

BIODIVERSITY BUILDING BLOCKS FOR POLICY

The b3verse: an R package suite to process cubes and calculate indicators

Ward Langeraert[1], Shawn Dove[2] & Jasmijn Hillaert[1]

[1]Research Institute for Nature and Forest (INBO)
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RESEARCH INSTITUTE NATURE AND FOREST

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Introduction

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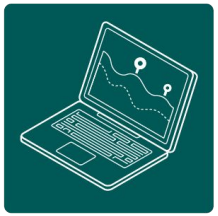
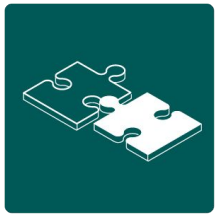
Introduction

Why occurrence cubes?



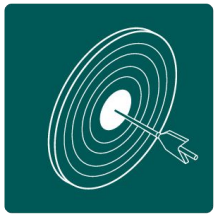
Challenges

The global biodiversity crisis requires **rapid, reliable and repeatable biodiversity monitoring data** which decision makers can use to evaluate policy.



Opportunities

Such information – from local to global level and within relevant timescales – calls for an **improved integration of data on biodiversity** from different sources.



Aim

B-Cubed is **standardising access to biodiversity data**, empowering policymakers to address the impacts of biodiversity change.

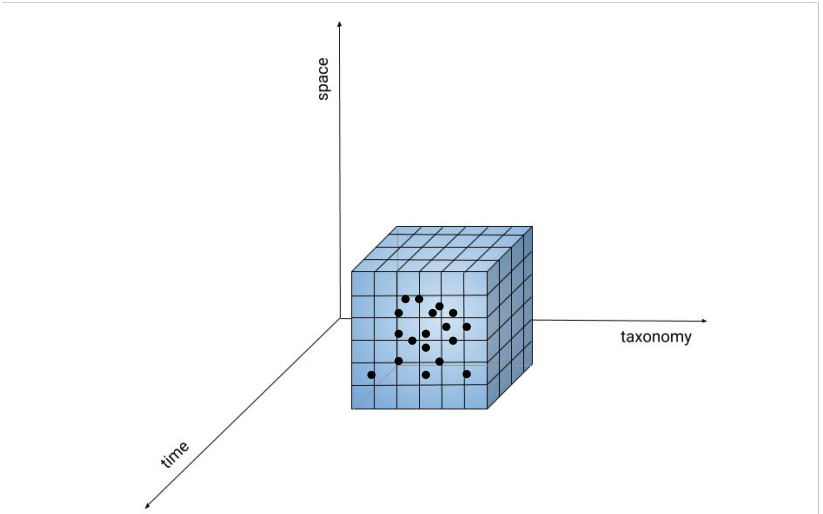
Introduction

What occurrence cubes?

- The concept of **occurrence cubes** developed during the TrIAS project to aggregate GBIF occurrences
  - **taxonomically**, e.g. species
  - **spatially**, e.g. EEA grid 1x1km
  - **temporally**, e.g. year

- Used for calculating emerging trends indicators

- Presented at TDWG2020 (see slides, abstract)
- Preprint (PDF) used in B-Cubed project proposal

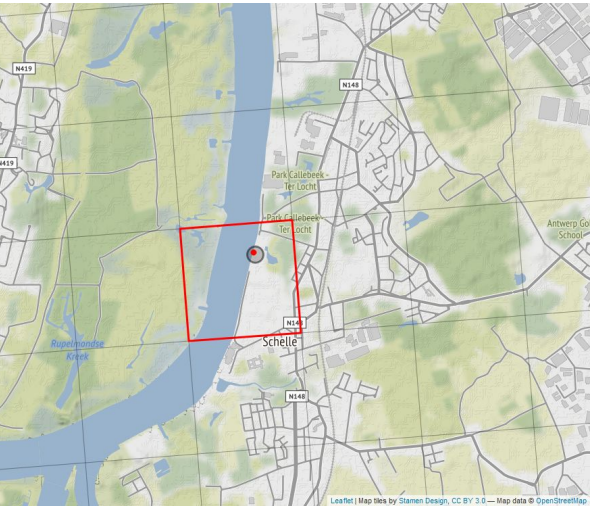


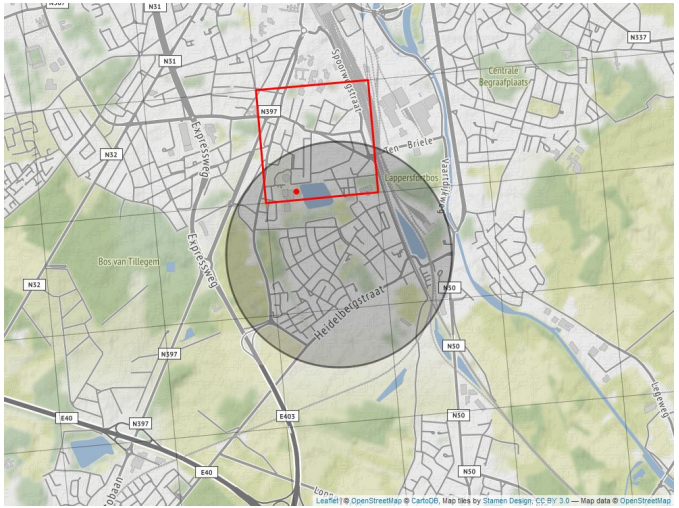
Oldoni D., Groom Q. & Desmet P. (2020)
https://speakerdeck.com/damianooldoni/occurrence-cubes

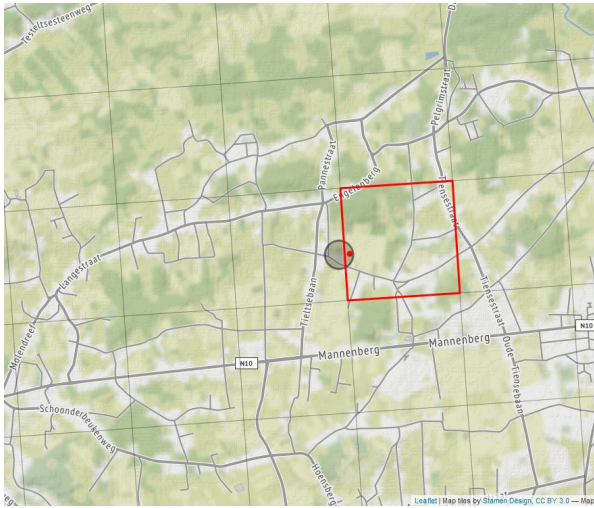
Introduction

What occurrence cubes?

- What about **spatial uncertainty**?
  - Random assignment to grid within uncertainty circle







Oldoni D., Groom Q. & Desmet P. (2020)
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Introduction

What occurrence cubes?

- Aggregation
  - Number of occurrences of a specific **taxon** in a specific **cell** in a specific **time interval**

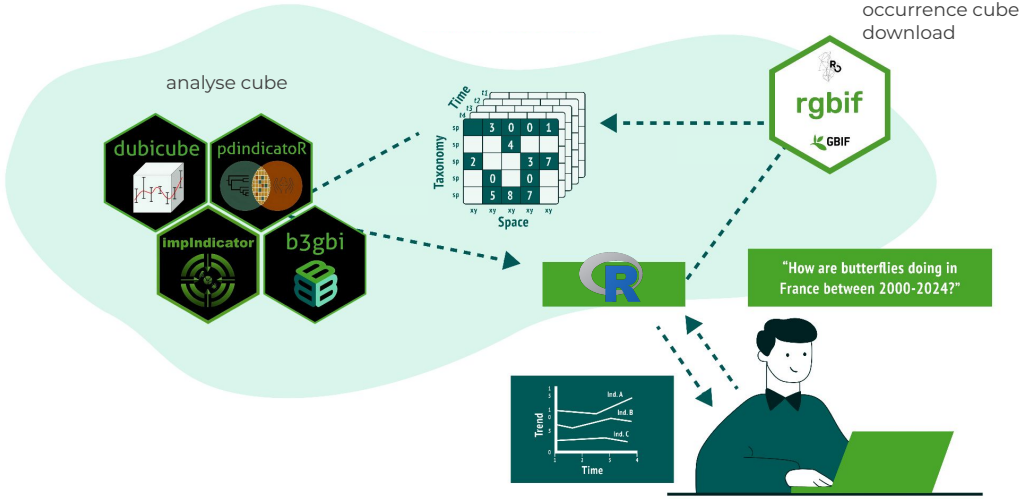
year	eea_cell_code	speciesKey	n	min_coord_uncertainty
2014	1kmE3886N3121	2889173	51	10
2014	1kmE3886N3122	2889173	109	10
…	…	…	…	…
2018	1kmE4047N3067	2889173	1	2828

Oldoni D., Groom Q. & Desmet P. (2020)
https://speakerdeck.com/damianooldoni/occurrence-cubes

Introduction

From cubes to indicators

- B-Cubed: create **reproducible** and **robust workflow**
  - Generate cubes
  - Process cubes
  - Analyse cubes
    - Statistical models
    - Indicator calculation
  - Visualise and interpret results



Introduction

From cubes to indicators

- B-Cubed: create **reproducible** and **robust workflow**
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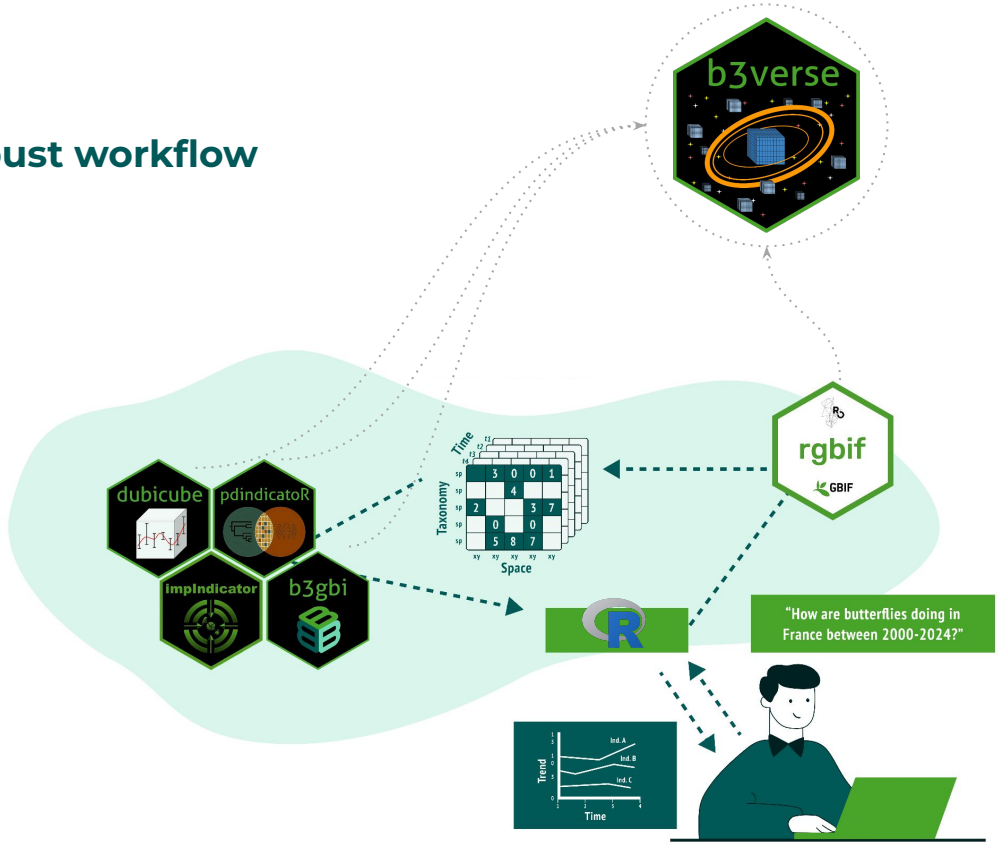
    - Indicator calculation
  - Visualise and interpret results

- Approach: Group of interconnected R packages
  - **b3verse**



b3verse, an ecosystem of R packages

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b3verse, an ecosystem of R packages

General overview

- **b3verse** R package ecosystem
  - 11 R packages
  - 1 dedicated frictionless data package
- Maintained via R-Universe platform

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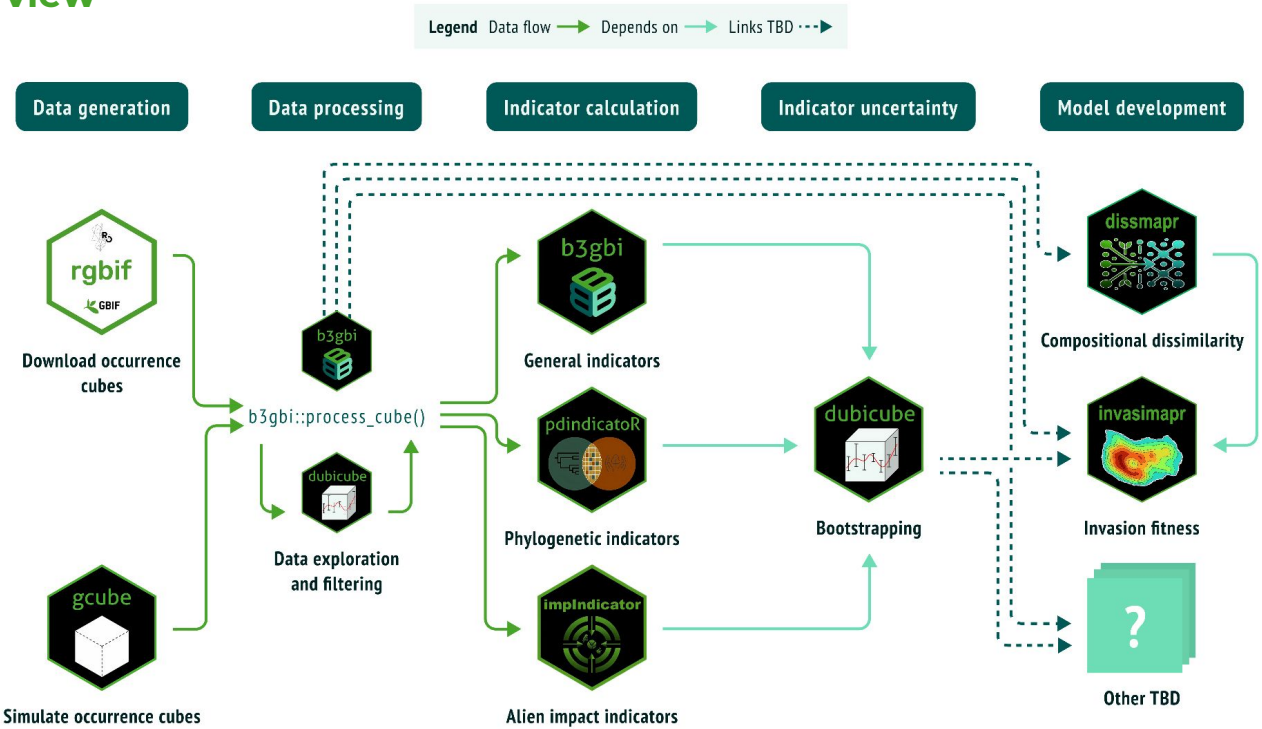
b3verse, an ecosystem of R packages

General overview



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b3verse, an ecosystem of R packages

Practical approach and technical implementation

The essentials

- Shared **software development guide**

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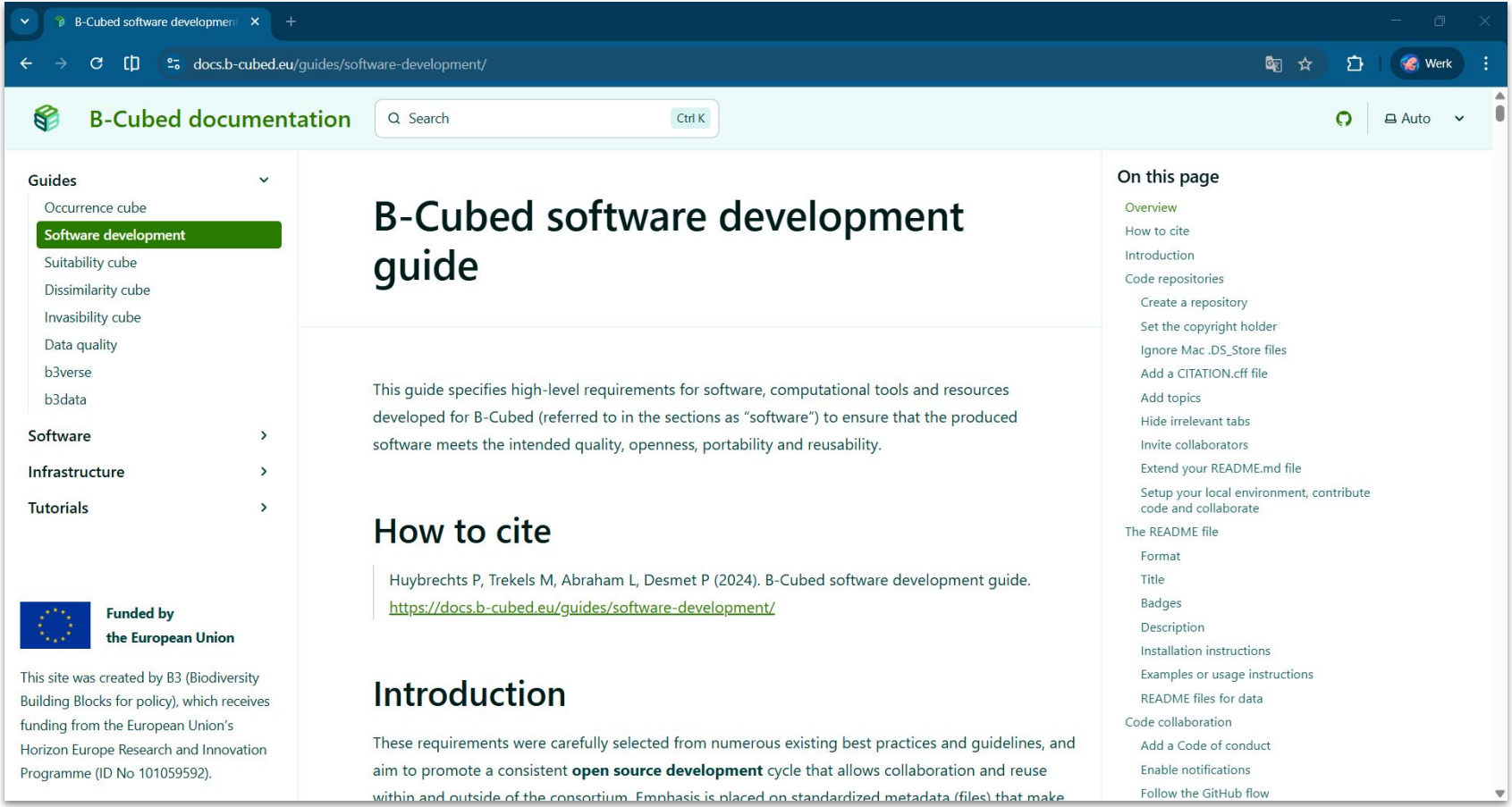
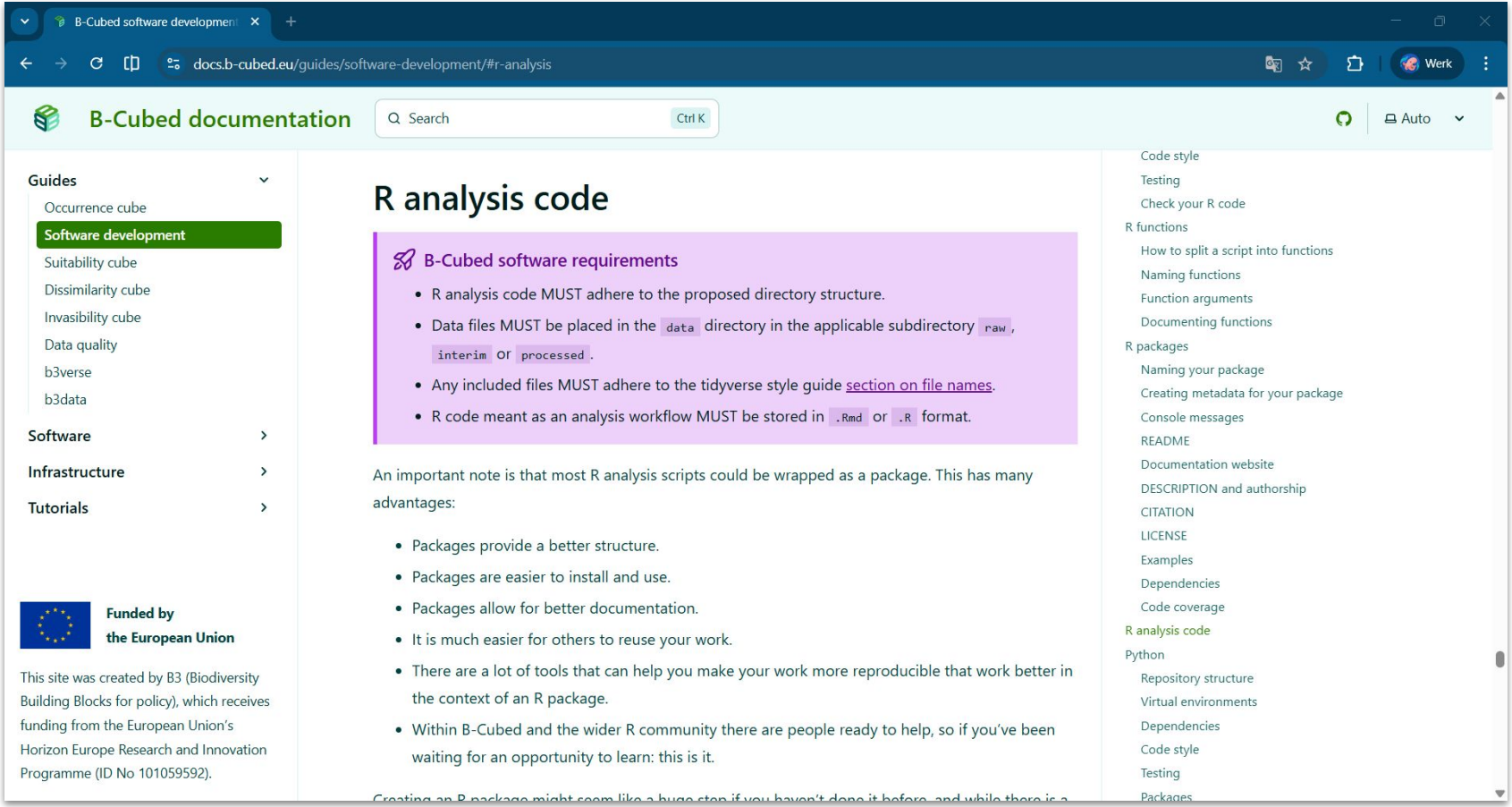


