TALES OF FRESHWATER FISH SPECIATION: BUILD YOUR OWN DICHOTOMOUS KEY

Kaite Cisz
Virginia Institute of Marine Science

Grade Level
9-12

Subject Area
Biology & Environmental Science

VA SEA is a collaborative project between the Chesapeake Bay National Estuarine Research Reserve, the Virginia Institute of Marine Science's Marine Advisory Program, and Virginia Sea Grant. The VA SEA project is made possible through funding from the National Science Foundation and William & Mary's Society of 1918 Endowment.

Title: Tales of Freshwater Fish Speciation: Build Your Own Dichotomous Keys

Focus: Applying skills acquired in younger grade levels on the application of dichotomous key to have students build their own utilizing freshwater fishes from Virginia housed at the Virginia Institute of Marine Science (online photographs or collection-based specimen loans).

Grade Level: High school Biology (9^{th}-12^{th}), AP Biology, and AP Environmental Science

Virginia Standards of Learning:

BIO.1/LS.1 The student will demonstrate an understanding of scientific and engineering practices by (b) planning and carrying out investigations and (f) obtaining, evaluating, and communicating information.

BIO.6 The student will investigate and understand that modern classification systems can be used as organizational tools for scientists in the study of organisms. Key ideas include (a) organisms have structural and biochemical similarities and differences, (c) developmental stages in different organisms can be used to classify organisms, and (f) systems of classification are adaptable to new scientific discoveries.

LS.3 The student will investigate and understand that there are levels of structural organization in living things. Key ideas include (c) similar characteristics determine the classification of organisms.

Learning Objectives:

✓ Students will utilize knowledge built in earlier grade levels on the applications of dichotomous keys and apply this knowledge to build their own keys.
✓ Students will understand how to classify species of freshwater fishes from Virginia and build on their skills by developing their own dichotomous keys, either utilizing the Nunnally Ichthyology Collection samples, or high-resolution photographs of these collection specimens.

Total length of time required for the lesson:

~40-60 minutes.

Vocabulary: **(review with students <u>before or during</u> the lesson as needed)**

- **Speciation (four types: allopatric, sympatric, parapatric, and peripatric speciation)**: the process by which new species arise (mutations, geographic distancing, etc.) across generations.
    - **Allopatric speciation** - a physical barrier leads to new species arising.
    - **Sympatric speciation** - adaptations occurring within the same region leads to a new species arising.

    - **Parapatric speciation** - partially separated geographical barriers (i.e., habitat loss) limiting gene flow leading to new species arising.
    - **Peripatric speciation** - isolation from the main grouping of the species across space and time leads to new species arising.
- **Dichotomous key**: an identification tool used by scientists to identify organisms based on a series of grouped categories that lead the user to the correct classification, or name.
- **Characters**: traits, used to best identify organisms.

Background Information:

A dichotomous key is an identification tool used by scientists to identify organisms based on a series of grouped, or alternate, categories that lead the user to the correct classification, or name. This tool is introduced to the Virginia curriculum in late elementary school and the SOLs require students to continuously build on this skill of classification in more complex contexts throughout their education. As a scientist, the ability to properly identify organisms in the field is critical for accurate management. However, when you have several species that look similar, sometimes this task is tricky, and building dichotomous keys are important for their fast and accurate identification. In the classroom, this skill can be fostered, and this lesson plan aims to "flip the classroom," allowing high school students to use what they know to now build their own dichotomous keys! This lesson also offers the opportunity for students to learn more about the Virginia Institute of Marine Science Nunnally Ichthyology Collection, established in the 1950s, with potential for classroom interactions with these freshwater fishes. Collections serve as a library of fishes, allowing for a representative animal in time and space to be preserved for science, education, and beyond!

Materials & Supplies:

Photographs of the fishes or collection specimen classroom loans ("collection baskets") are available for classrooms.

