

NatureServe Rapid Analysis of Rarity and Endangerment Conservation Assessment Tool (RARECAT) Documentation

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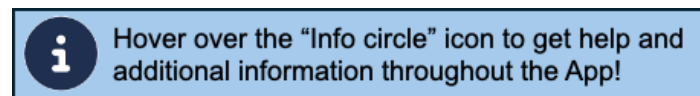


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1. Background

NatureServe Conservation Status Assessments quantify Rarity, Threat, and Trend Factors for target taxa to produce Conservation Assessment Status Ranks at global (G Rank), national (N Rank), or subnational scales (S Rank). NatureServe's RARECAT (Rapid Analysis of Rarity and Endangerment Conservation Assessment Tool) facilitates extraction, vetting, and filtering of distribution data, visualization of data quality and quantity over space and time, and calculation of the three fundamental factors of Rarity – Range Extent (also known as Extent of Occurrence/EOO), Area of Occupancy (AOO), and Number of Occurrences – for single taxa or multiple taxa concurrently. Doing so, RARECAT supports higher quality, efficiency, and standardization in Conservation Assessment Status ranking practice for both common and rare taxa. RARECAT can be accessed at <https://natureserve.shinyapps.io/RARECAT>.

To cite RARECAT, we suggest the following citation template:

NatureServe (2025). RARECAT version 2.1.1. Available from <https://natureserve.shinyapps.io/RARECAT>. Accessed [Date].

2. How-to Guide

2.1. *Application*

RARECAT is an R Shiny application hosted on NatureServe's shinyapps.io account (natureserve.shinyapps.io). Use your browser to navigate to the stable up-to-date version of RARECAT at the following URL: <https://natureserve.shinyapps.io/RARECAT>.

2.2. *Modes*

RARECAT has two modes of use: "Single Species Mode" and "Multispecies Mode".

RARECAT Single Species mode enables users to focus on a single taxon, providing the greatest degree of flexibility and specificity in the exact data included and vetted, the spatial and temporal filters applied, and the outputs generated. RARECAT Single Species mode should be considered when the target taxon is known to have patchy or uncertain data of varying quality, or unusual geographical, ecological, or life history attributes.

RARECAT Multispecies mode enables users to select a shared set of input data and filters to run relatively quick assessments across up to 100 taxa concurrently. RARECAT Multispecies mode should be considered when users might benefit from a relatively quick and preliminary assessment across multiple taxa, before drilling down into the details of a subset of them.

A powerful feature of RARECAT is that its two modes of use interact: Multispecies mode inputs and outputs can be fed back into Single Species mode for specific taxa in need of review; following review, Single Species mode output can then be sent back into Multispecies mode.

2.3. RARECAT Single Species

2.3.1. User Interface

RARECAT “Single Species” mode follows a relatively simple user interface with a single page including 6 components (Figure 1): 1) the Assessment menu, 2) the Data and Analysis panel, 3) the Map, 4) the Filters panel, 5) the Records Table, and 6) the Temporal Change panel.

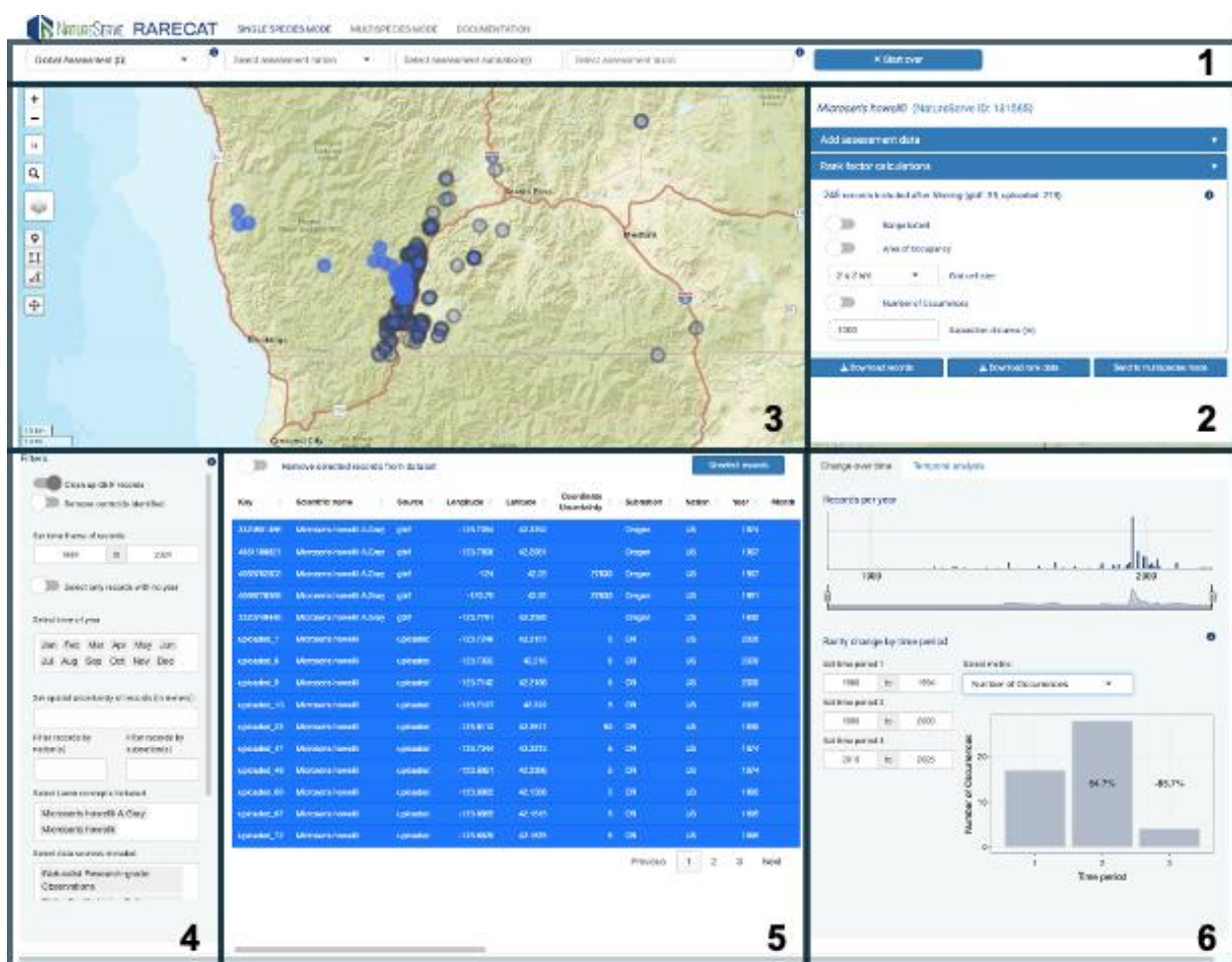


Figure 1: The RARECAT Single Species user interface comprises 6 components: 1) the Assessment menu, 2) the Data and Analysis panel, 3) the Map, 4) the Filters panel, 5) the Records Table, and 6) the Temporal Change panel.

2.3.1.1. Assessment Menu

The Assessment menu appears on the top of the page and prompts the user to select the two primary parameters needed to run a rank assessment: the assessment geography and the assessment taxon. The first three dropdown menus to the left of the Assessment menu enable users to select the geography of the rank assessment at one of three levels: global, national, or subnational.

The screenshot shows the Assessment menu interface. It features three dropdown menus for selecting assessment geography. The first dropdown menu is labeled 'Global Assessment (G)' and has a blue highlight. The second dropdown menu is labeled 'Select assessment nation' and shows 'Canada'. The third dropdown menu is labeled 'Select assessment subnation(s)' and shows 'British Columbia'. A map of North America is visible in the background.

