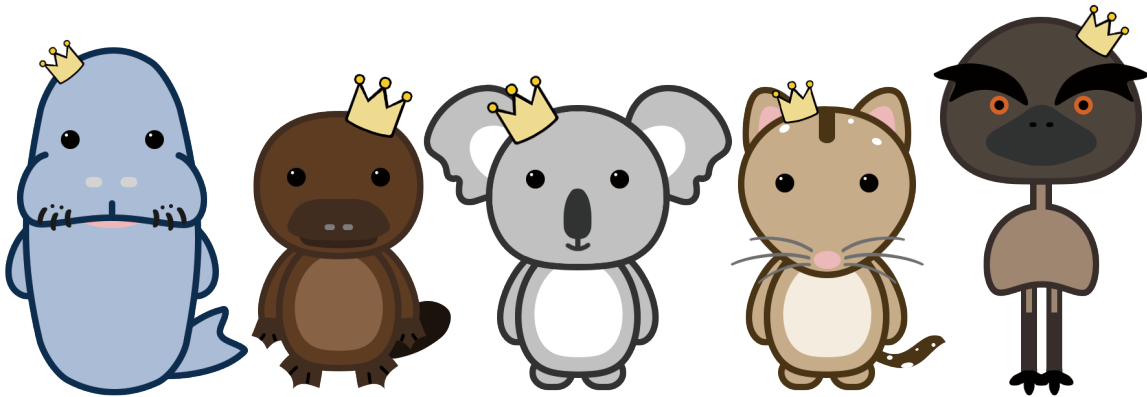


Introduction to specieshindex

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There are many ways to gauge research influence. We can simply sum up the number of publications or citations, which is a straight forward way without the need of any complicated mathematical formulas. On the other hand, there are more in-depth ways of quantifying research influence by using statistical indices. Some examples include the h -index, m -index, $i10$ index, $h5$ index, etc.

H -index (Hirsch 2005) is one of the main methods to measure publication influence objectively. It is calculated using the formula $h = \text{total publications (n) that have at least been cited n times}$, after sorting the publications by their citation counts in a descending order.

Currently, h -index is commonly used for assessing influence and academic productivity of authors, research institutions and journals (Braun, Glänzel, and Schubert 2005). Recently, this index has been also applied to quantify the research effort and influence associated with different species of living organisms (Fleming and Bateman 2016).

With this package, we can create a similar profile for different living organisms that would show their citation metrics, including total publications, total citations, h -index, etc. This will allow us to understand which species are receiving more research interest and develop the solutions to rectify the biases.

Installation

To get this package to work, make sure you have the following packages installed.

```
# Installation from GitHub
install.packages("rscopus")
install.packages("wosr")
install.packages("lens2r")
install.packages("taxize")
install.packages("XML")
```

```
install.packages("jsonlite")
install.packages("httr")
install.packages("dplyr")
install.packages("data.table")
devtools::install_github("jessicatytam/specieshindex", force = TRUE, build_vignettes = FALSE)

# Load the library
library(specieshindex)
```

You can find the full list of functions here: https://github.com/jessicatytam/specieshindex/blob/master/specieshindex_0.0.1.pdf.

Workflow

Specieshindex package performs two main steps that simplify calculating h -indices for different species:

1. Connecting to a literature database and downloading citation data for a given species
2. Computing various indices (including h -index) for a given species

Below, we outline how to perform these steps using our package.

Connecting to Scopus

Make sure you are connected to the internet via institutional access or acquire a VPN from your institution if you are working from home. Alternatively, the functions will also run if you are already a subscriber of Scopus.

Before initiating the retrieval of any data, make sure you have registered an API key from Scopus. Otherwise, the functions will not run (and is in fact illegal to download the data). You can register your key here. Use your API key as the function parameter “myAPI”.

For example, you can run:

```
#API key
API <- "your_api_key_from_scopus"

# Title only
CountSpT(genus = "Bettongia", species = "penicillata", APIkey = API)

#Title, abstract, and keywords
CountSpTAK(genus = "Bettongia", species = "penicillata", APIkey = API)
```

Connecting to Web of Science

No key is need to extract data from Web of Science if you are using this package from your institution’s location. You will need to set up your session ID before gaining access to the Web of Science database. Run the following line of code to do so.

```
sid <- auth(username = NULL, password = NULL)
```

You won't have to set your ID again until your next session. You are required to be at your institution for this to work since the API is accessed via the IP address.

Connecting to The Lens

An individual token is required to extract data from Lens. If your institution is not a subscriber of Lens, you will only be able to register for a 14-day token, which can be renewed. In addition, you might not be able to use the Fetch functions if the search results exceeds 1,000 records.

