INQUIRY & INVESTIGATION

Is That Minnow in Your Bait Bucket an Invasive Species? An Inquiry-Based Activity for Teaching Taxonomy in College-Level Courses

NABT BioClub RECOMMENDATION

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Abstract

Despite the importance that taxonomy and species identification have in our current understanding of ecology, evolution, and conservation of organisms, it is a challenging topic to teach. One of the primary reasons for this challenge is the lack of student motivation to learn organism classification and identification, which is often reinforced by curricula that do not show the practical value of taxonomic knowledge. This article describes an inquiry-based learning activity designed to show students the real-world value of organism identification. In this activity, students relate the misidentification of baitfish to the spread of invasive species via the baitfish industry. Students role play as fish ecologists and help a bait shop owner identify the specimens in their baitfish supply and subsequently develop a strategy to ensure that the business is not contributing to the spread of invasive species. By relating the field of taxonomy to species invasions, instructors can show students that they are learning information and gaining skills that have utility outside of the classroom. We found this to be an appealing alternative to other species identification activities, which typically focus on low-level learning, and we are excited to share our approach with the readers of The American Biology Teacher.

Key Words: *taxonomy; identification; fish; invasive; inquiry-based; motivation.*

○ Introduction

The field of taxonomy, which focuses on species classification, relatedness, and identification, is critical to our current and continued understanding of evolution, ecology, and conservation of organisms (Winsor, 2009; Tsang et al., 2016). Over the past 20 years, despite the historical and current importance of taxonomy, the natural sciences have entered a "taxonomic impediment" in which resources and numbers of experts have been steadily decreasing, leading to gaps in taxonomic knowledge (Lipscomb et al., 2003; Wheeler et al., 2004). Two primary reasons for the apparent decline of taxonomy are the lack of funding and employment opportunities for strict taxonomists (Coleman, 2015). In academic settings, the disinterest and lack of motivation among students to learn taxonomy and organism identification is reciprocated by instructors and has contributed to the decline of taxonomy (Leather & Quicke, 2010; Cajaiba, 2014; Pisupati, 2015). Teaching organism classification and species identification has multiple challenges, and central issues for many instructors include fostering motivation and promoting higher levels of learning (e.g., application and evaluation; Gotelli, 2004; Baum et al., 2005; Scott et al., 2012; Yamanoi et al., 2012).

Inquiry-based learning (IBL) can significantly promote and improve students' autonomy and intrinsic motivation by emphasizing the role that students have in the classroom (Sansone & Harackiewicz, 2000; Deci & Ryan, 2001; Fink, 2003). IBL activities allow students to think critically about content-based questions and use provided materials to reach their own conclusions, with the instructor serving primarily as a facilitator (Ebert-May et al., 2003). The independence and feeling of ownership that students gain from IBL activities, when compared to traditional lectures, significantly improves overall student learning in biology courses (AAAS, 2011; Kusurkar et al., 2011). Additionally, undergraduates typically want to collect and analyze their own data and apply their findings and conclusions to real-world problems (AAAS, 2011). Although there are many examples of excellent IBL activities for biological and ecological courses (e.g., Heinrich et al., 2017; Bartlow & Vickers, 2020), they are quite rare for taxonomy curricula, especially those with a strong species identification component.

"Species invasions are some of the greatest ecosystem threats in the Anthropocene and can result in species extinctions, reduced ecosystem service value, and even societal conflict."

Here, we provide an IBL activity designed to show students the real-world value of taxonomic knowledge and organism identification. The activity revolves around societal, economic, and ecological issues that arise when organisms are misidentified.

The American Biology Teacher, Vol. 83, No. 4, pp. 240–246, ISSN 0002-7685, electronic ISSN 1938-4211. DOI: https://doi.org/10.1525/abt.2021.83.4.240.

Specifically, students use a role-playing activity to relate the misidentification of baitfish to the spread of invasive species by the baitfish industry.