Figure 2: The Assessment menu enables users to select the geography of the rank assessment at one of three levels: global, national, or subnational. Dropdown menus 2 and 3 will only show corresponding options if a national or subnational assessment is selected.

The fourth component of the Assessment menu enables users to select the taxon to be assessed and the associated data to be used in the assessment. To begin, type a taxon name in the text box labeled “Select assessment taxon”; this will open up the taxon options panel. Currently, RARECAT suggests taxonomic names included within the NatureServe Taxonomy Backbone served via the NatureServe Explorer API and the Global Biodiversity Information Facility (GBIF) Taxonomic Backbone served via the GBIF API (Figure 3A). The taxon selected from the first taxon options panel will become the overall taxon associated with this assessment and its name will appear on the top of the Data and Analysis Panel (Figure 5).

After an assessment taxon name is selected, the taxon options panel will display all taxonomic concepts listed by GBIF as being associated with the assessment taxon name selected (Figure 3B). The user is prompted to select all taxon concepts that apply and should be included in the assessment. Taxon concepts included will be highlighted in blue; click to deselect and the row will no longer be highlighted in blue. Once all relevant taxon concepts are selected, users can take one of two routes to move forward with selecting relevant GBIF data to be included in the assessment: to “Start the assessment with all records (up to 5000)” or to “Select specific datasets” (Figure 3B).

Clicking on “Start the assessment with all records (up to 5000)” will prepare RARECAT to load all available records from GBIF up to 5000 records; if the taxon concepts selected have records that total less than 5000 records, all records will be included; if the taxon concepts selected have records that total more than 5000 records, RARECAT will include up to 5000 records spread over the last 5 decades (see “Methodology” section for additional details). Clicking on “Select specific datasets” will open a new panel that displays the exact tallies of records across all GBIF datasets, divided in two separate categories: “Occurrences”, refers to all records that are not labeled as basisOfRecord “HUMAN OBSERVATION” in GBIF (primarily specimen data from biocollections); “Human Observations” refers to all records labeled as basisOfRecord “HUMAN OBSERVATION” in GBIF (primarily data from citizen and community science projects like iNaturalist or eBird). From

both categories, users can choose to “Include all datasets”, “Exclude all datasets”, or select individual datasets by clicking/unclicking them. In addition, a “Maximum records to include per dataset” text box allows users to select a limit number of records to be loaded per dataset which will be shared across all datasets in that category (Figure 4).

A)

Scientific name	Source	ID	Common name	G rank	Phylum	Kingdom
Quercus prinus	NatureServe	1271933	Chestnut Oak	G5	Archaea	Plantae
Quercus prinus	GBIF	8421105				
Quercus prinus	GBIF	7931933				
Quercus prinus plananoides	GBIF	8366259				
Quercus prinus plananoides	GBIF	2878481				
Quercus prinus parvifolia	GBIF	3906294				
Quercus prinus tomentosa	GBIF	7948192				

B)

Scientific name	Key	Number of GBIF records
Quercus prinus M.A.Curtis	7931933	3
Quercus prinus L.	8421105	495
Quercus montana Willd.	3981118	751

Start assessment with all records (up to 5000) Select specific datasets

Figure 3: The taxon options panel enables users to select all relevant taxonomic concepts that should be included in the assessment. A) First, all taxon names in the NatureServe and GBIF taxonomic backbones associated with the name typed in the “Select assessment taxon” text box are returned. B) After a taxon is selected from either the NatureServe or GBIF taxonomy, all taxonomic concepts linked to it within the GBIF taxonomic backbone are returned; taxonomic concepts highlighted in blue will be included in the assessment.

A)

Occurrences Human Observations

☐ Include all datasets ☐ Exclude all datasets Maximum records to include per dataset: 1000

Dataset

FLUX - Pacific Union College Herbarium	10
Washington State University Herbarium	7
Washington State University Marion Center Herbarium	7
The New York Botanical Garden Herbarium (NY)	2
R. L. McGregor Herbarium Vascular Plants Collection	1

Previous 1 2 Next

Start assessment with selected data

B)

Occurrences Human Observations

☒ Include all datasets ☐ Exclude all datasets Maximum records to include per dataset: 1000

Dataset

Calculus Research-grade Observations	5
--------------------------------------	---

Previous 1 Next

Start assessment with selected data

Figure 4: Clicking on “Select specific datasets” enables users to select records of the assessment taxon associated with given datasets of “Occurrences” (primarily data from biocollections) or “Human observations” (primarily data from citizen and community science projects).

2.3.1.2. Data and Analysis Panel

The Data and Analysis panel summarizes the main inputs into and outputs from the ranking assessment (Figures 5 and 6). The top section of this panel, titled “Add assessment data”, enables users to add records for the taxon under assessment to the analysis from one or more of two sources: 1) open online data repositories including the Global Biodiversity Information Facility and associated sources queried via respective Application Programming Interfaces, 2) one or more comma-separated values (CSV) files added by the user. On the left of the “Add assessment data” section, the “Add records from CSV” toggle switch enables users to upload a one or more CSV files containing records for the assessment taxon (Figure 5). CSV files downloaded from widespread biodiversity data platforms and repositories such as GBIF, iNaturalist, SEINet, Biotics are all accepted (see [Methodology](#) for additional details on accepted input CSV formats). On the right of the “Add assessment data” section, the “Add records from GBIF” toggle switch enables users to add to the assessment the GBIF records which were selected from the taxon options panel, either using the general GBIF data request or by selecting specific datasets (Figure 4). The box below the “Add records from GBIF” toggle switch will display either the specific datasets and records selected or the number of records to be downloaded from GBIF overall (Figure 5).

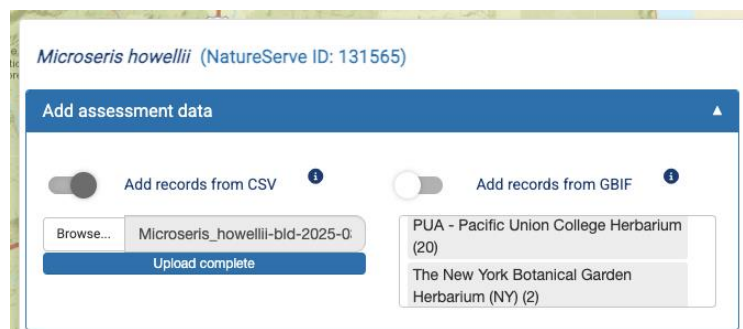


Figure 5: The top section of the “Data and Analysis” Panel displays the assessment taxon and the data inputs selected and/or loaded by the user. Distribution records for the target taxon can be added to an assessment using the Data and Analysis Panel via two main ways: by turning on the “Add GBIF records” toggle to import records from GBIF and associated online data sources, and/or by turning on the “Add records from CSV” and browsing to a local folder on the user’s machine.

Sliding the respective toggle switch will add the preloaded records to the analysis. Below, we discuss a third way for users to add records to the assessment, which involves drawing point records directly on the map using the “Draw a point record” tool (see Figure 7).

Once records are added to the assessment and map by sliding one or both toggle switches, the “Add assessment data” section is automatically collapsed and the “Rank factor calculations” section is displayed and opened. The “Rank factor calculations” section displays the number and source of records added to the analysis and enables the user to turn on the calculation for one or more of the three metrics of Rarity: Range Extent, Area of Occupancy, and Number of Occurrences (Figure 6). Sliding the respective toggle switch will enable the calculation of each metric: the metric’s value will appear to the right of the metric’s toggle and the metric’s spatial representation will be displayed on the map (Figure 6). Symbology for the three Rarity metric spatial layers is as follows: Range Extent is displayed as a large gray polygon surrounding all

mapped point records; Area of Occupancy is displayed as sets of blue square/rectangular grid cells of the chosen grid cell size; and the Number of Occurrences is displayed as red circular buffers around each point records, intersecting red circular buffers are considered part of the same “Occurrence”. See [Methodology](#) section to learn more about how the three metrics of Rarity are quantified.