https://docs.b-cubed.eu/guides/software-development/



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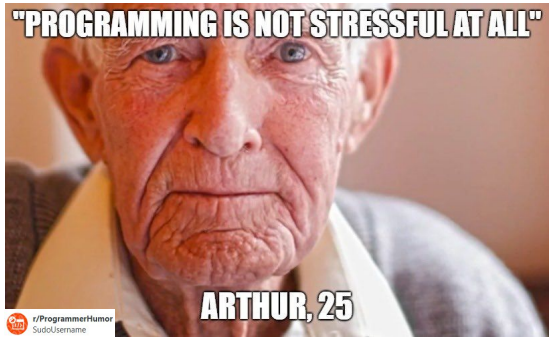
b3verse, an ecosystem of R packages

Practical approach and technical implementation

The essentials

- Shared **software development guide**
  - Including evaluation



BIODIVERSITY BUILDING BLOCKS FOR POLICY

M8 Second quality assessment report of B3 software

23/02/2026

Author(s): Peter Desmet, Lissa Breugelmans, Shawn Dove, Katelyn Faulkner, Sanne Govaert, Quentin Groom, Sandra MacFadyen, Luisa Machado, Damiano Oldoni, Lien Reyserhove, Duccio Rocchini, Maxime Ryckewaert, Hanno Seebens, Maarten Trekels, Toon Van Daele, Mukhtar Yahaya

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This project receives funding from the European Union's Horizon Europe Research and Innovation Programme (ID No 101059592). Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the EU nor the EC can be held responsible for them.

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Practical approach and technical implementation

The essentials

- Shared **software development guide**
  - Including evaluation
  - Cooperation on GitHub + automated checks

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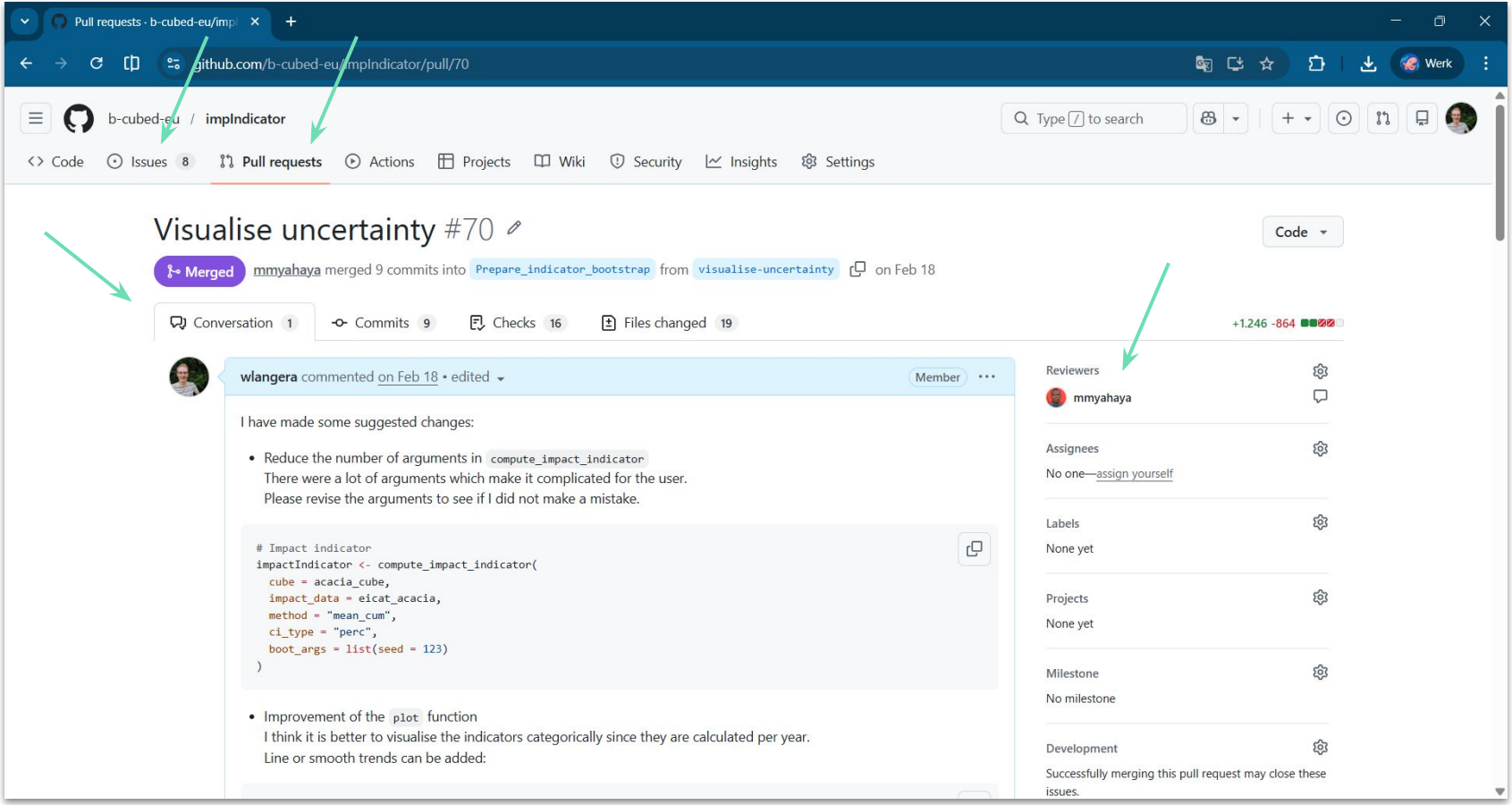

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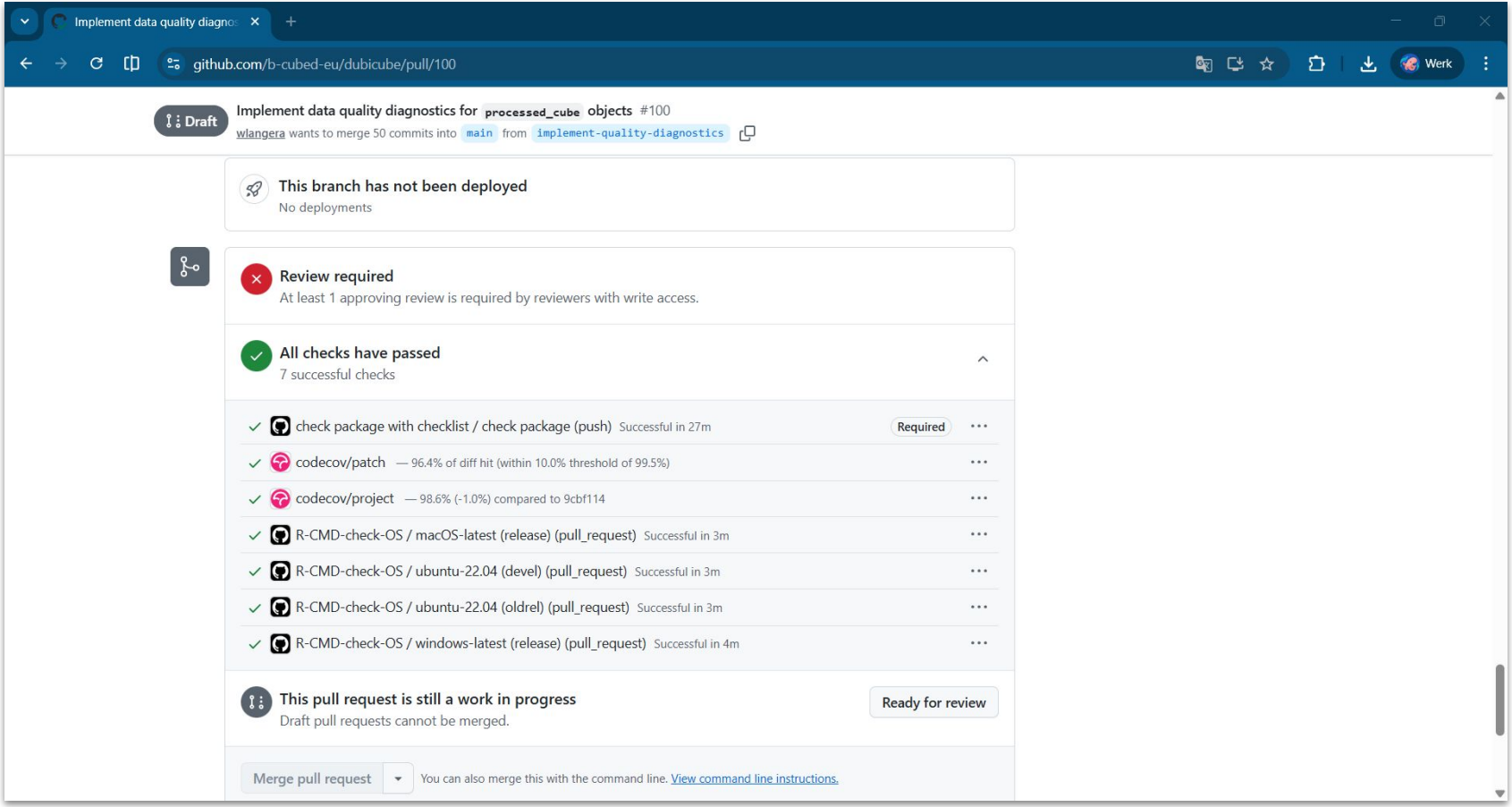

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b3verse, an ecosystem of R packages

Practical approach and technical implementation

The essentials

- Shared **software development guide**
- **R-universe** platform:
  open platform for running personal CRAN-like package repositories (more info)
  - **Searchable catalogue** for R software, articles, datasets
  - **Visible and accessible** to a big audience, easy installation
  - **Automatic updates and compilation** whenever changes are pushed to GitHub

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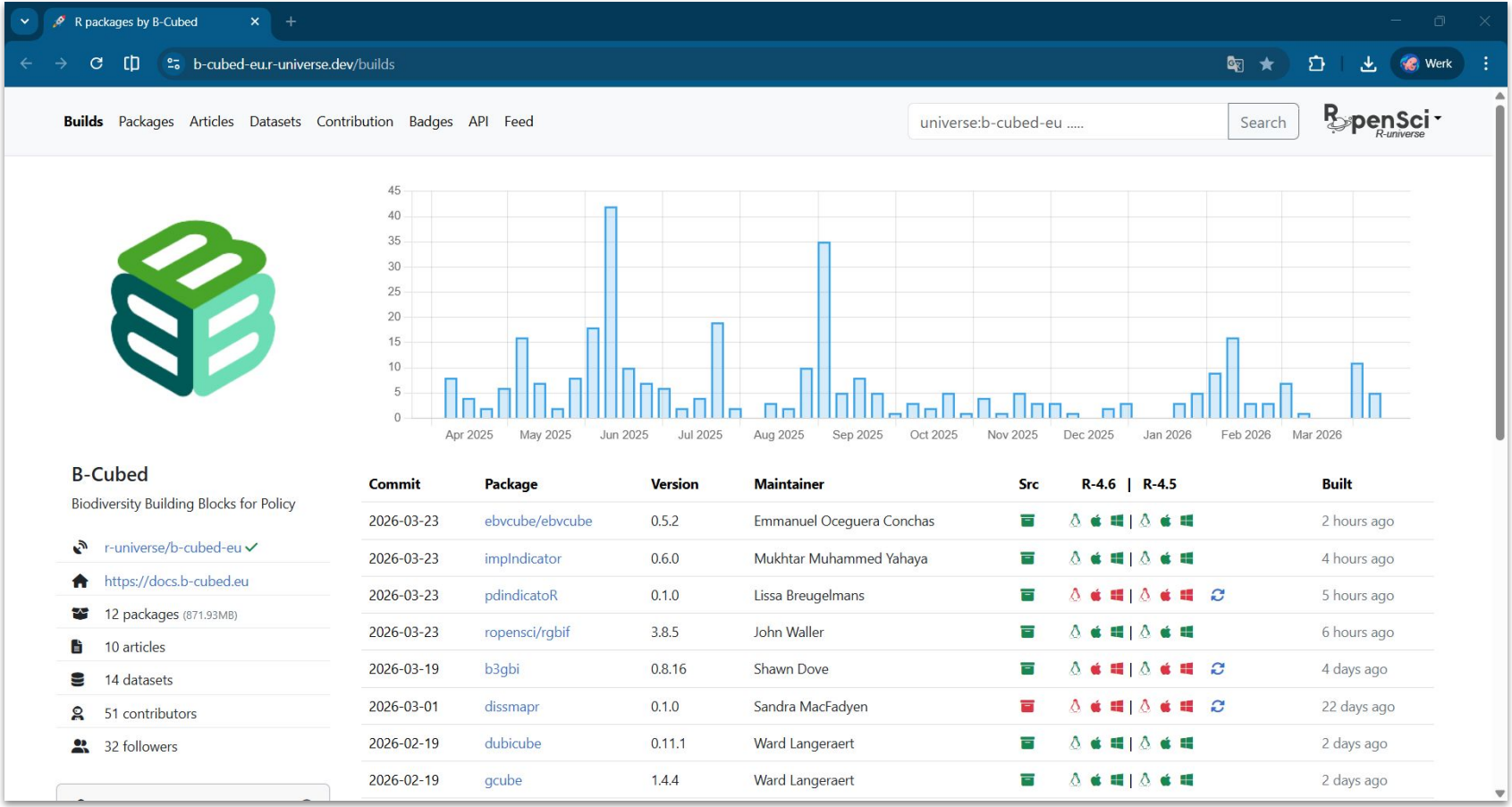

https://b-cubed-eu.r-universe.dev/

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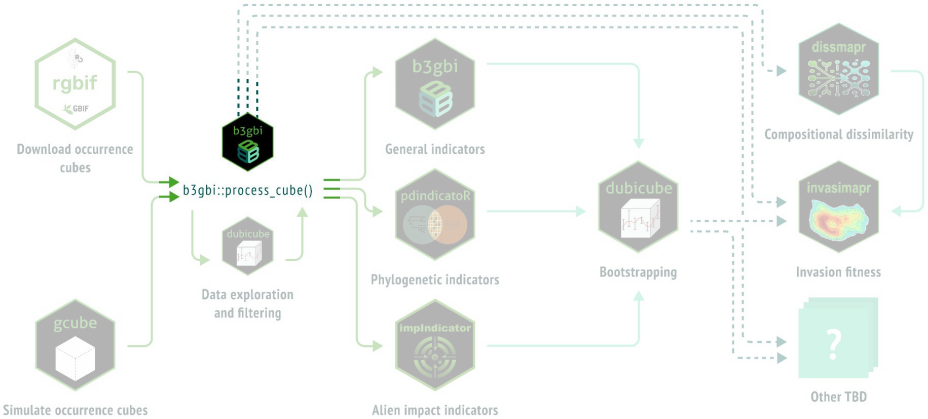
Practical approach and technical implementation

The essentials

- Shared **software development guide**
- **R-universe** platform
- Gatekeeper validation function **b3gbi::process_cube()**
  - Structural **consistency and harmonization**
  - **Interoperability** across packages



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Practical approach and technical implementation

The essentials

- Shared **software development guide**
- **R-universe** platform
- Gatekeeper validation function **b3gbi::process_cube()**
- Visibility and outreach
    - Central documentation and tutorials