○ Using Baitfish to Show the Importance of Organism Identification

Baitfish provide an excellent opportunity to link organism identification with real-world environmental issues. Fish species used as bait are often categorized as "target" and "nontarget" baitfish (Drake & Mandrak, 2014) – target species being legal to use as bait and nontarget species being illegal. Nontarget baitfish include invasive species as well as native species that should not be used as bait, including gamefish. Nontarget baitfish are typically used as bait when the specimen is misidentified as a target baitfish or when there is no effort to properly identify a specimen before using or selling it as bait. Further, most baitfish, such as certain minnow, darter, and sucker species, are relatively small-bodied and can be notoriously challenging to identify and differentiate (Schroeder, 2006). Misidentification of nontarget species as target baitfish, when paired with the accidental or purposeful release of unused baitfish into lakes and rivers by anglers, can result in the spread of invasive species (Litvak & Mandrak, 1993; Drake & Mandrak, 2014).

Species invasions are some of the greatest ecosystem threats in the Anthropocene and can result in species extinctions, reduced ecosystem service value, and even societal conflict (Vander Zanden et al., 1999; MEA, 2005; Estévez et al., 2015). By relating the importance of proper organism identification to this current environmental issue, instructors can show students that they are learning information and gaining skills that have utility outside of the classroom. We found this to be an appealing alternative to other species identification activities, which typically focus on low-level learning (e.g., remembering and recall) and result in students learning how to identify organisms for the sole purpose of doing well on summative assessments (Crowe et al., 2008; Pisupati, 2015).

○ Activity Overview & Materials

Objectives & Student Learning Outcomes

Our activity is designed to promote intrinsic motivation and assign real-world value to taxonomy and species identification by relating the misidentification of baitfish to the spread of invasive species via the fishing industry. After the activity, students should be able to (1) identify fish species using a dichotomous key, (2) classify specimens as target or nontarget baitfish, and (3) explain environmental consequences of organism misidentification.

Class Design

In this activity, students work in small groups of three to five and role play as a group of fish ecologists and environmental consultants. Students will be assisting the new owner of a bait shop with the identification of the baitfish being sold (provided by the instructor) and help them develop a strategy to ensure that they are not contributing to the spread of invasive species (the role-playing scenario is detailed below in the "Student Handout Material" section).

This laboratory activity is designed for a college-level biology course that has a strong organism identification component. We implemented the activity in two sections of a lab-based fish ecology course, with 24 students in each section. For each lab section, the activity took 3.5 hours to complete. However, because many courses do not have extended labs, the activity can be split across multiple class periods, as there are multiple distinct components: (1) background information and an introduction to the activity by the instructor; and (2) the role-playing activity, which consists of (a) baitfish identification and classification and (b) developing a strategy that a bait shop owner can implement to avoid spreading invasive fishes. Alternatively, various aspects can be adjusted to complete the activity in a single, shorter class period. For example, instructors can reduce the number of specimens that students identify and assign the written portion of the activity as homework to be completed as a group and turned in at a later time.

Instructor Preparation

We recommend that the instructor read the following four papers while developing their specific lesson plan. The following papers provide useful background information on the baitfish industry and species invasions, as well as the negative environmental consequences of species invasions:

- Litvak & Mandrak, 1993 – "Ecology of freshwater baitfish use in Canada and the United States"
- Drake & Mandrak, 2014 – "Ecological risk of live bait fisheries: a new angle on selective fishing"
- Pimentel, Zuniga & Morrison, 2005 – "Update on the environmental and economic costs associated with alien-invasive species in the United States"
- McKinney & La Sorte, 2007 – "Invasiveness and homogenization: synergism of wide dispersal and high local abundance"

The instructor should determine specific details of the role-playing activity they will be implementing. One key consideration is where the role-playing scenario will take place. Our hypothetical scenario took place in Wisconsin (the state our university is in) because it is legal to use certain live fishes as bait throughout the state. However, if an institution is located in a state where baitfish use is prohibited, the instructor may want to have their scenario take place in a different state or region to ensure that the activity remains realistic. The instructor should make a list of target baitfish and possible invasive fish species in the state in which the scenario is taking place. We have provided example baitfish lists for Wisconsin and Minnesota, which can be used if the instructor chooses either of those states for the scenario (Table 1). Descriptions of baitfish regulations, target (legal) baitfish, and invasive fishes can be found in state fishing regulation handbooks, which are typically available anywhere fishing licenses are sold or on state department of natural resources websites (WI DNR 2019; MN DNR 2020).

Finally, the instructor should ensure that all needed materials are accounted for – the baitfish samples (detailed below) can take up to two weeks to prepare and organize, especially if the instructor is unable to purchase baitfish and has to collect all of their own specimens.