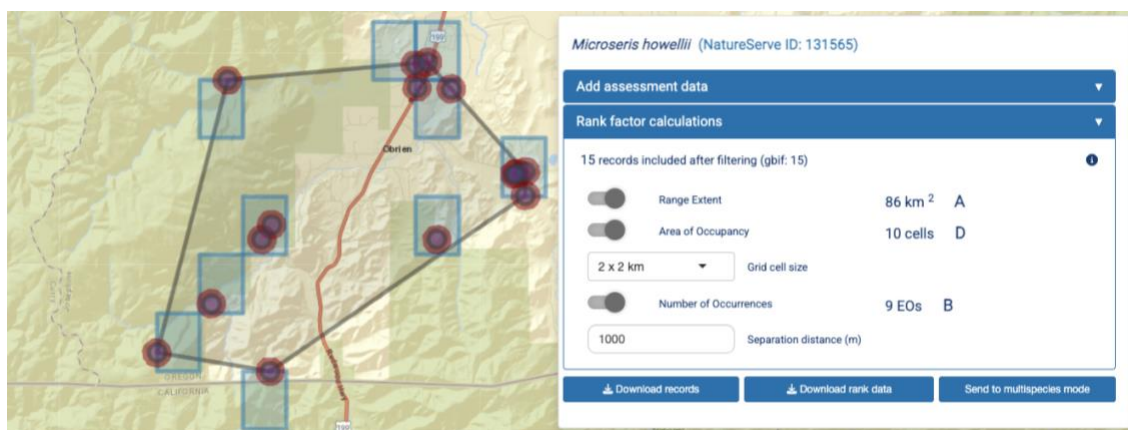


Figure 6: Once records are added to the map, the three metrics of Rarity – Range Extent, Area of Occupancy, and Number of Occurrences – can each be calculated and mapped by turning on the respective toggle in the “Rank factor calculations” section. Range Extent is displayed as a large gray polygon surrounding all mapped point records; Area of Occupancy is displayed as sets of blue square/rectangular grid cells of the chosen grid cell size; and the Number of Occurrences is displayed as red circular buffers around each point records, intersecting red circular buffers are considered part of the same “Occurrence”.

The imported, selected, and filtered records can be exported from RARECAT using the “Download records” button; the Rarity metric values calculated, as well as additional information about the target taxon (derived from the NatureServe Explorer API), can be downloaded as a comma-separated values (CSV) file formatted as a NatureServe Rank Calculator using the “Download rank data” button (see [Outputs](#) section for more details). The “Send to multispecies mode” button can be used to send newly calculated outputs to Multispecies mode and we will discuss its use in the [“RARECAT Multispecies”](#) section of this document.

2.3.1.3. Map

The interactive map enables the user to explore, select, and filter records that have been added to the ranking assessment for the target taxon. Once added, records are displayed on the map as gray circle markers that scale with the map’s zoom level. Current map functionality includes: zooming in/out buttons, restoring map to full extent (i.e. North America), changing basemap (toggle between ESRI World Street Map, ESRI World Terrain, ESRI World Imagery, and OpenStreetMap), drawing point record, drawing selection box, drawing selection polygon, and dragging drawn shapes. The buttons available to support map functionality are described in Figure 7.

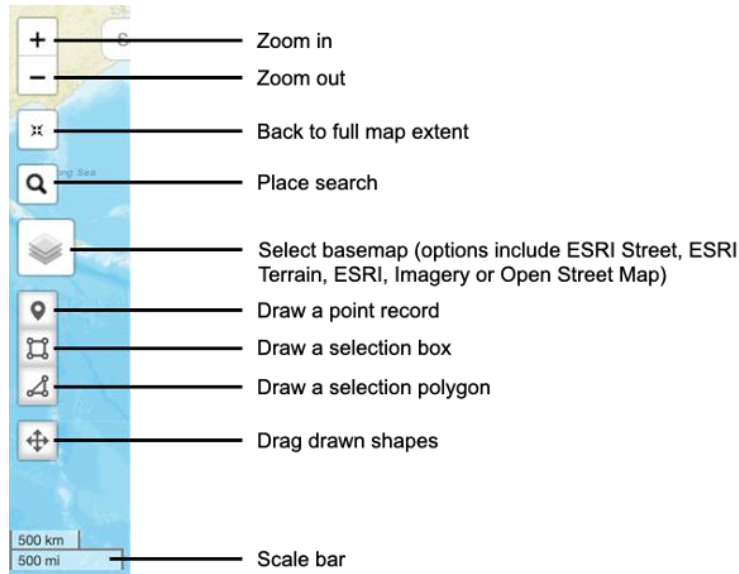


Figure 7: Functionality available within the interactive mapping interface.

Of particular note, the “Draw a point record” button enables users to create data or add to uploaded data by selecting particular locations on the map, while the “Draw a selection box” and “Draw a selection polygon” buttons enable users to select subsets of records to be examined more closely and/or removed (Figure 8).



Figure 8: The “Draw a selection box” and “Draw a selection polygon” buttons enable the user to select a subset of mapped records to be sent to the interactive Records Table.

2.3.1.4. *Filters Panel*

The Filters Panel in the bottom left of the Single Species page enables selecting filters that are applied wholesale to the Rank Assessment dataset, thus providing users with greater flexibility and efficiency in narrowing down the most desirable dataset to quantify Rarity metrics. Available filters are described in Figure 9. Find additional details in the [Filters](#) subsection of the [Methodology](#) section.

Filters

☒ Clean up GBIF records

☐ Remove centroids identified

Set time frame of records

1884 to 2024

☐ Select only records with no year

Select time of year

Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Nov Dec

Set spatial uncertainty of records (in meters):

Filter records by nation(s)

Filter records by subnation(s)

Select taxon concepts included

Microseris howellii A.Gray Microseris howellii

Select data sources included

PUA - Pacific Union College Herbarium
R. L. McGregor Herbarium Vascular Plants Collection
The New York Botanical Garden Herbarium (NY)
Washington State University Herbarium
Washington State University Marion Ownbey Herbarium

Select record types included

PRESERVED_SPECIMEN HUMAN_OBSERVATION

Select element occurrences by rank

E H C

Apply filter to remove GBIF records identified as jurisdiction centroids

Select the level of maximum spatial uncertainty in meters (i.e. DarwinCore field "coordinateUncertaintyInMeters") for inclusion of records; defaults to NULL, i.e. all records are included. Records for which spatial uncertainty in meters is unavailable are always included in the filtered dataset

Limit Rank Assessment to the US or Canada; defaults to all nations for which records are available

Limit Rank Assessment to one or more identified taxon concepts for the selected target taxon; defaults to all taxon concepts for which records have been added

Filter records by basis of record (i.e. DarwinCore field "basisOfRecord"); defaults to all data sources which have been used to add records to the Rank Assessment

Apply default filters to clean up uploaded GBIF records

Limit Rank Assessment to specific time frame; defaults to year of first record and year of last record as start and end years, respectively

Select all records with no known year so they can be assessed from Map and Records Table

Limit Rank Assessment to records collected in specific months across all years included

Limit Rank Assessment to one or more of NatureServe's subnational entities (i.e. US States/territories and/or Canadian provinces; defaults to all subnations for which records are available)

Filter records by data source; defaults to all data sources which have been used to add records to the Rank Assessment

If uploaded records have populated EO Rank values, filter those records by respective EO Rank; defaults to all records being included and records with no value for EO Rank are always included

Figure 9: Description of filters available from the Filters panel.

