

# Teaching notes: Distributions CURE- Exploring species distribution changes and their drivers

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# **CURE SUMMARY**

Species are typically found within a geographic range that is determined by physical tolerances and biological interactions. However, the geographic range for a species may change over time as local conditions become unfavorable or new areas become more favorable. In this CURE, students will develop their own research questions to explore changes in species distributions using digitized natural history collections (dNHC) data. Students will compare present species distributions, using resources such as iNaturalist and/or their own field observations, with historical distributions using dNHC data. Working in teams, students will select species of regional importance or interest and develop research questions and form hypotheses. Using tools developed in this course, students will access, download, and clean dNHC data, georeference records, and use mapping tools to develop visualizations. This research will allow students to draw conclusions on how species ranges have shifted over time, and then explore other data - climate, invasive species, urbanization - to form new hypotheses on the drivers of the range shifts they observe. By using publicly available digitized collections to answer student-led research questions, students gain ownership of the research question and learn to leverage existing, open-access databases to answer ecological questions.

*Intended Audience:* Undergraduate, all levels. Suitable for in-person, hybrid, or online courses in biology or environmental science.

Learning Time: Flexible, from 8-15 weeks

**Required Resources:** Access to computers and internet. All tools and data needed to complete this CURE are freely available online (<u>iDigBio</u>, <u>GBIF</u>, <u>iNaturalist</u>, <u>QGIS</u>). No physical materials are needed.

Optional Tools: <u>R Studio</u> (free and open-source)

## STUDENT LEARNING OBJECTIVES

- 1. Develop a research question: formulate testable hypotheses and state their predictions.
- 2. Describe the potential utility, along with the biases and uncertainties, in specimen and observational data.
- 3. Download and clean digital collections data.
- 4. Compare and agree upon analytical approaches to be employed.
- 5. Analyze data to create and interpret informative graphs or other data visualizations.
- 6. Alter research strategies through an iterative process.
- 7. Contribute observations to natural history databases to augment data available for analysis.
- 8. Prepare and present results/conclusions to peers in oral and/or written format.

# DESCRIPTIONS OF ACTIVITIES AND ASSESSMENTS

Teams of students will generate their own research questions and hypotheses after selecting a species (or multiple species) of their choice. They will develop skills in data analysis using data collected from portals such as GBIF, iNaturalist, and iDigBio, as well as tools including Excel, R Studio, and QGIS. Formative assessments will include exercises and worksheets, as well as intermediate data products (e.g., a successfully cleaned dataset). As a summative assessment, students will produce a final product (research paper and/or presentation) that will draw conclusions about changes in distribution of their species.

# **CURRICULUM MATERIALS PROVIDED**

\*Core materials shared across all BCEENET CUREs

- Species Distributions: Interactions Between Organisms and their Environment
- Introduction to iNaturalist and GBIF- Digital Natural History Resources
- Introduction to Taxonomy and Taxonomic Name Changes
- Downloading and Cleaning Data from iDigBio
- \*<u>Putting Specimens on the Map: An Introduction to Georeferencing</u> (Sorojsrisom & Johnson, 2022)
- \*<u>Mapping Specimen Occurrence Data with QGIS</u> (Bronson, 2021)
- Extension to Mapping Specimen Occurrence Data with QGIS and Excel
- \*Spatial Analysis in QGIS and Excel (Kerney & Whitfeld, 2021)
- Extension to Spatial Analysis in QGIS and Excel

# STATEMENT ON EQUITY AND INCLUSION

This CURE promotes the participation and inclusion of students from diverse backgrounds in natural history-based research by providing a structured sequence of fully online research activities in a flexible learning environment that uses open-source and free software. This format reduces "opportunity gaps" by providing a high-quality, authentic research experience that is available to any student with a computer and internet access. These activities can be used to explore species distribution changes and their potential causes anywhere in the world using taxa of interest to those students. Students can engage with questions and taxa that inspire them to practice scientific competencies, such as collaboration, iteration, and consideration of alternative hypotheses. The flexible structure of this CURE allows students to explore taxa of their choice, thereby engaging their curiosity, and permits place-based research, providing opportunities to inform local stakeholders and fellow community members. Students may also choose to contribute their own observations of their taxon of interest via iNaturalist, engaging them with a diverse, global community of experts and enthusiasts. Such interactions can promote a sense of belonging and encourage students to identify as researchers.