1. Create an account with Lens.
2. Go to <https://www.lens.org/lens/user/subscriptions#scholar> and select your desired Scholarly API.
3. Request access.

Other arguments and syntax

Additional keywords

There is an optional parameter `additionalkeywords` that can be included to make your search more precise. This is achieved by expanding your query string and restrict the search to records that include specified combination of the additional keywords. The additional keywords can be a single word, e.g. "conservation", but better yet, you can parse a string with Boolean operators, e.g. "conserv* OR protect* OR reintrod* OR restor*". The Boolean operator "AND" has already been implemented in the code to link the Latin name and the additional string. To learn more about search language, you can visit [here](#) and [here](#).

Here are some examples of searches including additional keywords:

```
# Title only
CountSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(consrv* OR protect* OR reintrod* OR restor*)", APIkey = API)
CountSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* W/5 ecolog*)", APIkey = API)
CountSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(breed* OR reprod* OR fertil* OR fecund*)", APIkey = API)
CountSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* AND NOT popular)", APIkey = API)
CountSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "NOT (phylog* OR taxonom*)", APIkey = API)

# Title, abstract, and keywords
CountSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(consrv* OR protect* OR reintrod* OR restor*)", APIkey = API)
CountSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* W/5 ecolog*)", APIkey = API)
CountSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(breed* OR reprod* OR fertil* OR fecund*)", APIkey = API)
CountSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* AND NOT popular)", APIkey = API)
CountSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "NOT (phylog* OR taxonom*)", APIkey = API)
```

If no additional keywords are parsed, the extraction will include all publications related to the species. In this case, you MUST include `API key =` to specify your API key, otherwise your key will be read as an additional keyword and result in an error.

Synonyms

Some species have had their classification changed in the past, resulting in multiple binomial names and synonyms. Synonyms can be added to the search strings to get the maximum hits. If you have more than 1 synonym, you can parse a list (the list should be named “synonyms”) into the argument.

```
CountSpT("Osphranter", "rufus", synonyms = "Macropus rufus", additionalkeywords = "conserv*", API)
```

Count and Fetch Syntax

The searches are performed using species Latin name. The relevant functions take two parts of a Latin binominal species name as their main parameters, e.g. “*Bettongia*”, “*penicillata*”. Make sure you are using binomial names instead of common names as required by the code.

We have implemented functions that check the available number of relevant records (Count) and functions that download these records (Fetch) for a given species. Count and Fetch functions have two versions, with suffixes T and TAK, respectively. In these functions, the suffix ‘T’ is for title and ‘TAK’ is for title, abstract, or keywords. These terms are used to indicate where in the records you want your search terms to be found in. While ‘T’ only finds the publications with the binomial species name in the title, ‘TAK’ will find records with the name in title, abstract or keywords.

It is recommend that you run a quick search using functions `CountSpT()` or `CountSpTAK()` before actually fetching the records since this can be a tedious process. Both functions give a search count of the number of records found on the databases.

`specieshindex` supports multiple databases, including Scopus, Web of Science, and Lens. To differentiate between them, the suffix of the Count and Fetch functions have been labeled with the database’s name, with the exception of Scopus.

```
#scopus requests
API <- "your_api_key_from_scopus"
CountSpT(genus = "Bettongia", species = "penicillata", APIkey = API)
FetchSpT(genus = "Bettongia", species = "penicillata", APIkey = API)

#web of science requests
#no tokens or api keys needed if session ID has been set as shown previously
CountSpT_wos(genus = "Bettongia", species = "penicillata")
FetchSpT_wos(genus = "Bettongia", species = "penicillata")

#lens requests
token <- "your_lens_token"
CountSpT_lens(genus = "Bettongia", species = "penicillata", token = token, size = 50000)
FetchSpT_lens(genus = "Bettongia", species = "penicillata", token = token, size = 50000)
```

The additional `size` parameter is set to `size = 50000` by default. If your token only allows for 14-day access, set `size = 1000`, which is the maximum volume of documents to be downloaded. The Count functions should work and will yield the correct number of documents. However, the Fetch functions will only work if the number of documents is 1,000 or less.

Extracting citation records

`CountSpTAK()` should yield more results since it also looked for the binomial name in the abstract and keywords, in addition to the title. Now that you know exactly how many publications there are for this species, and it is greater than 0, you can proceed to fetch the data. If your record count is 0, there might be a problem with the Latin name of the species, e.g. a typo.

As you may expect, some species have been studied more than the others (Simko 2015; Krause and Robinson 2017), resulting in more publications. Therefore, if there are more than a few thousand citation records found, it will take a considerably longer time to download them all, unless you are using a computer with high processing power and fast internet connection.

