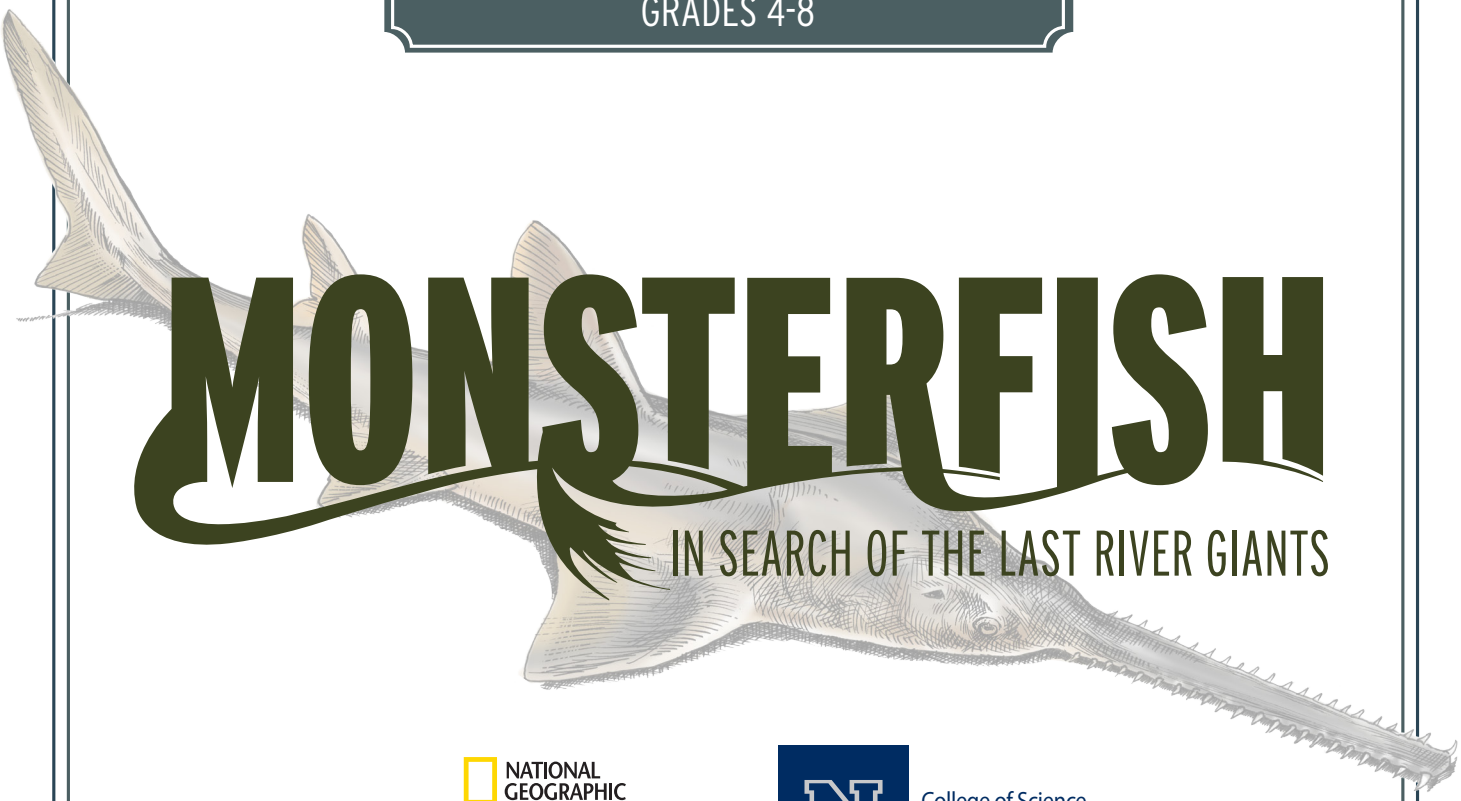
EDUCATOR'S GUIDE
GRADES 4-8



MONSTERFISH

IN SEARCH OF THE LAST RIVER GIANTS

NATIONAL GEOGRAPHIC MUSEUM

College of Science
University of Nevada, Reno

Welcome!

