A database of foraging guilds of seabirds

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Abstract

The foraging guilds of terrestrial birds have been a focus of past studies, however little is known about the guilds in seabirds, except for certain species and localities. To overcome this gap, here we developed the Foraging Guilds of Seabirds database (FGSdb) by compiling a global database of 311 seabird species (from a total of 346 known, representing 90% of all seabird species) and assigning to each of them their diet types and foraging strategy. Diets included categories such as mollusks and fish and strategies included categories such as diving or aerial capture. In turn, both diets and strategies were classified into subcategories, such as herbivores and surface foragers, respectively. Across all seabirds, there were 22 types of diets and 30 types of strategies to capture prey. The number of diet categories for a species varied between 1 and 11, and the number of strategies varied from 1 to 9. We provide R code to exemplify how to use the database to, for example, get the number of species that belong to a certain category. Our database provides a useful resource database for future studies in evolutionary ecology. For instance, could reveal different statistical patterns and be integrated with other types of data, e.g. body size, to analyze the evolutionary constraints associated with the inter-specific variation in these foraging traits. Future extensions of this work include extending this database to other birds or animal groups and developing a GUI to explore the data.

Background and Summary

Understanding ecological functional groups is relevant given that their diversity ultimately affects the functioning and stability of ecosystems. Within functional groups, particularly ecological guilds, are groups of species that exploit the same resources, or that exploit different resources in a related way. They do not necessarily belong to the same niche or are phylogenetically related, but for practical reasons often are. However, they do match the general concept of functional groups as exploiting the same resources can perform the same or highly similar ecosystem function (Simberloff & Dayan 1991, Wilson 1999).
Often, ecological guilds are studied by identifying the dietary categories that species use or the different behaviors or strategies they use to get those diets (Uetz et al. 1999, Cardoso et al. 2011, Kissling et al. 2014, Collard et al. 2021). Different studies have reported the guilds of a different group of taxa (eg. De Graff et al. 1985, Gonzalez-Salazar et al. 2014), and birds are a good example given the abundant data that exists regarding their behavior.
Guilds of birds have fundamental ecological importance as they participate in ecosystem services (that include seed dispersal, and pollination), environmental management, and conservation. Despite the guild structure of terrestrial bird communities has been characterized (De Graff et al. 1985, González-Salazar et al. 2014), the guild of seabirds at a global scale remains unstudied but restricted to particular communities or specific taxa (Shealer 2002). Moreover, automatized large data compilations have not enumerated the detailed diversity of diets or strategies a single species can have (eg. Hulbert et al. 2021). Seabirds are a functional group and refer to all birds that live in the ocean environment, including marine and coastal. Seabirds are a paraphyletic group (including the orders Procellariiformes, Charadriiformes, Sphenisciformes, Pelecaniformes, Phaethontiformes, and Suliformes) and have independently and convergently acquired different adaptations to pelagic and aquatic life (Hackett et al. 2008).
Here we built a database of foraging guilds of seabirds, including data on their different diet types and foraging behaviors each species has, and a hierarchical classification of them. Diet types refer to which type of species they eat, for example, mollusks, fish, or algae, and foraging behavior or strategies refer to which behavior they use to capture prey; diving, and aerial pursuit, among others (see Wilson 2004 for a graphical depiction). We envision that this database could have multiple applications, from studies in marine ecology to environmental assessments.

Methods

We built The Foraging Guilds of Seabirds database (FGSdb; Hernandez and Arroyo 2023; available at

https://doi.org/10.5281/zenodo.10258241) by compiling data on dietary niche breadth and prey capture flexibility were manually obtained from the Handbook of the Birds of the World (HBW; https://birdsoftheworld.org/bow/home). We used as an initial reference for diet guilds the classification of foraging guilds of North American breeding birds (De Graaf et al. 1985; González-Salazar et al.2014). Each of the dietary assignations was based on at least one type of method, including fecal exploration (e.g. Aylor and O'Halloran1997), stomachal observation (e.g. Barret et al. 2007), or isotopic (e.g. Torres et al. 2006).
Each of these groups was subcategorized into larger groups. The definition of the relevant foraging strategies was made based on the following literature: Ainley 1977, Duffy 1980, Duffy 1983a, Duffy 1983b, Duffy & Jackson 1986, Burger 1988, Marine 1988, Croxall & Cooper 1985, Camphunysen and Garthe 2004). The classification of strategies was made based on Ashmole (1971). The definition of diets was based on definitions in the literature, for example, e.g. cannibal, and opportunistic feeder, and also based on well-defined fine-grain taxonomic groups, e.g. fish, crustaceans, etc. The classification of diets was based on the classical definitions of the food chain, primary consumers, etc.

Data Records

Briefly, we built a relational database with a first table containing the species and their strategies and diets affiliations, as a vector. In the second table, we put the strategies and their classification, and in the third table, we put the diets and their classification. For a total of 311 seabird species (from a total of 346 known, BirdLife International 2012), we defined a total of 30 strategies and 22 diets.
The number of strategies they had ranged from 1 to 9, with an average of 2.71. The number of diet categories to which a species belongs ranges from 1 to 11, with an average of 3.75. The ratio diet/strategies of 0.74 (~3/4), meaning that on average with four strategies they can exploit up to three diet items**.** The most frequent among seabird species were scavenging pursuit diving (or bottom feeding) and surface seizing and the less diverse were battering or drowning ship follows and cannibalism. The most frequent diets were fish, crustaceans, and cephalopods, and the least diverse were chaetognaths, lampreys, and polychaetes. 19 specialist species had a single diet and strategy, and on the other extreme, there was a species with 9 diets and 11 strategies, *Larus smithsonianus*.

