

ISSUES: DATA SET

Building Biodiversity Datasets for Invasive Species

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A dense mat of European frog-bit (*Hydrocharis morsus-ranae* L.), identified by the green heart-shaped leaves and small, white flowers with three petals.

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THE ECOLOGICAL QUESTION:

How does invasive European frog-bit spread and impact native communities?

FOUR DIMENSIONAL ECOLOGY EDUCATION (4DEE) FRAMEWORK

- **Core Ecological Concepts:**
 - Organisms
 - Abiotic and biotic features of the environment
 - Resources and regulators
 - Community
 - Habitat type - wetlands
 - Species diversity
 - Competition
- **Ecology Practices:**
 - Quantitative reasoning and computational thinking
 - Data skills
 - Computer skills: spreadsheets
 - Designing and critiquing investigations
 - Study design
- **Human-Environment Interactions:**
 - Human dependence on the environment
 - Human accelerated environmental change
 - Anthropogenic impacts
 - How humans shape and manage resources/ecosystems/the environment
 - Conservation Biology
- **Cross-cutting Themes:**
 - Systems
 - Spatial & Temporal
 - Biogeography
 - Native/alien/invasives

WHAT STUDENTS DO:

In this module, students explore the spread of the invasive aquatic plant European frog-bit (*Hydrocharis morsus-ranae* L.) and design a dataset for evaluating the impacts of this species on native ecosystems. In the first two Activities, students access a publicly available dataset to map the spread of European frog-bit, evaluate how the invasion has changed over time, and reflect on ways humans would be impacted by the invasion and could work to slow or stop the spread of the species. In the next Activity, they use online literature sources to explain the specific affects of invasive aquatic plants on plants, animals, and humans. In the last three Activities, they create a dataset template based on a protocol for sampling European frog-bit in Saginaw Bay, Michigan. They create files and folders using best data management practices. They go through the steps of translating a written protocol to a fillable data template in Microsoft Excel. Finally, they assess which questions related to European frog-bit impacts could be addressed by their data. In the final Assessment, students demonstrate their understanding of vocabulary, human impacts on invasive species, and the importance of data in ecology and begin the process of designing a dataset addressing new questions on an invasive species of their choosing.

STUDENT-ACTIVE APPROACHES:

Group Discussion (option for reflection questions), Brainstorming (independent), Inquiry-based Learning

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STUDENT ASSESSMENTS:

Students complete formative assessments throughout and a final assessment at the end of the module. Assessments include written answers, independent research, and data design. Answers may be graded according to the provided answer key, used to check for understanding, or discussed as a class.

CLASS TIME:

3-4 hours

COURSE CONTEXT:

Introductory biology or ecology course for life science majors

SOURCES:

Hansen, S., Cahill, B., Hackett, R., Monfils, M., Goebel, R., Asencio, S., and Monfils, A. 2022. Aggregated occurrence records of invasive European frog-bit (*Hydrocharis morsus-ranae* L.) across North America. Biodiversity Data Journal. Occurrence dataset <https://doi.org/10.15468/jsab2y> accessed via GBIF.org

ACKNOWLEDGEMENTS:

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OVERVIEW OF THE ECOLOGICAL BACKGROUND

Invasive species and associated ecosystem changes are a threat to global biodiversity. European frog-bit (*Hydrocharis morsuse-ranae* L.) is an invasive aquatic plant introduced to North America in 1932 and spreading throughout southern Canada and the northeastern and midwestern United States (Minshall 1940, Dore 1968, Hansen et al. 2022). Data are critical for understanding two questions: 1) How is this species spreading? and 2) How does this species impact the ecosystems it spreads to? In this module, students will explore the first question by accessing publicly available data and analyzing them through maps and reflecting on ways humans can impact the spread of European frog-bit. They will read about the effects of invasive aquatic plants and design a data template that could be used to sample European frog-bit and its habitat in Saginaw Bay, Michigan. By completing these activities, students should gain an understanding of how data inform invasive species research and conservation and be able to design and apply data using best practices.

LEARNING OBJECTIVES:

Upon completion of this module, each student will be able to:

- Explain the role of data in monitoring the spread and assessing impacts of invasive species
- Access publicly available biodiversity data through a data aggregator
- Analyze and interpret publicly available biodiversity data through mapping
- Identify ways humans impact the spread of invasive species and data about invasive species
- Describe the effects of invasive species on plant communities
- Apply vocabulary and concepts related to biodiversity datasets
- Translate plant diversity field sampling protocols to data collection template
- Formulate research questions that could be addressed using data

DATA SETS

The main dataset used for mapping is publicly available online (Hansen et al. 2022). Instructors and students do not need to download the dataset to use it for mapping as GBIF will automatically generate the maps, which can be altered directly on the website. Students will design the data template in Excel, so instructors will have access to an example Excel file with notes.

ExampleDataTemplate.xlsx: For instructors, an example data template that can be used to assess student submitted Excel files.

References

Dore, W. 1968. Progress of the European frogbit in Canada. *Canadian Field-Naturalist* 82: 76-84.

Hansen, S., Cahill, B., Hackett, R., Monfils, M., Goebel, R., Asencio, S., and Monfils, A. 2022. Aggregated occurrence records of invasive European frog-bit (*Hydrocharis morsus-ranae* L.) across North America. Biodiversity Data Journal. Occurrence dataset <https://doi.org/10.15468/jsab2y> accessed via GBIF.org

Minshall, W. H. 1940. Frog-bit *Hydrocharis morsus-ranae* L. at Ottawa. *Canadian Field-Naturalist* 54: 44-45.

STUDENT INSTRUCTIONS

Introduction

Non-native species are organisms that have been introduced to an area where they did not evolve and do not naturally occur. Most non-native species are first introduced by humans, intentionally or unintentionally. In many cases, non-native species are beneficial to us; for example, many of the crops we grow for food, ornamental plants we enjoy, and animals we keep as pets or livestock are non-native. In some cases, however, non-native species can become invasive. **Invasive species** are non-native species that have negative impacts on the area where they are introduced. Invasive species can harm ecosystems by outcompeting native organisms for limited resources like space, food, and sunlight and altering the physical environment. There is growing concern as associated ecosystem changes threaten global **biodiversity** (the diversity of organisms on Earth). Economic losses and conservation efforts to manage biological invasions have cost nearly 1.3 trillion US dollars in the past five decades (Diagne 2021). Scientists, natural resource managers, and other biodiversity professionals work to understand the spread and impacts of non-native species so they can reduce harmful impacts as much as possible.

European frog-bit (EFB; *Hydrocharis morsus-ranae*) is a non-native aquatic plant in the Laurentian Great Lakes region of North America. It can be recognized by floating heart-shaped leaves and white flowers (Figure 1). It was intentionally introduced as an ornamental aquatic plant in Ottawa, Ontario in 1932 and has since spread (unintentionally) throughout Ontario, Quebec, and the northeastern and midwestern United States (Minshall 1940, Dore 1968). In Michigan, EFB inhabits coastland wetlands of the Great Lakes and inland waterbodies such as lakes, rivers and streams, and waterbodies created by humans (e.g., canals, retention ponds, reservoirs). Saginaw Bay, Michigan has been populated by EFB since 2013 (Figure 2). Conservation professionals believe it may be negatively impacting local species and environmental conditions, but so far research is limited.