To fetch the citation records, you can run:

```
# Title only
FetchSpT(genus = "Bettongia", species = "penicillata", APIkey = API)

#Title, abstract, and keywords
FetchSpTAK(genus = "Bettongia", species = "penicillata", APIkey = API)
```

Similar to the Count functions above, Fetch functions also have the argument `additionalkeywords` that allows you to refine your search.

For example, you can run:

```
# Title only
FetchSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(consrv* OR protect* OR reintrod* OR restor*)", APIkey = API)
FetchSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* W/5 ecolog*)", APIkey = API)
FetchSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(breed* OR reprod* OR fertil* OR fecund*)", APIkey = API)
FetchSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* AND NOT popular)", APIkey = API)
FetchSpT(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "NOT (phylog* OR taxonom*)", APIkey = API)

# Title, abstract, and keywords
FetchSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(consrv* OR protect* OR reintrod* OR restor*)", APIkey = API)
FetchSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* W/5 ecolog*)", APIkey = API)
FetchSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(breed* OR reprod* OR fertil* OR fecund*)", APIkey = API)
FetchSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "(popul* AND NOT popular)", APIkey = API)
FetchSpTAK(genus = "Bettongia", species = "penicillata",
  additionalkeywords = "NOT (phylog* OR taxonom*)", APIkey = API)
```

In larger datasets, duplicates may appear, although usually in low numbers. It is up to the user to decide which documents to keep or remove.

Adding language as a variable (Scopus only)

The default of the parameter `language` is set to 0. To retrieve the language for each document, set `language = 1`. This will create an extra variable called 'language' in the output. Since it adds language as an extra

field to the Scopus query, it will take longer to download the records as opposed to the default. This will also create a few duplicated records. Again, it is up to the user to decide which documents to exclude afterwards.

For example, if you want to retrieve documents with the language variable, you can run:

```
FetchSpT(genus = "Ailuropoda", species = "melanoleuca", language = 1, APIkey = API)
```

Possible errors

If the error **Bad Request** (HTTP 400) occurs in this step, try connecting to the internet via institutional access, instead of the one at home. This error might be caused by some authorisation issues.

It is important to make sure you have spelt the genus and species name accurately when entering the function. If unsure, you can go to the Global Names Resolver for verification. This is where the above functions are linked to for checking via the package **taxize** (Chamberlain and Szöcs 2013). If the desired species is not in the index, it is possible that it has just been discovered and not officially listed yet, or the name has been changed and is no longer in use. Whether or not old synonyms are accepted depends on if they still exist in the database.

Simple counts

These functions do simple calculations with various parameters for the sets of downloaded citations for a given species. This information could provide insights into the behaviour of the other, more complicated, indices.

TotalPub() sums up the total publications from the search.

For example:

```
TotalPub(Woylie)
#> [1] 113
```

TotalCite() sums up the total citations of all the records from the search.

For example:

```
TotalCite(Woylie)
#> [1] 1903
```

TotalJournals() counts the number of unique journals that the species have appeared in.

For example:

```
TotalJournals(Woylie)
#> [1] 55
```

SourceType counts the total number of items for each document type.

For example:

```
SourceType(Woylie)
#>   Article Review
#> 1      110      3
```

`YearsPublishing()` counts the number of years since the first publication of the species.

For example:

```
YearsPublishing(Woylie)
#> [1] 44
```

Statistical indices

Statistical indices can provide deeper insights than the simple counts and ratios described above. They take a few parameters into consideration, such as time, total citations, total publications, and their distributions, to compute the index. Here we implemented the following statistical indices of research impact for species: *h*-index, *h5* index, *m*-index, and the *i10* index.

Use `SpHindex()` to compute the *h*-index (Hirsch 2005) for a given set of records. It sorts the citation counts in descending order and then finds the largest number of publications (*n*) that have EACH been cited at least *n* times.

For example:

```
SpHindex(Woylie)
#> [1] 26
```

The *h5* index computes the *h*-index for the past 5 years.

For example:

```
SpH5(Woylie)
#> [1] 6
```

You can calculate *h*-index for publications published after a certain date. To subset the time with a specific lower limit, you can use `SpHAfterdate()`. Make sure the date parameter is in the exact format of yyyy-mm-dd. Using a different format or using slashes or hyphens will return an error.

For example:

```
SpHAfterdate(Woylie, "2000-01-01")
#> [1] 20
```

The *m*-index is an *h*-index adjusted for the age of publication. The *m*-index is calculated using the `SpMindex()` function, which first computes the *h*-index and then divides it by the number of years of publication activity, i.e. number of years since the oldest publication in the dataset was published:

$$m = h / \text{years publishing}$$

For example:

```
SpMindex(Woylie)
#> [1] 0.591
```

The *i10* index is another variant of the *h*-index, which only takes into account publications with at least 10 citations. The *i10* index can be calculated using `SpI10()`, which simply counts the publications that has 10 or more citations.