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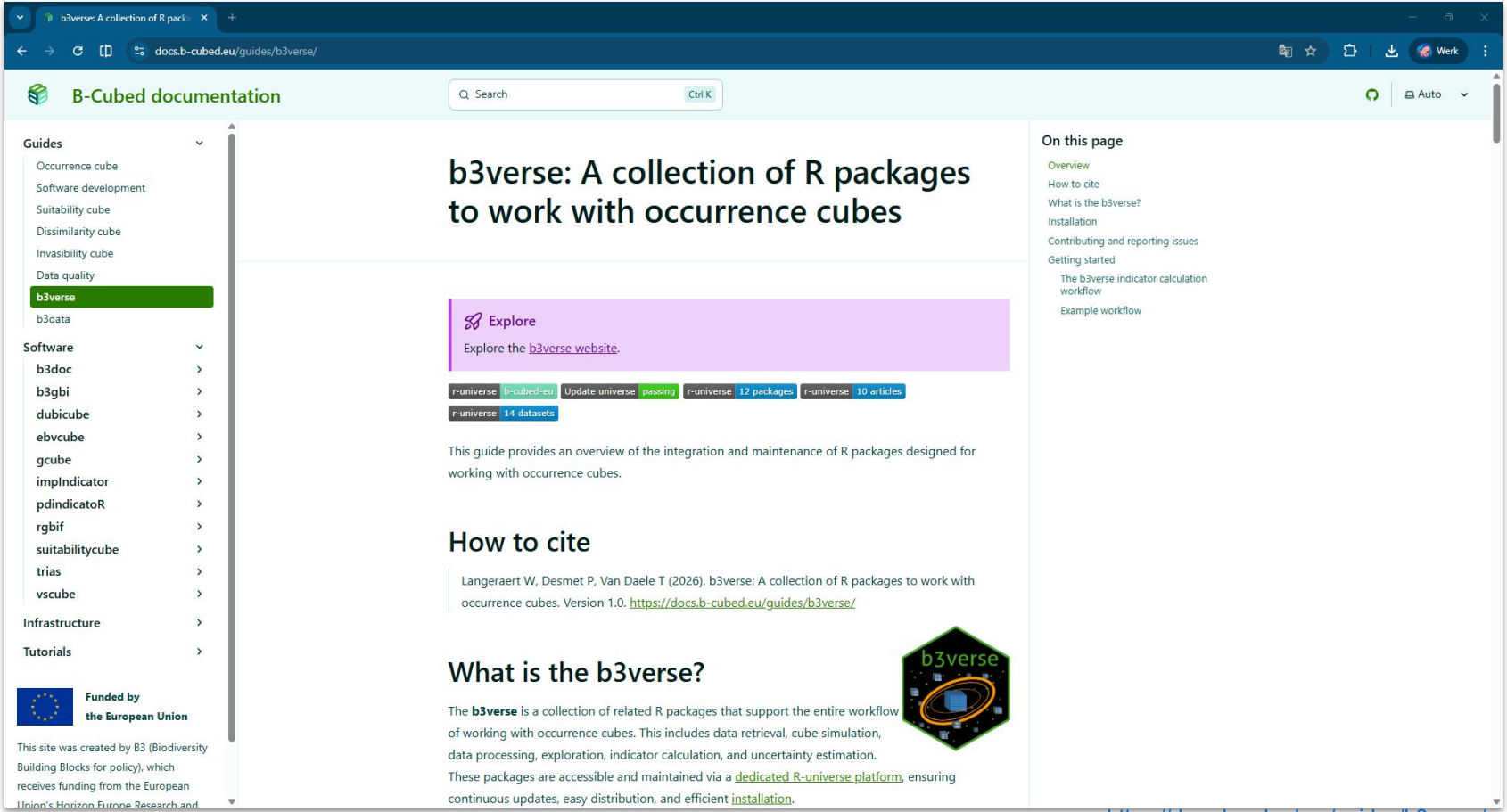
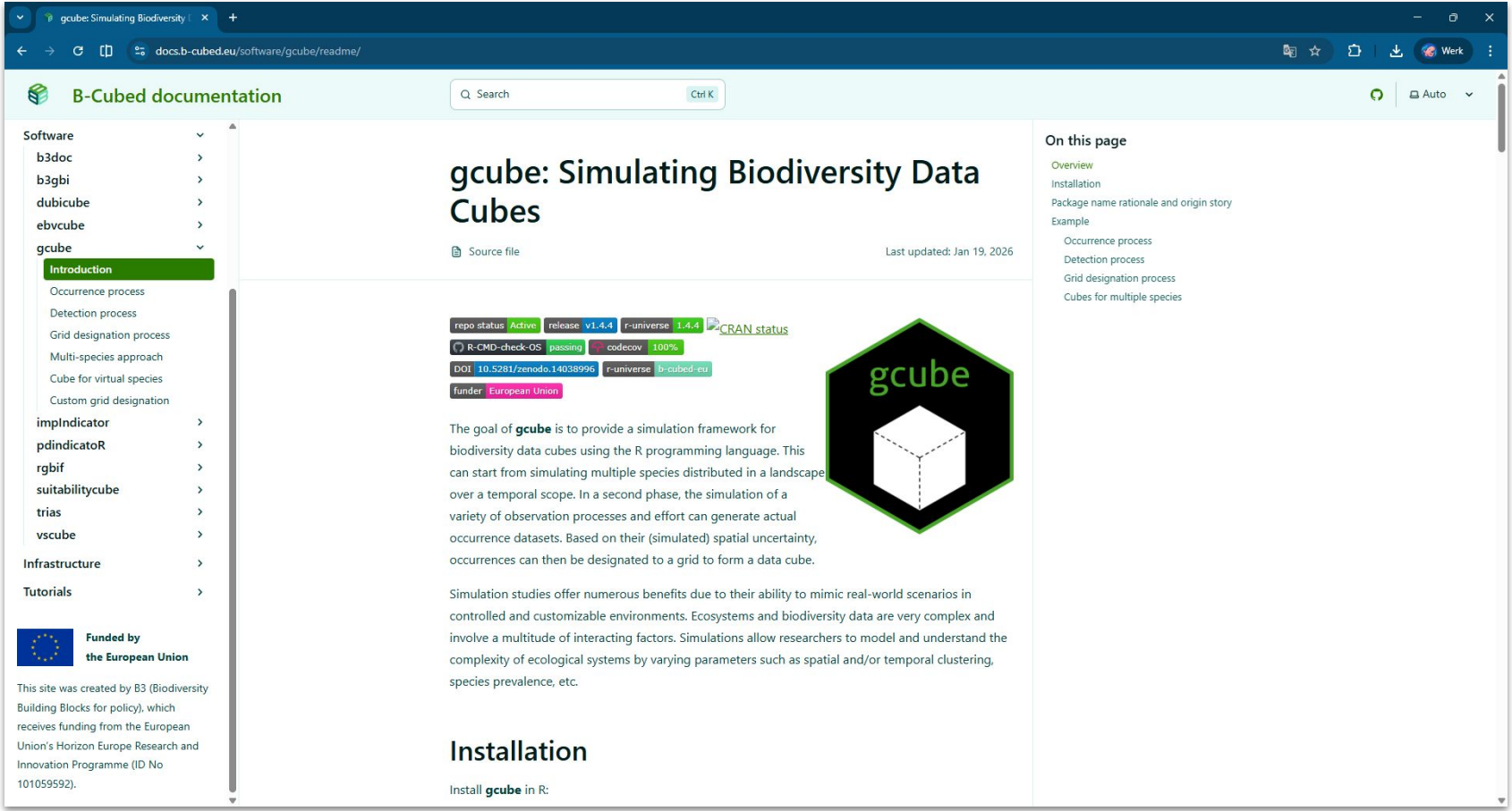


https://docs.b-cubed.eu/guides/b3verse/



https://docs.b-cubed.eu/software/gcube/readme/

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Practical approach and technical implementation

The essentials

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- Gatekeeper validation function **b3gbi::process_cube()**
- Visibility and outreach
    - Central documentation and tutorials
        - Documentation helper package **b3doc**:

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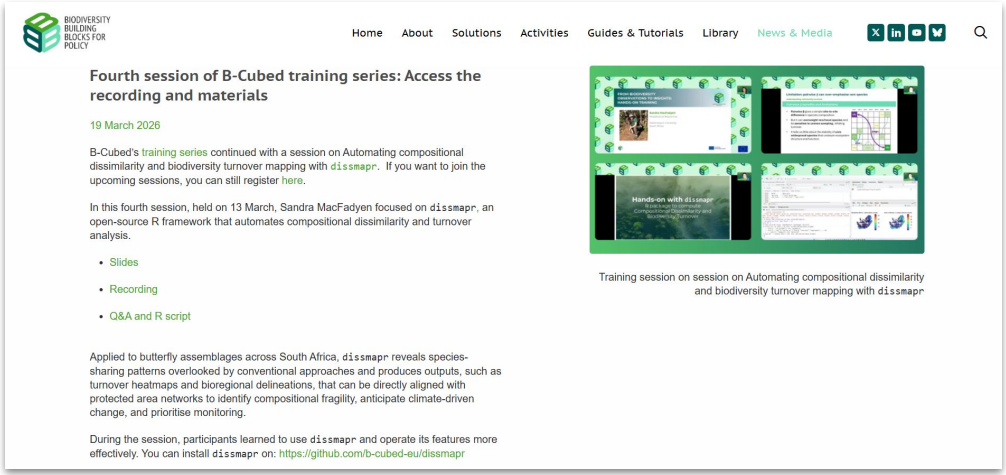
b3verse, an ecosystem of R packages

Practical approach and technical implementation

The essentials

- Shared **software development guide**
- **R-universe** platform
- Gatekeeper validation function **b3gbi::process_cube()**
- Visibility and outreach
  - Central documentation and tutorials
    - Documentation helper package **b3doc**
  - Training sessions and workshops



b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Documentation

- **b3doc**

Indicator workflow

- **rgbif, gcube, b3gbi, pdindicatoR, mpIndicator, dubicube**

Modelling cubes

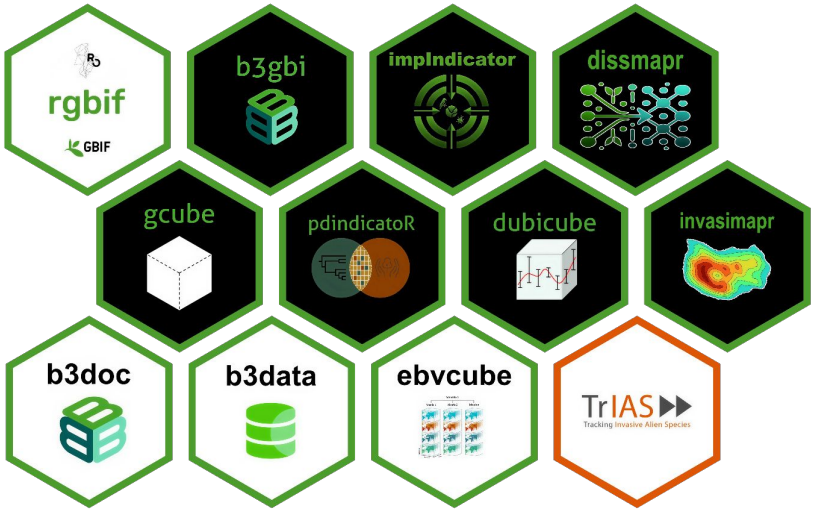
- **dissmapr, invasimapr**

Other projects

- **ebvcube, trias**

Data

- **b3data**



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A closer look at the b3verse packages

Documentation

- **b3doc**
  - Create Markdown pages for the B-Cubed documentation website

See earlier

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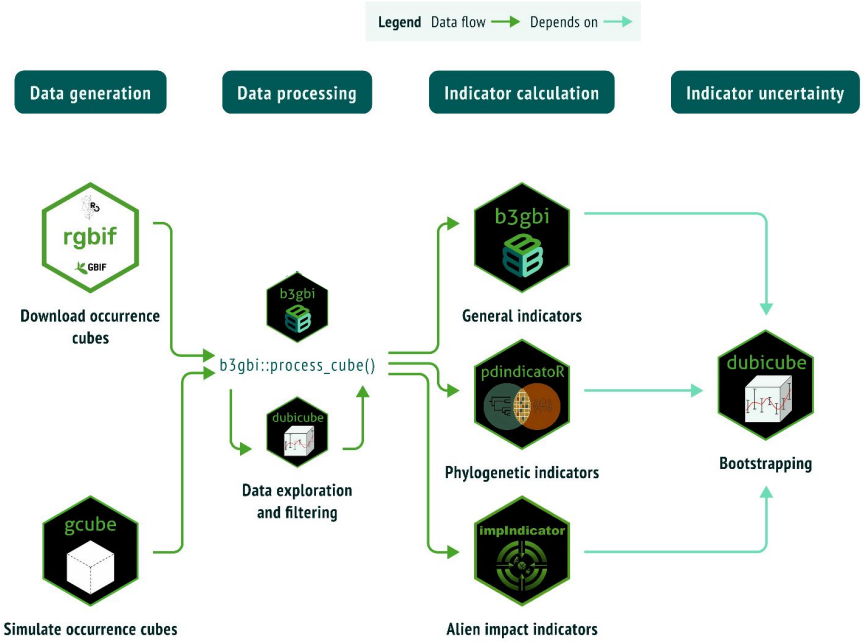
A closer look at the b3verse packages

Indicator workflow



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A closer look at the b3verse packages

Indicator workflow

- **rgbif**
  - Search and retrieve data from GBIF

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A closer look at the b3verse packages

Indicator workflow

- **rgbif**
  - Search and retrieve data from GBIF

- Download occurrences
- Match taxon names
- View dataset metadata
- … download occurrence cubes :)

See later

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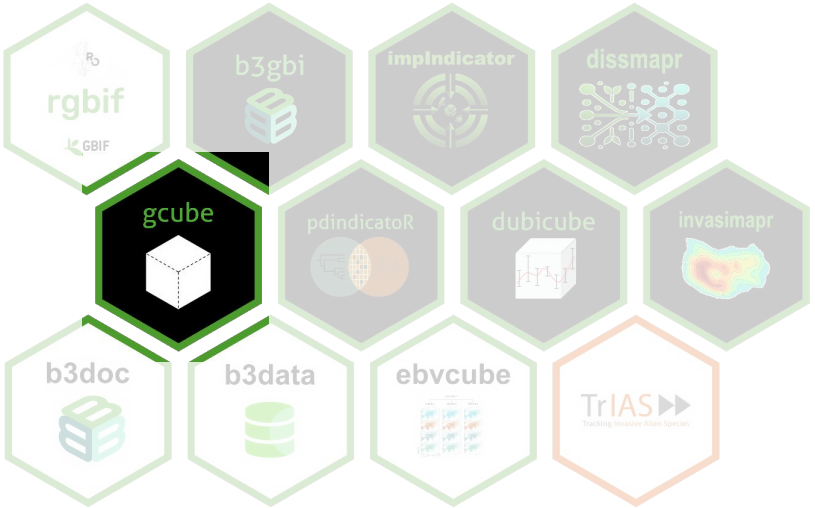
A closer look at the b3verse packages

Indicator workflow

- **gcube**
  - Simulation of occurrence cubes



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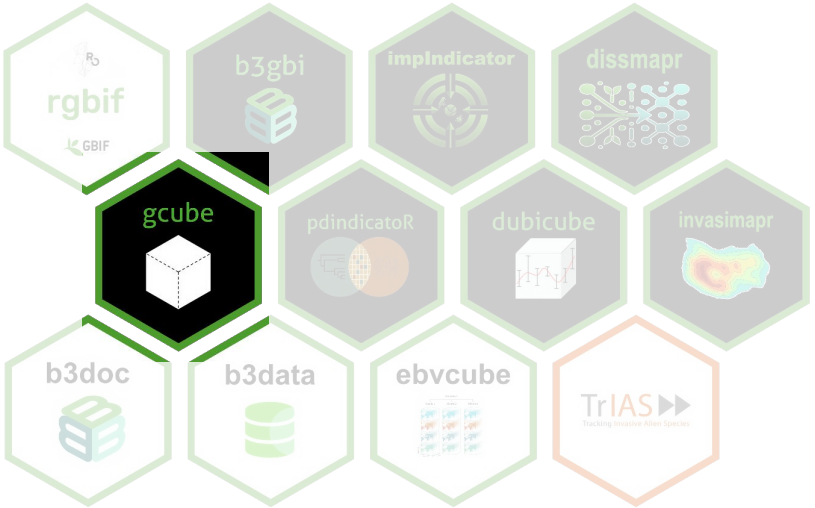
A closer look at the b3verse packages

Indicator workflow

- **gcube**
  - Simulation of occurrence cubes

- Monte Carlo simulation
  - Occurrence process
  - Detection process
  - Grid designation process
- Virtual species
- Custom occurrence datasets



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A closer look at the b3verse packages

Indicator workflow

- **b3gbi**
  - Calculate general biodiversity indicators from occurrence cubes

See later

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A closer look at the b3verse packages

Indicator workflow

- **pdindicatoR**
  - Calculate phylogenetic indicators from occurrence cubes

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A closer look at the b3verse packages

Indicator workflow

- **pdindicatoR**
  - Calculate phylogenetic indicators from occurrence cubes

- Input
  - Occurrence cube
  - Phylogenetic tree
  - (spatial grid for visualisation)

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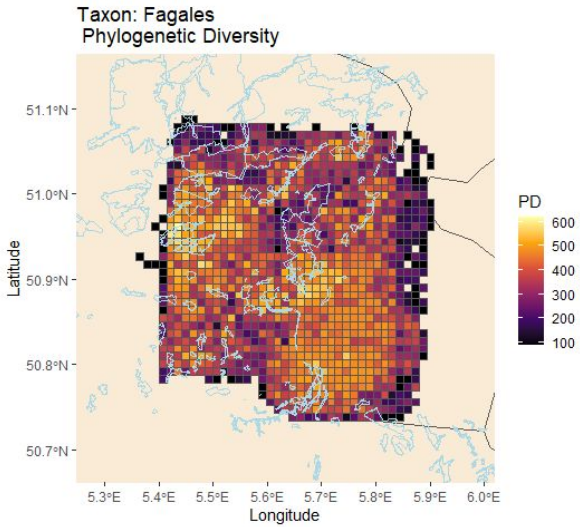
A closer look at the b3verse packages

Indicator workflow

- **pdindicatoR**
  - Calculate phylogenetic indicators from occurrence cubes

- Input
  - Occurrence cube
  - Phylogenetic tree
  - (spatial grid for visualisation)
- Calculation of phylogenetic diversity
  - Sum of branch lengths



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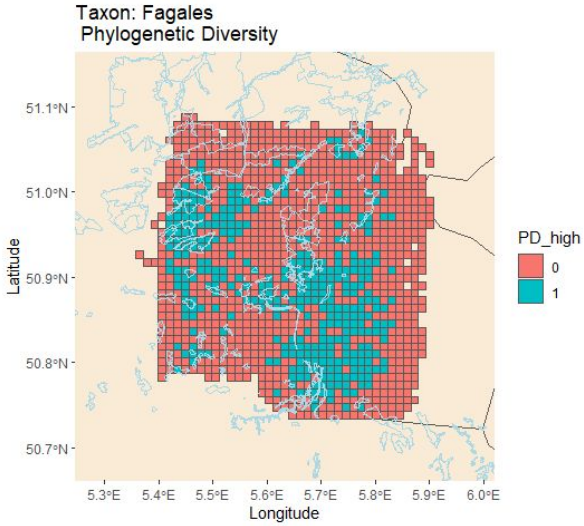
A closer look at the b3verse packages

Indicator workflow

- **pdindicatoR**
  - Calculate phylogenetic indicators from occurrence cubes

- Input
  - Occurrence cube
  - Phylogenetic tree
  - (spatial grid for visualisation)
- Calculation of phylogenetic diversity
  - Sum of branch lengths
- Proportion high PD grid cells in protected areas
  - Cut-off value
  - Spatial grid with protected areas



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A closer look at the b3verse packages

Indicator workflow

- **impIndicator**
  - Calculate alien impact indicators from occurrence cubes

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A closer look at the b3verse packages

Indicator workflow

- **impIndicator**
  - Calculate alien impact indicators from occurrence cubes

- Input
  - Occurrence cube
  - EICAT assessment data
    - massive (MV), major (MR), moderate (MO), minor (MN), or minimal concern (MC)

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Indicator workflow

- **impIndicator**
  - Calculate alien impact indicators from occurrence cubes

- Input
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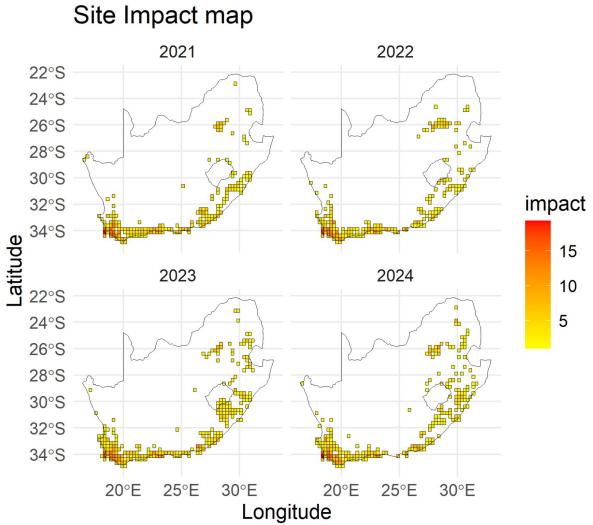
    - massive (MV), major (MR), moderate (MO), minor (MN), or minimal concern (MC)
- Calculation of impact of alien species
  - Site impact indicator