- **Photographs**: This can be done in two formats, online or as print outs. The key to this activity is that color is often not a good character, so black and white photographs would be sufficient.
    - Online: Please use the provided PowerPoint slides to assign each group one slide at time to identify key characters of each fish. Students can do so in groups using classroom technology provided.
    - Printed: Please print and cut each of the seven fishes and provide one to each group. Groups will pass the fishes after each rotation.
- **Collection Baskets**: The Virginia Institute of Marine Science (VIMS) Nunnally Ichthyological Collection serves as a library of fishes that can be loaned and used in your own classroom! VIMS policy is to *lend, donate, and exchange material freely* and each request is subject to

review by the collection manager, Sarah Huber. *All costs of processing and shipping specimens are covered by VIMS, and detailed records of all transactions are maintained.*

- To arrange a loan for your classroom, please contact the collection manager (Sarah Huber) with plenty of time for your request prior to teaching the lesson in your classroom, referencing this lesson plan for the correct specimens requested: **contact the collection manager**.
- Note: all fishes must be returned in proper condition.
- (more information: https://www.vims.edu/research/facilities/fishcollection/overview/)

Teacher Preparation:

To review previous concepts on dichotomous keys please feel free to utilize previous lesson plan published by VA SEA in Spring 2024: **Fish Detectives: Identifying Fishes Using a Dichotomous Key** (**https://www.vims.edu/research/units/centerspartners/map/education/profdev/VASEA/vasea_dichotomouskeys_cisz2024.pdf**). This lesson plan targets younger audiences (4^{th}-8^{th} grade) and can be utilized as a homework assignment before this lecture is conducted to refresh students on this skill.

Decide how specimens will be utilized in the classroom (online or in person baskets) and allow at least one month for loan collection baskets to arrive if this option is selected.

Procedure:

1. To re-familiarize students with dichotomous keys (as needed) a previous lesson plan published by Kaitlyn Cisz can be utilized as an in-class review, homework assignment, or up to the discretion of the teacher. **Fish Detectives: Identifying Fishes Using a Dichotomous Key**
    a. **Lesson Plan (PDF):** **https://www.vims.edu/research/units/centerspartners/map/education/profdev/VASEA/vasea_dichotomouskeys_cisz2024.pdf**
    b. **PowerPoint and Handouts:** **https://www.vims.edu/research/units/centerspartners/map/education/profdev/VASEA/lessons.php**
2. Prepare specimens: either request loans (at least one month in advance) or photographs.
3. Review key vocabulary with students (as needed) and utilize PowerPoint in the classroom (as needed).

Assessment:

Activity questions and various reflection checkpoints are found within each lesson plan. This should be used to help gauge student understanding of the material and highlight any areas of further assistance or attention going forward.

References:

Online images were drawn by and belong to Kaitlyn Cisz (krcisz@vims.edu). If any questions arise, please contact krcisz@vims.edu. All freshwater fish photographs were taken by and belong to Miguel Montalvo and Larsen Palmgren. If any questions arise, please contact mmontalvo@vims.edu and ltpalmgren@wm.edu respectively. For potential access to a Nunnally Ichthyology Collection "basket" of loaned fishes for the dichotomous key activity (in-person pick up or mail) please contact Sarah Huber at skhuber@vims.edu. Specific loan instructions can be found under the Materials & Supplies section listed above.

Handouts/Worksheets:

Tales of Freshwater Fish Speciation: Build Your Own Dichotomous Keys

Name_____

Date_____

Activity 1: What is a species?

Scientists have long argued, and are still arguing, about the best way to define a **species**. In biology, we define a species as a group of individuals that can or already does interbreed. These species are then named using a universal standard known as **binomial nomenclature**, or the combination of two words using the genus and species in Latin. Around the globe, several languages are spoken and result in varying common name for species – think of this like a nickname. However, all scientists follow binomial nomenclature to communicate species the same globally. In this case, organisms are referred to, or classified, in italics with the genus capitalized first, followed by the species lowercase. For example, you, as a human, are known as *Homo sapiens*. In this case *Homo* is the genus and uppercase, while *sapiens* is the species and lowercase.