# **IMPLEMENTATION TIMELINE**

### **Overview**

	Topics	Activities & Assessments
Week 1	How do we estimate the distributions of species?	Make observations using iNaturalist, explore dNHC databases, reflect on dNHC data
Week 2	What are the challenges in estimating species distributions?	Form research teams, practice data cleaning, learn GeoLocate for georeferencing
Week 3	What is our species of interest?	Identify focal species, summarize its taxonomic history, pose research hypotheses
Week 4	What are the data available to understand the distribution of our species of interest?	Download and clean dNHC data, consider potential biases in data, draft methods section
Week 5	What are the data available to understand the distribution of our species of interest?	Continue data cleaning, peer review methods, refine methods to address bias and feedback
Week 6	What is the observed pattern in distribution of the focal species?	Map dNHC data using QGIS, draft results section
Week 7	What are next steps to understanding the pattern?	Peer review of results and conclusions drafts, discuss causality, propose methods to explore mechanisms, create an ArcGIS StoryMap
Week 8	What is the importance of the observed pattern?	Present final project results

Note- This syllabus is written for 8-weeks, but there are notes in the Detailed Timeline that follows about potential areas for expansion up to 15 weeks.



# **Detailed Timeline**

### Week 1 (Engage): How do we estimate the distributions of species?

- Before the first class session, students will sign up and download iNaturalist to make 10 observations of a species of their choice. (Part I of Introduction to iNaturalist & GBIF- Digital Natural History Resources Assignment)
- Students discuss their iNaturalist observations in class, comparing them with other students' observations.
- Students complete the GBIF activity (Part II of Introduction to iNaturalist & GBIF- Digital Natural History Resources Assignment). You may ask your students to choose a species from their iNaturalist observations for the assignment.
- Students complete "The Power of Data Standards" activity. Note: This activity may take a significant amount of time. You may choose to have your student complete only part of the activity.
- For homework, there is a written reflection on "The Global Museum" paper; ask students to compare the content of the abstract to the introduction.

### Materials Needed

- Introduction to iNaturalist & GBIF- Digital Natural History Resources Assignment
- iNaturalist mobile app and Video tutorials
- <u>GBIF Tutorial BLUE Resource</u> (Ellwood, 2020)
- Exercise: The Power of Data Standards (Golay et al., 2020)
- Paper: The Global Museum (Bakker et al., 2020)

### Assessments

- Introduction to iNaturalist and GBIF- Digital Natural History Resources. Students note what kinds of data are curated in natural history collections, how complete they are, and how these data are used to generate ideas about where species are found.
- The Power of Data Standards activity
- Homework: Written reflection on The Global Museum paper. Ask students to compare the content of the abstract to the introduction.

### Potential Add-ons

- The activities included in week 1 can easily be distributed over 2 weeks for a longer implementation timeline. This will be impacted by the depth in which you cover the topics.
- Ask students to do more field observations via iNaturalist and interact with some of the tools on iNaturalist, such as communities of experts and the data review process. Depending on course focus, instructors may explore what influences species distributions (abiotic and biotic factors), how to characterize and predict niches (niche modelling), and what current anthropogenic changes are causing species distributions to change (case studies).



### Week 2: (Explore) What are the challenges in estimating species distributions?

- Form research teams
- Students consider bias in digital natural history data. Ask students to predict possible biases and test those biases with some quick searches on the data portals they explored last week. This will provide students with additional practice with searching databases.
- Students will complete the "Cleaning Biodiversity Data" activity
- Students will complete the "Putting Specimens on the Map" activity. This will provide students with the opportunity to practice georeferencing with GeoLocate.