This exhibition takes you and your students on an expedition around the world to learn about monster fish and their habitats. Monster fish (for the purposes of this exhibition) are aquatic giants, a diverse assemblage of awe-inspiring and fascinating freshwater fish that grow to over 6 feet in length or weigh more than 200 pounds.

You will meet and follow the adventures of Zeb Hogan, Ph.D., a University of Nevada biologist, National Geographic Explorer, photographer and television host, as he travels to six continents (North America, South America, Europe, Africa, Asia and Australia) to find, study and protect these underwater leviathans. In total, the project has involved more than 100 scientists, two dozen fish species and most of the major rivers on Earth.

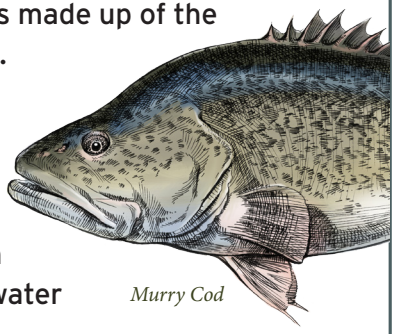
These iconic creatures and the habitats they call home are beautifully portrayed in life size sculptures, photos and illustrations organized by geographical area. Together with video from Nat Geo WILD Monster Fish documentaries, interactive experiences, a water calculator and more, this exhibition provides an exciting learning opportunity for you and your students. Enjoy!

The Science Behind Monster Fish

Biology is the study of living organisms and their interactions on the Earth.

Biodiversity is when the number of organisms, the variety of organisms and their genetic variation are explored in an ecological region, such as a biome, or a smaller area such as an ecosystem.

Healthy Ecosystems: An ecosystem is a geological region that is made up of the community of living (Biotic) and non-living (Abiotic) components. Examples of larger ecosystems could be a specific forest (Olympus forest in Oregon or the Allegheny forest in Pennsylvania) or desert (Mohave Desert in California or the Great Basin Desert found in Nevada, Utah, Idaho and southern Oregon). Ecosystems may also be smaller in geographical region or limited to a specific lake or river. Rivers are considered freshwater ecosystems (Krough, 2011).



Murry Cod

Sustainability: In order for an ecosystem to remain healthy and long-lived, the biological systems within the ecosystem need to remain productive and diverse. Sustainable and healthy ecosystems are essential for the survival of living organisms, including humans (James, Magee, Scerri and Steger, 2015).

Geographical distribution of water: The major sources of where water can be found on the Earth include oceans, icecaps and glaciers, groundwater, freshwater and salt water lakes, the atmosphere, rivers and biological organisms (see chart below). With all the available water on Earth, only a mere 2.5 percent is considered freshwater and what living organisms need to survive (USGS, 2014).

Source	Percent of Total Water on Earth
Oceans, seas and bays	96.5
Ice caps, glaciers, permanent snow	1.74
Ground water, soil, permafrost	1.713
Freshwater lakes	0.007
Salt water lakes	0.006
Atmosphere	0.001
Rivers / swamps	0.001
Biological Water (in living things)	0.0001

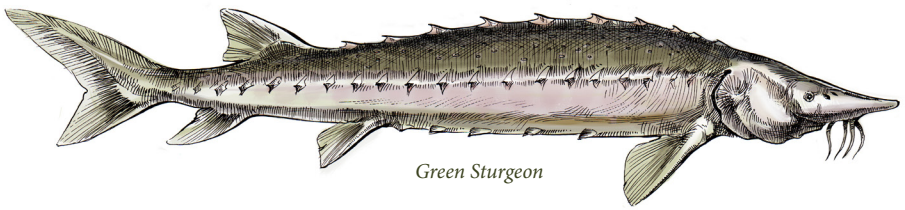
Although freshwater rivers contain a very small amount of the total water available on Earth, they do maintain a very important ecosystem and provide sustainability to ecological regions. In order for fish to be able to survive and grow to very large sizes (monster fish), the conditions of the ecosystem must be sustainable and productive over time.