2.3.1.5. Occurrences Table

The interactive Occurrences Table enables the user to examine basic metadata on the subset of point records selected from the map using the "Draw a selection box" and "Draw a selection polygon" buttons (see Figure 4). The basic metadata reported for each record are: 1) the unique ID or Key (which hyperlinks to the available online page for the record, if recognized); 2) the Scientific Name associated with the record; 3) the Source of the record in RARECAT (one of gbif, uploaded, or drawn); 4) the longitude and latitude of the record as unprojected coordinates; 5) the spatial uncertainty of longitude/latitude coordinates, if available (DarwinCore field coordinateUncertaintyInMeters); 6) the state, province, or NatureServe Subnation (i.e. the US State/territory or Canadian province) the record overlaps; 7) the country or NatureServe Nation (US or Canada) the record overlaps; 8) the year the record was

collected; 9) the month the record was collected; 10) the name of the dataset in which the record is included; 11) the Institution or Organization which owns or provides the record; 12) the type or basis of the record (i.e. specimen, occurrence, human observation, etc.); 13) the rank of the element occurrence (Biotics field EORANK) if the record has been uploaded from a Biotics input file; 13) the record source or url for additional details. The interactive Occurrences Table enables removing single records at a time (by clicking on the corresponding row) or all records by turning on the “Remove selected records from dataset” toggle. Selected records can be unselected by clicking the “Unselect records” button.

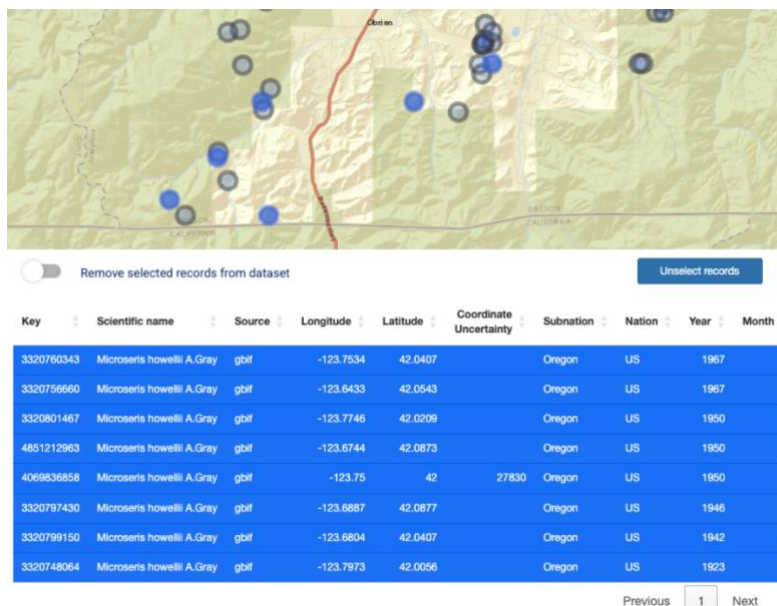


Figure 10: The interactive Occurrences Table reports basic metadata for the records selected from the map and enables removing single records at a time (by clicking on the corresponding row) or all records by turning on the “Remove selected records from dataset” toggle. Selected records can be unselected by clicking the “Unselect records” button.

2.3.1.6. Temporal Change Panel

The Temporal Change panel provides a temporal breakdown and summary of the records included and rarity metrics calculated within the Rank Assessment. The starting dataset underlying the graphs and analyses in the Temporal Change Panel corresponds to the entire set of records being included on the Map, but additional temporal filters can be applied to these analyses specifically. The Temporal Change panel includes two tabs: the “Change over time” tab (Figure 11) and the “Temporal analysis” (Figure 12) tab. The “Change over time” tab includes two visualizations: 1) the “Records per year” barchart shows the number of records per unit time (Figure 11) across all years included in the Rank Assessment time frame (as specified in the time frame filter of the Filters Panel, see Figure 7); 2) the “Rarity change by time period” barchart summarizes the percentage change in each metric of rarity across up to 3 multi-year time periods (Figure 12). The “Change over time” tab allows interactivity by enabling the user to update the time frame of the “Records per year” barchart using the date range slider

below the barchart, as well as updating the years shown in the year range text boxes for Time periods 1-3 in the “Rarity change by time period” barchart. The metric displayed in the “Rarity change by time period” barchart can be updated using the dropdown menu.

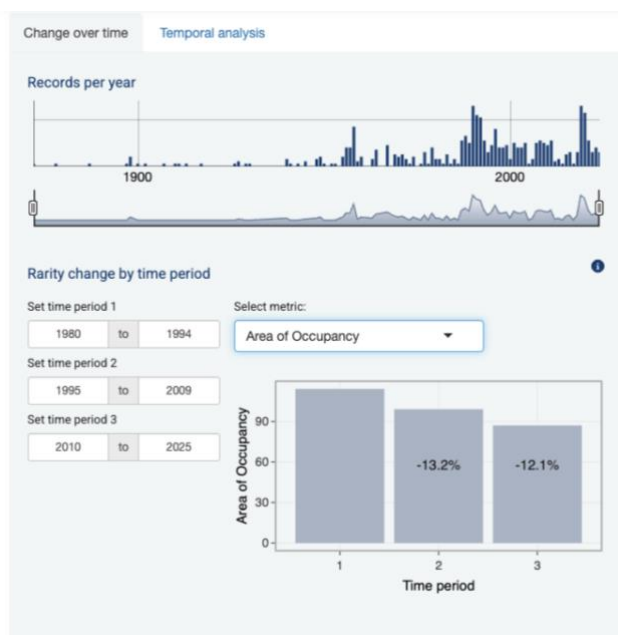


Figure 11: The “Change over time” tab of the “Temporal Change” panel provides a breakdown of the number of records per unit time (“Records per year” visualization) and estimates of percentage change in each metric of rarity across up to 3 multi-year time periods (“Rarity change by time period” visualization).

The “Temporal analysis” tab allows users to generate bias-corrected estimates of the rate and modeled probability of observation for the assessment taxon that takes into account the intensity of recording across time and space for a broader reference taxon which contains the assessment taxon (such as the genus, family, or class the assessment taxon belongs to). To run this analysis, users are prompted to select the taxonomic resolution of the reference taxon (one of “genus”, “family”, “order”, “class”, “phylum”, “kingdom”) and the start year to determine how far back temporal estimates should stretch. Visualizations in the “Temporal analysis” tab summarize 1) the yearly number of observations for the target taxon, 2) the yearly number of observations of the reference taxon, 3) the yearly proportion of observations of the target taxon as a function of observations of the reference taxon, and 4) the modeled probability of observation of target taxon across years given the spatial and temporal rate of observation of the reference taxon. Visualizations 3 and 4 provide are different approaches to the same question: can we get closer to the true the ecological signal of yearly change in local abundance for the assessment taxon once we correct for variation in recording intensity across space and time? For more details in these analyses, see [Methodology](#) section.