For example:

```
Spi10(Woylie)
#> [1] 54
```

All indices in one go

Rather than calling each function to calculate the indices in turn, you can get them all in one go. The `Allindices()` function conveniently returns a dataframe with most of the above indices. This allows for quick creation of dataframes with multiple species, analyses and plotting.

For example:

```
Allindices(Woylie, genus = "Bettongia", species = "penicillata")
#>      genus_species      species      genus publications citations journals
#> 1 Bettongia_penicillata penicillata Bettongia      113      1903      55
#>  years_publishing h      m i10 h5
#> 1      44 26 0.591 54 6
```

There is an additional argument `sourcetype` with the default set to `sourcetype = 0`. If set to `sourcetype = 1`, the output of `Allindices()` will include the output of `SourceType()`.

For multiple species, `rbind()` (or `dplyr::bind_rows()` if `sourcetype = 1`) can be used to stitch the outputs together, which will be used below.

Worked examples with Scopus

To demonstrate how the `speciesindex` package could be helpful in the real world, I will be comparing the citations of 4 species of marsupials. They are the woylie (*Bettongia penicillata*), quokka (*Setonix brachyurus*), platypus (*Ornithorhynchus anatinus*), and koala (*Phascolarctos cinereus*). I used `FetchSpTAK()` for all of these datasets. I have included these sets of data in the package but you can also extract the data from Scopus for the most updated records.

```
dim(Woylie)
#> [1] 113 20
dim(Quokka)
#> [1] 242 20
dim(Platypus)
#> [1] 321 20
dim(Koala)
#> [1] 773 20
```

As shown here, there were 113 records (publications) for the woylie, 242 records for the quokka, 321 records for the platypus, and 773 records for the koala. They all have a total of 20 variables, e.g. citations, journals, DOI, etc., representing bibliometric information downloaded from Scopus for each publication. I have skipped the steps of fetching the data from Scopus since it had already been demonstrated above.

Comparing indices

Next, we calculate research productivity and influence indices using the `Allindices()` function:


```
W <- Allindices(Woylie, genus = "Bettongia", species = "penicillata")
Q <- Allindices(Quokka, genus = "Setonix", species = "brachyurus")
P <- Allindices(Platypus, genus = "Ornithorhynchus", species = "anatinus")
K <- Allindices(Koala, genus = "Phascolarctos", species = "cinereus")
```

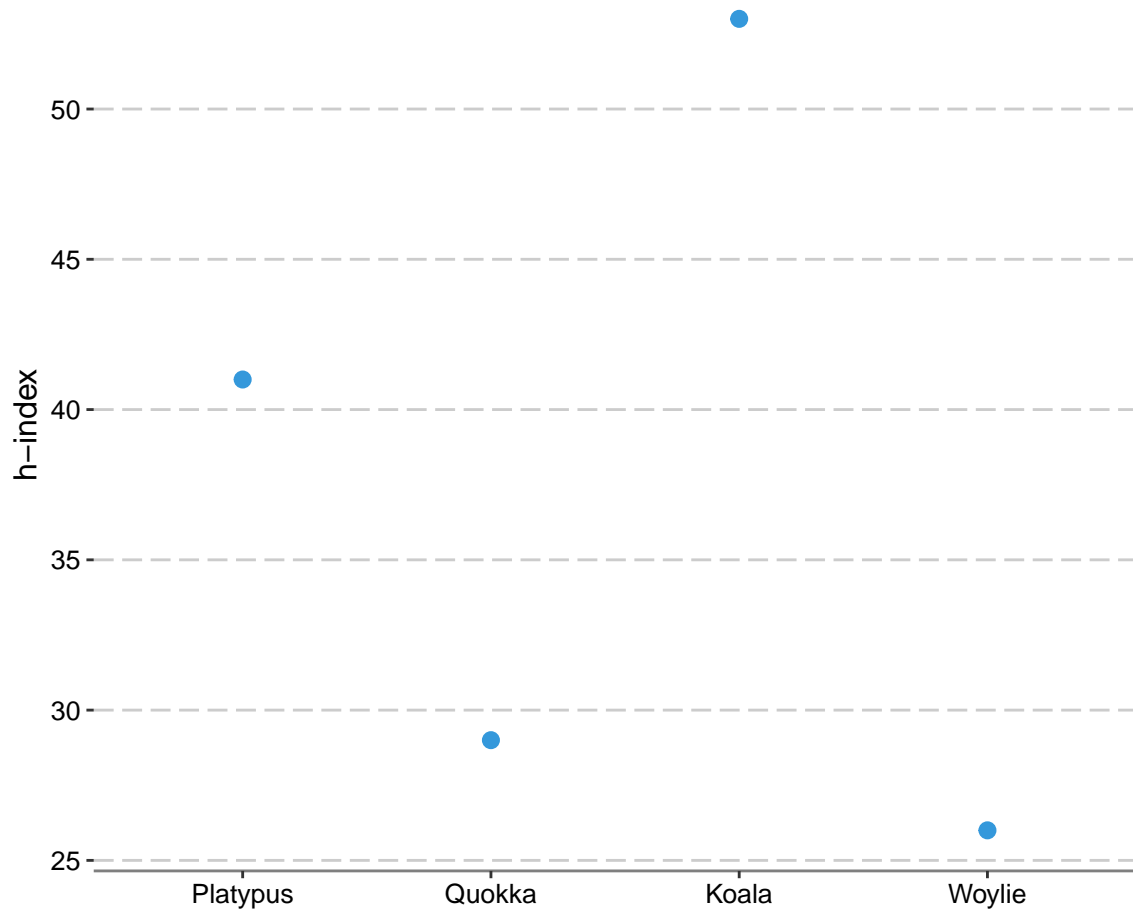
If you want to compare and analyse them against each other, you can use the function `rbind()` to combine indices for all four species into a single dataframe:

```
CombineSp <- dplyr::bind_rows(W, Q, P, K) #combining the citation records
CombineSp
#>      genus_species      species      genus publications citations
#> 1 Bettongia_penicillata penicillata Bettongia      113      1903
#> 2 Setonix_brachyurus brachyurus Setonix      242      3427
#> 3 Ornithorhynchus_anatinus anatinus Ornithorhynchus      321      6365
#> 4 Phascolarctos_cinereus cinereus Phascolarctos      773      14291
#> journals years_publishing h      m i10 h5
#> 1      55      44 26 0.591 54 6
#> 2     107      67 29 0.433 121 3
#> 3     153      68 41 0.603 177 6
#> 4     227     140 53 0.379 427 12
```