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  - Occurrence cube
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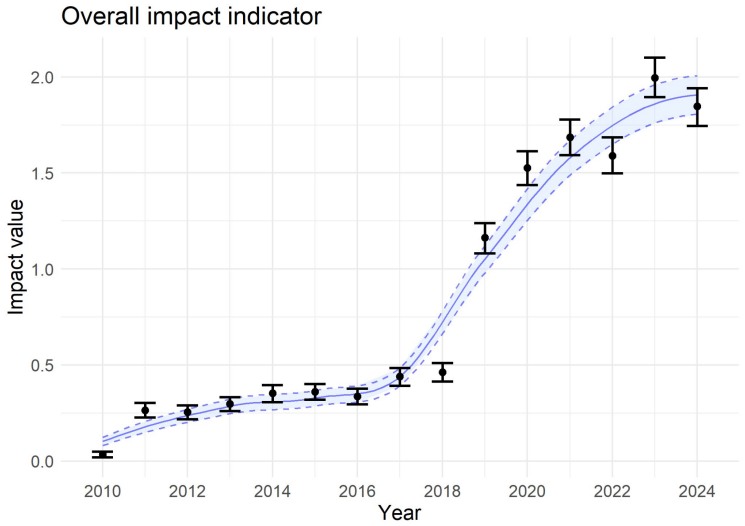
- Calculation of impact of alien species
  - Site impact indicator
  - Overall impact indicator



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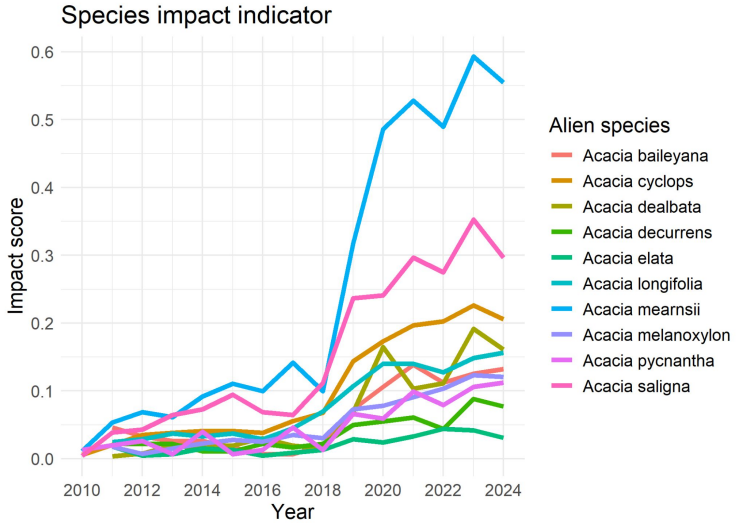
- Calculation of impact of alien species
  - Site impact indicator
  - Overall impact indicator
  - Species impact indicator



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Indicator workflow

- **dubicube**
  - Data exploration for occurrence cubes and uncertainty calculation for indicators

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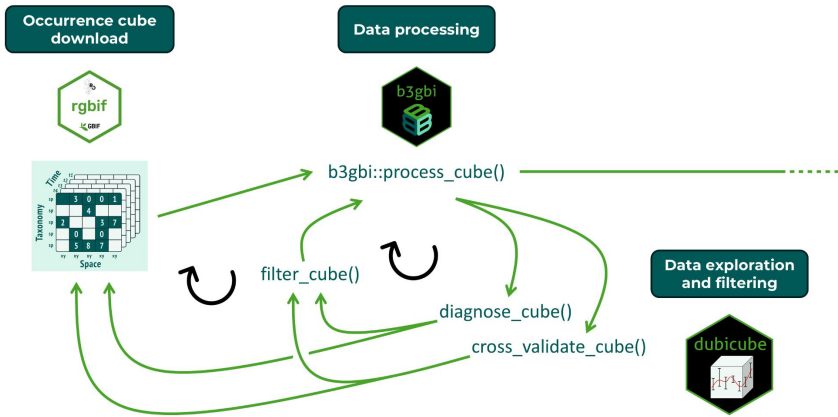
Indicator workflow

- **dubicube**
  - Data exploration for occurrence cubes and uncertainty calculation for indicators

- Data quality diagnostics

```
> diagnose_cube(cube)

Data cube diagnostics
---------------------
● OK - temporal_min_points
  Cube contains observations across 6 years.

● OK - temporal_missing_years
  Cube contains 0 missing years.

● OK - spatial_min_cells
  Cube contains observations across 5 grid cells.

● VERY_IMPORTANT - spatial_max_uncertainty
  Cube contains 90 records where the coordinate uncertainty is larger than the grid cell resolution.

● OK - spatial_miss_uncertainty
  Cube contains 0 records with missing coordinate uncertainty.

● NOTE - taxon_min_taxa
  Cube contains observations across 3 taxon keys.

● OK - obs_min_records
  Cube contains 90 observation records (rows).

● OK - obs_min_total
  Cube contains a total of 90 observations.
```



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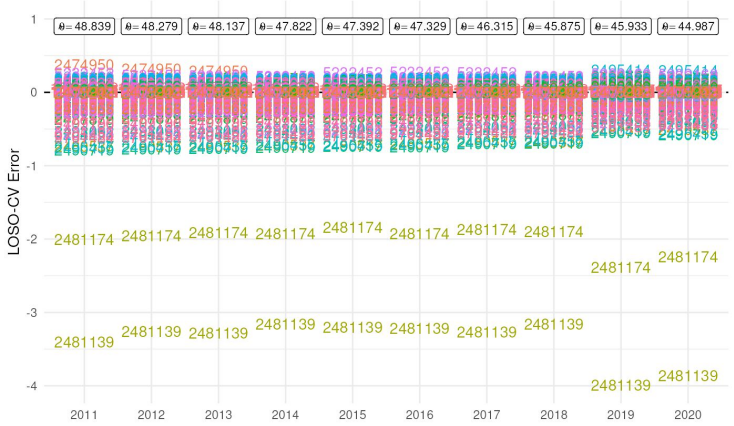
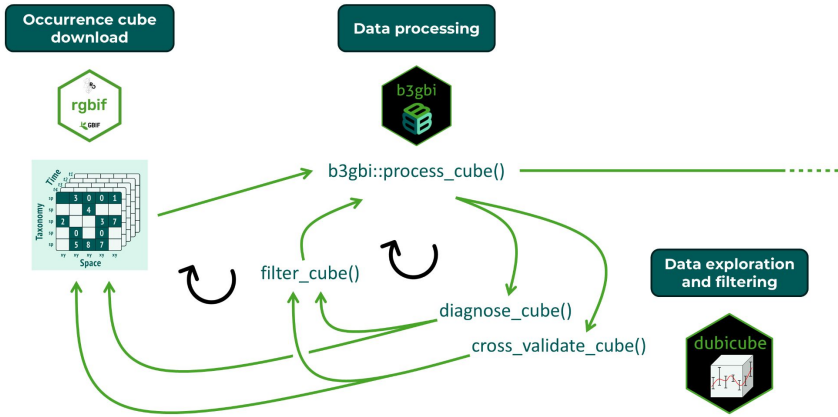
A closer look at the b3verse packages

Indicator workflow

- **dubicube**
  - Data exploration for occurrence cubes and uncertainty calculation for indicators

- Group-level sensitivity analysis





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Indicator workflow

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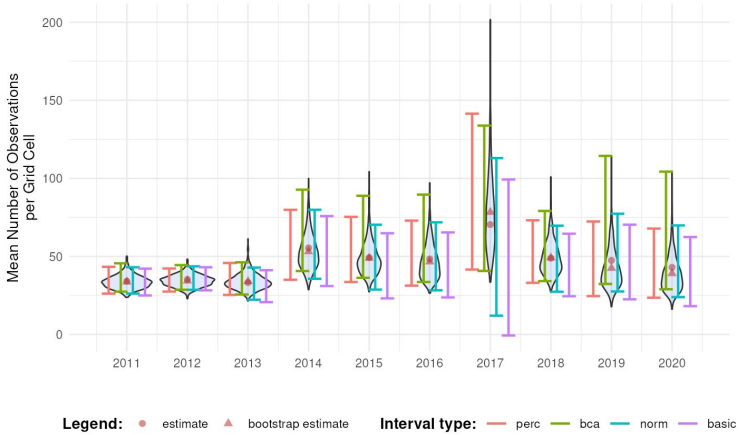
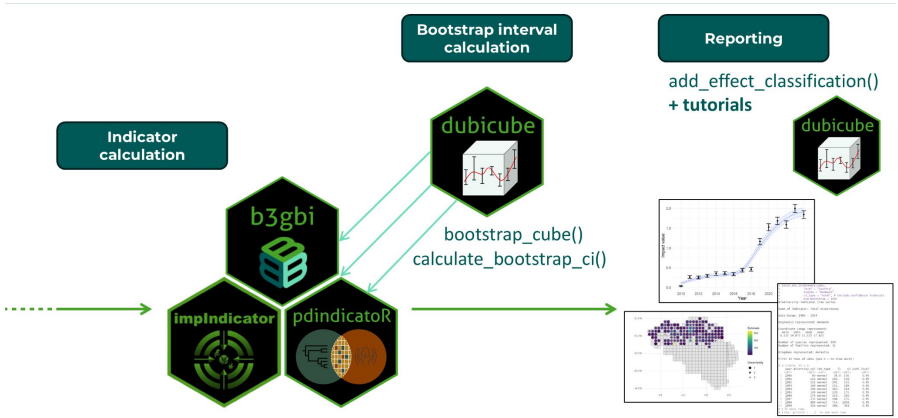
- Indicator uncertainty calculation





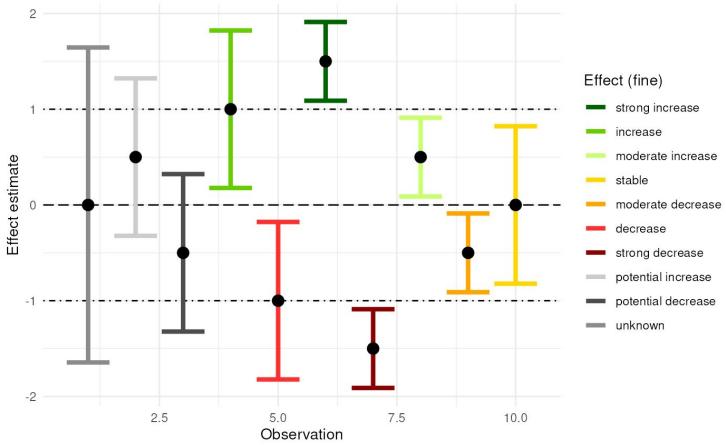
b3verse, an ecosystem of R packages

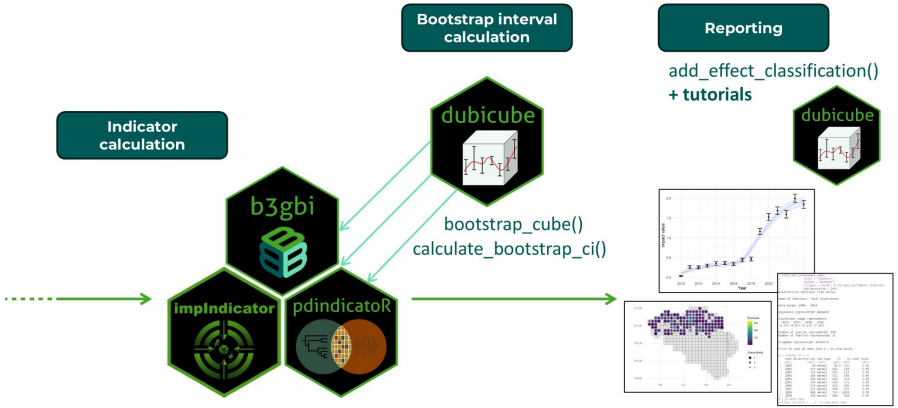
A closer look at the b3verse packages

Indicator workflow

- **dubicube**
  - Data exploration for occurrence cubes and uncertainty calculation for indicators

- Indicator interpretation and visualisation (see also the **effectclass** package)





b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Modelling cubes

- **dissmapr**
  - Analyse and map multi-site compositional dissimilarity (ζ-diversity)

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b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Modelling cubes

- **dissmapr**
  - Analyse and map multi-site compositional dissimilarity (ζ-diversity):

    How do biological communities change in response to environmental and geographic gradients?

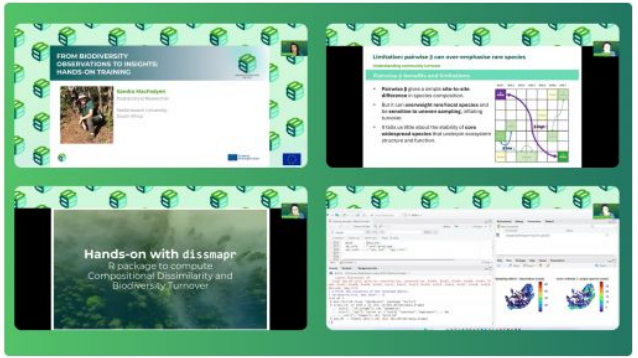
Fourth session of B-Cubed training series: Access the recording and materials

19 March 2026

B-Cubed's training series continued with a session on Automating compositional dissimilarity and biodiversity turnover mapping with `dissmapr`. If you want to join the upcoming sessions, you can still register here.

In this fourth session, held on 13 March, Sandra MacFadyen focused on `dissmapr`, an open-source R framework that automates compositional dissimilarity and turnover analysis.

- Slides
- Recording
- Q&A and R script



Training session on session on Automating compositional dissimilarity and biodiversity turnover mapping with `dissmapr`

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b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Modelling cubes

- **invasimapr**
  - Estimate and map invasion fitness

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A closer look at the b3verse packages

Modelling cubes

- **invasimapr**
  - Estimate and map invasion fitness:

    Can a species successfully establish at a site, given local environmental conditions and resident community structure?

B-Cubed training series continues: Access the second session recording and materials

5 March 2026

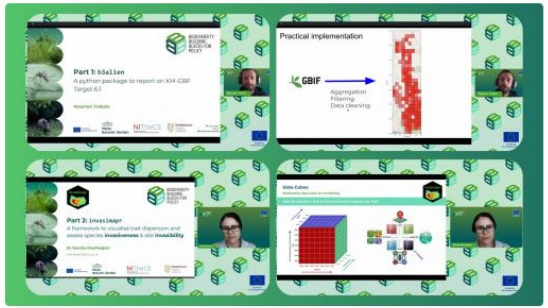
B-Cubed's training series continued with a session on Occurrence cubes and biological invasions. Even if you missed previous sessions, you can still register here to join the upcoming ones.

The second session, held on 27 February, focused on occurrence cubes and their application to biological invasions.

- Slides
- Recording
- Q&A

During the session, Maarten Trekels (Meise Botanic Garden) presented the possibilities of the b3alien Python package, which provides a technical solution to support tracking Target 6 of the Kunming-Montreal Global Biodiversity Framework (KM-GBF).

Sandra MacFadyen (Stellenbosch University) delved into the details of the Invasibility Cube, which integrates trait, environmental (and site), and community (species) data to quantify invasion fitness and generate spatial indicators of site invasibility and species and/or trait invasiveness.



Session on 27 February - Occurrence cubes and biological invasions

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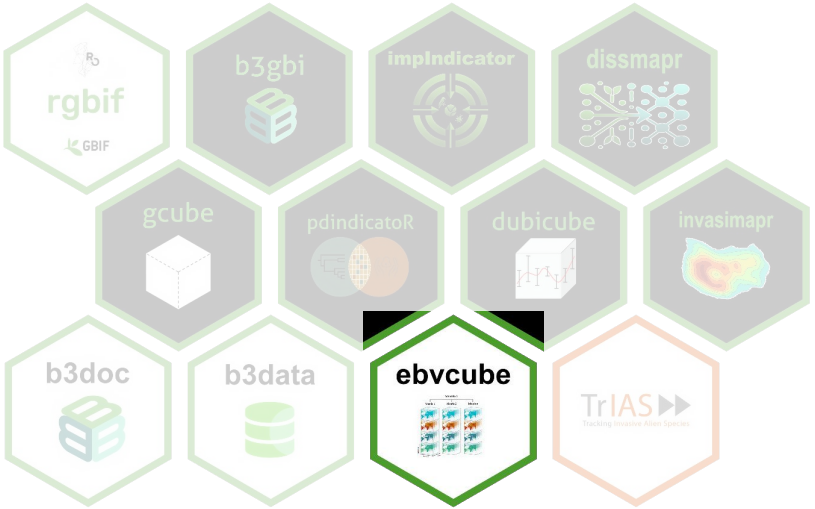
b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Other projects

- **ebvcube**
  - Access and visualise data cubes of Essential Biodiversity Variables (EBVs)



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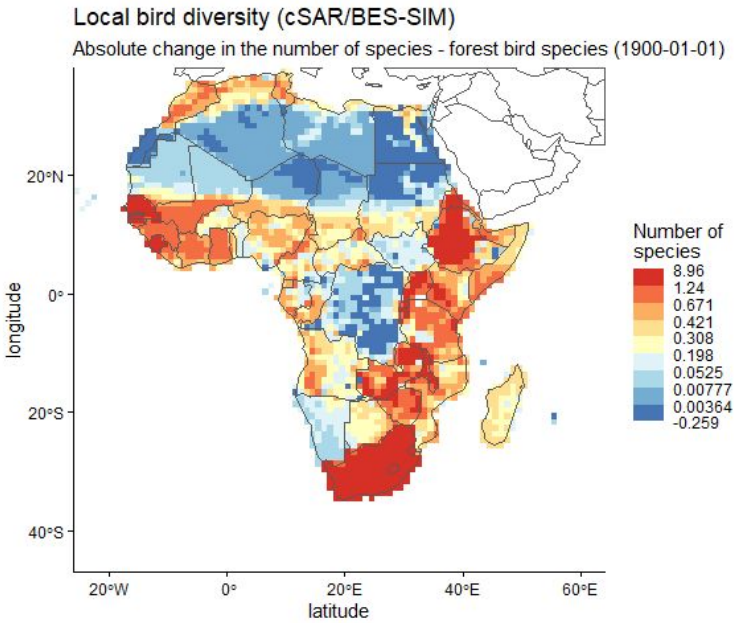
b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Other projects

- **ebvcube**
  - Access and visualise data cubes of Essential Biodiversity Variables (EBVs)

- Work with data of the EBV netCDFs
  → downloaded from the EBV Data Portal
- Visualise data



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A closer look at the b3verse packages

Other projects

- **trias**
  - Functionality for the TrIAS and LIFE RIPARIAS projects

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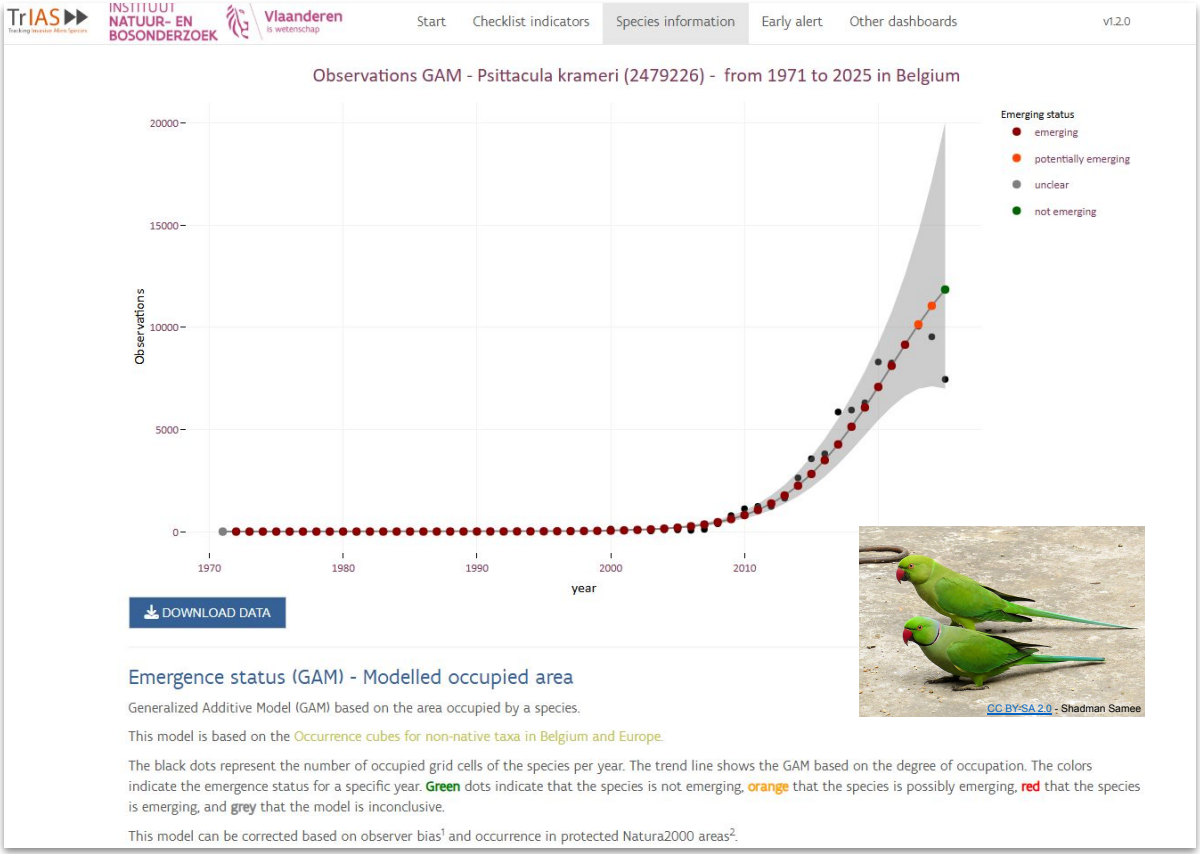
A closer look at the b3verse packages