### Materials Needed

- GBIF or iDigBio database
- <u>Cleaning Biodiversity Data: A Botanical Example Using Excel or RStudio</u> (Gaynor, 2020)
- Putting Specimens on the Map: An Introduction to Georeferencing (Sorojsrisom & Johnson, 2022)
- Paper: Data Organization in Spreadsheets (Broman & Woo, 2018) (for instructor reference)
- Species Distributions: Interactions Between Organisms and their Environment activity

### Assessments

- Turn in team member list. Students submit a brief reflection on species searched for and brainstormed ideas for potential bias in digital natural history databases for those species
- Complete Cleaning Biodiversity Data assignment (Gaynor, 2020)
- Complete Putting Specimens on the Map (Sorojsrisom & Johnson, 2022)

### Potential Add-ons

- The Cleaning Biodiversity Data assignment and the Putting Specimens on the Map assignment could be split over two weeks to expand the CURE implementation, allowing for more in depth coverage.
- Expanded reading and consideration of digital natural history data, such as the value of museums, the role of citizen science, vouchered vs. observational data, etc. Either actual or virtual museum visits can help students see what collections look like and how they differ from exhibits.

### Week 3: (Engage) What is our species of interest?

- This week, student teams will identify a focal species for which there is sufficient data and articulate the hypothesis they will test.
- Students work through the Introduction to Taxonomy and Taxonomic Name Changes activity
- Student research their chosen species, briefly characterizing life history and ecological parameters that influence the distribution of that species



### Materials needed

- GBIF or iDigBio database
- Introduction to Taxonomy & Taxonomic Name Changes
- Access to library resources for background research on natural history of the focal species

### Assessments

- Introduction to Taxonomy & Taxonomic Name Changes activity
- Student teams briefly present their findings and hypothesis to the class.
- Homework: Students write a narrative about the biases of the data they are using for their species and how they plan to address these biases.

### Potential Add-ons

- Student teams summarize the taxonomic history of their focal species and taxonomic synonyms for their focal species in a brief (2 minute) presentation.
- There are many possibilities here to expand the consideration of taxonomy and nomenclature, including species concepts, how species are described, the role of morphological and molecular (DNA) characters in how we understand species, and a consideration of complicated scenarios, such as hybrid zones, ring species, cryptic species complexes, and introgression.

# Week 4: (Explore) What are the data available to understand the distribution of our species of interest?

- Using the focal species they chose last week, students will download the maximum amount of data available from iDigBio. Students will need to include searches for all taxonomic synonyms of their focal species. Students should consider the potential biases in their downloads.
- Students will complete Downloading and Cleaning Data from iDigBio. This will include sections of *Cleaning Biodiversity Data: A Botanical Example Using Excel or RStudio (Gaynor, 2020).*

### Materials needed

- iDigBio, GBIF, and iNaturalist
- Downloading and Cleaning Data from iDigBio activity
- <u>Cleaning Biodiversity Data: A Botanical Example Using Excel or RStudio</u> (Gaynor, 2020)

### Assessments

- Submit a copy of cleaned data set for review.
- Submit a draft Methods section for peer review (next week).

### Potential Add-ons

- More iteration on finding and cleaning data, including georeferencing, can be useful.
- You may ask students to consider how a knowledge of taxonomic synonymy, complexity, or cryptic diversity in their species might change the data that they choose to use or consider



reliable. Students can also be asked to read and respond to papers that have used a similar approach.

# Week 5: (Explore) What are the data available to understand the distribution of our species of interest?

- If students have not completed the data cleaning assignment from week 4, additional cleaning may take place this week.
- Students create a final narrative description of the potential bias in their data and a proposal for how to address that bias in their study (independently or as a team).
- Students will peer review the drafts of their methods sections (homework from week 4). Their methods should include how they plan to analyze the distribution changes of their chosen species.
- Students should leave this class with a final dataset to be reviewed.