After preparing the data, we are ready to make some plots. For example, using the package `ggplot2`, we can plot the h-index and m-index. When comparing the indices, it is important to remember that their scales may differ drastically. Therefore, putting the variables in the same plot may generate plots that do not make a lot of sense.

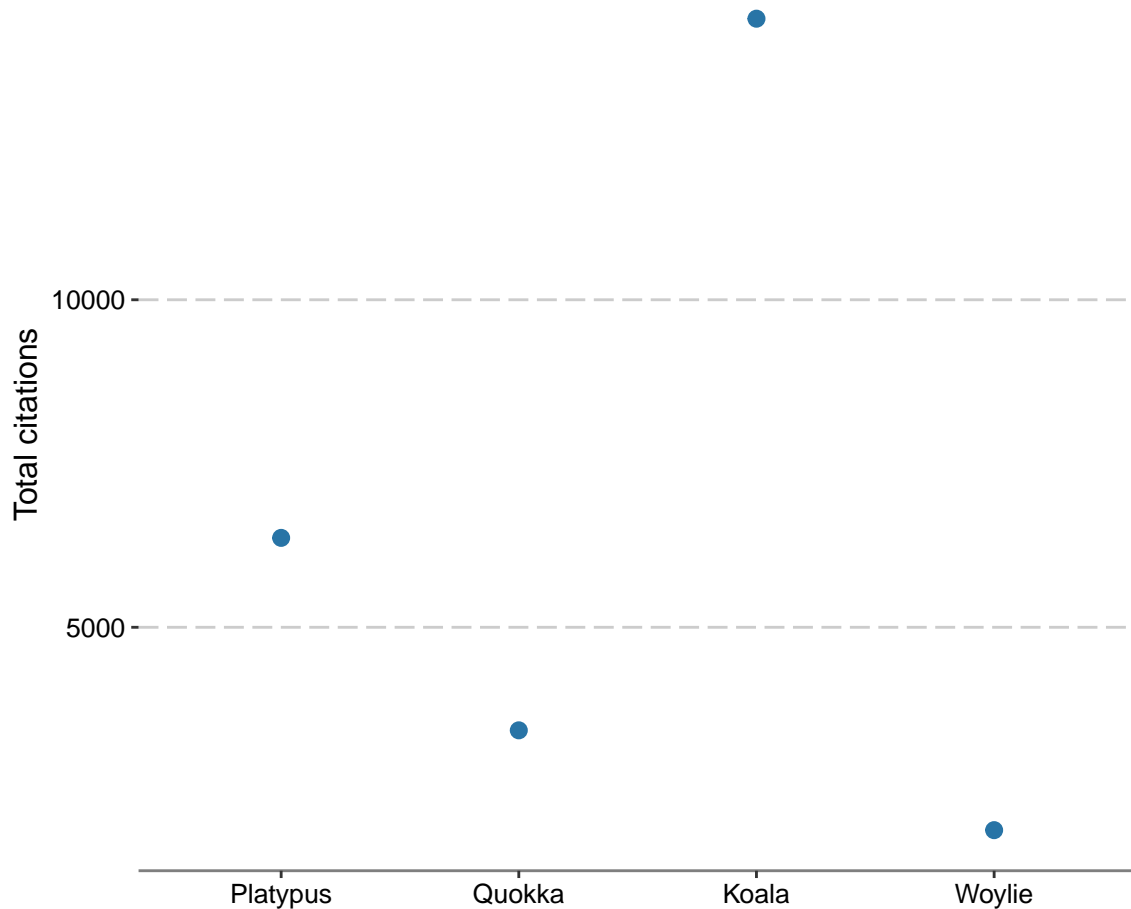
We first plot the h-index:

```
# h-index
library(ggplot2)
ggplot(CombineSp, aes(x = species)) +
  geom_point(aes(y = h,
                 colour = "H-index"),
            size = 2.5) +
  labs(y = "h-index",
       colour = "Index") +
  scale_x_discrete(labels = c("Platypus", "Quokka", "Koala", "Woylie")) +
  scale_colour_manual(values = c("H-index" = "#3498DB")) +
  theme(axis.title = element_text(size = 12,
                                   colour = "black"),
        axis.title.x = element_blank(),
        axis.text = element_text(size = 10,
                                   colour = "black"),
        axis.line.x = element_line(colour = "grey50"),
        plot.background = element_rect(fill = "white"),
        panel.background = element_rect(fill = "white"),
        panel.grid.major.y = element_line(colour = "grey80",
                                           linetype = "longdash"),
        panel.grid.major.x = element_blank(),
        panel.grid.minor = element_blank(),
        legend.position = "none")
```