Materials

- Becker, 1983 – "Fishes of Wisconsin" (or regionally appropriate dichotomous key)
- Hand lenses or magnifying glasses
- Nitrile gloves

Table 1. Common fishes in Wisconsin and Minnesota that may or may not be target (legal) baitfish. Note that there are differences in species that can be used as bait between the two states, and this is not an exhaustive list of species that are nontarget baitfish.

Fish Species or Group	Wisconsin		Minnesota	
	Target Baitfish?	Invasive Species?	Target Baitfish?	Invasive Species?
Species in Cyprinidae [a]	Yes	No	Yes	No
Suckers	Yes	No	Yes	No
Mudminnow	Yes	No	Yes	No
Madtom	Yes	No	Yes	No
Stonecat	Yes	No	Yes	No
Killifish	Yes	No	No	No
Topminnow	Yes	No	No	No
Silverside	Yes	No	No	No
Sticklebacks	Yes	No	No	No
Trout-perch	Yes	No	No	No
Darters	Yes	No	No	No
Sculpins	Yes	No	No	No
Bullhead	No	No	Yes	No
Cisco	No	No	Yes	No
Lake Whitefish	No	No	Yes	No
Mooneyes	No	No	Yes	No
Goldeyes	No	No	Yes	No
Goldfish	No	Yes	No	Yes
Common Carp	No	Yes	No	Yes
Round Goby	No	Yes	No	Yes
Largemouth Bass	No	No	No	No
Northern Pike	No	No	No	No
Brook Trout	No	No	No	No
Channel Catfish	No	No	No	No

[a] Not all species in the family Cyprinidae are target baitfish. Goldfish and common carp are in Cyprinidae but are illegal to use as bait and are invasive.

- Wash bottle filled with tap water
- Paper towels
- Glass jars with preserved baitfish (detailed in the next section below)
- Plastic trays
- Student activity worksheet (which should include the material in the "Role-Playing Scenario" and "Student Instructions, Prompts & Questions" sections below)
- List of target baitfish species and invasive species that students might find
- Data collection sheet (Table 2)

Baitfish Samples

Glass jars with ≥24 preserved baitfish specimens (or fewer if there are time constraints) will be distributed to each group (one jar per group). Having baitfish collected from a relatively local bait shop is a particularly appealing aspect of this activity, as it provides students with additional intrinsic motivation to engage. However, we realize that this may not be possible everywhere. In these locations, collecting minnow and other small-bodied fish species with an institutional collection permit will serve the same purpose. We purchased fish from a store in Wisconsin that offered a "minnow mix" baitfish selection. Fish were preserved initially in 10% formalin and transferred to 70% ethanol for permanent preservation (Kumar & Hassan, 2015). Because we were able to purchase a "minnow mix," which included target bait species and nontarget baitfish, we did not add additional specimens to the baitfish jars before distributing them to students. However, because certain regions do not permit the sale of "minnow mixes," different species (e.g., fathead minnows, golden shiners, and creek chubs) can be purchased separately and mixed together prior to the activity to serve the same purpose. Preserved specimens of invasive species (e.g., small common carp or round gobies) or native species not intended for baitfish use (e.g., northern pike or largemouth bass) can also be added to the baitfish jars before students begin the activity. Adding additional specimens ensures that students will identify species not intended for bait use

Table 2. Data sheet for students to complete while identifying baitfish specimens. We provide six examples of potential target and nontarget baitfish specimens found in a baitfish sample.

Species	Target Baitfish?	Invasive Species?	Identifying Characteristics	Number in Sample
Fathead Minnow	Yes	No		15
Common Carp	No	Yes		1
Largemouth Bass	No	No		2
Goldfish	No	Yes		1
Brook Stickleback	No	No		2
Common Shiner	Yes	No		3

and shows the utility of taxonomic knowledge and proper identification in the fishing industry. Although adding specimens to the baitfish jars takes away some realism of the activity, if students identify only two or three species of target baitfish, the activity loses its primary purpose of demonstrating potential transport of invasive species. Finally, we recommend having an even distribution of both the number of species and the number of specimens in each jar. Although there will still be inherent variability among student groups, this minimizes the chances of groups having vastly different species and numbers of specimens to identify. The instructor should go through the baitfish that will be distributed to the students to be sure they know which species are present. This will ensure that the instructor can play the role of facilitator and properly guide students when they have questions or become confused while identifying specimens.