Science Standards Connection

A trip to the Monster Fish Exhibition supports the following Next Generation Science Standards (NGSS) as related to the respective Disciplinary Core Ideas (DCI) and progressions in the NGSS as outlined in Appendix E and detailed in specific standards by grade level as outlined in the table below.

The Monster Fish Exhibition falls under the Cross Cutting Concepts (CCC) of Cause and Effect, Scale, Proportion and Quantity, Systems and Models, Structure and Function, and Stability and Change. Additionally, visiting the Monster Fish Exhibition supports the Practices of Science and Engineering (PSE) by allowing children to 1) ask questions; 2) use and explore models; 3) participate in simple investigations; 4) analyze and interpret data; 5) use mathematics and some computational thinking; 6) construct explanations; 7) engage in argumentation from evidence; and 8) obtain, evaluate and communicate information.

Life Science (LS)	Earth and Space Science (ESS)
LS1-1 Structure and function LS1-2 Growth and development of organisms LS1-3 Energy flow in organisms LS1-4 Information processing (Catfish and whiskers) (Paddlefish electroreceptors for rostrum) (Electric Eels use electric current discharges)	ESS2-1 Earth materials and energy flow ESS2-3 Global water distribution ESS2-5 Biogeology (living things can affect the physical characteristics of the environment)
LS2-1 Interdependent relationships in ecosystems LS2-2 Biogeochemical cycles LS2-3 Ecosystem dynamics LS2-4 Social and group behaviors	ESS3-3 Human impact on Earth systems ESS3-4 Global climate change
LS3-1 Inheritance of traits LS3-2 Variation of traits	
LS4-1 Evidence of common ancestry LS4-2 Natural selection LS4-3 Adaptation LS4-4 Biodiversity and human relationships	