Figure 1. A thick mat of flowering European frog-bit in Michigan

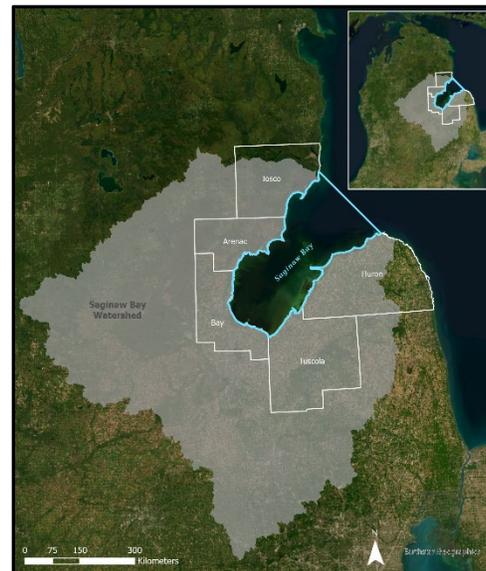


Figure 2. Saginaw Bay, Michigan, and surrounding counties

How would a scientist know and be able to explain what is happening with EFB in Saginaw Bay? Would they have to guess based on other species they are familiar with? Would they have to sit in a wetland all year and watch changes happen? No and no. Scientists use **data** to answer their questions. Data are the units of information. Data provide context for information and records of knowledge. Much of what you know about science comes from **data** that were collected, put in the context of a particular question or topic (becoming **information**), and then disseminated to other members of the scientific community and the public (becoming **knowledge**; Brackett 2013). Data take many forms, including lists, tables, or even notes in a notebook. Data are fundamental in the study and preservation of biodiversity, as they allow us to inventory biological organisms or systems, track changes over time, and combine efforts from multiple researchers toward a common goal. By recording what we observe, we are making sure others can use the same information to verify or refute our conclusions.

Data vs. Datum

The word “**data**” is a plural noun used for multiple pieces of information. The word “**datum**” is the singular form of the noun used for a single piece of information. For example, one temperature measurement produces one datum, and temperature measurements at several points over time produce many data. You will almost always deal with many data, not just one individual datum, so “**data**” is the more commonly used form of the word.

Scientists studying EFB want to know two things: 1) How is EFB spreading? and 2) How is EFB impacting the ecosystems it spreads to? In this module, you will explore the first question by accessing publicly available data and visualizing them through maps (Activities I and II). Then, you will read about the impacts of invasive aquatic plants and consider how EFB could be impacting ecosystems in Michigan (Activity III). Finally, you will explore the second question on EFB impacts by creating a data template that could be used to sample EFB and its habitat in Saginaw Bay (Activities IV and V).

Activity I: Map the Spread of European Frog-bit

A scientist's first step when investigating any research question is typically to explore the information that is already available. One type of information is **scientific literature**, or papers written and reviewed by scientists that describe research projects and their results. Along with exploring scientific literature, many scientists also explore publicly available data to help inform their research. There are several websites that allow people to submit data that are free and usable by anyone. Observations of organisms made by **community scientists**, or members of the public who are interested in science and want to contribute to scientific efforts, are an important source of these publicly available data. Scientists can use these data resources to identify where a species is located, how it is changing over time, what species it interacts with, and many more questions.

Because of the potential for EFB to negatively affect the ecosystems it is not native to, it's important to understand how EFB is spreading so we can take measures to stop the spread to adjacent areas, especially when negative ecological impacts are expected. You will be accessing a publicly available dataset of EFB occurrences through the Global Biodiversity Information Facility (GBIF) to map the spread of EFB over time. GBIF is a **data aggregator**, meaning it houses data from many sources in one central place online. The dataset you will explore was published by scientists who aggregated publicly available data from multiple websites and sources, cleaned and standardized them, and re-published them online (Hansen et al. 2022). These include data from community scientists, targeted research efforts, natural history collections, government surveying efforts, and many more types of data sources.

1. Follow the link to the dataset "Aggregated occurrence records of invasive European frog-bit (*Hydrocharis morsus-ranae* L.) across North America"

<https://www.gbif.org/dataset/71454d8a-6e9c-49f5-bf37-353f9ad2e2b9>

You are now on the main GBIF page for the dataset you will be using.

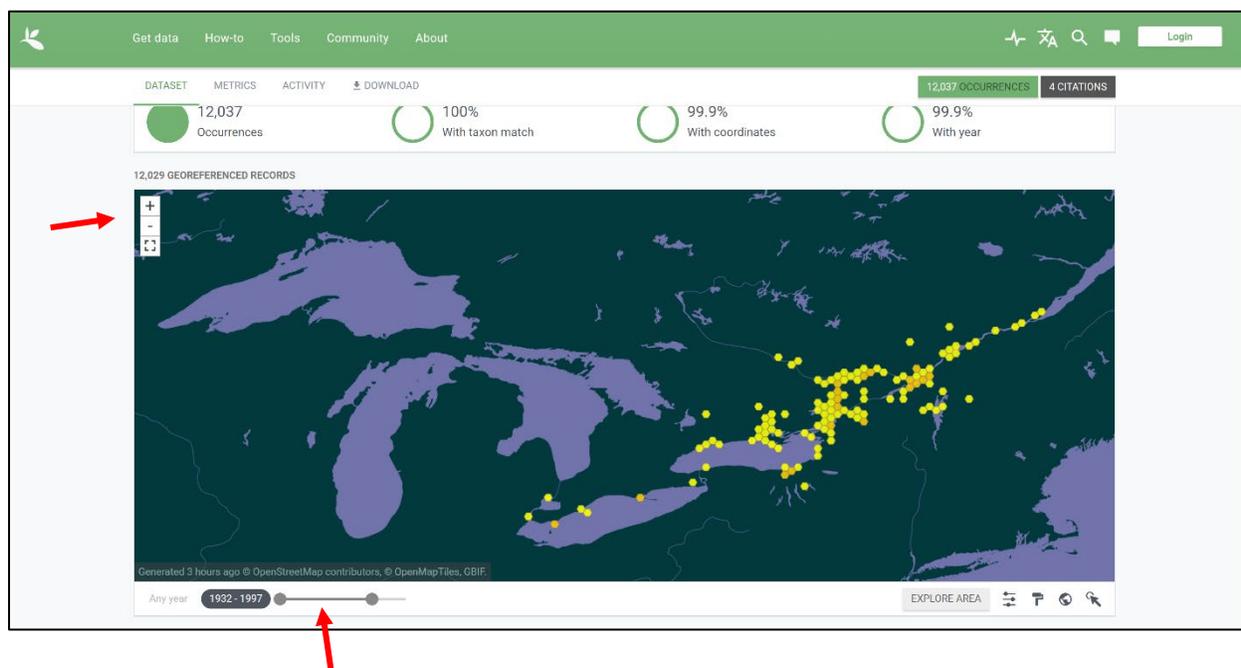
The screenshot shows the GBIF dataset page for "Aggregated occurrence records of invasive European frog-bit (*Hydrocharis morsus-ranae* L.) across North America". The page includes a navigation bar with "Get data", "How-to", "Tools", "Community", and "About". The main content area features a title, publication information (published by Biodiversity Data Journal, Hansen et al. 2022), and a summary of the dataset. Key statistics are displayed: 12,037 occurrences, 100% with taxon match, 99.9% with coordinates, and 99.9% with year. A map shows the distribution of records across North America, with a concentration of yellow dots in the eastern and southern regions.