We had the necessary Institutional Animal Care and Use Committee (IACUC) and state scientific collectors permit necessary to collect, preserve, and use fish specimens for teaching purposes. The instructor must obtain the necessary institutional permits to preserve and use vertebrate specimens in a classroom setting.

Beginning the Activity

In the beginning of class, the instructor should give an overview of the relationship between the recreational baitfish industry and the spread of invasive species. Additionally, giving a brief description of the negative ecological and environmental consequences of species invasions will help set the stage for the activity. The instructor should also go over baitfish regulations and target (legal) and nontarget (illegal) baitfish in their state. Even though students will be given a list of target baitfish, this will introduce students to specimens they might have in their baitfish sample.

Depending on the students' experience identifying fishes, it may be necessary to cover general characteristics of common baitfish species in the area. Fathead minnows, golden and common shiners, darters, and suckers tend to be common baitfish species throughout the United States (Drake & Mandrak, 2014). However, if students have a firm grasp on external anatomy of fishes and appropriate terminology, a well-written dichotomous key (such as Becker, 1983 – "Fishes of Wisconsin") will suffice.

Implementing the Activity

After the instructor has provided background information and explained the activity, students should get into their groups of three to five and receive their baitfish sample (the jar of baitfish), a plastic tray, a dichotomous key, magnifying glasses, a wash bottle, and, if desired, gloves. Initially, students will remove all baitfish from their jar. Before attempting to identify specimens, we recommend that students sort fish into broad groups based on body shape and general appearance (Figure 1). It can be overwhelming to students when they first remove dozens of fishes onto their trays, so initially sorting them into broad groups can help alleviate some of that stress. All fishes should stay wet (tap water is fine) throughout the identification process to avoid desiccation. As previously mentioned, these fishes can be challenging not only to identify, but also to differentiate among species. Fish identification can be a frustrating process for students, so it is important for the instructor to normalize the struggle of identification to ensure students that they are not alone in the challenge. Walking through the dichotomous key with students when they begin to misidentify specimens can be extremely helpful and shows students that it can be a tedious process – and that is OK!

While identifying specimens, students should fill out their data sheet (Table 2) while referencing the list of target and invasive species. Specimens will be categorized as target baitfish; nontarget baitfish but a native species; or nontarget baitfish and an invasive

Figure 1. An example of what students might see when they remove the baitfish specimens from their jars. Fathead minnows (**A**), golden shiners (**B**), and brook sticklebacks (**C**) are target baitfish in Wisconsin. Common carp (**D**), however, are invasive minnows.

species. For simplicity, we assumed that all nonnative fish species had the potential to be an invasive species. After identification and classification, students should work together in their groups to answer questions 1–5 on their handout. However, if there are time constraints, the questions on the handout can be assigned to students as homework.

○ Student Handout Material

Role-Playing Scenario

A bait shop called [instructor should use creative freedom to come up with a name] in [state or specific region of the instructor's choice] has been sold to a new owner and is now under new management. The new owner, like many baitfish retailers, is aware of the threat that baitfish use and transport can have on recipient aquatic ecosystems. The owner is less than impressed with the current organization of baitfish being sold by the store. The bait shop currently has a single, aerated tank labeled "minnow mix" that houses all the baitfish. The owner also noticed that there are multiple species in the tank. The owner and management team want to change how they organize baitfish in the store to ensure that they are not contributing to the spread of invasive species. The new owner, wanting the expert advice of fish ecologists, decides to hire outside consultants (you and your group of colleagues) to identify the specimens and make a recommendation on how best to proceed in order to reduce potential impacts of their baitfish on recipient ecosystem.