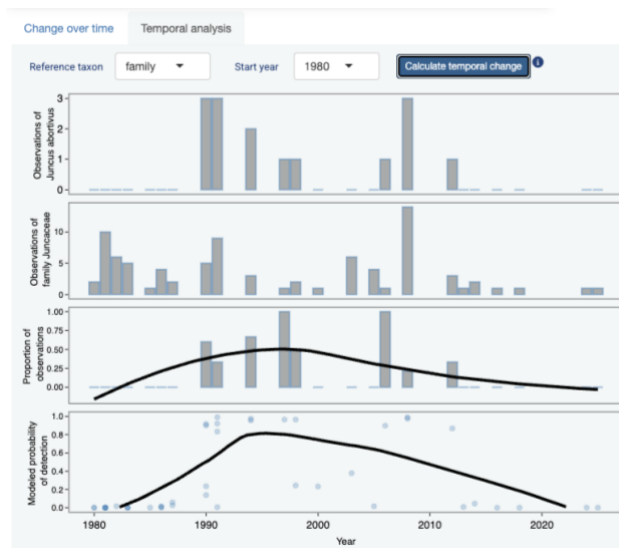


Figure 12: The "Temporal Analysis" tab of the "Temporal Change" panel enables users to generate bias-corrected estimates of the rate and probability of observation for the assessment taxon in light of observations for a broader reference taxon which the assessment taxon belongs to (see [Methodology](#) for more details on these analyses).

2.3.2. Workflow

Step 1. Select assessment geography

Begin a rank assessment by selecting the geography of the assessment from the ["Assessment menu"](#) on the top left of the page. Global (G) Rank assessments are selected by default and no change is needed from the user if moving forward with a global assessment. For National (N) and Subnational (S) assessments, use the respective Dropdown menus to select the desired nation/subnation (see [Figure 2](#)).

Step 2. Select assessment taxon

Once the correct assessment geography is selected, proceed to select the assessment taxon using the "Select assessment taxon" search bar on the right of the ["Assessment menu"](#) on the top of the page: if the taxon being ranked has an existing recognized NatureServe Global Element ID (i.e. EGT ID) available on NatureServe Explorer or a recognized GBIF taxon available from GBIF.org, the user should search for and select it using the "Select assessment taxon" search bar (see [Figure 3](#)); else, the assessment can move forward without the selection of an existing NatureServe Element or GBIF taxon and the taxon being ranked will simply be "New taxon".

Step 3. Select and preload input data

In the process of selecting the assessment taxon from the ["Assessment menu"](#), work through the steps in the taxon options panel superimposed on the Map. This will enable you to preload all GBIF records (up to 5000) available for the assessment taxon or dive in and select/deselect the specific datasets including records of the assessment taxon (see [Figure 4](#)). The preloaded GBIF data selected will appear under the "Add GBIF records" toggle switch in the "Add

assessment data” section of the [“Data and Analysis”](#) panel (see [Figure 5](#)). Preload additional records from a comma-delimited values (CSV) file by browsing your local files using the “Browse” button under the “Add records from CSV” toggle switch in the “Add assessment data” section of the [“Data and Analysis”](#) panel (see [Figure 5](#)).

Step 4. Load and map data

Load and map data preloaded in the “Add assessment data” section of the [“Data and Analysis”](#) panel by sliding the respective toggle switch (see [Figure 5](#)). These data are now included in the [Map](#) for further assessment and filtering, and will be used in the assessment and calculation of rarity metrics and temporal summaries.

Step 5. Explore, vet, and filter records

After adding data to the [Map](#), proceed to verify that the data loaded accurately represent the assessment taxon’s distribution and range to the best of your knowledge. Unreliable, erroneous, or irrelevant records should be removed from the assessment. Removal of records can be done using by navigating to and/or selecting single or multiple records through the Map interface (see [Figure 7](#) and [Figure 8](#)) or, by applying filters to the whole dataset using the [“Filters” panel](#) (see [Figure 9](#)). Verify and seek additional details on the records selected from the map using the [“Occurrences table”](#) (see [Figure 10](#)). In addition, the [“Temporal Change” panel](#) can also be used to verify the breakdown of records over years to further inform filtering over time.

Step 6. Quantify rarity metrics

Once you have narrowed down a suitable and accurate set of point records for the assessment taxon, you can now proceed to calculate one or more of the rarity metrics and associated Rank factors by sliding on or off the corresponding toggle switch from the [“Data and Analysis” panel](#) (see [Figure 6](#)), and choosing the desired parameters for each (e.g. grid cell size for “Area of Occupancy” or separation distance for “Number of occurrences”).

Step 7. Refine assessment inputs and rarity metrics

Further updates to the underlying set of point records included in the assessment will lead to automatic updates to the value of each rarity metric included in the assessment.

Step 8. Explore changes over time

Use the “Change over time” tab of the [“Temporal Change” panel](#) to explore variation in the number of records per unit time for the assessment taxon and estimate percentage changes in rarity metrics over up to three user-specified time periods (see [Figure 11](#)). Use the “Temporal analysis” tab of the [“Temporal Change” panel](#) to generate bias-corrected estimates of the change in the rate and probability of observing the assessment taxon across years given the overall rate of observation of a broader reference taxon such as the family or order to which the assessment taxon belongs (see [Figure 12](#)).

Step 9. Download outputs

Once you are happy with the input data and have obtained reliable values of each rarity metric for the assessment taxon, you can proceed to download from the [“Data and Analysis” panel](#): 1)

the filtered set of point records and associated metadata via the “Download records” button; 2) the formatted rank calculator Excel file including the values of the rarity metrics quantified, as well as additional information about the assessment, via the “Download rank data” button. See [Outputs](#) for additional details.

Step 10. Clear map and start new assessment

Once you have downloaded the all necessary outputs for the current assessment, start a new assessment by clicking on the “Start over” button to the top right of the [“Assessment menu”](#). Alternatively, a new assessment may be started by refreshing the App in your browser window.

2.3.3. Outputs

Two types of tabular output can be generated from RARECAT: 1) a comma-separated values (CSV) file with all filtered and vetted records included in the assessment (that is, all records added to the Map); 2) an Excel workbook (.xlsx) file with all Rank Factor values calculated for the assessment taxon, formatted as a NatureServe Conservation Rank Calculator file, plus additional information about the assessment in a separate tab.

2.3.3.1. Analysis Records

Records included in the assessment – that is the records added to the map at the time – can be downloaded by clicking the “Download records” button. This will prompt your browser to download a CSV file with the following naming convention: target taxon’s scientific name, “RARECAT_assessment_records”, present date. The downloaded CSV includes a table where each row represents a single record included in the assessment and the following fields are reported for each record: key (DarwinCore field [occurrenceID](#)), scientificName (DarwinCore field [scientific Name](#)), prov (the data source or “provenance” for the record, one of: gbif, uploaded, drawn), longitude (DarwinCore field [decimalLongitude](#)), latitude (DarwinCore field [decimalLatitude](#)), coordinateUncertaintyInMeters (DarwinCore field [coordinateUncertaintyInMeters](#)), stateProvince (DarwinCore field [stateProvince](#)), countryCode (DarwinCore field [countryCode](#)), year (DarwinCore field [year](#)), month (DarwinCore field [month](#)), datasetName (DarwinCore field [datasetName](#)), institutionCode (DarwinCore field [institutionCode](#)), basisOfRecord (DarwinCore field [basisOfRecord](#)), EORANK (Biotics field [EO Rank](#)), references (the underlying URL for the record), egt_uid (NatureServe Global Element Unique Identifier), el_code (NatureServe ELCODE), collectionCode (DarwinCore field [collectionCode](#)), recordedBy (DarwinCore field [recordedBy](#)), recordNumber (DarwinCore field [recordNumber](#)), accessRights (Dublin Core field [accessRights](#)), taxonKey (DarwinCore field [taxonID](#)), samplingProtocol (DarwinCore field [samplingProtocol](#)).