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You will map several time periods (using the Map tool within GBIF) to look at the spread of EFB in Michigan America over time. Maps are a form of **data visualization**, or representing data through graphs and pictures to make them more meaningful.

2. Find the slider along the bottom of the automatically generated map and try moving each end of the bar to change the first and last years displayed on the map. Notice how the points on the map change. You may adjust the map aesthetic in the bottom right corner if you want. You will want to zoom in on Michigan for the following questions using the “+” button.



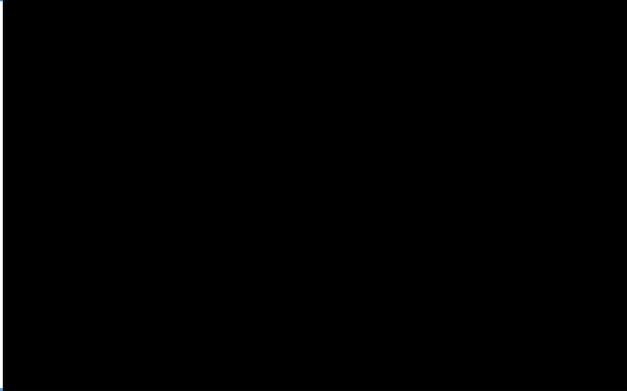
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3. For each of the time periods below, paste a picture of the map showing EFB occurrences in Michigan over those years. You can take a screenshot and crop it to only the map or use the Snipping Tool (accessible via the Search bar on your computer). After pasting your picture, set Wrap Text to In Front of Text so you can move it on top of the table.

| | |
|-------------------------------|--------------------|
| 1932 – 2021 (all time) | 1990 – 1995 |
| 1996 – 2000 | 2001 – 2005 |
| 2006 – 2010 | 2011 – 2015 |

2016 – 2021



4. During what time period do you first see EFB in Michigan?

5. Between which time periods do you see the slowest spread? Between which time periods do you see the fastest spread?

6. Conservation professionals want to know how EFB is spreading. Specifically, they want to know how the extent of the non-native range is expanding or contracting in different areas and whether the spread appears to be speeding up or slowing down in different areas. In your own words, describe the spread of EFB based on the maps you created. Address at least one of the two questions listed relative to specific areas of the state and/or time periods.

7. As you know, scientists and conservation professionals explore and analyze data to make decisions. Now that you have visualized the EFB data by making maps, imagine you are a conservation professional making a decision about where to start some EFB management efforts (like applying herbicides or pulling EFB plants out by hand). You have limited resources so you have to prioritize one area to start with. Which area do you choose and why?

Presence and Absence

The occurrences in this dataset include both “presence” and “absence” records, meaning sometimes people submitted a record when they saw EFB and sometimes people made a record when they looked for EFB and didn’t see it. Absence records are really useful for scientists who want to know where a species is and is not located, but they can also lead to inaccurate depictions of the data if every occurrence record is treated like a presence. In this dataset, the absence records coincide geographically with the presence records, so they do not significantly change the distribution year to year. Think about what would happen if someone wanted to use this dataset to make a decision and didn’t pay attention to the type of record.

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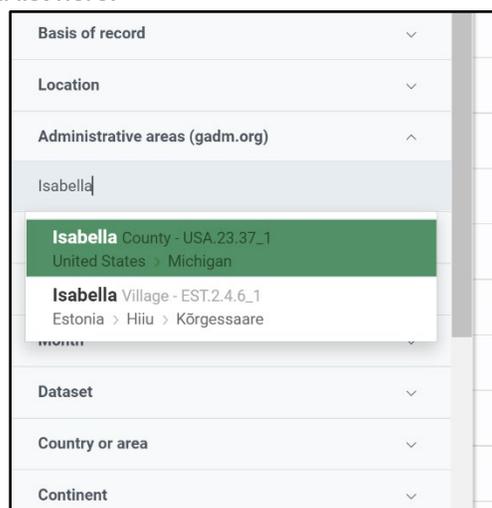
Activity II: Explore EFB Data in Michigan Counties

How do you know if European frog-bit has been introduced to a specific area? You can check to see whether there has ever been a reported sighting by accessing all EFB occurrence data in GBIF.

1. Go to gbif.org and click “Get data” at the top of the screen.
2. This will open a drop-down menu. Click “Occurrences.”

| Scientific name | Country or area | Coordinates | Month & year | Occurrence status | Basis of record |
|---|--------------------------|---------------|--------------|-------------------|--------------------|
| <i>Mesophyllum lichenoides</i> (J.Ellis) Me.Lermoi... | Spain | | 2022 January | Present | Preserved specimen |
| <i>Eptesicus fuscus</i> subsp. <i>fuscus</i> | United States of America | 41.3N, 72.9W | 2022 January | Present | Preserved specimen |
| <i>Araeopteron</i> Hampson, 1893 | Chinese Taipei | 25.0N, 121.5E | 2022 January | Present | Human observation |
| <i>Cyanistes caeruleus</i> (Linnaeus, 1758) | Germany | 52.3N, 8.9E | 2022 January | Present | Human observation |
| Croton L. | Brazil | 9.7S, 55.5W | 2022 January | Present | Preserved specimen |
| <i>platysteale ovalifolia</i> (focke) garay & dunst. | Brazil | 1.1S, 48.4W | 2022 January | Present | Preserved specimen |
| <i>Nucella lapillus</i> (Linnaeus, 1758) | France | 47.1N, 2.2W | 2022 January | Present | Human observation |
| <i>Gryllodes sigillatus</i> (Walker, 1869) | United States of America | 21.3N, 158.0W | 2022 January | Present | Preserved specimen |
| <i>Geastrum schmidelii</i> Vittad. | Poland | 52.6N, 21.3E | 2022 January | Present | Human observation |
| <i>Exidia saccharina</i> Fr. | Poland | 53.2N, 20.9E | 2022 January | Present | Human observation |
| <i>Flammulina elastica</i> (Sacc.) Redhead & R.H.L... | Poland | 53.0N, 20.7E | 2022 January | Present | Human observation |
| <i>Flammulina elastica</i> (Sacc.) Redhead & R.H.L... | Poland | 53.6N, 14.8E | 2022 January | Present | Human observation |

