considering all islands (gamma diversity). For this purpose, we used the kernel.alpha function in the 'BAT' package (Cardoso et al., 2015; Mammola & Cardoso, 2021). The net change in functional richness was calculated as the difference between present and original functional richness. Then, we estimated the functional richness for each island, considering original and present avifaunas, using the kernel.alpha function in the 'BAT' package (Cardoso et al., 2015; Mammola & Cardoso, 2021). Also for each island, we calculated net change in functional richness as the difference between present and original functional richness." (lines 260 to 268).

Discussion

L348-349. "Overall numbers of introductions may thus eventually surpass the overall number of extinctions." Isn't that already the case at the population level on the studied islands here?

Response: No, the average number of introduced bird species per island is higher than that of extinct species, but the total number of introduced bird species across islands (considering all islands) is lower than that of extinct species (Fig. S3.7). Following the reviewer's comment, we believe that the sentence needs rephrasing: "The total number of introductions may thus eventually surpass the total number of extinctions on islands." (lines 367 and 368).

L350. The title is a little bit confusing to read, rephrase?

Response: We have rephrased it to: "Changes in species composition lead to changes in functional composition" (line 369).

L351. Maybe use "in the ecological and morphological traits" instead of "in the functional composition" to fit better to the introduction

Response: We changed it accordingly.

L408 and L424. These two paragraphs can be combined in one because they use the same references and both tackle the functional issues associated to introductions and extinctions (i.e. non-compensation of functional roles & functional homogenization over all islands)

Response: We have combined the two paragraphs into one, as suggested: "The combined effect of bird extinctions and introductions resulted in a higher average island species richness (Fig. S3.7) and an increased prevalence of most traits (Fig. 1). However, this decreased average island functional richness (Fig. 2a), indicating that introduced species tend to be functionally closer to remaining native species than what extinct species were, resulting in a more compact cloud of points in the multidimensional trait space. In a hypothetical island assemblage with two species of birds, one frugivore and one granivore, the extinction of the frugivore would decrease functional richness, whereas the introduction of several granivore species would increase the prevalence of this trait class, but not functional diversity. The net result of extinctions and introductions in such an island would be a functionally impoverished assemblage, despite the higher prevalence of granivores. Accordingly, we also observed a decrease of assemblage functional evenness (Fig. 2b) and found that, whereas extinct species were functionally more unique than those that persist, introduced species were by contrast functionally less unique (Fig. 2c). The non-random extinction and introduction of bird species was already known to impair the functional diversity of island bird assemblages (Boyer & Jetz, 2014), since introduced species do not compensate for the functional roles of extinct species (Sobral et al., 2016; Sayol et al., 2021). Moreover, the overall decrease in functional richness considering all islands also suggests that island bird assemblages might be becoming functionally homogenized (lower functional beta diversity). Recent studies have shown that the introduction of functionally similar species is promoting functional homogenization of native bird assemblages on oceanic archipelagos (Sobral et al., 2016; Sayol et al., 2021).” (lines 442 to 445).

L465-466. In the brackets: (e.g. carnivores, nectivores, very larged-bodied birds, forest and canopy foragers, and forest), what does “and forest” mean?

Response: We apologize for the lack of explanation. This is now changed to: “birds occurring in forests” (line 483).

Figures & Tables

Figure 1. The column E and I must be defined, I assume they refer to Extinct and Introduced but it should be clearly mentioned.

Response: Yes, we have now added the following text: “Columns ‘E’ and ‘I’ show only the significant results of the null models performed for each trait class for extinct and introduced species, respectively, (…)” (lines 687 and 688).

Great job, thanks for this paper!

Response: Thank you for your time!

REVIEWER COMMENTS TO AUTHOR

Referee: 2

Comments to the Author

Comments to the Author

After carefully reading the responses to reviewers and the manuscript, I find that the revised manuscript has improved substantially. All my concerns have been properly addressed or clarified.

Response: Thank you again for all the comments and suggestions, which have greatly improved the manuscript.

I only have a minor comment left. In lines 102 to 109, I would avoid any priority claims: "To our knowledge, this is the first study that uses both morphological and ecological traits to measure functional diversity based on the hypervolume approach". First, I am not sure if only including body size could be considered as studying morphology. Second, I think it is more convincing if you justify the novelty of your work based on the question you address, and not by claiming to be the first to use a particular technique in a particular set of traits.

So, my suggestion would be to delete the sentence from "To our knowledge" (Line 102) to "In addition" (Line 105) and emphasise more the last part of the paragraph: why investigating the effect of each trait alone could give more clues on how certain traits can favour extinctions or introductions and the ecosystem consequences of that.

Response: We followed the reviewer's suggestion and removed both sentences. In addition, we also highlighted the importance of studying the effects of each trait: "We expect to provide new insights on the link between the changes in taxonomic and functional diversity by evaluating the changes of each individual trait after species extinctions and introductions. By studying the changes of each individual trait, we provide clues on which traits appear to promote extinctions or introductions, shedding new light on how ecosystem functions could be affected in the future. For example, the loss of nectivore species and their replacement by granivores (i.e. seed predators) can disrupt well-established mutualistic plant-animal interactions, particularly through reduced pollination and seed dispersal (Caves et al., 2013; Carpenter et al., 2020), drastically impairing the future of insular native forests (Şekercioğlu et al., 2004). With this functional perspective, we aim to gain valuable insights into the ecology of island bird assemblages and thus understand how to maintain their remaining functional diversity." (lines 111 to 121).