Other projects

- **trias**

- Trends of invasive species in Belgium
  - alien species portal

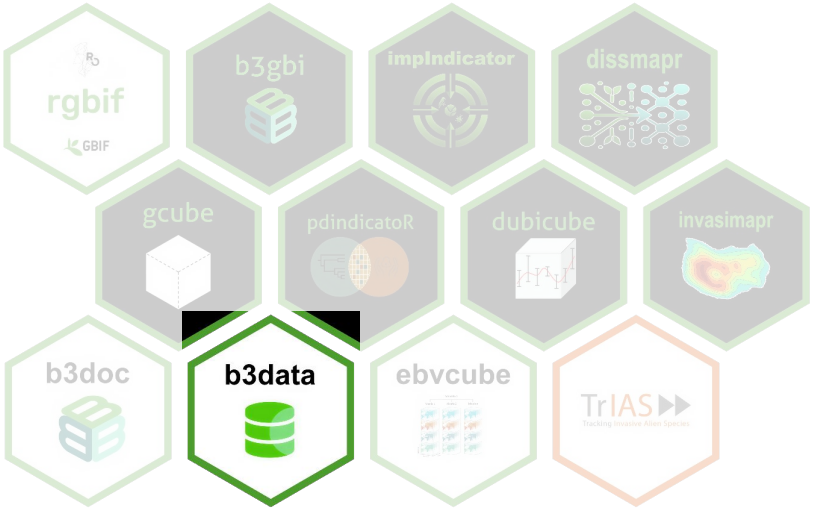


b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Data

- **b3data**
  - Frictionless data package for the b3verse



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b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Data

- **b3data**
  - Frictionless data package for the b3verse

- Frictionless?
  - **Problem**: Data are often messy, missing context (metadata), and difficult to move between different software tools
  - **Solution**: Frictionless Data = open-source toolkit and set of standards designed to make data "interoperable" → it works everywhere

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b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Data

- **b3data**
  - Frictionless data package for the b3verse

- Frictionless?
- Data package?
  - Bundles raw data files (like CSVs) with their "instruction manual"
    - `datapackage.json`: A machine-readable file that describes the data's schema, origin, and license

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b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Data

- **b3data**
  - Frictionless data package for the b3verse

- Dedicated data package for **b3verse** packages
  - Example occurrence cubes
  - Spatial reference grids
- All datasets are version-controlled on Zenodo
- Can be loaded directly into R

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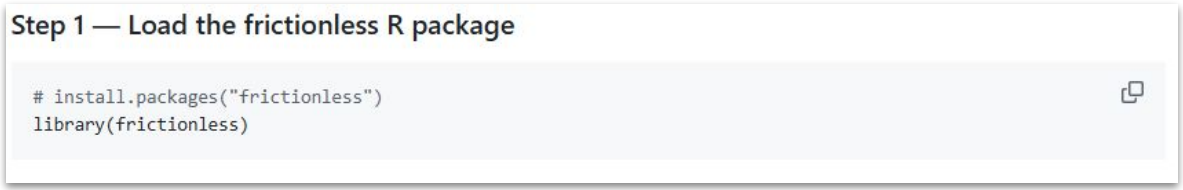
b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Data

- **b3data**
  - Frictionless data package for the b3verse
    - See also this guide



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b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Data

- **b3data**
  - Frictionless data package for the b3verse
    - See also this guide

Step 2 — Read the package descriptor from Zenodo

The content of the data package can be consulted using `read_package()`.

```
b3data_package <- read_package("https://zenodo.org/records/15211029/files/datapackage.json")
b3data_package
#> A Data Package with 2 resources:
#> • bird_cube_belgium_mgrs10
#> • mgrs10_refgrid_belgium
#> For more information, see <https://doi.org/10.5281/zenodo.15211029>.
#> Use `unclass()` to print the Data Package as a list.
```


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b3verse, an ecosystem of R packages

A closer look at the b3verse packages

Data

- **b3data**
  - Frictionless data package for the b3verse
    - See also [this guide]

Step 3 — Import a resource (dataset)

Tabular datasets can be loaded using `read_resource()`.

```
bird_cube_belgium <- read_resource(b3data_package, "bird_cube_belgium_mgrs10")
head(bird_cube_belgium)
#> # A tibble: 6 × 8
#>    year mgrscode specieskey species          family     n mincoordinateuncerta…¹
#>   <dbl> <chr>         <dbl> <chr>            <chr>  <dbl>                  <dbl>
#> 1  2000 31UDS65     2473958 Perdix perdix    Phasi…     1                   3536
#> 2  2000 31UDS65     2474156 Coturnix coturn… Phasi…     1                   3536
#> 3  2000 31UDS65     2474377 Fulica atra      Ralli…     5                   1000
#> 4  2000 31UDS65     2475443 Merops apiaster  Merop…     6                   1000
#> 5  2000 31UDS65     2480242 Vanellus vanell… Chara…     1                   3536
#> 6  2000 31UDS65     2480637 Accipiter nisus  Accip…     1                   3536
#> # ℹ abbreviated name: ¹mincoordinateuncertaintyinmeters
#> # ℹ 1 more variable: familycount <dbl>
```


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Downloading cubes with rgbif

Ward Langeraert

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Downloading cubes with rgbif

Download cubes from script

- We can get occurrence cubes directly with **rgbif**
- What do we need?
  a. GBIF credentials
  b. SQL query
  c. R script

https://dyte.io/blog/automation-at-dyte/

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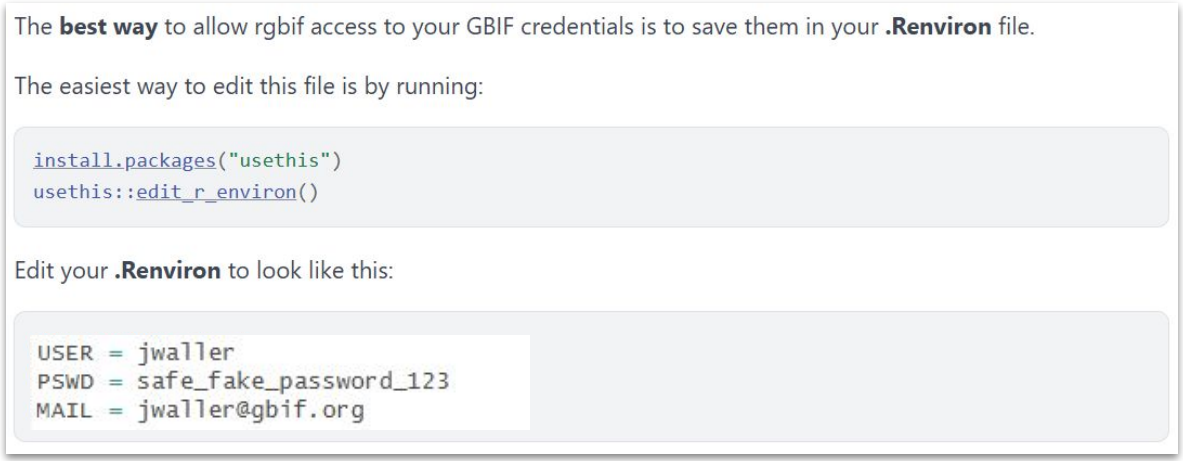
Downloading cubes with rgbif

Download cubes from script

a. GBIF credentials

- See this **rgbif** tutorial
- Problems with access rights? → contact helpdesk@gbif.org



The **best way** to allow rgbif access to your GBIF credentials is to save them in your **.Renviron** file.

The easiest way to edit this file is by running:

```
install.packages("usethis")
usethis::edit_r_environ()
```

Edit your **.Renviron** to look like this:

```
USER = jwaller
PSWD = safe_fake_password_123
MAIL = jwaller@gbif.org
```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Downloading cubes with rgbif

Download cubes from script

b. SQL query

- Training session 24 February 2026
- Tutorials: **rgbif** website, B-Cubed documentation, GBIF website

B-Cubed training series begins: Access the first session recording and materials

24 February 2026

B-Cubed's training series has officially started, showcasing emerging approaches that help make biodiversity data more actionable in practice. If you haven't signed up yet, register here to join the upcoming sessions.

The first session, held on 20 February, introduced participants to a service from the Global Biodiversity Information Facility (GBIF) that enables users to easily create and download species occurrence cubes from GBIF-mediated data using SQL queries.

- Slides
- Recording
- Q&A

The session provided an overview of the service and live demonstrations with practical examples. It was led by Andrew Rodrigues (GBIF) and Lina Estupinan Suarez (Martin Luther University Halle-Wittenberg), who guided participants through the service and answered questions in the Q&A.

Session on 20 February - Creating species occurrence cubes

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Downloading cubes with rgbif

Download cubes from script

b. SQL query

Select dimensions (temporal, spatial, taxonomical)

```
GBIF_MGRSCode(
  1000,
  decimalLatitude,
  decimalLongitude,
  COALESCE(coordinateUncertaintyInMeters, 1000)
) AS mgrsCode,
```

```
SELECT
  -- Dimensions:
  \"year\",
  GBIF_MGRSCode(
    1000,
    decimalLatitude,
    decimalLongitude,
    COALESCE(coordinateUncertaintyInMeters, 1000)
  ) AS mgrsCode,
  speciesKey,
  species,
  \"order\",
  family,
  genus,
  -- Measurements
  COUNT(*) AS n,
  MIN(COALESCE(coordinateUncertaintyInMeters, 1000)) AS minCoordinateUncertaintyInMeters,
  -- Higher taxon measurement
  IF(ISNULL(\"order\"), NULL, SUM(COUNT(*)) OVER (PARTITION BY \"order\", \"year\")) AS orderCount
FROM
  occurrence
WHERE occurrenceStatus = 'PRESENT'
  AND countryCode = 'BE'
  AND \"year\" >= 2007
  AND \"year\" <= 2023
  AND (coordinateUncertaintyInMeters <= 1000 OR coordinateUncertaintyInMeters IS NULL)
  AND speciesKey IS NOT NULL
  AND NOT ARRAY_CONTAINS(issue, 'ZERO_COORDINATE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_OUT_OF_RANGE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_INVALID')
  AND NOT ARRAY_CONTAINS(issue, 'COUNTRY_COORDINATE_MISMATCH')
  AND class = 'Aves'
GROUP BY
  \"year\",
  mgrsCode,
  speciesKey,
  \"order\",
  family,
  genus,
  species
ORDER BY
 \"year\" ASC,
  mgrsCode ASC,
  speciesKey ASC
```

Downloading cubes with rgbif

Download cubes from script

b. SQL query

Select dimensions
(temporal, spatial, taxonomical)

Measurements
(observations, uncertainty, effort)

```
SELECT
  -- Dimensions:
  \"year\",
  GBIF_MGRSCode(
    1000,
    decimalLatitude,
    decimalLongitude,
    COALESCE(coordinateUncertaintyInMeters, 1000)
  ) AS mgrsCode,
  speciesKey,
  species,
  \"order\",
  family,
  genus,
  -- Measurements
  COUNT(*) AS n,
  MIN(COALESCE(coordinateUncertaintyInMeters, 1000)) AS minCoordinateUncertaintyInMeters,
  -- Higher taxon measurement
  IF(ISNULL(\"order\"), NULL, SUM(COUNT(*)) OVER (PARTITION BY \"order\", \"year\")) AS orderCount
FROM
  occurrence
WHERE occurrenceStatus = 'PRESENT'
  AND countryCode = 'BE'
  AND \"year\" >= 2007
  AND \"year\" <= 2023
  AND (coordinateUncertaintyInMeters <= 1000 OR coordinateUncertaintyInMeters IS NULL)
  AND speciesKey IS NOT NULL
  AND NOT ARRAY_CONTAINS(issue, 'ZERO_COORDINATE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_OUT_OF_RANGE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_INVALID')
  AND NOT ARRAY_CONTAINS(issue, 'COUNTRY_COORDINATE_MISMATCH')
  AND class = 'Aves'
GROUP BY
  \"year\",
  mgrsCode,
  speciesKey,
  \"order\",
  family,
  genus,
  species
ORDER BY
 \"year\" ASC,
  mgrsCode ASC,
  speciesKey ASC
```

Downloading cubes with rgbif

Download cubes from script

b. SQL query

Select dimensions
(temporal, spatial, taxonomical)

Measurements
(observations, uncertainty, effort)

Filter data
(NULL values, invalid data)

```
SELECT
  -- Dimensions:
  \"year\",
  GBIF_MGRSCode(
    1000,
    decimalLatitude,
    decimalLongitude,
    COALESCE(coordinateUncertaintyInMeters, 1000)
  ) AS mgrsCode,
  speciesKey,
  species,
  \"order\",
  family,
  genus,
  -- Measurements
  COUNT(*) AS n,
  MIN(COALESCE(coordinateUncertaintyInMeters, 1000)) AS minCoordinateUncertaintyInMeters,
  -- Higher taxon measurement
  IF(ISNULL(\"order\"), NULL, SUM(COUNT(*)) OVER (PARTITION BY \"order\", \"year\")) AS orderCount
FROM
  occurrence
WHERE occurrenceStatus = 'PRESENT'
  AND countryCode = 'BE'
  AND \"year\" >= 2007
  AND \"year\" <= 2023
  AND (coordinateUncertaintyInMeters <= 1000 OR coordinateUncertaintyInMeters IS NULL)
  AND speciesKey IS NOT NULL
  AND NOT ARRAY_CONTAINS(issue, 'ZERO_COORDINATE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_OUT_OF_RANGE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_INVALID')
  AND NOT ARRAY_CONTAINS(issue, 'COUNTRY_COORDINATE_MISMATCH')
  AND class = 'Aves'
GROUP BY
  \"year\",
  mgrsCode,
  speciesKey,
  \"order\",
  family,
  genus,
  species
ORDER BY
 \"year\" ASC,
  mgrsCode ASC,
  speciesKey ASC
```

Downloading cubes with rgbif

Download cubes from script

b. SQL query

Select dimensions
(temporal, spatial, taxonomical)

Measurements
(observations, uncertainty, effort)

Filter data
(NULL values, invalid data)

Group and sort data

```
SELECT
  -- Dimensions:
  \"year\",
  GBIF_MGRSCode(
    1000,
    decimalLatitude,
    decimalLongitude,
    COALESCE(coordinateUncertaintyInMeters, 1000)
  ) AS mgrsCode,
  speciesKey,
  species,
  \"order\",
  family,
  genus,
  -- Measurements
  COUNT(*) AS n,
  MIN(COALESCE(coordinateUncertaintyInMeters, 1000)) AS minCoordinateUncertaintyInMeters,
  -- Higher taxon measurement
  IF(ISNULL(\"order\"), NULL, SUM(COUNT(*)) OVER (PARTITION BY \"order\", \"year\")) AS orderCount
FROM
  occurrence
WHERE occurrenceStatus = 'PRESENT'
  AND countryCode = 'BE'
  AND \"year\" >= 2007
  AND \"year\" <= 2023
  AND (coordinateUncertaintyInMeters <= 1000 OR coordinateUncertaintyInMeters IS NULL)
  AND speciesKey IS NOT NULL
  AND NOT ARRAY_CONTAINS(issue, 'ZERO_COORDINATE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_OUT_OF_RANGE')
  AND NOT ARRAY_CONTAINS(issue, 'COORDINATE_INVALID')
  AND NOT ARRAY_CONTAINS(issue, 'COUNTRY_COORDINATE_MISMATCH')
  AND class = 'Aves'
GROUP BY
  \"year\",
  mgrsCode,
  speciesKey,
  \"order\",
  family,
  genus,
  species
ORDER BY
 \"year\" ASC,
  mgrsCode ASC,
  speciesKey ASC
```

Downloading cubes with rgbif

Download cubes from script

c. R script

```
# SQL query
my_sql_query <- "..."

# Start a download on GBIF servers
cube_download <- rgbif::occ_download_sql(
  user = Sys.getenv("USER"),
  pwd = Sys.getenv("PSWD"),
  email = Sys.getenv("MAIL"),
  q = my_sql_query
)
```


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Downloading cubes with rgbif

Download cubes from script

c. R script

```
# SQL query
my_sql_query <- "..."

# Start a download on GBIF servers
cube_download <- rgbif::occ_download_sql(
  user = Sys.getenv("USER"),
  pwd = Sys.getenv("PSWD"),
  email = Sys.getenv("MAIL"),
  q = my_sql_query
)
```

```
# Check status of download and wait to finish
rgbif::occ_download_wait(cube_download)
#> status: preparing
#> status: running
#> status: succeeded
#> download is done, status: succeeded<<gbif download metadata>>
#>   ...
```


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Downloading cubes with rgbif

Download cubes from script

c. R script

```
# SQL query
my_sql_query <- "..."

# Start a download on GBIF servers
cube_download <- rgbif::occ_download_sql(
  user = Sys.getenv("USER"),
  pwd = Sys.getenv("PSWD"),
  email = Sys.getenv("MAIL"),
  q = my_sql_query
)

# Check status of download and wait to finish
rgbif::occ_download_wait(cube_download)
#> status: preparing
#> status: running
#> status: succeeded
#> download is done, status: succeeded<<gbif download metadata>>
#>   ...
```

```
# Retrieve the download from GBIF
occ_cube <- rgbif::occ_download_get(cube_download) |>
  rgbif::occ_download_import()
#> Download file size: 1.55 MB
#> On disk at ...
```


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Downloading cubes with rgbif

Download cubes from script

c. R script

```
# View cube
head(occ_cube)
#> # A tibble: 6 × 9
#>    year mgrscode specieskey species            order             family         genus        n mincoordinateuncertaintyi...¹
#>   <int> <chr>         <int> <chr>              <chr>             <chr>          <chr>    <int>                         <dbl>
#> 1  2022 31UDS48     2480964 Morus bassanus     Suliformes        Sulidae        Morus        1                         10000
#> 2  2022 31UDS48     2481174 Larus fuscus       Charadriiformes   Laridae        Larus        1                         10000
#> 3  2022 31UDS48     2481433 Fulmarus glacialis Procellariiformes Procellariidae Fulmarus     1                         10000
#> 4  2022 31UDS49     2481174 Larus fuscus       Charadriiformes   Laridae        Larus        2                         10000
#> 5  2022 31UDS49     2481342 Uria aalge         Charadriiformes   Alcidae        Uria         1                         10000
#> 6  2022 31UDS49     2481433 Fulmarus glacialis Procellariiformes Procellariidae Fulmarus     2                         10000
#> # ℹ abbreviated name: ¹mincoordinateuncertaintyinmeters
```

Disclaimer: I used a smaller query for this example than the query explained above (e.g. limited years, no order count).

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Highlighting the b3gbi R package

Shawn Dove

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the European Union

Analyse and plot your biodiversity data cube in 3 simple steps

INGEST

process_cube()

Import and validate species occurrence cube

Custom occurrence cubes can be downloaded for free from the gbif.org website or using the rgbif R package.