3. Click on “Scientific name” on the lefthand side and type in “Hydrocharis morsus-ranae L.” This will take you to all GBIF-published occurrences of EFB around the world.
4. Choose one county in Michigan. You can find a list here: <https://www.michigan.gov/som/about-michigan/michigan-counties>. If you have been to Michigan, you can choose a county you’ve visited or lived in. If you don’t live in Michigan, choose any county from the list.
5. In GBIF, click on “Administrative areas (gadm.org)” on the lefthand side and type in the name of the county you chose. (Don’t type “county”). GBIF will give several options once you start typing. Select the appropriate one.
6. How many occurrences of EFB have been recorded in the county? (the answer may be 0)



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7. Whether or not you live in Michigan, consider your own county. Imagine EFB spread to your county and became invasive. (*If you live in a country where EFB is native, think about a different invasive aquatic plant.*) Invasive aquatic plants can affect different types of water bodies in different ways. Think of a lake, pond, river, stream, or other water body in your county. What would happen to that water body if EFB were to invade?

Specific questions to consider:

- What types of animals, plants, or other organisms could it affect?
- How would EFB invasion affect the way humans use or interact with that water body?
- Who in your county would be most impacted by EFB invasion in that water body?
(*Think of the people who rely on the water or surrounding land for jobs, food, or recreation.*)

8. How would people in your county react to EFB invasion?

Specific questions to consider:

- Would people in your county care about EFB invasion?
- What would people in your county do to stop the spread of EFB or remove it from the water?
- Are there ways people in your county could accelerate the spread of EFB?
- Is there anything you could do to help prevent or stop the spread of EFB in your county?

(*Remember, observations recorded by community scientists are significant sources of data for many conservation projects.*)

Activity III: Investigate Literature on the Impacts of Invasive Aquatic Plants

As you know, EFB is an aquatic plant with leaves that float on the surface of the water. Unlike many terrestrial (land) plants, its roots do not need to attach to soil and can hang down into the water. European frog-bit can reproduce asexually through **stolons**, or stems that grow horizontally out from a plant and form new plants (Figure 3). In dense populations, tangled roots and stolons can create thick mats of EFB plants, as you saw in Figure 1. Many of the negative effects of invasive aquatic plants are related to this habit.

In Michigan, EFB is considered invasive due to its potential to cause harm, even though its specific negative effects on native ecosystems are not fully understood. We can infer some potential effects based on what is known about other invasive aquatic plants.

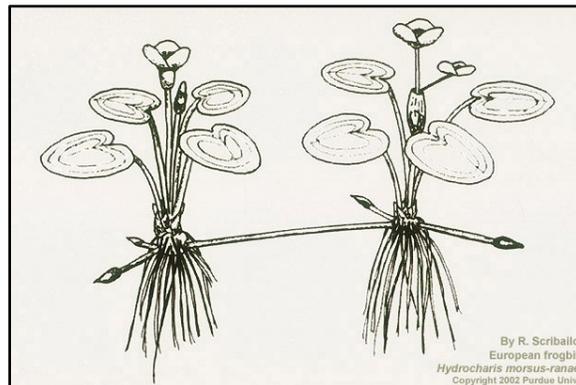


Figure 3. Two EFB plants connected by a stolon

Read about the effects of invasive species from the [National Wildlife Federation](#). Then, find at least one additional webpage or article that addresses the effects of aquatic invasive plants specifically. The webpage or article should come from a reputable source such as a governmental organization, university, or museum.

1. Provide a link to your additional webpage or article below.

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2. Based on your literature search and what you know about EFB, what are two specific ways EFB could affect other plants in the ecosystems it invades? Provide at least one sentence describing each effect.
3. Based on your literature search, what are two specific ways EFB could affect animals in the ecosystems it invades? (*Hint: Some effects could be positive.*) Provide at least one sentence describing each effect.

Activity IV: Create a Data Template

You are a scientist working in Saginaw Bay, Michigan. Based on what you know about the spread of EFB and the impacts of invasive aquatic plants, you are concerned EFB is negatively impacting native species and decreasing the biodiversity of the Bay. You decide to design a **sampling protocol**, or specific steps to collect information about the natural world and address a research question. You have already determined the materials and methods you will need to use to answer your question in Saginaw Bay, but there is another very important step before you are ready to begin sampling: prepare for data collection. Without a solid plan for collecting, organizing, and storing our data, we risk losing the context or losing the data altogether.

Activity IV.A: Set up your digital workspace

Your first step in planning for your data is setting up your digital workspace, which is where you'll store all your data files as you create them. In this case, your workspace will be a single folder on your computer.

1. Create a new folder anywhere on your computer. You will want to choose a location that is easily accessible where the folder will not get lost, such as your computer's Desktop or Documents. Name the folder "BLUE_BuildingDatasets_yyyymmdd." If you begin this module on January 23, 2024, your folder will be named "BLUE_BuildingDatasets_20240123."

Why did we name the folder this way? Here are some important concepts to consider when choosing file and folder names. Names should:

- Be descriptive and concise. Avoid very long file names and instead choose the minimum amount of information needed to remind you what is in the file or folder.
- Use capitalization and underscores to separate parts of the name.
- Avoid special characters such as !@<>?*#/"&. Most special characters are not machine-readable, meaning you will run into problems using these file names in a program like R or Python.
- Include dates in ISO 8601 format (yyymmdd).

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- Be consistent within a project. Ideally, multiple people should be able to use the same workspace with everyone knowing what all names mean and how to create their own names to match.



BLUE_BuildingDatasets_20230123

2. Save this Word document (this module) in your folder. Give it a descriptive name that will make sense to you later on and follows the guidelines above.

Activity IV.B: Translate the sampling protocol to a digital data template

Your digital workspace is ready. Time to make a data template so you can collect your data!

You used data to map the spread of EFB in Activity 1. The GBIF website provides a nice way of visualizing and interpreting data, but you didn't actually see any raw data. So what do data look like? One kind of data that you will encounter frequently are **tabular datasets**, which are groups of columns and rows with values representing each combination. In most cases, columns should contain the types of information collected (**fields**) and rows should contain each piece of information (**observations**).

Columns store fields, or the types of information collected

| | Restaurant name | City | State | Year established |
|---|------------------------|---------------|--------------|-------------------------|
| → | Cochon | New Orleans | Louisiana | 2006 |
| → | Waiahole Poi Factory | Kaneohe | Hawaii | 2009 |
| → | Indian Pueblo Kitchen | Albuquerque | New Mexico | 1976 |
| → | Turtle Tower | San Francisco | California | 2000 |

Rows store individual observations, or the pieces of information

Your data template will need to include spaces for all the data you want to collect in Saginaw Bay. Listing all the fields you want to collect in a table format ensures you don't forget what you need and allows you to easily see mistakes, missing data, or values that don't line up with what you expect. Using a template helps you be efficient in the field, avoid losing data, and makes sharing

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and storing data simpler and less prone to errors compared with unstructured notes. In this activity, you will figure out which data you need to collect and create a template in Excel.