### Materials Needed

- Downloading and Cleaning Data from iDigBio activity (for reference)
- <u>Cleaning Biodiversity Data: A Botanical Example Using Excel or RStudio</u> (Gaynor, 2020) (for reference)

### Assessments

- Final data for review, with a narrative description of the potential bias and a proposal for how to address that bias
- Final Methods section

### Potential Add-ons

- Students can employ georeferencing to expand and improve their datasets. They can use <u>Putting</u> <u>Specimens on the Map: An Introduction to Georeferencing</u> (Sorojsrisom & Johnson, 2022) from week 2 for reference.
- Expanding on the student's knowledge of the species by beginning to consider potential causal factors in the change of distribution.

### Week 6: (Explore) What is the observed pattern in distribution of the focal species?

- Student download and install QGIS (if needed).
- Students complete the <u>Mapping Specimen Occurrence Data with QGIS</u> (Bronson, 2021) activity individually.
- Using the <u>Mapping Specimen Occurrence Data with QGIS</u> (Bronson, 2021) activity as a reference, student teams map their own data points.
- Student teams add additional shapefiles (precipitation, temperature, landcover, elevation, etc.) to their map using the Extension to Mapping Specimen Occurrence Data with QGIS activity.



- At the end of the class, students will briefly present their findings for in-person peer review.
- For next class, students will turn in a copy of the beaver map of their data, and a draft of their results section.

### Materials Needed

- <u>Mapping Specimen Occurrence Data with QGIS</u> (Bronson, 2021)
- Extension to Mapping Specimen Occurrence Data with QGIS
- Spatial Analysis in QGIS and Excel (Kerney & Whitfeld, 2021) (optional add-on)
- Extension to Spatial Analysis in QGIS and Excel (optional add-on)

### Assessments

- Completed beaver map (submit individually)
- Completed team maps (submit one copy per team)
- Brief presentations by student teams on their draft maps and initial findings for peer review
- Draft Results section

### Potential Add-ons

- This week contains a large amount of student work on QGIS. Many students struggle with these activities, so you may wish to split this work over at least 2 weeks.
- Consider data layers as resources to ask questions about causality and incorporate analyses of causality in distributional changes.
- Use the Concave Hull plugin in QGIS to calculate how species ranges change over time. See: <u>Spatial Analysis in QGIS and Excel</u> (Kerney & Whitfeld, 2021). Students can them complete the Extension to Spatial Analysis in QGIS and Excel activity to create a line graph showing changes in species range size over time.

### Week 7: (Elaborate) What are next steps to understanding the pattern?

- Student teams will create a StoryMap of their results
- Students will create a conclusions draft and articulate their research plan to test potential causal mechanisms (part of the final presentation)
- Student teams will briefly present their results and conclusions to the class for peer review in a "laboratory meeting" format
- Lastly, the class will draft a peer rubric for final presentations

### Materials Needed

 <u>ArcGIS Storymap homepage</u> (Carroll, n.d.)- Students will need to create a free account to access Storymaps and associated tutorials

### Assessments

• Draft StoryMap



• Draft Conclusions section

### Potential Add-ons

Incorporating questions about causality will require substantially more time and should be
incorporated into the visual story telling aspect of the research and research products.
If causality will not be considered deeply, then students can iterate on how to best convey their
results and how to identify stakeholders with whom to share this information. Students can also
do several rounds of peer review and practice to increase confidence in their final product.

# Week 8: (Evaluate) What is the importance of the observed pattern?

• Students present to their peers and a wider audience (stakeholders/scientific community) if possible

### Assessments

- Student presentations on their research
- Final StoryMap
- Final research paper (or other final products)



# REFERENCES

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