Student Instructions, Prompts & Questions

1. Remove the baitfish specimens from your random grab sample of baitfish and identify them to species. Which species are currently in the "minnow mix" baitfish tank? Are any of the fishes invasive? Which species, when misidentified as target baitfish, are most concerning from an ecological standpoint? Complete your data sheet as you go.
2. How do you recommend that the new shop owner and management team organize their baitfish to ensure they are not contributing to the spread of invasive species? What training might the management team or employees need to take to make sure the organization remains consistent?
3. While completing your survey of baitfish, you talk with three different anglers who are purchasing bait from the store. You ask them where they plan to use the baitfish. What would you tell each angler about their plans to use baitfish during their trips? What recommendations about their baitfish use would you give each of them?
    1) Angler 1 is going to fish in a small, private lake that is nearby but has very few fish species.
    2) Angler 2 is going to fish in a river for a day in the same county as the bait shop but is then going to a river six hours away and plans on using the same baitfish.
    3) Angler 3 is passing through town on their way to fish in a different state, and just figured they would stop and get baitfish at the shop.
4. Based on your baitfish survey and interactions with the anglers, you also decide to make a recommendation to the new store owner about resources that should be provided to anglers when they purchase bait. What resources would you recommend?
5. What are some of the potential ecological and environmental consequences of misidentification of baitfish species?

Potential Student Responses

Student responses to the questions on the student handout will likely vary among groups in a single class and among classes at different institutions. The following are some ideal student responses with explanations, as well as common responses that we received while implementing this activity:

1. Answers for this question will be highly variable, based on the location of the bait shop, the fish that are native to the region, and whether the instructor adds additional specimens to the baitfish jars. However, students will likely identify a mix of target and nontarget baitfish, as well as invasive specimens. Students should recognize that the misidentification of invasive species as target baitfish is the most concerning misidentification.
2. Students should state that the new bait shop owner should have separate tanks for individual species, and that the specimens should be sorted and identified properly before being sold. Some of our students noted that the processes of identifying every specimen would be very tedious and time consuming. Those students then recommended that the bait shop hire a part-time employee to specifically ensure that fishes are properly identified and sorted. Students should identify the need for bait shop employees to be properly trained on how to differentiate the fishes that commonly get put into their tanks – both target and nontarget baitfish species. A common response from our students was that the owner should provide a dichotomous key for the fishes that are commonly found only in the tanks, as opposed to a comprehensive key for all fishes in the region. Similarly, some students suggested that, at a minimum, employees be trained on how to identify common invasive species. We thought these were especially great responses because they showed a balance of the students' recognition of the importance of taxonomy and the challenges associated with identification.
3. *Angler 1:* Students should identify that this angler can use the baitfish they purchased on the small, local lake. However, they should also note that the angler should not intentionally release their live baitfish when they are done fishing because they could introduce species that, although native to the area, may not be found in that specific lake.

    Angler 2: Similar to angler 1, students should recognize that the angler can use their baitfish in the relatively local river but should not release their baitfish. However, students should also say that they would tell the customer to not use the same baitfish in the river six hours away. They should suggest that the angler purchase different bait at a bait shop near the second river.

    Angler 3: Students should tell angler 3 that they should not purchase bait this far away from their fishing destination and recommend that they find a bait shop closer to the water body.
4. Students will likely come up with various suggestions for the bait shop owner. Many of our students recommended

that the bait shop employees distribute cards or flyers with pictures and identifying characteristics of nontarget baitfish to customers. They noted that many anglers will want to make their purchase quickly and leave the store, and so it wouldn't be feasible to give them an in-depth lesson about fish identification. Still, providing anglers with information about the risk of releasing misidentified baitfish and material to help them recognize certain nontarget baitfish would provide another line of defense beyond the bait shop employees.

5. Students should recognize that misidentification of baitfish can result in the spread of invasive species and lead to major ecological issues, including biotic homogenization and extinction of native species. Ideally, students should be able to give a correct response to this question after the assigned pre-reading and the activity introduction by the instructor. However, we chose this to be the last question on the worksheet to emphasize the importance of taxonomy and reinforce the practical, real-world value of organism classification. This question served as a good reminder for the students after completing a challenging activity.

○ Conclusion

The activity we designed includes multiple lesson-plan characteristics recommended by AAAS (2011). Specifically, it uses an IBL approach that demonstrates the real-world value of the topic being covered. Additionally, it allows students to collect their own data and apply it to a realistic, hypothetical problem that a business owner might encounter. By implementing this activity, we were able to show students that the ability to properly identify species is an important skill to have and that misidentification of organisms can lead to environmental crises. We found that this activity increased student motivation, and we believe that it has the capability to improve student learning in biology courses that have at least a small portion devoted to taxonomy and identification. We are excited to share our approach with the readers of *The American Biology Teacher*.

○ Acknowledgments

We thank Dr. Devin Wixon for assistance and advice with designing the activity.

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