Green Sturgeon

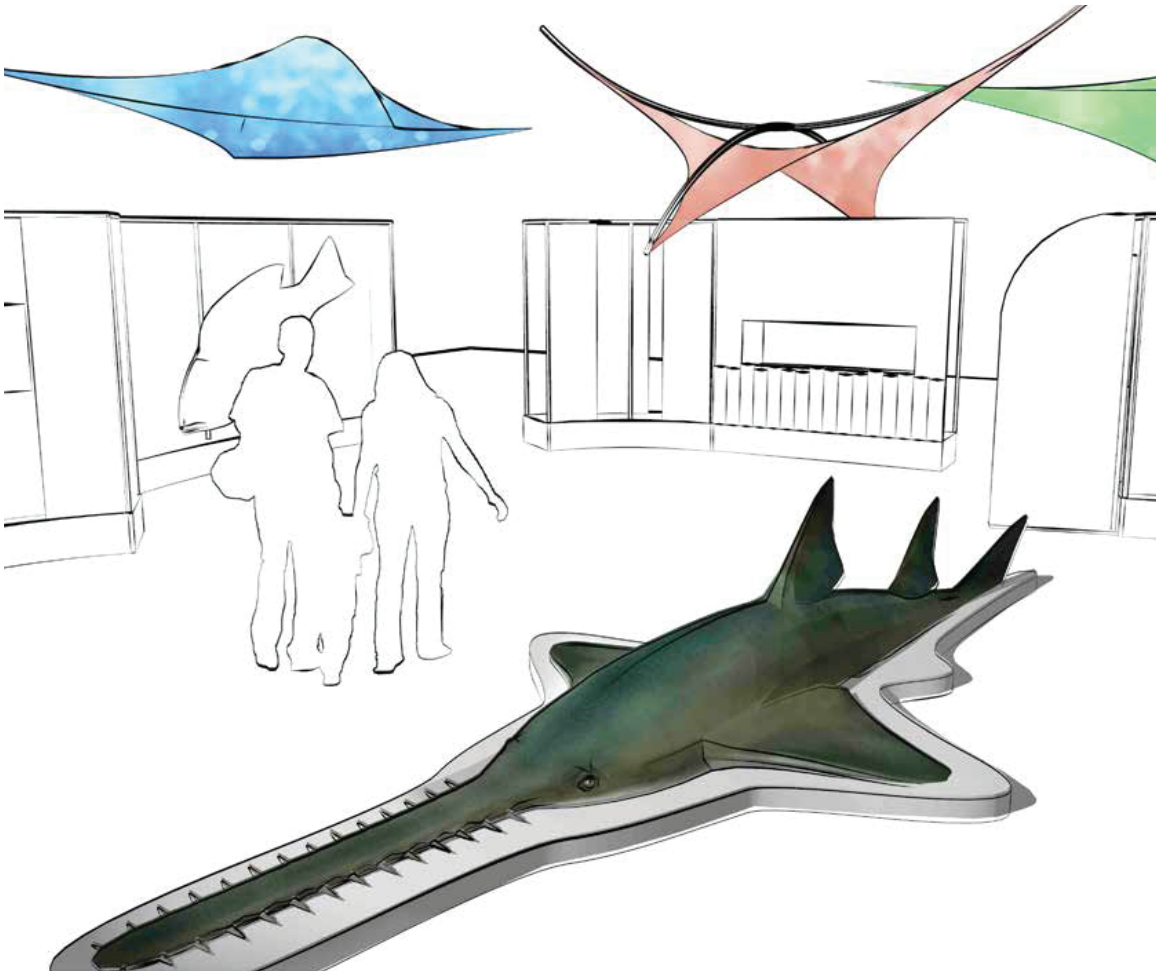
Intro Theater

On entering the exhibition, visitors can choose to sit, stand or pass through a theater space with terraced seating reminiscent of a riverbank. A child's musings about a local legend bring visitors face-to-face with a wondrous monster fish. The two-screen animation weaves together the child's imaginings with Zeb Hogan's descriptions of the very real enormous fish that populate waterways around the world.

Geography Sections

These large geography-based sections will profile several species and explore their connections to the habitat and peoples of each region. Life-size, lavishly detailed sculptures bring fish that live in murky water into vivid relief. Some are touchable, and in the case of the 20-foot sawfish, climbable. Custom illustrations present the folklore and mystery behind these fish. Visitors will learn firsthand about the sheer size of these goliaths and how anatomy provides clues about behavior. Be amazed as accompanying video reveals the slash-and-eat methods of the sawfish and the filter feeding behavior of the paddlefish, and shows a pregnant giant freshwater stingray giving birth.

In each section information will be presented about the local cultural importance of the fish, such as subsistence fishing for the pirarucu, the sturgeon's inclusion in the traditions of many Native American tribes, and the giant barb's representation in ancient carvings at Angkor. Several case studies investigate conservation challenges and solutions.



Interactives

Themed areas with tactile and digital interactives provide visitors with opportunities to learn about how monster fish grow, how scientists study them, and how anglers and other individuals can help fish survive.

Monster Size Me

Be the fish as you maneuver a marble through a circular obstacle course. Just like real fish, the longer the fish survives, the bigger it will grow. Avoid threats like invasive species and dams and collect positive impacts such as dam removal and habitat restoration to maximize growth. This game demonstrates both the threats that monster fish face and ways humans can help. Nearby panels and photos provide a case study of "Monster Fish Invaders," showing examples of monster fish as invasive species.

A Monster Mission

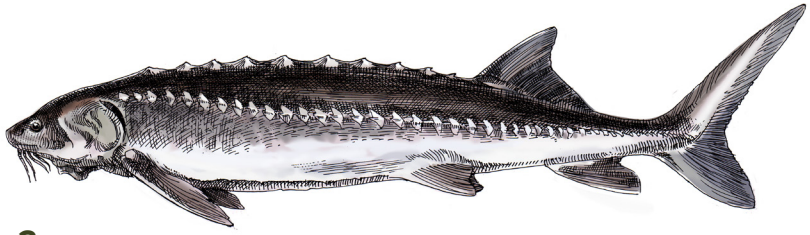
Be the scientist on up to five missions to experience how scientists find and learn about monster fish. Scan the fish to see if it was tagged in a prior field season and collect data, such as size and weight. Analyze movement patterns to identify areas of the river in need of protection. Test your observation skills and identify a mystery monster fish invading the river.