1. Review the sampling protocol below.

Protocol for Sampling Plant Diversity in Saginaw Bay

Sampling will occur for a total of 24 days from June to August. There are 96 plots already set up for sampling, and you will visit each plot once.

1. When you arrive at the sampling plot, use a GPS device to record the latitude and longitude.
2. Record the temperature and amount of dissolved oxygen in the water.
3. Record the depth of the water at the center of the plot using a standard meter stick.
4. Note whether European frog-bit is present or absent in the plot. If present, record the estimated percentage of the plot that is covered, as aerial percent cover (<https://cnhp.colostate.edu/cnhpblog/2009/11/24/field-techniques-percent-cover-estimation/>).
5. Examine European frog-bit for flowers.
6. Record the estimated aerial percent cover of each plant species. Because aquatic plants often overlap, total percent cover may exceed 100%.

2. Make a list of all the fields that will be collected. For example, Step 5 of the protocol instructs you to determine whether EFB is flowering, so EFB flowering is one field. (*Hint: Not all variables that should be recorded are explicitly stated in sampling protocols. For example, you should always record the date and name of collector(s), but this is not always indicated.*)

List of fields (columns) to be collected

EFB flowering

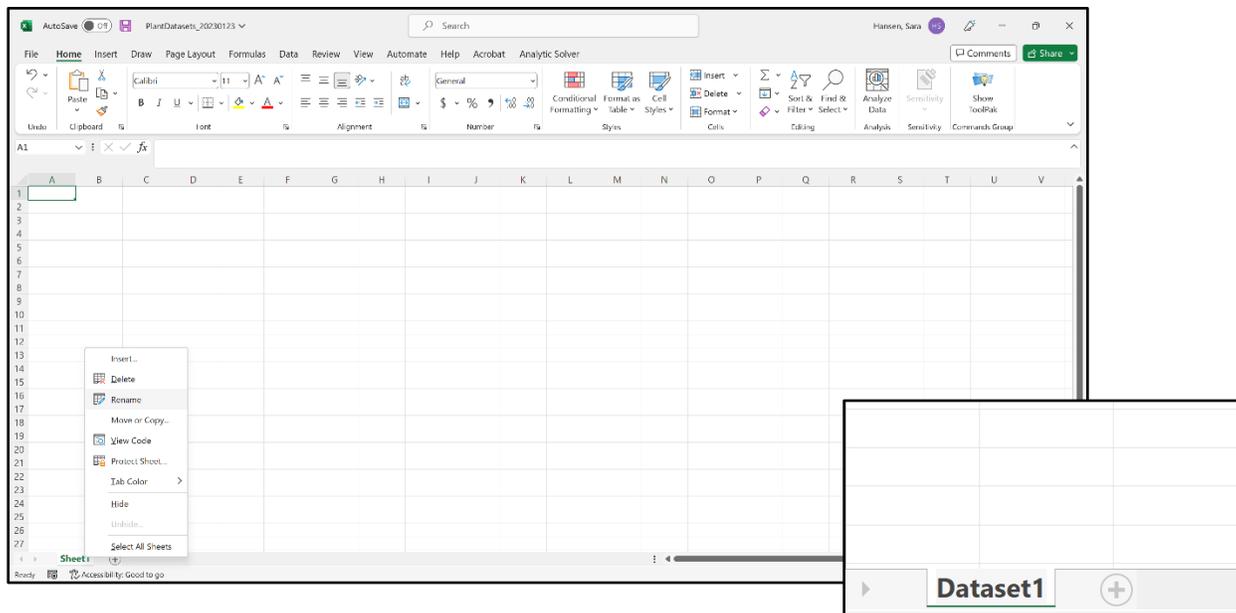


3. Open a blank Excel workbook. Save it in your digital workspace folder using a name that follows best practices as described in Activity IV.

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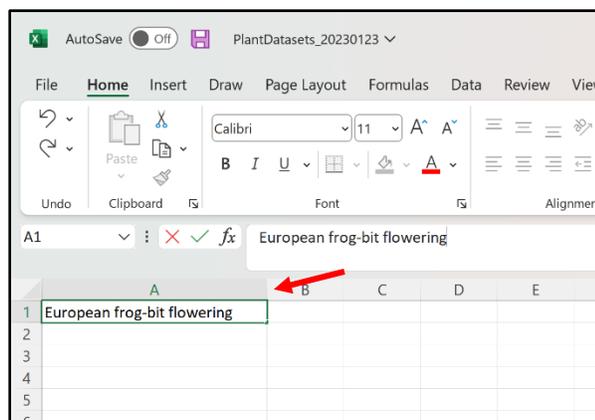
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- Rename Sheet1 to “Dataset1” by right-clicking (Windows) or double-clicking (Mac) the sheet name, selecting Rename, and typing the new name.



- Using your list of fields to be collected from Step 1, type row and/or column names that represent the information. Remember that columns should represent fields, or types of information, and rows should represent observations. In this case, consider each sampling plot an observation.

If your text runs over the cell, resize the column by double-clicking (Windows) or right-clicking (Mac) on the right side of the letter at the top. Create as many rows or columns as you think will be needed and name them however you feel is appropriate. When you are finished with your template, don't forget to save the Excel workbook.



Activity V: Confirm That Your Template Includes All Necessary Fields

Sometimes when you begin sampling, you realize your dataset template is not exactly how you need it for actual data collection. After beginning sampling, you may wish to change your dataset structure. That is perfectly okay! Just remember, you should do this at the very beginning, and once you settle on the structure you should keep it the same throughout the sampling. You

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should never have two separate datasets for the same protocol because then you may not be able to combine them.

Imagine you just sampled your first plot. You recorded your data using your dataset template and found that you had to keep separate notes for information that you didn't have space for in the template. You know that having a dataset and separate notes will not work well for the rest of the plots, so you decide to modify your template now that it is still early in your sampling.

1. Review the extra notes from one sampling plot below.

Plot #1 was located in the northeastern part of the Saginaw Bay shoreline. We started sampling at 10:55 am and finished at 11:13 am. The plot had flowering duckweed *Lemna minor* and fruiting starry stonewort *Nitellopsis obtusa*. No other species were observed.

2. What new fields (columns) should you add to your dataset template that you didn't include before?
3. Add a new sheet to your Excel workbook by clicking the "+" icon along the bottom. Name the new sheet "Dataset2."
4. You will now modify your original template based on the observations from one plot. This is a normal part of the process! Copy and paste your existing template in the "Dataset2" sheet. Add the new columns that you identified as missing based on the example notes.

Why did you create Dataset2 instead of just modifying Dataset 1?