2.3.3.2. Rank Calculator

The results of the assessment can be downloaded as an Excel workbook (.xlsx) file with two tabs: a Rank Calculator tab and an Assessment Details tab. The Rank Calculator tab is

formatted as a NatureServe Conservation Rank Calculator file, including all factors necessary to conduct a Conservation Rank Assessment, with the rank factor values calculated by RARECAT included in the respective rarity metrics fields. For more information on the NatureServe Conservation Rank Calculator, please visit <https://www.natureserve.org/products/conservation-rank-calculator>. The Assessment Details tab summarizes most of the details of the assessment, including taxon concepts and IDs included, filters applied to the input data, and parameters of the calculations.

2.4. RARECAT Multispecies

2.4.1. User Interface

RARECAT “Multispecies” mode can be accessed via the main navigation menu and consists of a simple single-page interface with two components: the “Assessment Parameters” panel, and the “Assessment Results” table.

2.4.1.1. Assessment Parameters Panel

The Assessment Parameters panel is open by default when first entering Multispecies mode. The panel summarizes in one single view all of the main selections and parameters available to the user to run a new assessment for multiple taxa concurrently (Figure 13). Specifically, the Assessment Parameters panel is divided into 4 sections which mirror the parameters and filters available to users in Single Species mode: 1. Set assessment geography, 2. Set assessment taxa, 3. Set additional filters, and 4. Set calculation parameters.

The screenshot shows the 'Rank assessment parameters' panel with the following sections:

- 1. Set assessment geography:** Includes a 'Select assessment type' dropdown menu currently set to 'Global (G)'.
- 2. Set assessment taxa:** Contains three input areas: 'Add taxon names from Rank Calculator file' with a 'Browse...' button, 'Add taxon names from observations CSV file' with a 'Browse...' button, and 'Type or paste species list' with a text area containing a list of species: *Microseris howelli*, *Juncus abortivus*, *Phynchospora filifolia*, and *Artemisia patersonii*.
- 3. Set additional filters:** Includes 'Select data sources to include' with checkboxes for 'OCCURRENCE' and 'HUMAN_OBSERVATION' (both checked), 'Clean up GBIF records' and 'Remove centroids identified' (both checked), 'Set max. spatial uncertainty (m)' with a text input, 'Select time frame' with a date range from 1900 to 2025 and a 'Remove records with no year' checkbox, and 'Select months included' with a grid of month checkboxes (Jan-Dec).
- 4. Set calculation parameters:** Includes 'Select AOO grid cell size' with a dropdown set to '2 x 2 km', 'Select occurrence separation distance' with a text input set to '1000', and 'Calculate temporal change in rarity metrics' with two date range inputs: 'Set time period 1' (1900 to 2025) and 'Set time period 2' (1985 to 2025).

At the bottom of the panel are two buttons: 'Start assessment' and 'Clear data'.

Figure 13: The Assessment Parameters panel summarizes in one single view all of the main selections available to the user to run a new assessment for multiple taxa concurrently, including assessment geography and taxa, data inputs and filters, and rank factor calculation parameters.

In the first section, users are prompted to select the assessment geography in a manner akin to Single Species mode, via one or more of three dropdown menus to “Select assessment type”, “Select assessment nation”, and “Select assessment subnation”. The second and third dropdown menus only appear if selecting National or Subnational assessment types.

In the second section, users are prompted to select the list of taxa to be assessed concurrently. There are three ways to upload a list of taxa in Multispecies mode: 1) via an existing Rank Calculator comma-separated values (CSV) file, where each row represents a different taxon to be assessed; 2) via one or more CSV files including observations of the multiple taxa to be assessed formatted similarly to CSV files used to upload observations in Single Species mode; 3) by typing and/or pasting a list of names from a spreadsheet or other source of text directly into a text box. See [Methodology](#) section for more details about acceptable formats for uploads.

In the third section, users can select additional filters to be applied broadly across all taxa in the assessment. These filters are a subset of the filters available from the [Filters](#) panel in Single Species mode, including filters to clean up GBIF records ([GBIF filter](#) and [Centroids filter](#)), set the [maximum spatial uncertainty of records](#), the [time frame](#) and collection [months](#) of records to be included. For more information on how these filters work, see the [Filters](#) subsection of the [Methodology](#) section.

In the fourth and last section, users can set the parameters for the calculation of rarity and change in rarity to be used broadly across all taxa in the assessment. Specifically, users can set the resolution of grid cells to be used to quantify Area of Occupancy and the separation distance to be used to define Element Occurrences. In addition, users can set the time frame of two time periods which will be used to calculate percentage changes in rarity metrics between time periods.

After inputting the assessment geography and a list of taxa to be assessed, as well as updating any of the data inputs, filters, or other parameters, the Multispecies assessment can be kicked off by clicking the “Start assessment” button.

2.4.1.2. *Assessment Results Table*

The Assessment Results table summarizes the main outputs from the Multispecies assessment, with each row in the table corresponding to each assessment taxon. The Assessment Results table is comprised of 12 columns (Figure 14): the Scientific Name (Assessment) column lists the names of the taxa included in the multispecies assessment; the Number of Records Included column reports the total number of point records used to calculate rank factor values for each taxon; the Range Extent (New) column reports the value and associated rank factor letter for the Range Extent metric newly calculated by RARECAT; the Range Extent (Previous) column includes a flag comparing the newly calculated Range Extent metric to the previously calculated Range Extent metric available via either NatureServe Explorer or a user-uploaded Rank Calculator file; the AOO (New) column reports the value and associated rank factor letter for the Area of Occupancy metric newly calculated by RARECAT; the AOO (Previous) column includes a flag comparing the newly calculated Area of Occupancy metric to the previously calculated Area of Occupancy metric available via either NatureServe Explorer or a user-uploaded Rank Calculator file; the Occurrence Count (New) column reports the value and associated rank factor letter for the Occurrence Count metric newly calculated by RARECAT; Occurrence Count (Previous) column includes a flag comparing the newly calculated Occurrence Count metric to

the previously calculated Occurrence Count metric available via either NatureServe Explorer or a user-uploaded Rank Calculator file; the Range Extent Change, AOO Change, and Occurrence Count Change columns report the estimates of percentage change in the respective rarity metric between the two time periods selected by users in the Assessment Parameters panel; the Reviewed column provides a flag for whether or not the corresponding taxon's rank assessment has been reviewed by the user in Single Species mode.

Rank assessment parameters											
Start assessment Clear data											
Scientific Name (Assessment)	Number Of Records Included	Range Extent (New)	Range Extent (Previous)	AOO (New)	AOO (Previous)	Occurrence Count (New)	Occurrence Count (Previous)	Range Extent Change	AOO Change	Occurrence Count Change	Reviewed
Microseris howellii	32	5284 (E)	↑	26 (E)		25 (C)	==	-92.8%	-99.2%	-99%	X Review assessment
Juncus abortivus	42	589161 (E)		39 (E)		39 (C)		-24%	-59.5%	-59.5%	X Review assessment
Rhynchospora filifolia	535	10793941 (E)		436 (F)		>300 (E)		-7.6%	-29.3%	-29.3%	X Review assessment
Artemisia patersonii	57	29457 (F)	==	42 (E)		37 (C)	==	-5.8%	-61%	-54.3%	X Review assessment
Download rank data										Previous 1 Next	

Figure 14: The Assessment Results table summarizes the main outputs from the Multispecies assessment, with each row in the table corresponding to each assessment taxon.