Or, create a simulated cube using the gcube R package.

b3gbi will handle the rest!

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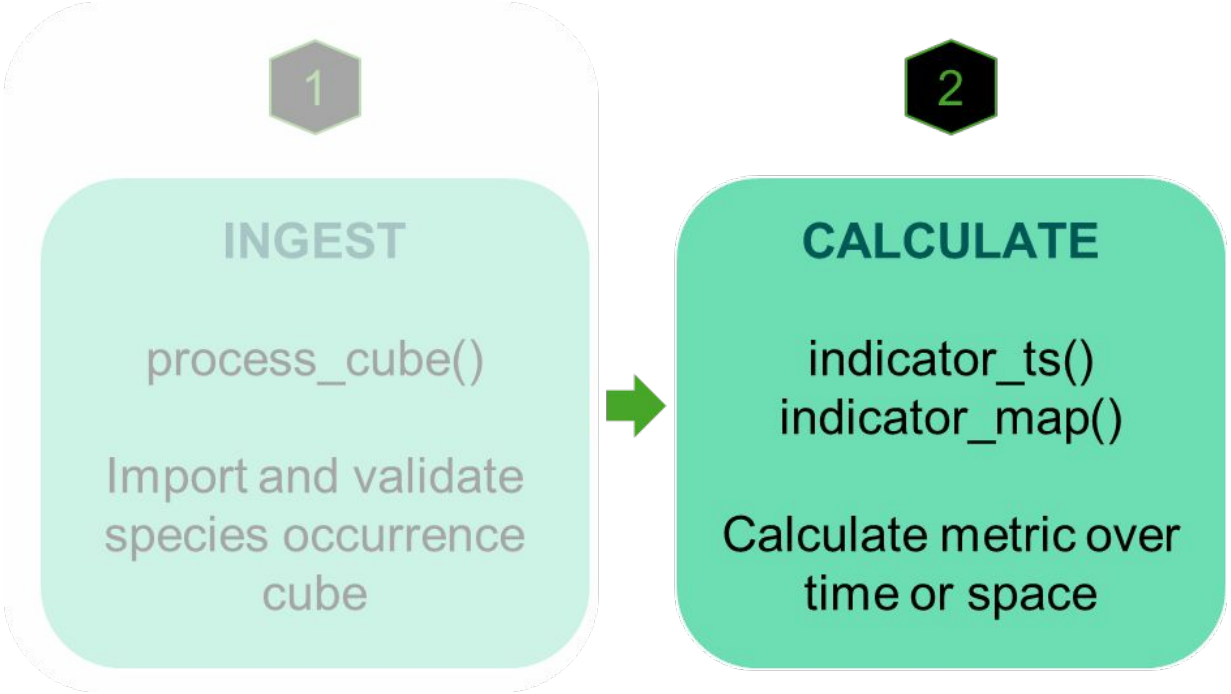
18 metrics available:

richness | evenness | Hill diversity | rarity | taxonomic distinctness | occupancy turnover | etc…

Integrated uncertainty calculation for time series

Crop grid using custom shape files



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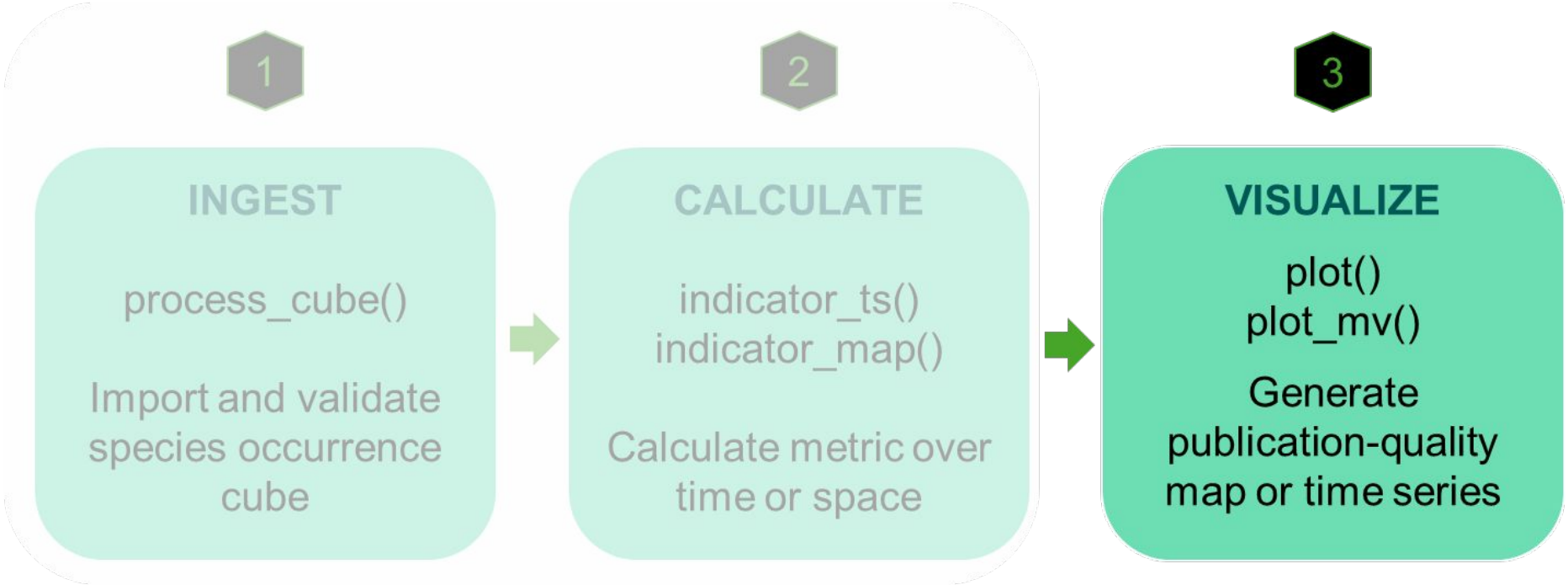

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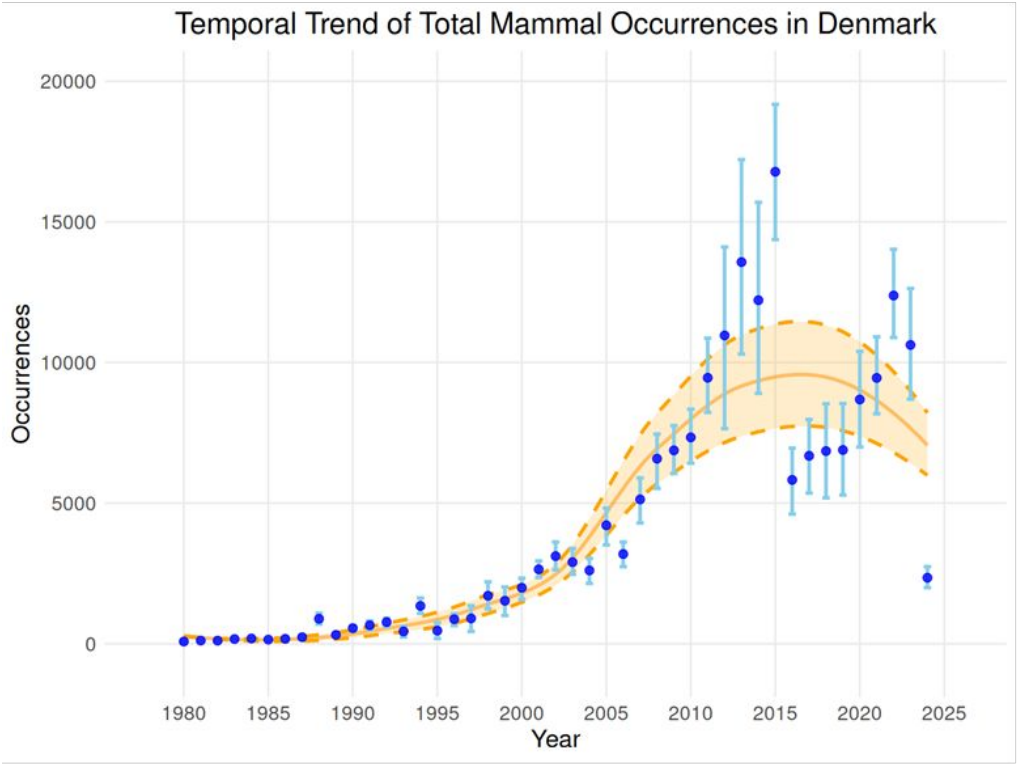

ggplot2 integration

3

VISUALIZE

plot()

Generate publication-quality map or time series

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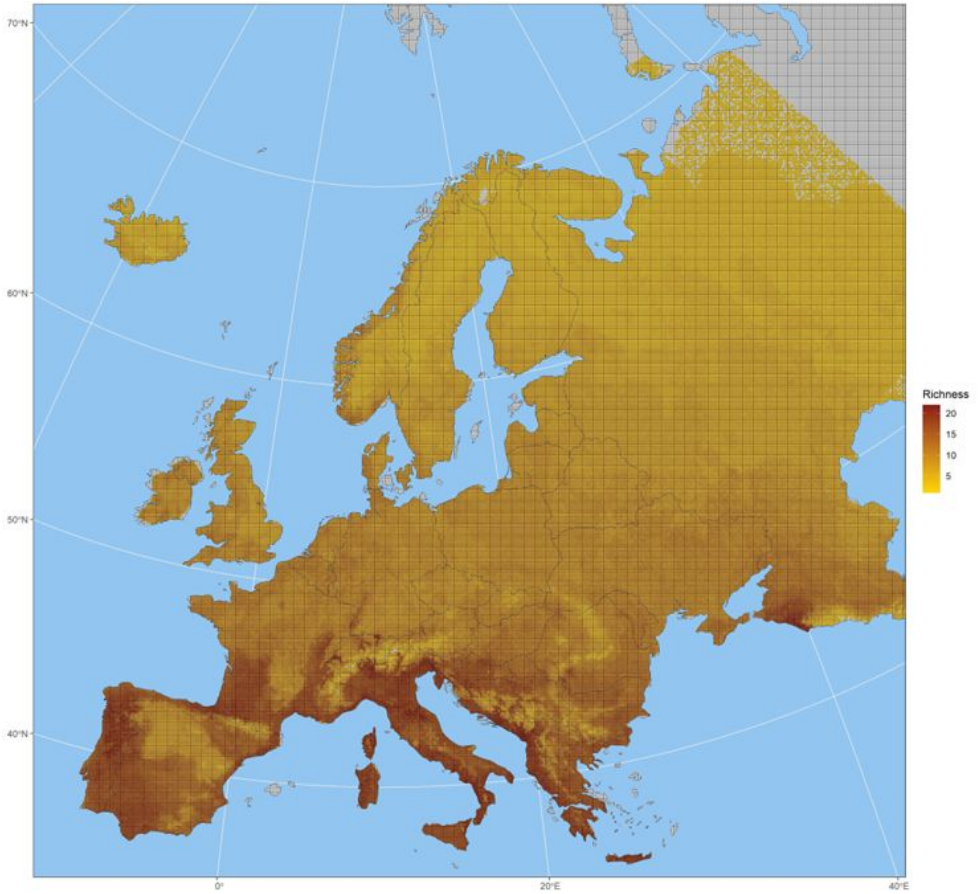

rnaturalearth integration

3

VISUALIZE

plot()

Generate publication-quality map or time series

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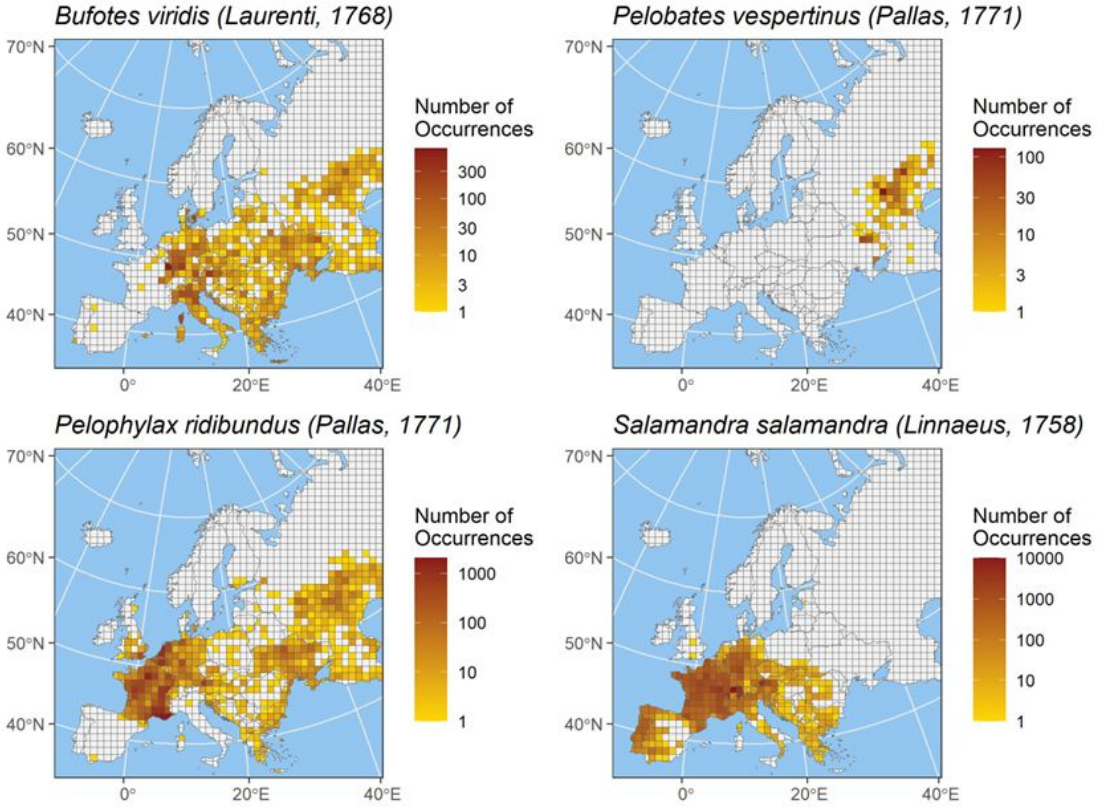
Species Occurrences



rnaturalearth integration

3

VISUALIZE

plot()

Generate publication-quality map or time series

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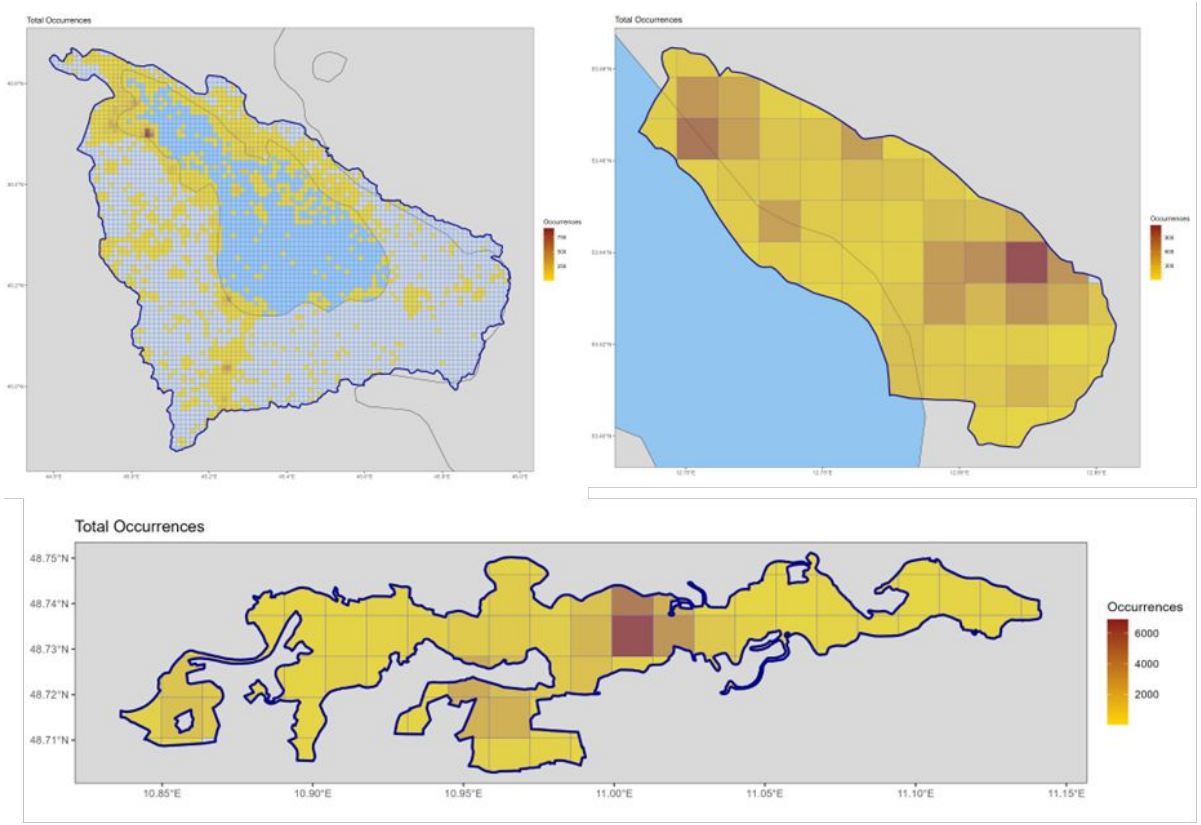

shapefile integration

3

VISUALIZE

plot()

Generate publication-quality map or time series

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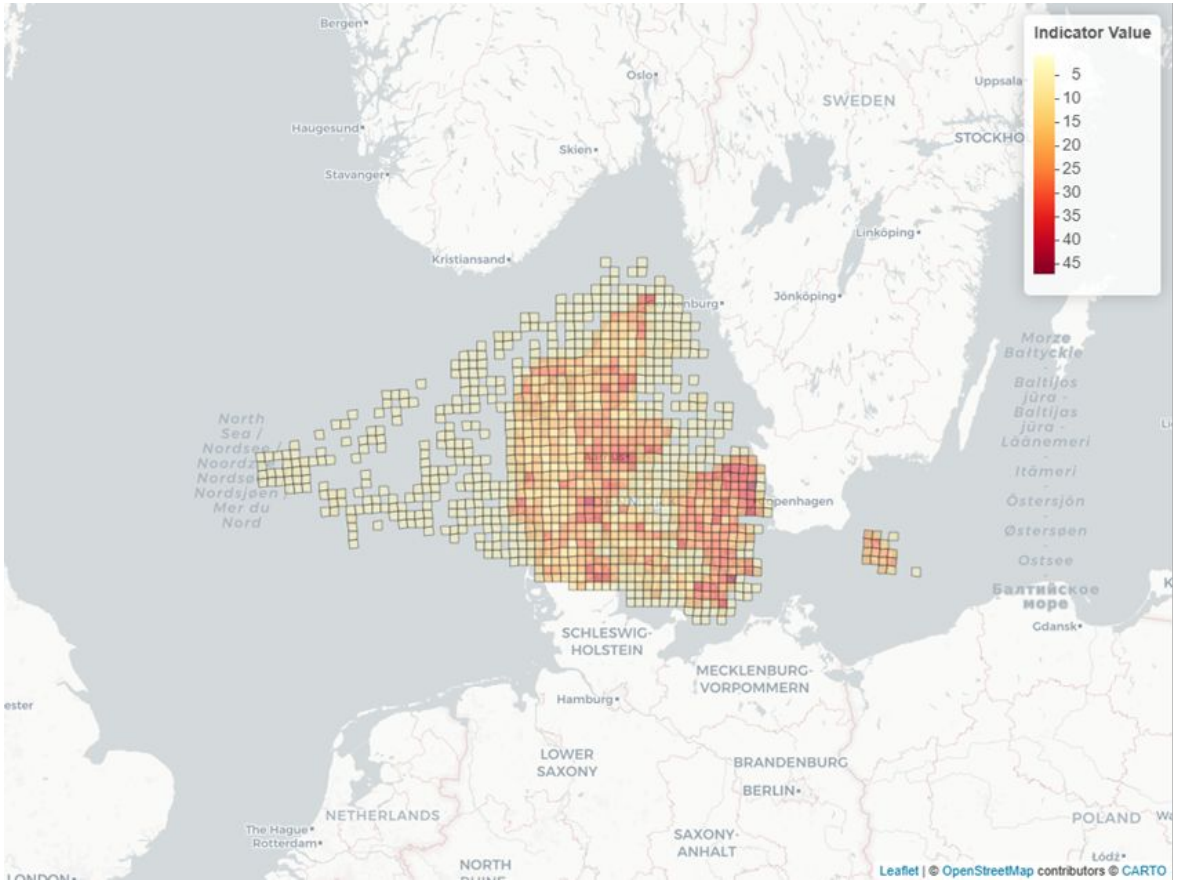

mapview integration

3

VISUALIZE

plot_mv()