Keeping track of different versions of documents, data, and data templates is always good practice. By creating the new sheet Dataset2 and copying the contents of Dataset1, you are preserving Dataset1 as it was before and can now modify the template in Dataset2. Now you will be able to see what changes you had to make and can improve your template design skills for next time.

5. Consider the impacts of invasive aquatic plants you learned about in Activity III. What are two questions about the impacts of EFB you could address using your data template?
6. Your instructor will provide you with an example template and one row of example data. If there are any fields in the example that you didn't include in yours, what purpose do you think they are serving? Would they be useful for answering your two questions?

Assessment

1. Fill in the blanks in the following sentences using terms in the Word Bank.
 - a. _____ species can be intentionally or unintentionally introduced by humans. They may be beneficial or become invasive and cause harm.
 - b. Invasive species are a threat to global _____, the diversity of organisms on Earth.
 - c. _____ are the units of information.
 - d. A lot of the publicly available data we have comes from _____, members of the public who contribute to scientific efforts.

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- e. Data represents data through graphs and pictures.
- f. In tabular datasets the fields, or types of information you collect, are stored in _____ and observations are stored in _____.
- g. File names should avoid _____, which are not machine-readable and will cause problems when programming.

Word Bank

| | | | | |
|---------------------|---------------|--------------|--------------------|------|
| columns | visualization | non-native | data | rows |
| community scientist | | biodiversity | special characters | |

2. What are three positive or negative ways humans can affect the spread and/or impact of invasive species?
3. You explored the spread and impacts of the non-native invasive species EFB. Now think about a different invasive species in your area (you can look online if needed). Imagine some ways this particular species would impact your area specifically. What is the species and what is one question you want to know that could be tested using data?
4. List the fields you would include in a data template to address your question.
5. You meet another scientist who believes they shouldn't have to worry about organizing their data because they are more concerned with going out in the field and sampling organisms. How would you explain why planning for and organizing data are important for all scientists?

Glossary

Non-native species: Organisms that have been introduced to an area where they did not evolve and do not naturally occur

Travel between continents contributes to the introduction of non-native species to new areas.

Invasive species: Non-native organisms that are causing or likely will cause biological and/or economic harm to native ecosystems

When invasive species outcompete native species for limited resources, they may partially or entirely take over an ecosystem.

Biodiversity: Diversity of living things on Earth or in a particular area

Humans threaten biodiversity by bringing about ecosystem changes that harm organisms and can cause their extinction.

Data: Units of information; provide context and record of knowledge

Scientists communicate information using data, so it is important for all scientists to understand how they work.

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Information: Data in context of specific problem, question, or topic

There is so much information available via the Internet, and much of it came from recorded data.

Knowledge: Acquired understanding; often learned from information

By completing this module, you will acquire knowledge of invasive species and biodiversity datasets.

Scientific literature: Papers written and reviewed by scientists that describe research projects and their results

By writing their methods and results and publishing them as scientific literature, scientists provide records of their research that are useful for other scientists.

Community scientist: Members of the public who are not scientists by career but contribute to scientific efforts

Research scientists can use publicly available data shared by community scientists to better understand local ecosystems and organisms.

Data aggregator: Website or other platform that groups together data from multiple sources

Data generated by research scientists and community scientists is publicly available through data aggregators like GBIF.

Data visualization: Representation of data through graphs and pictures to make them more meaningful in context

After exploring publicly available data, scientists can use data visualization techniques such as mapping to see how the data could be used to address their research questions.

Stolon: Horizontal plant stem that extends out and forms new plants

Because European frog-bit can reproduce via stolons, large populations can form dense mats on the surface of the water.

Sampling protocol: Specific set of steps and methods for collecting information about the natural world

Scientists employ sampling protocols to collect data on non-native species so they can assess whether the species are causing harm to native ecosystems.

Tabular dataset: Collection of rows and columns with values representing combinations

A tabular dataset stores data in a way that is easily readable by humans and machines.

Fields: In a dataset, the types of information collected; usually represented by columns

Two fields that you should always include in your datasets are the date and collector.

Observations: In a dataset, results of individual samples; usually stored in rows

In the vegetation sampling protocol, the observations are the quadrats, so there are 96.

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NOTES TO FACULTY

This module encourages students to explore two main concepts: 1) non-native, invasive plant species and 2) biodiversity data. If you want to teach only one of these concepts, the module can be split as follows.

- To cover only non-native, invasive plant species (how they spread and impact ecosystems), read the Introduction and complete Activities I, II, and III. In the Assessment, complete 1a-d, 2, and 3.
 - Objectives will be:
 - Explain the role of data in monitoring the spread and assessing impacts of non-native species
 - Access publicly available biodiversity data through a data aggregator
 - Visualize and interpret publicly available biodiversity data through mapping
 - Identify ways humans impact the spread of non-native species and data about them
 - Describe the effects of invasive species on plant communities
 - You will not need the associated Excel document.
- To cover only biodiversity data (what are they and how are they organized), read the Introduction and complete Activities III, IV, and V. (Note that Activity III provides important context to make the following data activities make sense.) In the Assessment, complete 1a-c, f, g, 3, 4, and 5.
 - Objectives will be:

- Explain the role of data in monitoring the spread and assessing impacts of non-native species
- Describe the effects of invasive species on plant communities
- Apply vocabulary and concepts related to biodiversity datasets
- Translate plant diversity field sampling protocols to data collection template
- Formulate research questions that could be addressed using data

This module is designed to be able to be completed individually by students. However, it is adaptable for group discussion wherever there are reflection and critical thinking questions. For example, students can work in groups to identify a priority area for management (Activity I question 7), find online literature (Activity III), and list fields to be collected in the data template (Activity IV.B question 2). You may also choose to lead class brainstorming discussions for some questions such as Activity II questions 7 and 8 and Activity V questions 5 and 6.

Activity I: Map the Spread of European Frog-bit

In Activity I, students will be exploring a specific dataset within GBIF. The easiest way to access the dataset directly is through the link provided. Because the dataset may be updated at some point in the future, it is a good idea to complete this activity before having students complete it so that you can determine the correct answers to the following questions. They are correct as written as of 2023-03-06.