The symbols and colors displayed in the Assessment Results table provide visual cues to highlight potential concerns with either the validity of the newly calculated factors or causes to consider additional information in a given taxon's rank assessment. In the Range Extent (Previous), AOO (Previous), and Occurrence Count (Previous) columns, the symbology is as follows: a grey equal sign indicates that the newly calculated value matches the previously calculated value from either NatureServe Explorer or a user-uploaded Rank Calculator file; a blue upward arrow indicates that the newly calculated value is higher than the previously calculated value, thus suggesting a potential change towards lower rarity; a red downward arrow indicates that the newly calculated value is lower than the previously calculated value, thus suggesting a potential increase in rarity and cause for concern. In the Range Extent Change, AOO Change, and Occurrence Count Change columns, more negative percentage change values are highlighted with warmer colors: -30% to -50% in yellow, -51% to -70% in orange, below -71% in red. In the Reviewed column, an X mark indicates rows that have not been reviewed by the user in Single Species mode while a check mark indicates rows that have been reviewed by the user in Single Species mode.

2.4.2. Workflow

Step 1. Select assessment geography

Begin a rank assessment by selecting the geography of the assessment from the top section of the ["Assessment Parameters"](#). Global (G) Rank assessments are selected by default and no change is needed from the user if moving forward with a global assessment. Selecting National (N) and Subnational (S) assessments will reveal the respective dropdowns which you can use to select the assessment nation(s) and subnation(s).

Step 2. Select assessment taxa

Once the correct assessment geography is selected, proceed to input a list of up to 100 taxa to be assessed concurrently from the second section of the [“Assessment Parameters”](#). The list of taxa can be entered via one of three ways: 1) using an existing Rank Calculator comma-separated values (CSV) file; 2) using one or more CSV files including observations of the multiple taxa to be assessed; 3) by typing and/or pasting it directly into a text box.

Step 3. Select additional filters and parameters

Use the next two sections of the [“Assessment Parameters”](#) panel to select spatial and temporal filters, as well as rarity metric calculation parameters, to be applied broadly across all taxa in the assessment.

Step 4. Start assessment

Click the “Start assessment” button to start the multispecies assessment.

Step 5. Review results table

Once the Multispecies assessment has finished running, RARECAT will display the [“Review results” table](#). Each row in the table corresponds to a taxon from the multispecies list.

Step 6: Send data to Single Species mode

To review a specific taxon, use the “Review” button from the corresponding table row in the [“Review results” table](#) to send the taxon’s assessment data inputs, filters, and parameters to Single Species mode. Use the full functionality of [Single Species mode](#) to review and update the taxon’s assessment inputs and outputs.

Step 7: Send data back Multispecies mode

Once you have reviewed and updated the taxon’s assessment inputs and outputs to the desired degree using [Single Species mode](#), you can send the resulting parameters and outputs back to Multispecies mode using the “Send to multispecies mode” button in the [“Data and Analysis” panel](#).

Step 8: Download output

To download data summarizing the results of the multispecies assessment, click on the “Download rank data” button. Results are formatted as a rank calculator Excel file where every row corresponds to a taxon in the multispecies assessment list.

Step 9: Clear data and start fresh

To start a new multispecies assessment click the “Clear data” button. Alternatively, a new assessment may be started by refreshing the App in your browser window.

2.4.3. Outputs

2.4.3.1. Rank Calculator

The results of the Multispecies assessment can be downloaded as an Excel workbook (.xlsx) file with two tabs: a Rank Calculator tab and an Assessment Details tab. The Rank Calculator tab is formatted as a NatureServe Conservation Rank Calculator file, including all factors necessary to conduct a Conservation Rank Assessment, with the rank factor values calculated by RARECAT included in the respective rarity metrics fields. For more information on the NatureServe Conservation Rank Calculator, please visit <https://www.natureserve.org/products/conservation-rank-calculator>. The Assessment Details tab summarizes most of the details of the assessment, including taxon concepts and IDs included, filters applied to the input data, and parameters of the calculations. In both tabs, each row of the represents a different taxon in the Multispecies assessment.

3. Methodology

3.1. Taxonomy

The “Search Bar” enables looking up taxon concepts based on two sources: NatureServe Taxonomic Backbone (accessed via the NatureServe Explorer API) and GBIF Taxonomic Backbone (accessed via the GBIF API). The user can choose the target taxon for a new rank assessment based on the taxon concept and ID listed by either one of these taxonomic sources. Alternatively, the user may move forward without selecting a taxon altogether and ranking a “New taxon”. After some text is entered in the Search Bar, taxon suggestions from both NatureServe and GBIF appear in a table below. More information on each taxon concept displayed can be accessed by clicking on the corresponding taxon ID (which provides a link to the relevant taxon page on NatureServe Explorer or gbif.org). The user is prompted to select a target taxon for the assessment by clicking on the relevant table row, which will become highlighted in blue.

Once a target taxon is selected for assessment, its name and ID will appear on the top of the Data and Analysis panel: this will be the umbrella target taxon for the current rank assessment. However, since a given taxon concept may have several synonyms or related infra-species, RARECAT provides an explicit breakdown of all records available from GBIF across all scientific names connected with the target taxon selected. This information is provided in a second table below the Search Bar. The options presented on this table correspond to all scientific names provided by the GBIF API as synonyms or infra-species of either 1) the GBIF taxon concept selected as target taxon, 2) the NatureServe element selected as target taxon, as well as all of the synonyms provided for it by the NatureServe Explorer API. The user is prompted to select all relevant scientific names related to the target taxon for which records ought to be included in the assessment.

3.2. Importing Data

Data can be imported into RARECAT from one or both of the following sources: 1) from GBIF using the “Add GBIF records” toggle; 2) from a local comma-delimited values (CSV) file on the user’s machine, using the “Add records from CSV”.

GBIF records are imported into RARECAT using the GBIF API via the R package SPOCC (<https://docs.ropensci.org/spocc/>). By default, switching on the “Add GBIF records” toggle on RARECAT will add all records available on GBIF across all scientific names selected from the Search Bar. However, the user is able to reduce the maximum number of records to be imported using the “max. Records” text box below the “Add GBIF records” toggle; this may lead to a situation where not all selected scientific names are added to the assessment. To ensure that all records associated with the user’s selected taxa are added to the assessment, the default maximum number of records should be kept as is.

3.3. *Mapping*

Mapping in RARECAT is done using the [Leaflet package for R](#) (Cheng et al. 2024). The Leaflet package expects all point data to be specified in latitude and longitude using WGS 84 (EPSG:4326). By default, when displaying this data, Leaflet projects everything to Web Mercator (also known as WGS 84/Pseudo-Mercator) projection (EPSG:3857). All records loaded directly from GBIF are always in WGS 84. Please note that RARECAT assumes that any longitude and latitude coordinate values uploaded by the user from a CSV file are in WGS 84. No spatial transformations are implemented in RARECAT prior to mapping records for exploration; errors are likely to emerge from the upload of records with longitude and latitude values not in WGS 84.

3.4. *Filters*

3.4.1. *GBIF Filter*

By default, the following filters are applied to GBIF records for the target taxon imported via the “Add GBIF records” toggle:

- Records have coordinates
- Records have some value at least for fields latitude, longitude, and basisOfRecord
- institutionCode does not equal “iNaturalist” (iNaturalist records are loaded independently from the iNaturalist API)
- latitude and longitude are both not 0
- basisOfRecord does not equal FOSSIL_SPECIMEN, LIVING_SPECIMEN, MATERIAL_SAMPLE
- occurrenceStatus equals PRESENT
- coordinateUncertaintyInMeters does not equal 999, or 9999
- samplingProtocol does not equal "from a cultivated plant of known (indirect) wild origin", or "grown"

- Only the first record is kept if there are duplicate records that have the exact same combination of latitude, longitude, speciesKey, and datasetKey

These default filters can be cleared by turning the “Clean up GBIF records” toggle off and reloading all GBIF records. When the “Clean up GBIF records” toggle is off, all available GBIF records are imported so long as they have both latitude and longitude coordinates and both do not equal 0.