Generate publication-quality map or time series

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b3gbi: a powerful and flexible indicators package

Supports multiple grid reference systems with automated detection:

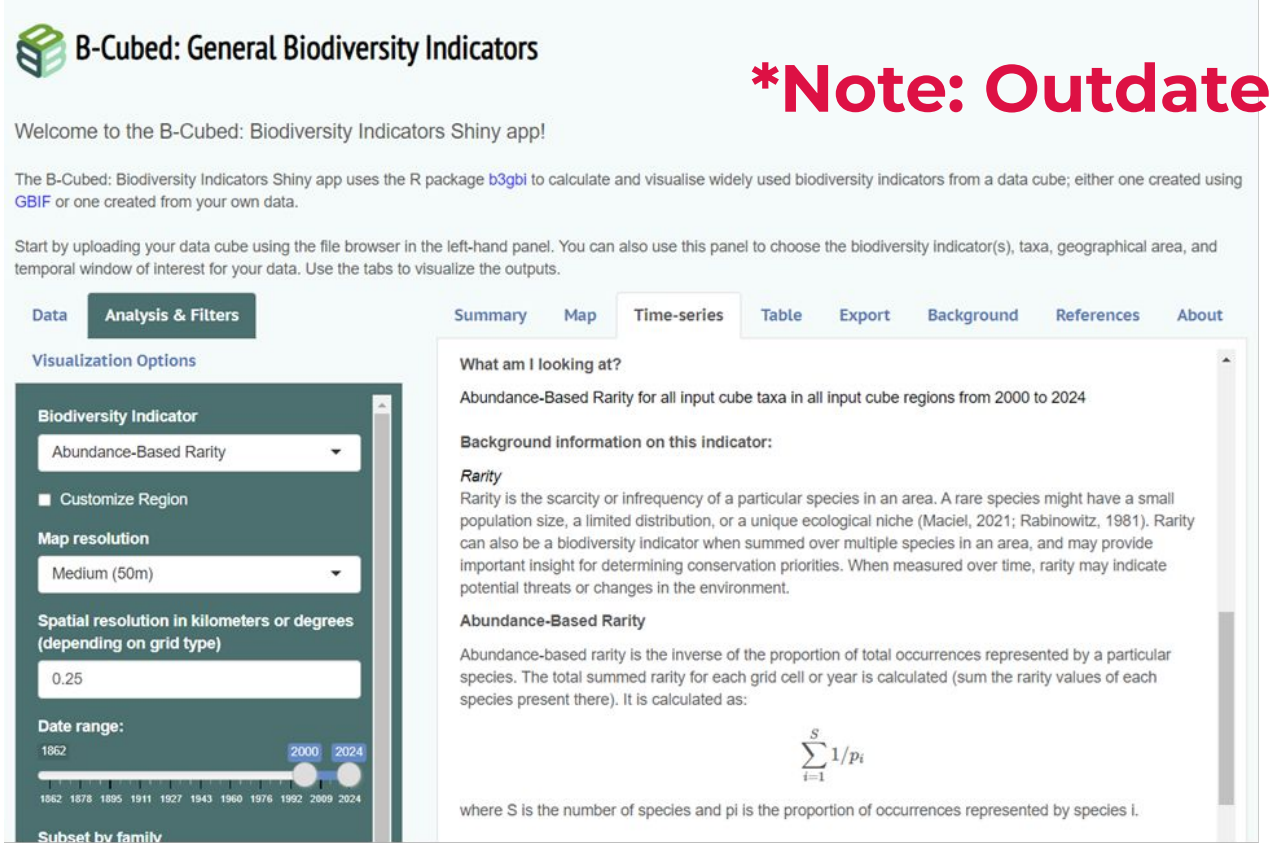
- Military Grid Reference System (MGRS)
- Extended Quarter Degree Grid Cells (EQDGC)
- European Environment Agency (EEA) reference grid
- Icosahedral Snyder Equal Area aperture 3 hexagonal (ISEA3H) reference grid

Plot your results using any compatible Coordinate Reference System (CRS)

Add custom ggplot2 code

Plot interactive maps with different base layers

Funded by the European Union



***Note: Outdated!**

Graphical user interface available

Download:
github.com/b-cubed-eu/b3gbi-gui

Online:
https://bcc9vd-shawn-dove.shinyapps.io/b3gbi-gui/

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BREAK TIME

visit https://github.com/shawndove/b3gbi-demo
if you want to follow along

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the European Union

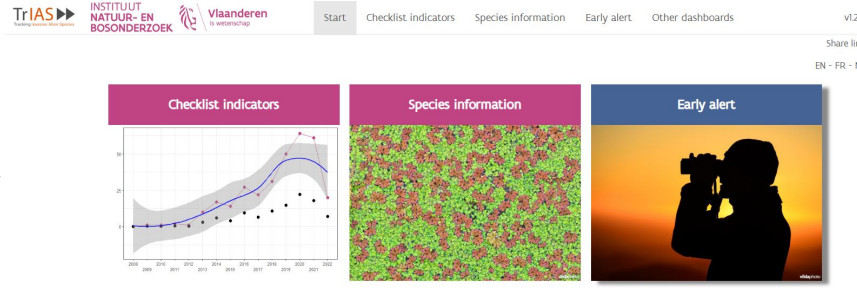
A practical case study using the b3verse

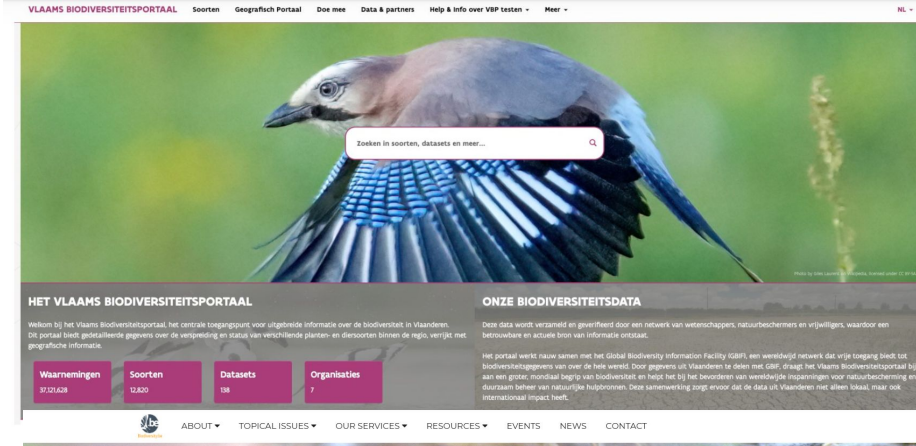
Jasmijn

Funded by
the European Union

Calculating regional indicators in Europe using the B-Cubed workflow

In this case study, the **B-Cubed workflows will be tested** for Flanders, a region of Europe where species occurrence data are abundant.





The expected results include

- Making the **selected indicators available** through a public dashboard that can serve as inspiration for other dashboards
- **Ensuring interoperability** by maintaining close contact with other dashboard maintainers, for instance, by providing all code in an R package.

Calculating regional indicators in Europe using the B-Cubed workflow

The implemented indicators can be subdivided into:

- **General biodiversity indicators** (based on **b3gbi**, for instance, cumulative species richness, relative species richness, etc.);
- **Phylogenetic indicators** (based on **pdindicatoR**);
- **Invasive Alien Species indicators** (based on **TrIAS** and **b3alien** but extended with additional indicators necessary for reporting (e.g. rate of establishment, proportion of non-native species, comparison of species occupancy between periods, TrIAS indicators);
- Extra indicators that are used for IAS reporting might be added to the list, based on stakeholder needs.

Extra attention will be given to a comparison between Natura 2000 versus non-Natura 2000 habitats when applying these indicators, calculation and interpretation of indicator uncertainty, and taking into account **survey effort.**

Funded by the European Union

WP6: Flanders case study | Home | General indicators | Phylogenetic indicators | IAS indicators | Comparing indicators

Flanders use case

Demonstrating B-Cubed workflows

unsplash | b3gbi | impIndicator | pdindicatoR

This dashboard showcases developed workflows within the B-Cubed project for the region of Flanders, a region of Europe where species occurrence data are abundant.

The implemented indicators in this dashboard can be subdivided into:

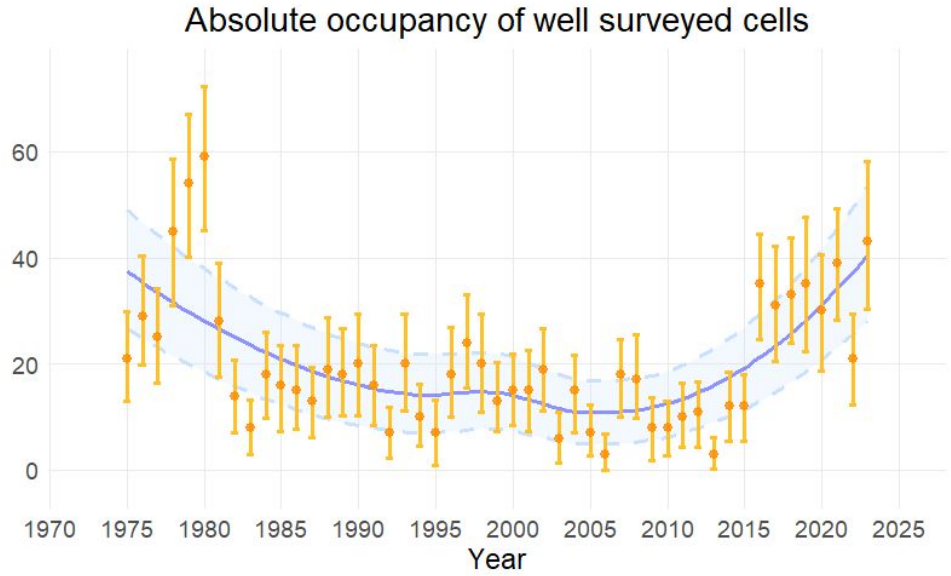
- General biodiversity indicators (based on b3gbi, for instance, cumulative species richness, relative species richness, etc.);
- Phylogenetic indicators (based on pdindicatoR);
- Invasive Alien Species indicators (based on impIndicator, TrIAS and b3alien)

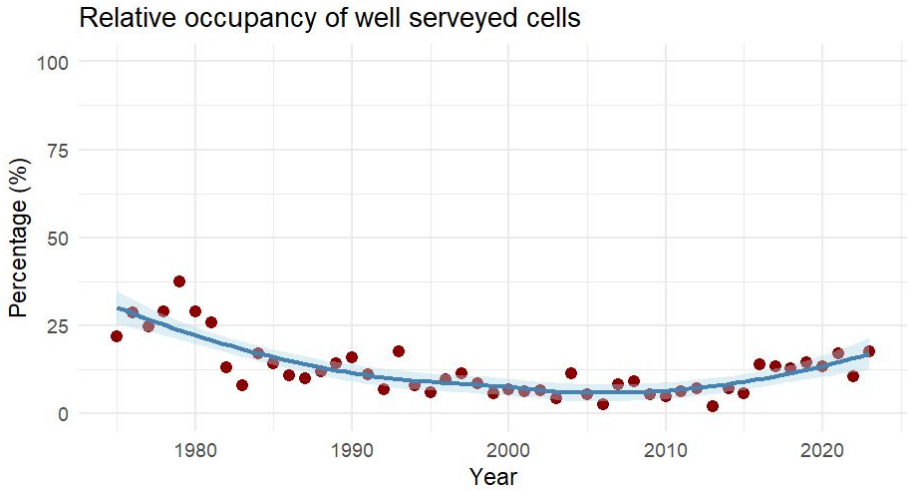
https://flanders.b-cubed.eu/

Union

General indicators

Centaurea cyanus





Florabank1 - A grid-based database on vascular plant distribution in the northern part of Belgium (Flanders and the Brussels Capital region)

Published by Research Institute for Nature and Forest (INBO)

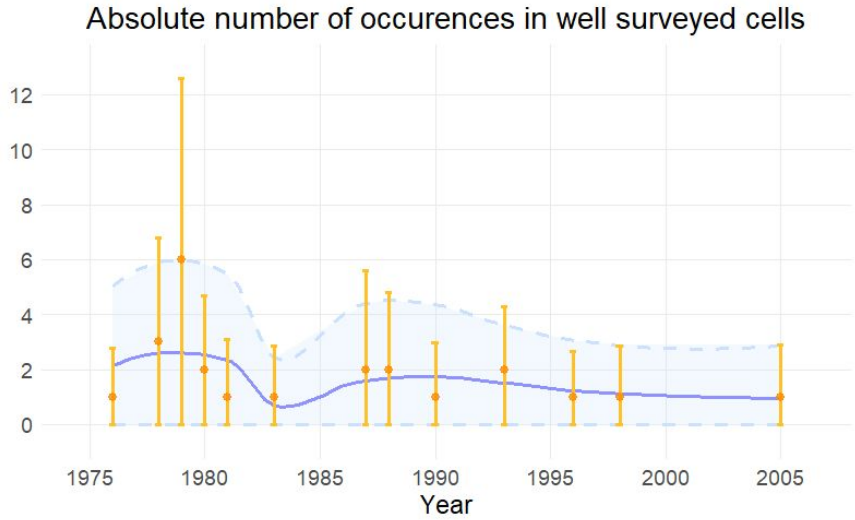
Van Landuyt W • Brosens D

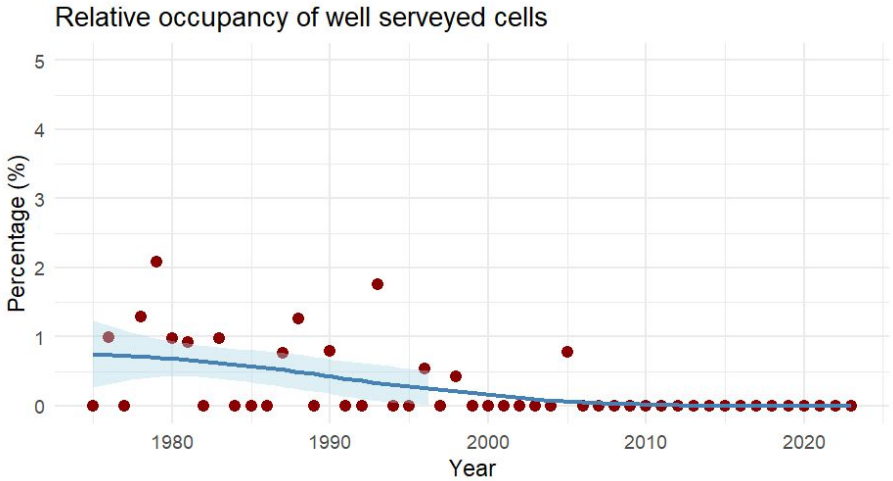
Biodiversity Building Blocks for policy

Funded by the European Union

General indicators

Arnoseris minima





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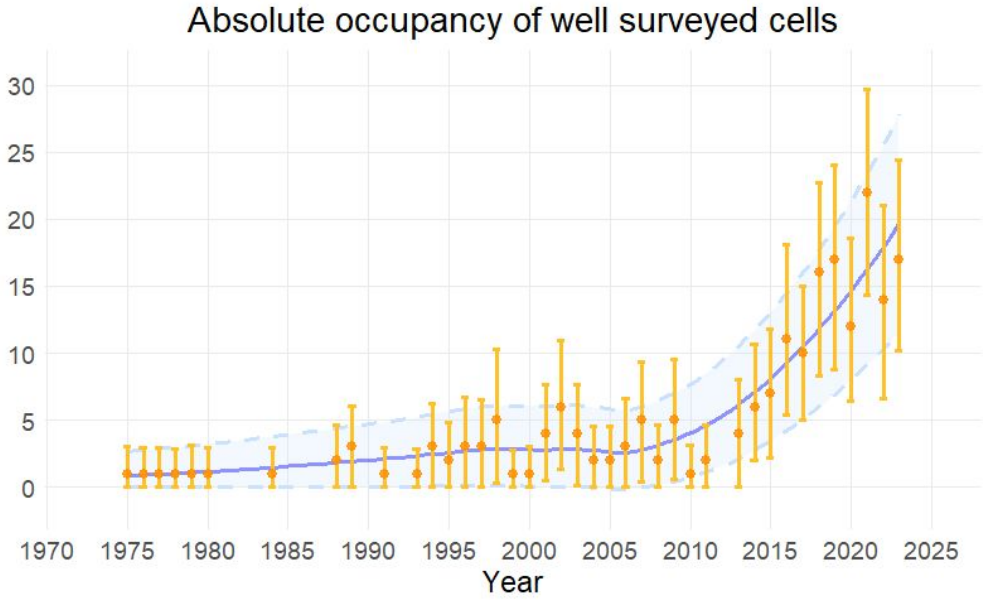
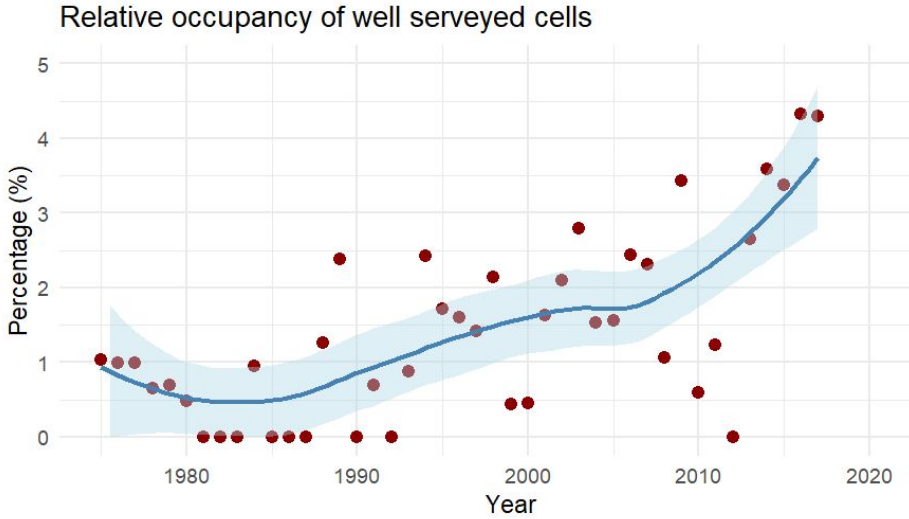
Van Landuyt W • Brosens D