We can also plot the total citations counts for comparison, since citations is an important factor in contributing to h-index.

```
# Total citations
ggplot(CombineSp, aes(x = species)) +
  geom_point(aes(y = citations,
                 colour = "Citations"),
            size = 2.5) +
  labs(y = "Total citations",
       colour = "Index") +
  scale_x_discrete(labels = c("Platypus", "Quokka", "Koala", "Woylie")) +
  scale_colour_manual(values = c("Citations" = "#2874A6")) +
  theme(axis.title = element_text(size = 12,
                                   colour = "black"),
        axis.title.x = element_blank(),
        axis.text = element_text(size = 10,
                                   colour = "black"),
        axis.line.x = element_line(colour = "grey50"),
        plot.background = element_rect(fill = "white"),
        panel.background = element_rect(fill = "white"),
        panel.grid.major.y = element_line(colour = "grey80",
                                           linetype = "longdash"),
        panel.grid.major.x = element_blank(),
        panel.grid.minor = element_blank(),
        legend.position = "none")
```



It seems like the h-index values are quite consistent with the total numbers of citations, i.e. the more the citations in total, the higher the h-index score. Therefore, the woylie, with the lowest number of citations has the lowest h -index. On the other hand, the koala, with the highest number of citations has the highest h -index.

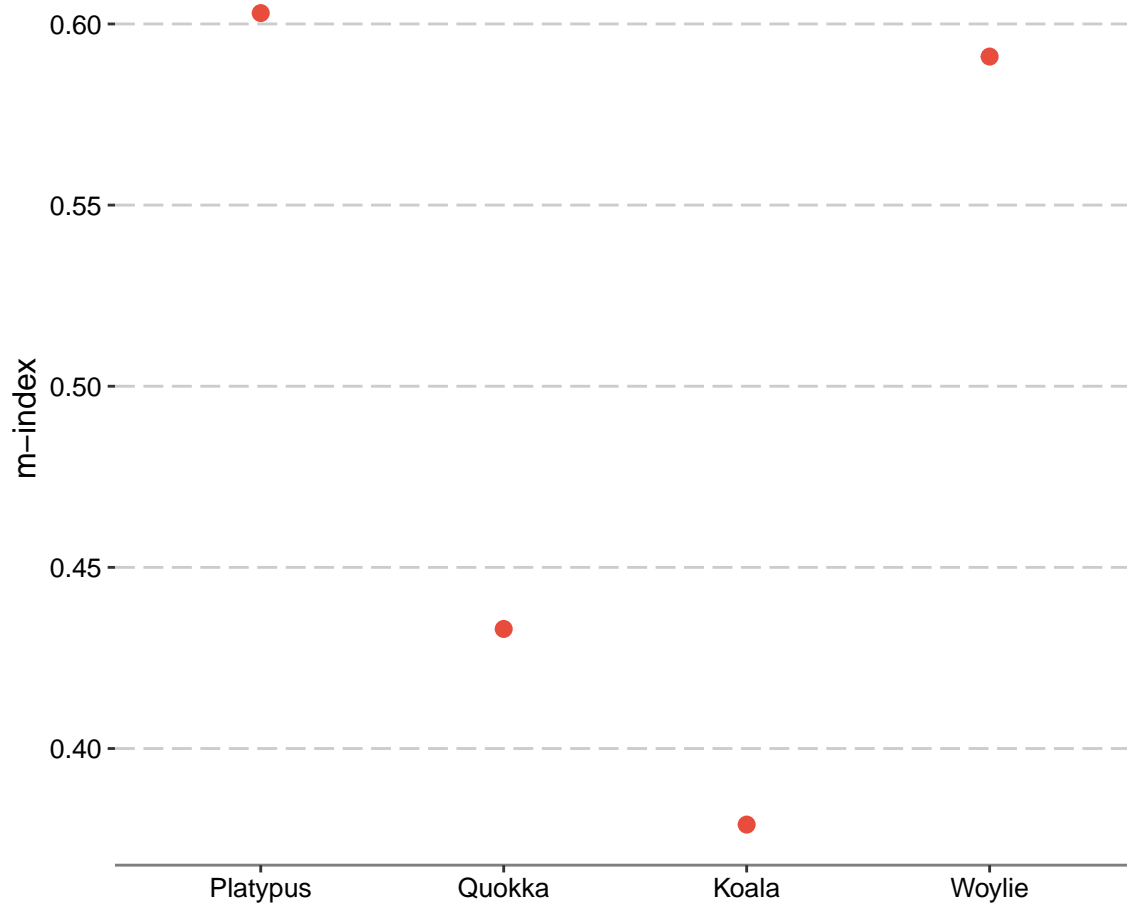
We next plot the m-index to see how it differs from the h-index. Recalling that m-index is calculated by dividing the h-index by the number of years of publication activity ($m = h/\text{years publishing}$), let us have a closer inspection at both the m-index:

```
# m-index
ggplot(CombineSp, aes(x = species)) +
  geom_point(aes(y = m,
                 colour = "M-index"),
            size = 2.5) +
  labs(y = "m-index",
       colour = "Index") +
  scale_x_discrete(labels = c("Platypus", "Quokka", "Koala", "Woylie")) +
  scale_colour_manual(values = c("M-index" = "#E74C3C")) +
  theme(axis.title = element_text(size = 12,
                                   colour = "black"),
        axis.title.x = element_blank(),
        axis.text = element_text(size = 10,
                                   colour = "black"),
```

```

axis.line.x = element_line(colour = "grey50"),
plot.background = element_rect(fill = "white"),
panel.background = element_rect(fill = "white"),
panel.grid.major.y = element_line(colour = "grey80",
                                   linetype = "longdash"),
panel.grid.major.x = element_blank(),
panel.grid.minor = element_blank(),
legend.position = "none")