3.4.2. *Centroids Filter*

Turning on the “Remove centroids identified” toggle will filter out all records identified as corresponding to jurisdiction centroids (e.g. city, county, state, or country centroids). Specifically, RARECAT does this by applying the following filters to GBIF records:

- Remove records that have georeferenceRemarks including the words “centroid”, “Centroid”, or “CENTROID”
- Removing records where uncertainty equals 301 or 3036, which are values known to be used to identify various kinds of jurisdiction centroids

3.4.3. *Time Frame Filter*

A time frame filter can be applied to exclude records from the rank assessment. This can be done by entering the start and end years for the desired analysis time frame in the respective text boxes under the “Set time frame of records” section of the “Filters” panel. It is important to note that records which do not have a value available for year or date will remain included in the analysis regardless of the time frame specified.

3.4.4. *No Year Filter*

All records with a missing value for Year can be selected at once by turning on the “Select only records with no year” toggle. This enables the user to further assess all records which do not have a year value, and could therefore be erroneous or misleading, by using the Map and the Records Table.

3.4.5. *Months filter*

3.4.6. *Spatial Uncertainty Filter*

Records can be excluded from the rank assessment based on a specified level of uncertainty in the precision of spatial coordinates. This can be done by entering the desired level of coordinate

uncertainty in meters above which records should be excluded. It is important to note that records which do not have a value available for spatial uncertainty will remain included in the analysis regardless of the coordinate uncertainty level specified.

3.4.7. Nation and Subnation Filters

Rank assessments can be limited to a given Nation (either the United States of America or Canada) or Subnation (US state/territory or Canadian province/territory; <https://www.natureserve.org/ns-network-directory>) by selecting the desired geographical unit using the “Filter records by nation(s)” and “Filter records by subnation(s)” dropdown menus in the “Filters” section. Note that only nations and subnations corresponding to records added to the map will be available for selection in the dropdown menus.

3.4.8. Taxon Filter

Rank assessments can be limited to a subset of taxon concepts for the target taxon by selecting the desired taxon concepts to be included using from the “Select taxon concepts included” box.

3.4.9. Data Source Filter

Given data sources can be included or excluded from the rank assessment using the “Select data sources included” box. The data source categories that can be selected, provided at least one record has been imported from that data source, are: “gbif” to include/exclude all records loaded from the GBIF API, not including iNaturalist records; “inat” to include/exclude all records loaded from the GBIF API where the institutionCode DarwinCore field equals to “iNaturalist”; “uploaded” to include/exclude all records uploaded by the user; “drawn” to include/exclude all records drawn by the user directly on the Map.

3.4.10. Basis of Record Filter

3.4.11. Element Occurrence Rank Filter

3.5. Rarity Metrics

3.5.1. Range Extent

Range Extent is one of the spatial metrics used in NatureServe Rank Assessments to quantify the rarity and endangerment of the species assessed. NatureServe’s definition of this metric follows the IUCN Red List of Threatened Species definition for Extent Of Occurrence (EOO): the area within the shortest continuous line that can be drawn to include all known, inferred, or projected locations of a species, excluding vagrancy. In practice, Range Extent is therefore calculated by drawing a minimum convex polygon around a minimum of three point records.

RARECAT calculates and maps Range Extent using the following steps:

1. Unprojected longitude and latitude coordinates in WGS 84 are reprojected to a suitable area projection, that is either Cylindrical Equal-Area projection for latitudes below 70 degrees or Lambert Azimuthal Equal-Area projection for polar areas (latitudes above 70 degrees).
2. A minimum convex polygon is drawn around all point records included in the assessment (provided there are at least 3 point records; a value of NA will be returned otherwise).
3. The area of the minimum convex polygon is calculated and returned in square kilometers in the “Data and Analysis Panel” to the right of the “Range Extent” toggle.
4. A minimum convex polygon is also calculated from the unprojected longitude and latitude coordinates (in WGS 84) for the purpose of mapping and is added to the map as a grey polygon.

Please note that the mapped Range Extent polygon and the Range Extent polygon used to calculate the Range Extent value are not equivalent as they are calculated over unprojected and projected space, respectively. The Range Extent polygon that is mapped could potentially be distorted or fail to encapsulate all point records mapped, especially for very large-ranging and/or circumpolar taxa. Irrespective of potential web mapping issues, the returned value for Range Extent represents the best approximation of the area of the minimum convex polygon in an equal-area projection. Additionally, the spatial configuration of some point records datasets may lead to issues in the calculation of a minimum convex polygon and, therefore, a Range Extent value; this is particularly the case for taxa where few outliers are geographically distant from the majority of point records.

Assignment of scores for Range Extent

3.5.2. *Area of Occupancy*

Area of Occupancy (AOO) is one of the spatial metrics used in NatureServe Rank Assessments to quantify the rarity and endangerment of the species assessed. NatureServe’s definition of this metric follows the IUCN Red List of Threatened Species definition: a statistic to represent the area of suitable habitat that a taxon occupies within its range extent. In practice, AOO is calculated by placing a grid over all selected taxon records within a user-defined area, with a default grid size of 2 km (alternatively, grid size can be set at 1km).

RARECAT calculates and maps Area of Occupancy using the following steps:

1. Unprojected longitude and latitude coordinates in WGS 84 are reprojected to Universal Transverse Mercator - a suitable area projection. Please note that all coordinates are reprojected to the UTM zone that corresponds to the minimum longitude value in the dataset.

2. The number of unique equal-area grid cells overlapped by the reprojected point records is counted, given the grid cell size specified by the user (2 x 2 km, by default, or 1 x 1 km).
3. Area of Occupancy is then calculated by multiplying the number of cells by 4 to obtain a value for area in kilometers squared.
4. For the purposes of mapping and visualization, a grid of the approximate user-specified cell size is created in WGS 84, cells that overlap points in WGS 84 are identified and added to the Map as blue square/rectangular cells. Note that because the web map is in unprojected Web Mercator all cells appear to be of the same size when mapped but will actually be of different areas depending on the longitude on which they fall. This may lead to slight differences in the number of AOO cells mapped versus the accurate AOO metric value displayed in the “Data and Analysis” panel.

3.5.3. *Number of Occurrences*

Number of Occurrences is one of the spatial metrics used in NatureServe Rank Assessments to quantify the rarity and endangerment of the species assessed. Based on the NatureServe methodology, an Occurrence (or Element Occurrence) is an area of land and/or water in which a species is, or was, present and should have practical conservation value for the Element as evidenced by potential continued (or historical) presence and/or regular recurrence at a given location. Therefore, for the purposes of ranking, it is necessary to derive occurrences from the point records at hand. In order to do so, individual point records within a certain “separation distance” of each other are grouped as part of the same Element Occurrence (EO); the occurrence may reflect a portion of a population (e.g., long distance dispersers) or a group of nearby populations (e.g., metapopulation).

RARECAT calculates and maps Number of Occurrences using the following steps:

1. Point records in WGS 84 are buffered by half of the specified separation distance (i.e. 500 meters if the user-specified separation distance is 1000 meters), such that an intersection between buffered point polygons would indicate a distance equal to or less than the specified separation distance between the unbuffered point records.
2. Buffered point polygons that cross each other are spatially dissolved into the same occurrence; note that two buffered point polygons will become part of the same occurrence even if they do not directly overlap but they both share overlap with a third buffered point polygon.
3. The number of individual spatially dissolved polygons is counted.
4. For the purposes of mapping, undissolved buffered point polygons are added to the map as red polygons.

3.5.4. *Temporal change in rarity metrics*