Let's practice. Please google and write the scientific names for the following organisms based on their English common names:

1. Striped bass _____
2. Atlantic horseshoe crab _____
3. Bluefin tuna _____
4. Clearnose skate _____
5. An animal of your choice: _____ _____

Although classifying organisms into their appropriate species names seems like an easy task, this field is always changing! Over time, mutations, land barriers, or even far distance from one another leads to new species to arise, otherwise known as **speciation**. This speciation can occur in a variety of ways such as a physical barrier (**allopatric speciation**), adaptations occurring within the same region (**sympatric speciation**), partially separated geographical barriers limiting gene flow (**parapatric speciation**), or even isolation from the main grouping of the species (**peripatric speciation**).

Below, please match the scenario exemplified to the correct type of speciation:

__Allopatric speciation
__ Sympatric speciation
__ Parapatric speciation
__ Peripatric speciation

a. Cichlid species, like Bluegill and Pumpkinseed Sunfish, are both in the same area but occupy different niches.
b. The Appalachian Mountains created an east versus west separation of Blacknose Dace.
c. The Virginia Slope Darter is distinct because it is isolated from other darters.
d. With habitat loss, there is a now a boundary between rocky substrate and habitat with sediment only for some fish species.

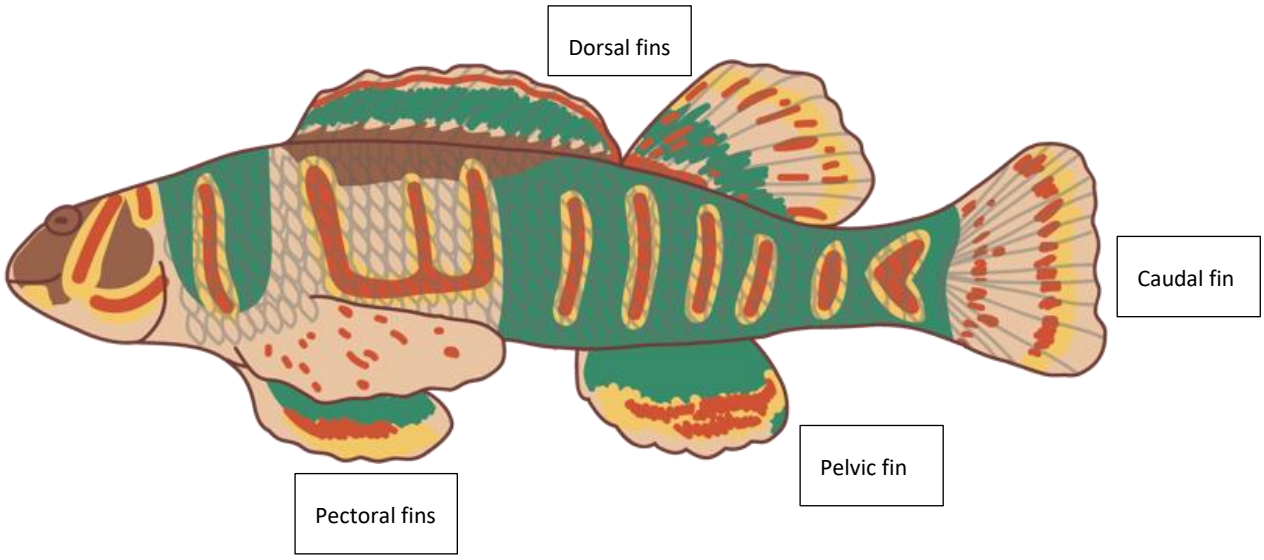
Defining a species and understanding why speciation occurs is only the first step. Scientists then have to identify and classify these organisms by their species names. The best way to do so: **dichotomous keys**.

Activity 2: REVIEW – How to select "good" characters?

Before we can build a dichotomous key, we have to understand what characters, or identifying traits/features, make a "good" character. In other words, there is no such thing as a key feature that is "good" or "bad" but some characters tell us more than others! They allow us to group species by their similarities and distinguish different species by their major differences. It is *your* job as a scientist to find characters that tell us the most about our animals!