```



We should also have a look at the related variable `years_publishing` (number of years since first publication for a given species).

```

# Years publishing
ggplot(CombineSp, aes(x = species)) +
  geom_point(aes(y = years_publishing,
                 colour = "Years publishing",
                 size = 2.5)) +
  labs(y = "Total years",
       colour = "Index") +
  scale_x_discrete(labels = c("Platypus", "Quokka", "Koala", "Woylie")) +
  scale_colour_manual(values = c("Years publishing" = "#950505")) +
  theme(axis.title = element_text(size = 12,
                                   colour = "black"),

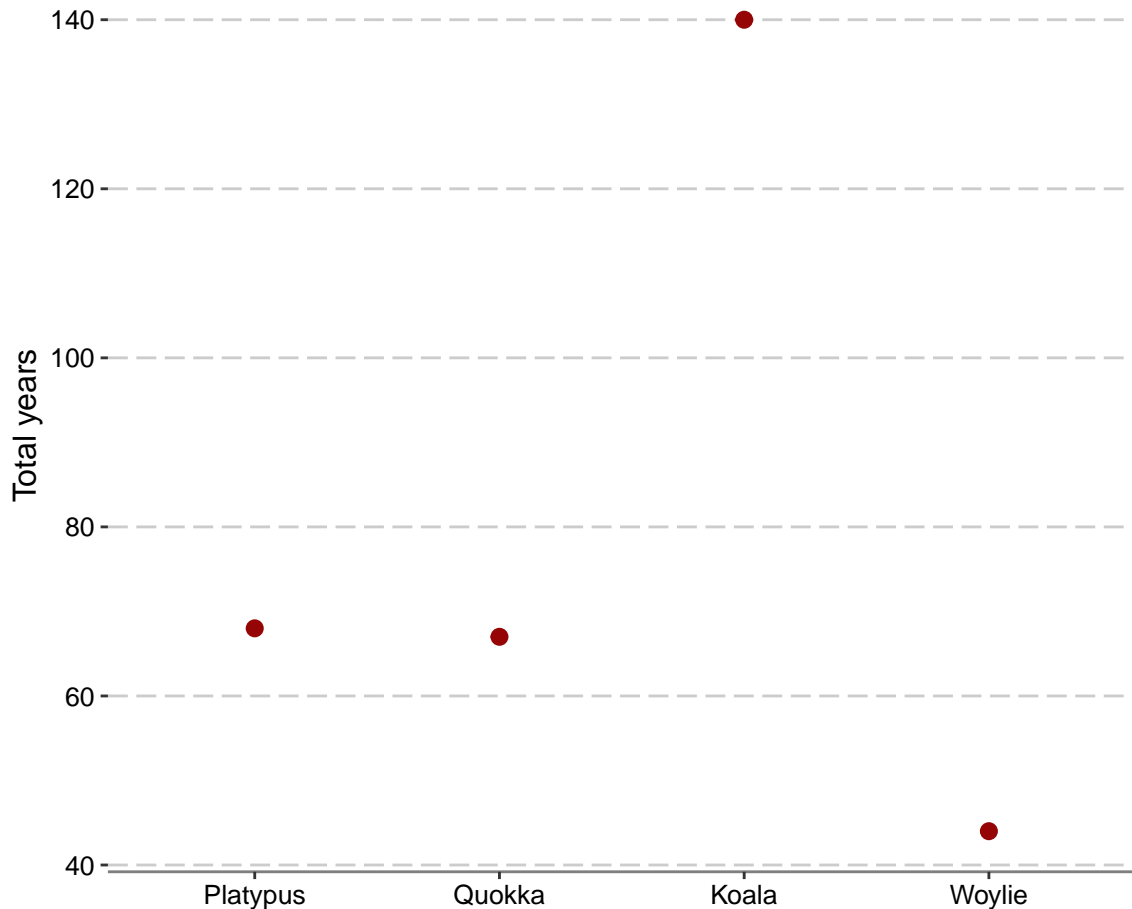
```

```

axis.title.x = element_blank(),
axis.text = element_text(size = 10,
                          colour = "black"),
axis.line.x = element_line(colour = "grey50"),
plot.background = element_rect(fill = "white"),
panel.background = element_rect(fill = "white"),
panel.grid.major.y = element_line(colour = "grey80",
                                  linetype = "longdash"),

panel.grid.major.x = element_blank(),
panel.grid.minor = element_blank(),
legend.position = "none")

```



In order to understand what yields a high m -index score, we should recall that the m -index is a ratio. A high m -index can be achieved by combination of a higher h -index and a lower `years_publishing` value. This explains why koala publications have a relatively low m -index, albeit highest h -index. Research on koalas has been produced for over 3 times longer than that on the woylie. Although the h -index of woylie publications was half of that of the koala, it had only been in the scientific scene for a few decades. Comparing the quokka to the platypus, we can see that their publications have both been around for a similar duration of time. 66 years for the quokka and 67 years for the platypus respectively. Since the platypus has a higher h -index than the quokka, this is thus consistent with the higher m -index score here.

Limitations