Funded by the European Union

General indicators

Ophrys apifera





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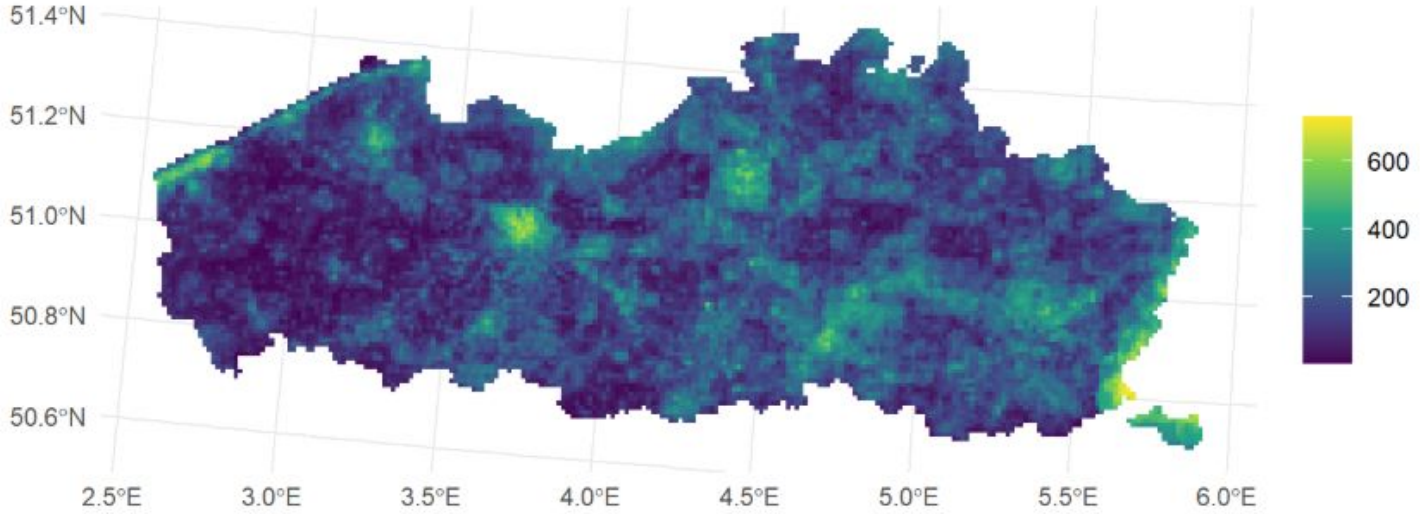
Biodiversity Building Blocks for policy

Funded by the European Union

General indicators

Observed species richness



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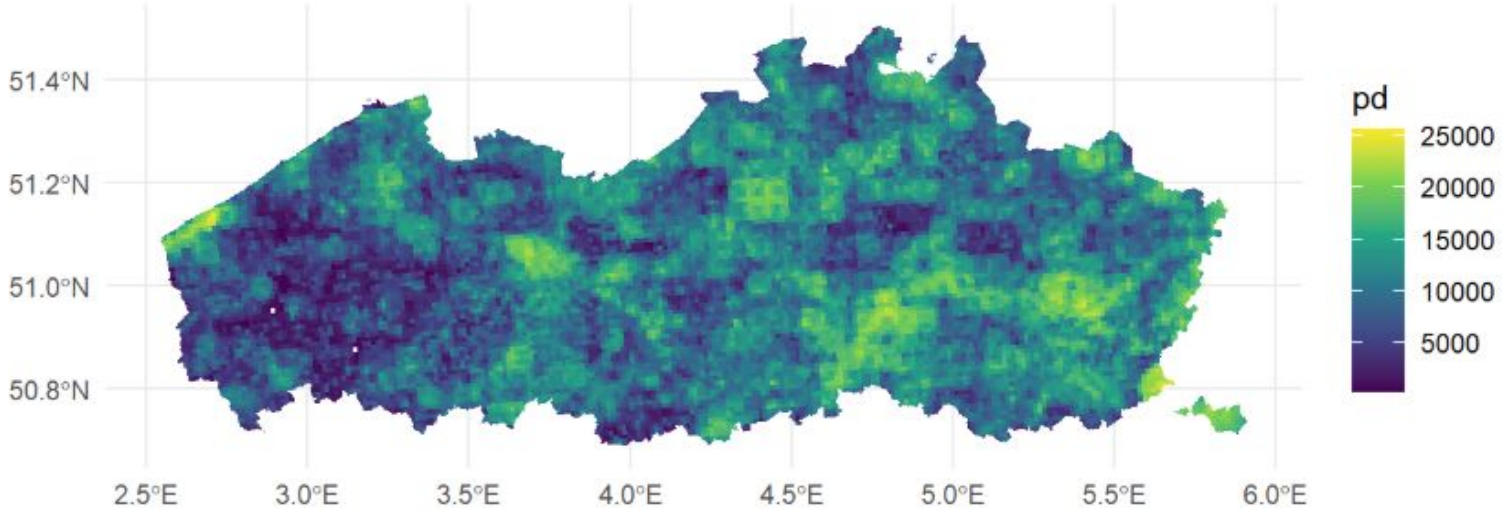
General indicators

Phylogenetic diversity



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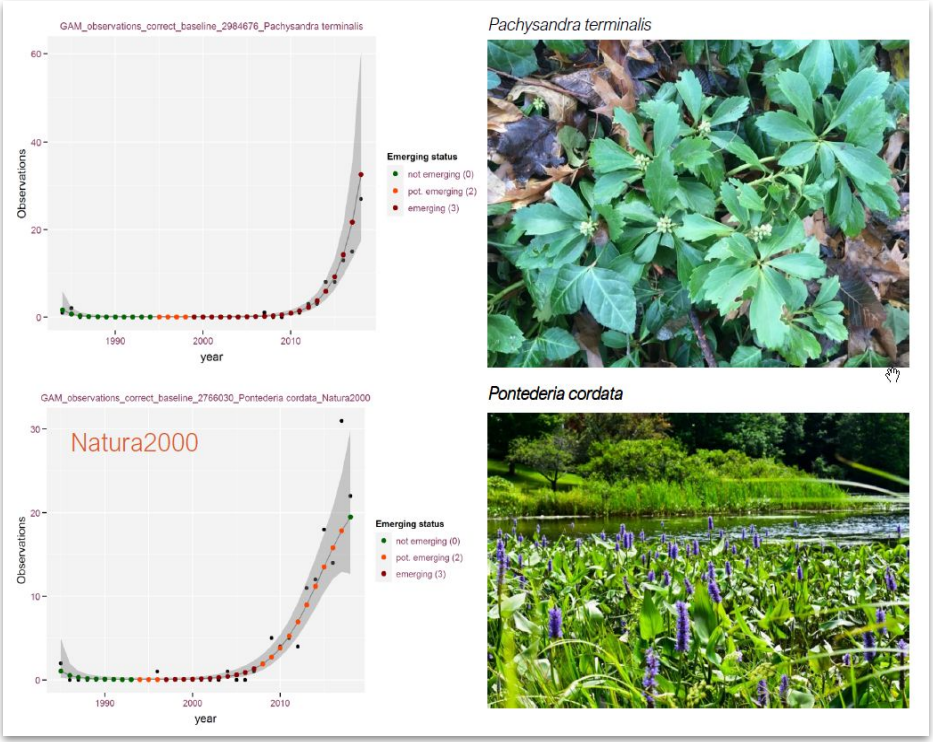
IAS indicators
TrIAS GAMs



Alien Species Portal

https://alienspecies.inbo.be

The TRIAS indicators (https://trias-project.github.io/indicators/)

Funded by the European Union

IAS indicators

https://trias-project.github.io/indicators/05_occurrence_indicators_preprocessing.html

Overview of TRIAS indicators

TrIAS
Tracking Invasive Alien Species

Checklist-based indicators

- Number of new introductions of alien species per year
- Cumulative number of introductions of alien species
- Pathways associated with introductions of alien species

Occurrence-based indicators

- Detect appearing and reappearing species per year
- Assessing emerging status of alien species
- Ranking species per emerging status
- Define taxonomic distribution of emerging species
- Species observations and occupancy in Belgian protected areas
- Status of alien species in Belgian protected areas

Alien Species Portal

https://alienspecies.inbo.be

Funded by the European Union

https://doi.org/10.1101/2025.11.17.688820

Target 6 (b3alien)

Kunming - Montreal
GLOBAL BIODIVERSITY FRAMEWORK

GBF HOME // TARGET 6

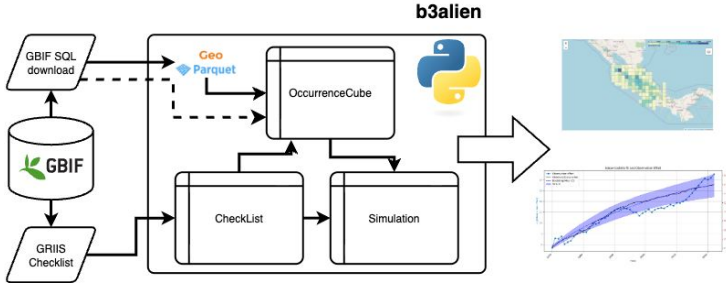
Target 6

Reduce the Introduction of Invasive Alien Species by 50% and Minimize Their Impact

Eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services by identifying and managing pathways of the introduction of alien species, preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species especially in priority sites, such as islands.

Following are the guidance notes prepared by the Secretariat for Target 6

b3alien: a Python package to calculate the Global Biodiversity Framework Target 6 Headline Indicator



B-Cubed training series continues: Access the second session recording and materials

5 March 2026

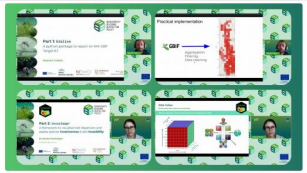
B-Cubed's training series continued with a session on Occurrence cubes and biological invasions. Even if you missed previous sessions, you can still register here to join the upcoming ones.

The second session, held on 27 February, focused on occurrence cubes and their application to biological invasions.

- Slides
- Recording
- Q&A

During the session, Maarten Trekels (Meise Botanic Garden) presented the possibilities of the b3alien Python package, which provides a technical solution to support tracking Target 6 of the Kunming-Montreal Global Biodiversity Framework (KM-GBF).

Sandra MacFadyen (Stellenbosch University) delved into the details of the Invasibility Cube, which integrates trait, environmental (and site), and community (species) data to quantify invasion fitness and generate spatial indicators of site invasibility and species and/or trait invasiveness.



Session on 27 February - Occurrence cubes and biological invasions

Funded by the European Union

Target 6 (b3alien)

Year	Annual_Rate	Annual_Rate_Error
2019	6.498157	1.035277
2020	6.660950	1.121160
2022	6.822542	1.216755
2024	6.992717	1.318645
2025	7.177649	1.417874

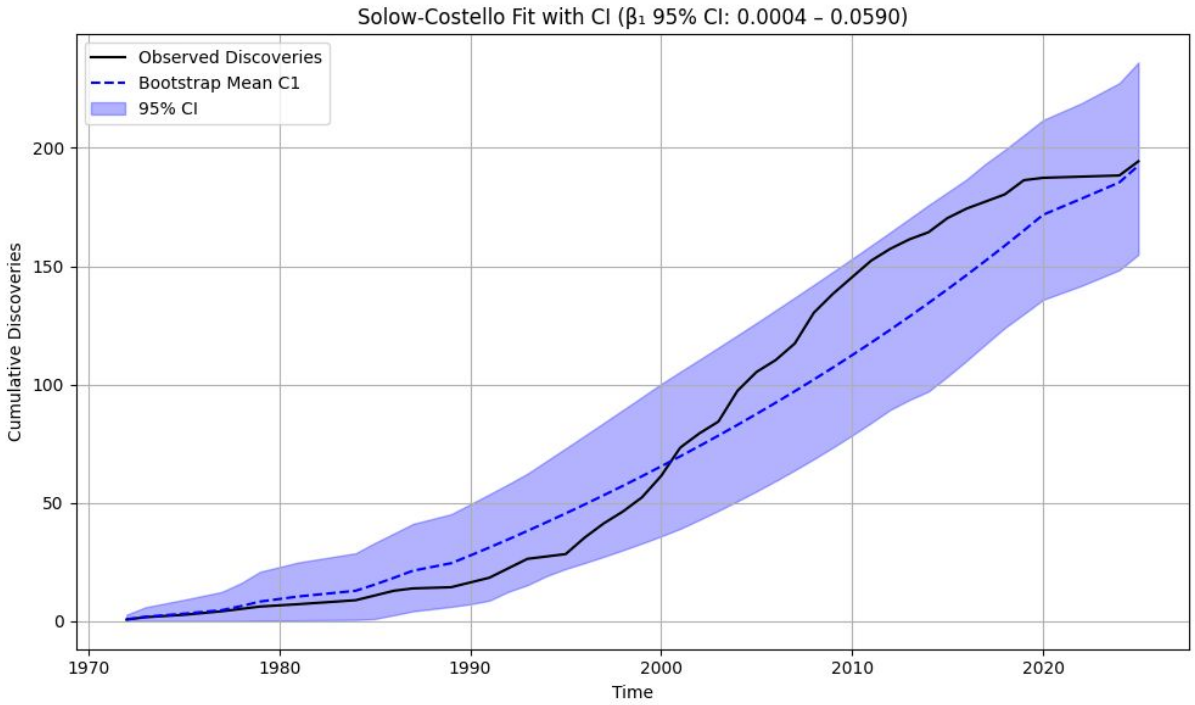
Best case scenario

CHECKLIST DATASET | REGISTERED FEBRUARY 12, 2019

Global Register of Introduced and Invasive Species - Belgium

Published by Invasive Species Specialist Group ISSG

Desmet P • Reyserhove L • Oldoni D • Groom Q • Adriaens T • Vanderhoeven S • Pagad S



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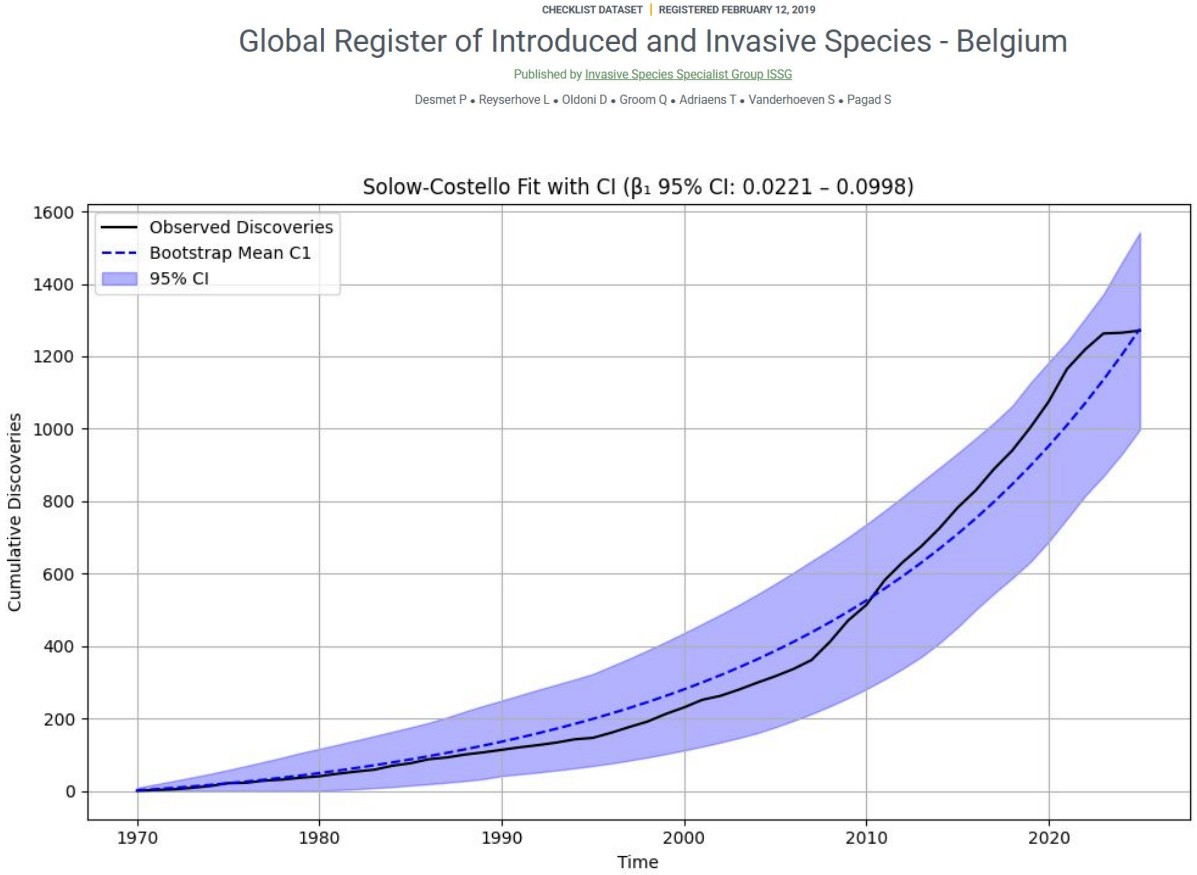
Target 6 (b3alien)

Year	Annual_Rate	Annual_Rate_Error
2021	57.713091	7.638794
2022	61.226267	8.923800
2023	64.972153	10.442058
2024	68.965698	12.222458
2025	73.223060	14.304139

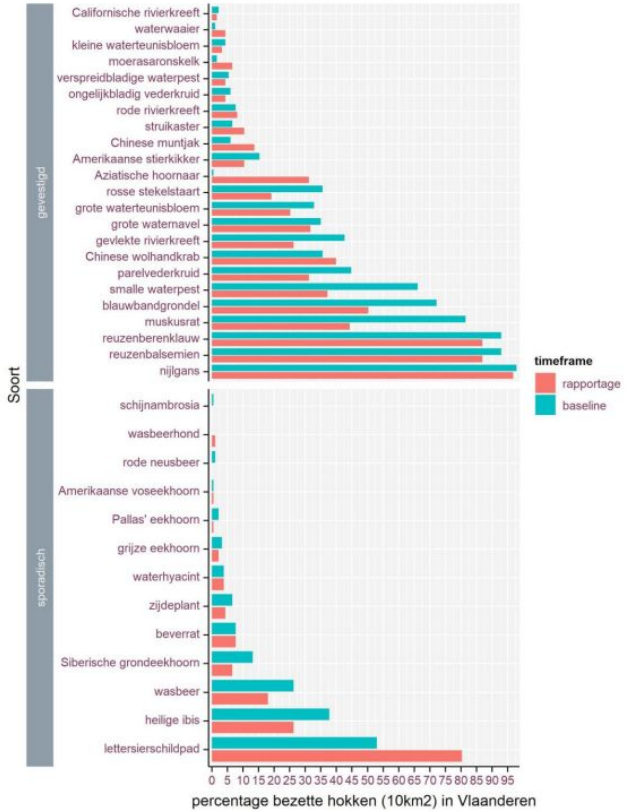
Worst case scenario



Funded by the European Union

IAS indicators

EU concern occupancy species (update of existing indicator)



Adriaens et al. 2020
(doi.org/10.21436/inbor.19288287)

Alien Species Portal

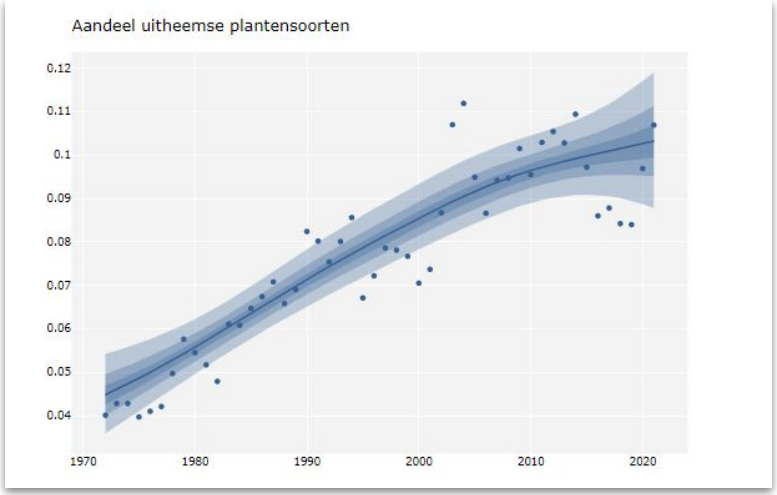
https://alienspecies.inbo.be

Funded by the European Union

IAS indicators

Extra: Percentage of exotic plants per km2 (update of existing indicator)

https://www.vlaanderen.be/inbo/indicatoren/aandeel-uitheemse-planten



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b-cubed.eu @BCubedProject B-Cubed Project B-Cubed Project @b-cubed.eu

Thank you!

Ward Langeraert, Shawn dove &
Jasmijn Hillaert

B-Cubed Newsletter

This project receives funding from the European Union's Horizon Europe Research and Innovation Programme (ID No 101059592). Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the EU nor the EC can be held responsible for them.

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