Below we will practice how you can look at a fish and pick out characters that may be more helpful when building our dichotomous keys! Unfortunately, color is often **not** a good character to use to identify fishes because their colors can change throughout the year (i.e., breeding) or lose their color in a fish collection based on the chemicals they are stored in (i.e., ethanol). Some "good" characters to look for may be: shape of the head (i.e., round vs blunt), shape of the tail (round vs forked), striping patterns, size of the eye, etc.

Let's practice on Cynthia the Candy Darter, *Etheostoma osburni*, below.



What observations can you make about Cynthia that may make "good" characters for a dichotomous key?

Great work! Now, let's work with some real fishes to build your own dichotomous keys…

Activity 3: Dichotomous Key – Build Your Own!

Now that you have learned and practiced how a dichotomous key works, it is your turn to create one! Since 1970, graduate students, undergraduate students, and invited scientists at the Virginia Institute of Marine Science (VIMS) have attended "Roanoke Round-up." This field trip to the Appalachian rivers and streams of western Virginia is important to study the evolution of these freshwater fishes. After the fish are collected, they are identified using dichotomous keys and labeled in jars to be preserved and added to a collection. This collection, known as the Nunnally Ichthyology Collection at VIMS, serves a library for fishes, with their labels detailing the time, location, and species collected.

Using the fish in front of you please write down all the characteristics, or "good" characters, you think make this fish identifiable:

Fish ____:

You are now the expert of your fish in your new group! Each of you need to take turns sharing what characters you each found about your fish with the group, taking notes as you go!

Fish A	Fish B	Fish C	Fish D	Fish E	Fish F	Fish G

Using a colored marker, **circle** what characters are unique to each fish in your columns.

Using a pencil, **underline** any shared characters you have found and write them down in the space below with the shared character and any fishes that share with character:

Now, use the space provided to try and build your own dichotomous key! This can be tricky, but remember, you write two similar characters and direct the guide using “go to #...” format! For example, your guide *may* look like:

1.
    a. The fish has a rounded tail… go to number 2
    b. The fish has a forked tail… go to number 3

The key to building this identification tool is to start with the most shared characters and end with the unique characters used to classify each fish you circled above!

Once you are done, switch papers with someone outside of your group and try each other’s keys out to make sure they work!

Activity 4: Reflection

1. In one or two complete sentences, explain why classifying species is important.

2. What was the most challenging part about creating your dichotomous key? Fully explain your answer in complete sentences for full credit.

3. How many fish species did you classify correctly with your dichotomous key? _____

4. What could you have done differently to increase the accuracy of your dichotomous key?

5. Why would your answer to question #4 allow you to correctly identify more fish? Answer in complete sentences.

Answer Keys:

Tales of Freshwater Fish Speciation: Build Your Own Dichotomous Keys

(~40-60 minutes)

Name_____

Date_____

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Let's practice. Please google and write the scientific names for the following organisms based on their English common names:

1. Striped bass _____***Morone saxatilis***_____
2. Atlantic horseshoe crab _____***Limulus polyphemus***_____
3. Bluefin tuna _____***Thunnus thynnus***_____
4. Clearnose skate _____***Rostroraja eglanteria*** _____
5. An animal of your choice: ___ **Ex. Red fox** __ ____ ***Ex. Vulpes vulpes*** _____

Although classifying organisms into their appropriate species names seems like an easy task, this field is always changing! Over time, mutations, land barriers, or even far distance from one another leads to new species to arise, otherwise known as **speciation**. This speciation can occur in a variety of ways such as a physical barrier (**allopatric speciation**), adaptations occurring within the same region (**sympatric speciation**), partially separated geographical barriers limiting gene flow (**parapatric speciation**), or even isolation from the main grouping of the species (**peripatric speciation**).