Currently, the input option for search requests is limited to species Latin names. Although common names are synonymous with the binomial names, they are comparatively much less explicit. There could be multiple species using the same common name, which will require extra steps to specify which is the particular species that is being studied. Moreover, there are other fields of research that use species' common names in the titles of their work without meaning the actual species, e.g. as a product/project name.

Another limitation is that only species-level searches using binomial names are enabled at the moment. This is because of homonymous (Remsen 2016) genus names between some plant and animal taxa. For example, the genus *Prunella* represents both a taxon of herbaceous plants and passerines. Additional parameters will have to be added to identify the exact taxon in question.

Finally, access to databases depends on location and whether or not your institution is a subscriber of said database. Scopus requests must be sent via a subscriber's internet provider. This include universities and individuals who have paid for annual Scopus subscription. This is easily addressed by connecting to your institution's network. Hence, it might not work at all if you are working from home. The error **Bad Request (HTTP 400)** will be returned in this case. Web of Science requests must be sent from the IP address of your institution, else the user is required to register for an account. Lens Fetch requests can only be made by users who's institution is a subscriber.

Implications and future uses

Although the development of this package is still in its infancy, it is nonetheless a valuable tool for reserchers looking to examine research biases between species. Some functions that could be added in the future include search requests for higher classification levels, e.g. genus, class, etc., and to include other emerging indices that are being used to calculate research influence. The results of the species h-index will show us the research interest each taxon receives. More investigations will then follow to explore the reasons why and how the knowledge gap affected species conservation and the depth of understanding we have for them.

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