Interactives (Cont.)

Fishin' Decision

Be the angler as you learn the value of responsible recreational fishing. Zeb Hogan often works with recreational anglers who understand where to find fish and how to catch them responsibly. In this digital interactive you can catch fish, consult fishing guidelines, and decide whether to "keep" or "release." See how many correct choices you can make.

White Sturgeon



Minnow or Monster?

Step onto a large scale with your group to see your equivalent weight in monster fish. You might learn, for example, that "your group weighs the same as a quarter of a white sturgeon." Learn about the connection between getting old and getting big as you count the rings on otoliths — fish ear bones with growth rings like a tree. Examine historical records of fish lengths to see how finding truly large fish is increasingly difficult.

Go Fish

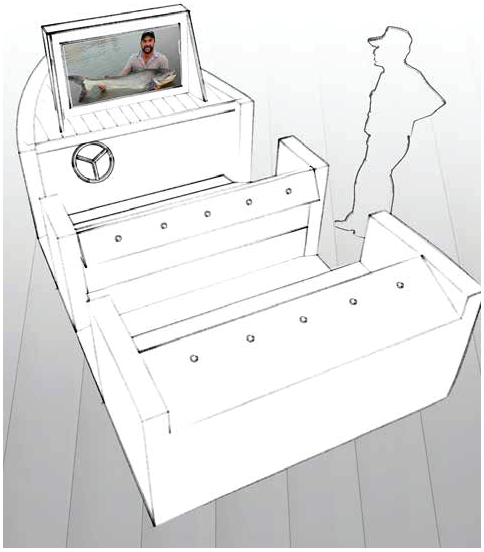
Designed with the youngest visitors in mind, a stylized riverbank is lined with four fishing poles and four release chutes. Use magnetic fishing poles to catch fish from among the river's rolling waves. Place the fish gently into a chute for release into the river. These actions reinforce the message of fun and safe fishing for both people and fish.

Balancing Act

Freshwater is a resource in high demand. Finding a way to balance human with ecosystem needs is the only way to ensure healthy rivers where fish can grow to monster size. This interactive is designed to give visitors an understanding of the hidden water costs in services and products consumed. As visitors adjust sliders indicating home water use, diet, energy use and product consumption, an animated river filled with fish on a large display monitor responds accordingly. The water level will rise or fall as more and less water-intensive elements are selected.

Monster Fish Video Expedition

Climb aboard a stylized boat to go on expedition with Zeb Hogan, Ph.D., National Geographic Fellow and host of the Nat Geo Wild series "Monster Fish." From jumping out of helicopters to taking part in local rituals, witness the lengths to which he goes to find and document the world's monster fish. Choose from among five button-activated videos.



Spectacular Sculptures

World-renowned Staab Studios created five life-size sculptures for the exhibition. Watch the sculpting process: vimeo.com/108572559

Freshwater Sawfish, *Pristis Perotteti*

Pirarucu, *Arapaima Gigas*

Exhibition Flow

NORTH AMERICAN FISH TALES
- American Paddlefish sculpture
- Sturgeon video
- Native American stories
- Illustrated myth

GIANTS OF THE AMAZON
- Pirarucu sculpture
- Fish diversity video
- Illustrated myth

VIDEO EXPEDITIONS
- A selection of global stories featuring Dr. Zeb Hogan

LIVE FISH TANKS
(Optional)

ASIA'S RIVER BEHEMOTHS
- Goonch sculpture
- Giant Barb sculpture
- Angkor relief sculpture recreation
- Fish diversity video
- Illustrated myth

MONSTERS DOWN UNDER
- Freshwater Sawfish sculpture
- Australia's Wild North video
- Indigenous stories
- Illustrated myth

INTRODUCTION
Theater with two-screen animation

INTERACTIVE STATIONS
- Tactile and digital interactives
- Custom illustrations, photographs, video
- Scientific equipment

Freshwater Stingray

How to Use This Guide

Before Visiting the Exhibition

This guide contains activities that introduce your students to aquatic freshwater giants called monster fish, the aquatic ecosystems in which they live, and different regions of the world explored by Zeb Hogan, Ph.D. and his Explorer team. There is information for educators and resources to prepare students for the experience within the exhibition. Preparing children with some background information and activities will allow them to better enjoy the experience of the Monster Fish Exhibition.