Table 1. List of tables of the database and their content description.

Table	**Content description**
taxonomy	a data frame where in the 311 rows are the species' scientific names and five columns contain species' taxonomic classification: order, family, genus, common names, and scientific name
species_strategies_diets	a data frame where in the 311 rows are the species' scientific names and two columns with the abbreviations of each species' strategies and diets
diets_classification	a data frame of the classification of each diet type into herbivore, parasite, primary consumer, secondary, tertiary/quaternary, or opportunistic
strategies_classification	a data frame of the classification of each strategy type into species that capture prey under the surface, at the surface, both (surface and air), and in the air, etc
species_diets	a data frame where each row is a species, and each column has the abbreviation of a species diet.
species_strategies	a data frame where each row is a species, and each column has the abbreviation of a species' strategy
species_diets_class.	a data frame where each row is a species, and each column has the abbreviation of a species' diet's categorization
species_strategies_class.	a data frame where each row is a species, and each column has the abbreviation of a species' strategy's categorization
species_diets_matrix	a matrix where each row is a species, and each column are species' diet. Cells are filled with 0 or 1.
species_strategies_matrix	a matrix where in rows are species and in columns are species' strategies. Cells are filled with 0 or 1.
sp_diets_class_matrix	a matrix where in rows are species and in columns are species' strategies categories. Cells are filled with 0 or 1.
sp_strategies_class_matrix	a matrix where in rows are species and in columns are species' diets categories. Cells are filled with 0 or 1.

Technical Validation

Many diet and behavior assignments were based on more than one reference and the main source of our database, the HBW, has been submitted to many revisions, for which is a reliable source. On the other hand, we explored some statistical patterns in the dataset that could give some indication of a nonrandom organization of the data. We correlated the number of diets and strategies per species, and there was a positive correlation of 0.39 ($P<0.05$). Under a random scenario, we should expect no correlation, so this indicates that our data has a structure.

Usage Notes

This database has different utilities, such as being a reference for studies at a local scale, and that seek for example, to understand the redundancy (and subsequently other properties such as ecosystem functioning) of a community, or to use the communities as ecological indicators of other features of the ecosystem (O'Connell et al. 2000).
We based our definition of guilds mostly on previous classifications of terrestrial birds (De Graf et al. 1985, González-Salazar et al. 2014) and there are common guilds in both the terrestrial and marine environment, such as species that eat fish, arthropods, etc., but there are differences. For example, in terrestrial environments granivores are common, but absent in marine, and on the other hand cephalopods are absent in terrestrial environments. In comparison with previous studies, here we took a step forward and defined a higher level of guild structure for both strategies and diets. The FGSdb can be implemented for example, in the R environment using the “dbplyr” library to access the data or “SQRLite” to make a SQL database and explore it (R Core Team 2021).
Here is some R code to retrieve 1) for a given species, their diets and strategies (including their classification), 2) for a given diet or strategy (or their classification), the species that have them. (To distinguish the comments from the code, we will write the comments of the code in the font Times New Roman and the code itself in Courier New).

First, we upload the libraries and write the ‘cbind.fill’ function, which we will need below.

```
library(readxl)

library(plyr)

cbind.fill <- function(...){
nm <- list(...)
nm <- lapply(nm, as.matrix)
n <- max(sapply(nm, nrow))
do.call(cbind, lapply(nm, function (x)
rbind(x, matrix(, n-nrow(x), ncol(x)))))
}
```

Then, we upload the documents, and define them as data frames,

```
strategies_diets=read_excel("FGSdb.xlsx", sheet="species_strategies_affiliations")
```

Alternatively, call the file by,

```
strategies_diets=read.table("species strategies and diets.txt", sep="\t", h=T)

strategies_diets=as.data.frame(strategies_diets)

diets_class=read_excel("FGSdb.xlsx", sheet="diets_hierarchy")

diets_class=as.data.frame(diets_class)
```

Now let’s explore the database. Let’s look at the diets of a given species, for example, in the row 302 we found the species ‘*Larus michahellis*’

Let’s see the list of species,

```
strategies_diets$'scientific_name'
```

let’s select, for example, the species in the row 302,

```
strategies_diets[302, ]
```

Alternatively, for a given species we can get the row number,

```
which(strategies_diets$'scientific_name'=='Larus michahellis')
```

Now let’s make a data frame with the diets abbreviations,

```
out.d=data.frame()
for (i in 1:311){
split.d=strsplit(strategies_diets$diets[i],split=',')[[1]]
out.d=cbind.fill(out.d, split.d)
}

out.diet=t(out.d)
```

Let’s look at in this database some diet definition. Let's look at the diet classification,

```
diets_class
```

For example, for cannibals, whose abbreviation is Z,

```
aZ=which(diets_class$'diet abbreviation'=='Z')

diets_class[aZ,]
```

So, for cannibals, Z, let’s look at all the species that are cannibals,

```
sp.z=vector()
for (i in 1:ncol(strategies_diets)){
sp=which(out.diet[,i]=='Z')
sp.z=c(sp.z, sp)
}

strategies_diets$'scientific name'[sp.z]
```

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Author Contributions

JH and JIA made the database. JIA and JH wrote the paper.

Competing interests

We declare no competing interests.