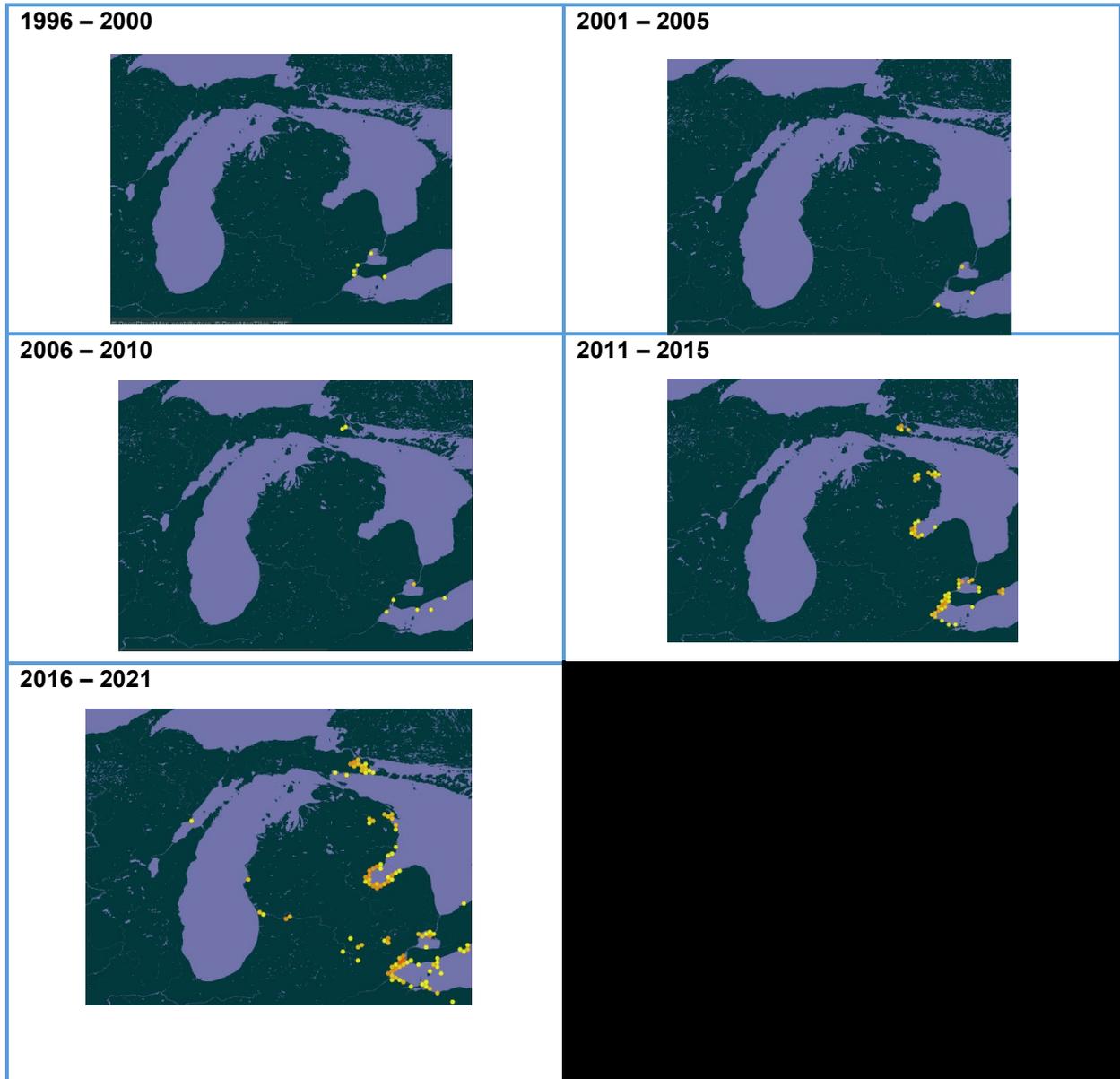
Sometimes the GBIF mapping tool is slow. If any errors occur (e.g., “503” on the map when trying to move the slider), try refreshing the page. Allow plenty of time for this activity.

3. For each of the time periods below, paste a picture of the map showing EFB occurrences in Michigan over those years. You can take a screenshot and crop it to only the map or use the Snipping Tool (accessible via the Search bar on your computer). After pasting your picture, set Wrap Text to In Front of Text so you can move it on top of the table.

| | |
|--|---|
| <p>1932 – 2021 (all time)</p>  | <p>1990 – 1995</p> <p>This is a reference map, before EFB invaded Michigan. Students may be confused about why there are no points. Show them that there are points elsewhere, just not in MI yet.</p>  |
|--|---|

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4. During what time period do you first see EFB in Michigan? 1996-2000
5. Between which time periods do you see the slowest spread? 1996-2000 and 2001-2005
Between which time periods do you see the fastest spread? 2006-2010 and 2011-2015

These questions are asking students to compare two maps from consecutive time periods. Answers may vary and it is up to you which ones to accept. Students may write the slowest spread is between the 1990-1995 map and the 1996-2000 map or the fastest spread is between the 2011-2015 map and the 2016-2021 map. Both show understanding and are acceptable alternatives to the given answers.

6. Conservation professionals want to know how EFB is spreading. Specifically, they want to know how the extent of the non-native range is expanding or contracting in different areas and whether the spread appears to be speeding up or slowing down in different areas. In your own words, describe the spread of EFB based on the maps you created. Address at least one of the two questions listed relative to specific areas of the state and/or time periods.
- 1) The invasion is changing over time by moving further inland in the state, expanding north and west, becoming more dense in invaded areas
 - 2) The invasions appears to be speeding up in most areas, particularly in the southeast portion which had only a few observations up through 2010 and then suddenly got much denser
- Lots of answers are acceptable as long as they show critical thinking about what the maps represent.
7. As you know, scientists and conservation professionals explore and analyze data to make decisions. Now that you have visualized the EFB data by making maps, imagine you are a conservation professional making a decision about where to start some EFB management efforts (like applying herbicides or pulling EFB plants out by hand). You have limited resources so you have to prioritize one area to start with. Which area do you choose and why?
- Again, lots of answers could be acceptable if they are choosing only one areas. A couple options:
- Prioritize the western part of the state because it is most recently invaded and could be “saved.”
 - Prioritize Saginaw Bay, eastern upper peninsula, or southeastern lower peninsula because they are the most dense invasions

Activity II: Explore EFB Data in Michigan Counties

6. How many occurrences of EFB have been recorded in the county? (the answer may be 0)
likely <5000
7. Whether or not you live in Michigan, consider your own county. Imagine EFB spread to your county and became invasive. (*If you live in a country where EFB is native, think about a different invasive aquatic plant.*) Invasive aquatic plants can affect different types of water bodies in different ways. Think of a lake, pond, river, stream, or other water body in your county. What would happen to that water body if EFB were to invade?

Specific questions to consider:

- What types of animals, plants, or other organisms could it affect?
- How would EFB invasion affect the way humans use or interact with that water body? Who in your county would be most impacted by EFB invasion in that water body?

(*Think of the people who rely on the water or surrounding land for jobs, food, or recreation.*)

Students should address at least one of the questions above and may address questions not listed.

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Possible effects on other organisms could be providing food for them, providing habitat, or outcompeting them. It is unlikely that an invasive aquatic plant would directly affect an organism that is not part of the aquatic ecosystem. It is also unlikely for EFB to cause local species to “completely die out” or disappear.

Effects on humans should be relevant to the area and species. A fisher will be negatively affected if EFB causes fish to die more frequently. A landowner might not like how EFB looks in the water. A boater could have a harder time moving through the water if there are thick mats.