Below, please match the scenario exemplified to the correct type of speciation:

_**b**_Allopatric speciation

_**a**_ Sympatric speciation

_**d**_ Parapatric speciation

_**c**_ Peripatric speciation

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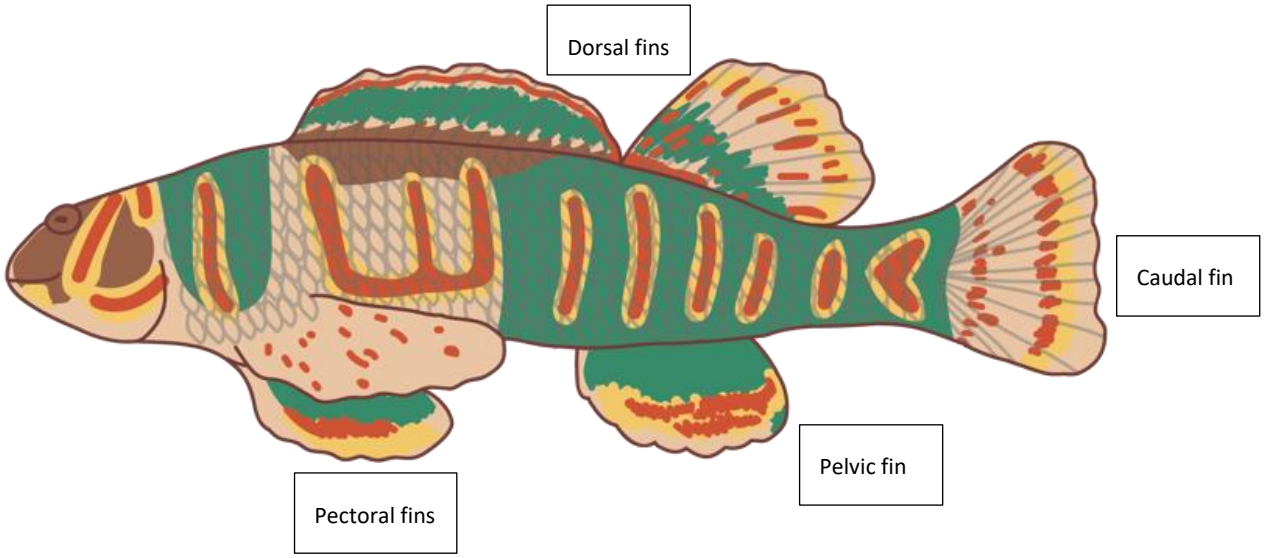
Below we will practice how you can look at a fish and pick out characters that may be more helpful when building our dichotomous keys! Unfortunately, color is often **not** a good character to use to identify fishes because their colors can change throughout the year (i.e., breeding) or lose their color in a fish collection based on the chemicals they are stored in (i.e., ethanol). Some "good" characters to look for may be: shape of the head (i.e., round vs blunt), shape of the tail (round vs forked), striping patterns, size of the eye, etc.

Let's practice on Cynthia the Candy Darter, *Etheostoma osburni*, below.



What observations can you make about Cynthia that may make "good" characters for a dichotomous key?

Answers will vary. Students *may* say: Rounded tail, two dorsal fins, stripes along the body, rounded ("blunt") head/nose, stripe on head, oval scale shape, etc.

Great work! Now, let's work with some real fishes to build your own dichotomous keys…

Activity 3: Dichotomous Key – Build Your Own!

Now that you have learned and practiced how a dichotomous key works, it is your turn to create one! Since 1970, graduate students, undergraduate students, and invited scientists at the Virginia Institute of Marine Science (VIMS) have attended "Roanoke Round-up." This field trip to the Appalachian rivers and streams of western Virginia is important to study the evolution of these freshwater fishes. After the fish are collected, they are identified using dichotomous keys and labeled in jars to be preserved and added to a collection. This collection, known as the Nunnally Ichthyology Collection at VIMS, serves a library for fishes, with their labels detailing the time, location, and species collected.

This answer key will vary based on fish selected for the final draft. Divide the students into 7 groups and give them ten minutes to complete the first portion of the activity, to identify key characters of their assigned fish.

Using the fish in front of you please write down all the characteristics, or "good" characters, you think make this fish identifiable:

Fish __**#**__:

Answers will vary depending on starting fish (see chart below).

Once the students finish looking at their fish, take one member from each group, and form 7 new groups to have a "jigsaw activity."

You are now the expert of your fish in your new group! Each of you need to take turns sharing what characters you each found about your fish with the group, taking notes as you go!

Student observations will vary and students may focus on different characters they see. Some key characters *could* be:

Fish A	Fish B	Fish C	Fish D	Fish E	Fish F	Fish G
• Rounded ("blunt') head/nose • Rounded tail • Diamond pattern around the center of the body • Stripe by eye • Rounded dorsal (top) fins	• One dorsal ("top") fin • Forked tail • Diamond shaped scales	• Rounded ("blunt') head/nose • Rounded tail • Light coloration near edge of fins	• Pointed head/nose • Rounded tail • Dark coloration at the tip of the fins • Two dorsal fins	• One dorsal fin • Forked tail • Long head/nose	• Rounded ("blunt") head/nose • "scales" on head • Small, colored eye • Forked tail • One dorsal (top) fin	• Rounded ("blunt") head/nose • Big eye • Stripe through eye • Vertical stripes on the body • Rounded tail

Using a colored marker, **<u>circle</u>** what characters are unique to each fish in your columns.

Using a pencil, **<u>underline</u>** any shared characters you have found and write them down in the space below with the shared character and any fishes that share with character:

Now, use the space provided to try and build your own dichotomous key! This can be tricky, but remember, you write two similar characters and direct the guide using “go to #...” format! For example, your guide *may* look like:

2.
    c. The fish has a rounded tail… go to number 2
    d. The fish has a forked tail… go to number 3

The key to building this identification tool is to start with the most shared characters and end with the unique characters used to classify each fish you circled above!

Once you are done, switch papers with someone outside of your group and try each other’s keys out to make sure they work! - **Once done, have groups swap their dichotomous keys and see if they work! If needed, individuals can make their own keys for all fishes to practice this skill instead of doing a jigsaw activity.**

Activity 4: Reflection

1. In one or two complete sentences, explain why classifying species is important.

We need to properly identify fishes in order to know what we caught and create policies to protect them.

2. What was the most challenging part about creating your dichotomous key? Fully explain your answer in complete sentences for full credit.

Answers will vary. The point of this question is to have a group discussion about the activity and dichotomous keys.

3. How many fish species did you classify correctly with your dichotomous key? __**0-7**___

4. What could you have done differently to increase the accuracy of your dichotomous key?

Answers will vary. Pick better characters, look carefully at all fishes, etc.

5. Why would your answer to question #4 allow you to correctly identify more fish? Answer in complete sentences.

Answers will vary. For example, spending more time on each fish may be helpful to pick better characters for students who in this activity may have worked at a fast pace.

Appendices:

Fish A: Snubnose Darter, *Etheostoma simoterum*

Image Credit: Miguel Montalvo & Larson Palmgren

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Fish B: White Shiner, *Luxilus albeolus*

Image Credit: Miguel Montalvo & Larson Palmgren

Fish C: Wounded Darter, *Etheostoma vulneratum*

Image Credit: Miguel Montalvo & Larson Palmgren

✂ ----------

Fish D: Rainbow Darter, *Etheostoma caeruleum*

Image Credit: Miguel Montalvo & Larson Palmgren

Fish E: Cutlips Minnow, *Exoglossum maxillingua*

Image Credit: Miguel Montalvo & Larson Palmgren

✂ ----------

Fish F: Bluehead Chub, *Nocomis leptocephalus*

Image Credit: Miguel Montalvo & Larson Palmgren

Fish G: Banded Darter, *Etheostoma zonale*

Image Credit: Miguel Montalvo & Larson Palmgren