8. How would people in your county react to EFB invasion?

Specific questions to consider:

- Would people in your county care about EFB invasion?
- What would people in your county do to stop the spread of EFB or remove it from the water?
- Are there ways people in your county could accelerate the spread of EFB?
- Is there anything you could do to help prevent or stop the spread of EFB in your county?

(Remember, observations recorded by community scientists are significant sources of data for many conservation projects.)

Again, this should be relevant and informed by the student’s understanding of EFB and their community.

Ways humans could affect the spread are provided in the link (carrying on boats/gear, unintentional release from a garden or aquarium, escape from captivity, effects of climate change that is accelerated by humans in specific ways including pollution and overconsumption)

Things the student can do include sharing data when they see EFB, volunteering to help remove it from water, avoiding invasive species as ornamentals, cleaning boots/gear/boats/etc.

Activity III: Investigate Literature on the Impacts of Invasive Aquatic Plants

Read about the effects of invasive species from the [National Wildlife Federation](#). Then, find at least one additional webpage or article that addresses the effects of aquatic invasive plants specifically. The webpage or article should come from a reputable source such as a governmental organization, university, or museum.

1. Provide a link to your additional webpage or article below.

Any source that is reputable and includes information about aquatic invasive plants (must be aquatic, must be plants but the source can include other types of species as well).

2. Based on your literature search and what you know about EFB, what are two specific ways EFB could affect other plants in the ecosystems it invades? Provide at least one sentence describing each effect.

Decreasing light to submerged species, crowding out other floating species, outcompeting them for nutrients, decreasing oxygen, increasing or decreasing pH, decreasing plant diversity

3. Based on your literature search, what are two specific ways EFB could affect animals in the ecosystems it invades? (*Hint: Some effects could be positive.*) Provide at least one sentence describing each effect.

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Negative: Decreasing oxygen in the water that is available for fish and invertebrates, alter water flow or block pathways for animals to travel, altering native plant community that animals rely on

Positive: Food source, habitat (e.g. frogs can sit on the leaves), absorb toxic chemicals to improve water quality

Activity IV: Create a Data Template

Activity IV.B: Translate the sampling protocol to a digital data template

2. Make a list of all the fields that will be collected. For example, Step 5 of the protocol instructs you to determine whether EFB is flowering, so EFB flowering is one field. (*Hint: Not all variables that should be recorded are explicitly stated in sampling protocols. For example, you should always record the date and name of collector(s), but this is not always indicated.*)

List of fields (columns) to be collected

EFB flowering

Full credit if students get all of these (or decide how many they need):

- Date
- Collectors
- Latitude
- Longitude (Latitude and Longitude may be given as one)
- Water temperature
- Dissolved oxygen
- Water depth
- EFB presence/absence
- EFB percent cover
- Percent cover of other species (technically these would be multiple fields, as students will see in the example later on)

Activity V: Confirm That Your Template Includes All Necessary Fields

2. What new fields (columns) should you add to your dataset template that you didn't include before?

Full credit if at least two are given:

- Plot number/name/identifier
- Part of bay/shoreline
- Sampling start time
- Sampling end time
- Flowering status of other species
- Fields for *Lemna minor* and *Nitellopsis obtusa*

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4. You will now modify your original template based on the observations from one plot. This is a normal part of the process! Copy and paste your existing template in the "Dataset2" sheet. Add the new columns that you identified as missing based on the example notes.

When evaluating the student's templates, use the given example dataset (that you will show them for question 6) as a rough guide. Only the top row of the Excel sheet should be filled, because those are the names of the fields (columns). At a minimum, students should have columns for all of the fields they listed.

5. Consider the impacts of invasive aquatic plants you learned about in Activity III. What are two questions about the impacts of EFB you could address using your data template?

A few options (others can be appropriate as well):

- Does EFB affect the number of plant species in a plot?
- Is there an association between EFB and water temperature and dissolved oxygen? (some aquatic plants are known to alter these)
- Does EFB affect the presence/amount of [a specific plant]? (For example, is more EFB associated with less or more *Lemna minor*?)
- Are specific EFB life stages associated with life stages of other plants? (For example, when EFB is flowering are other species not flowering or flowering less often?)
- Does more EFB (greater percent cover) have a greater effect (relative to any of above questions)?
- Is EFB associated with more or less invasive or native species?

6. Your instructor will provide you with an example template and one row of example data. If there are any fields in the example that you didn't include in yours, what purpose do you think they are serving? Would they be useful for answering your two questions?

Show students the Excel template by providing them the file to look at on their own or showing it on your screen/projector. There is a sheet in the Excel template called "InstructorNotes" that provides some instructions for implementation. You should delete that sheet before distributing to students.

There will probably be some fields in the example that students didn't include in their template. This is a good opportunity for students to discuss with each other or as a whole class. Answers will vary and should just demonstrate an understanding of 1) whether the example differs from their own template and 2) how specific fields provide data to answer specific questions.

Assessment

1. Fill in the blanks in the following sentences using terms in the Word Bank.

- a. **Non-native** species can be intentionally or unintentionally introduced by humans. They may be beneficial or become invasive and cause harm.
- b. Invasive species are a threat to global **biodiversity**, the diversity of organisms on Earth.
- c. **Data** are the units of information.

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- d. A lot of the publicly available data we have comes from **community scientist** members of the public who contribute to scientific efforts.
 - e. Data **visualization** represents data through graphs and pictures.
 - f. In tabular datasets the fields, or types of information you collect, are stored in **columns** and observations are stored in **rows**.
 - g. File names should avoid **special characters**, which are not machine-readable and will cause problems when programming.
2. What are three positive or negative ways humans can affect the spread and/or impact of invasive species?

Positive: Remove them from invaded areas, help stop the spread by avoiding them as ornamentals, help stop the spread by washing off boats/gear etc., provide data as community scientists

Negative: Intentionally introduce, unintentionally introduce as ornamentals, spread between waterways on boats/gear, damage ecosystems through climate change/pollution/agriculture/etc. so that invasive species are more likely to establish and/or cause harm

3. You explored the spread and impacts of the non-native invasive species EFB. Now think about a different invasive species in your area (you can look online if needed). Imagine some ways this particular species would impact your area specifically. What is the species and what is one question you want to know that could be tested using data?

The species can be any kind of organism, not just an aquatic plant. Impacts and questions will probably be similar to those in the activities. If students are copy and pasting an impact or question directly from an earlier answer, encourage them to think of something new.

4. List the fields you would include in a data template to address your question.

Students should list at least five fields to demonstrate a basic understanding. More fields are ideal. They will be similar to the fields listed for EFB sampling in Saginaw Bay but should not be copy and pasted.

5. You meet another scientist who believes they shouldn't have to worry about organizing their data because they are more concerned with going out in the field and sampling organisms. How would you explain why planning for and organizing data are important for all scientists?

Again, an answer that isn't copy and pasted from earlier is appropriate if it makes sense in context.