At the Exhibition

Educators should read this guide to prepare for visiting the exhibition. Become aware of the major sections of the exhibition along with activities and interactive components. Share the exhibition map and descriptions with your students and make a plan for how you will encounter the different sections of the Monster Fish Exhibition. If you have conducted any of the "Before Visiting the Exhibition" activities with your students (page 11 of this guide), be sure to make clear connections between this information and the pre exhibition content. When you arrive, have students explore the exhibition in teams of two-four, imagining that they are visiting the different regions of the world while looking for and recording evidence that supports the sustainability of large fish. The groups can explore the sections in any order, as long as they visit them all by the end of the tour.

After Visiting the Exhibition

Select from the activities in the "After Visiting the Exhibition" (page 19) to follow up and build upon the experiences in the Monster Fish Exhibition. There are activities that provide opportunities to research more information, as well as activities that can extend the Monster Fish experience and related science into the classroom and beyond.

Website: http://www.unr.edu/science/zeb-hogan

Other Resources: At the end of the guide there are lists of additional resources and links that support and expand upon the content of the Monster Fish Exhibition.

Have Fun!

Taimen

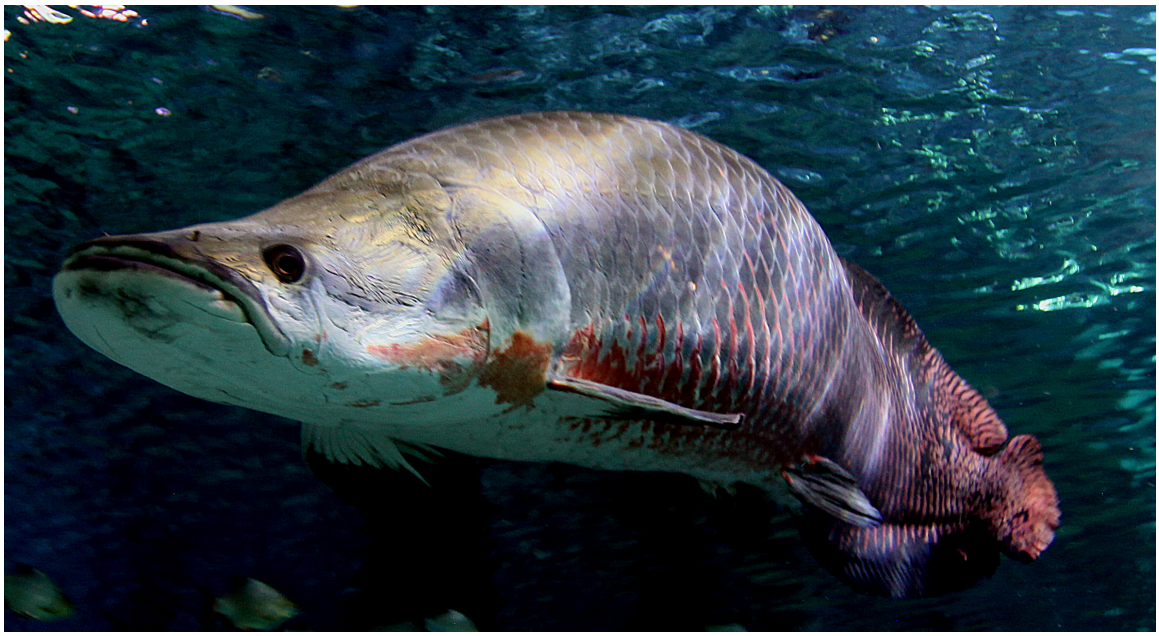
Before Visiting the Exhibition:
Introducing Monster Fish

Mekong Giant Catfish

Show students the photo of the Mekong giant catfish (above). Ask them to observe the fish and look for clues about how big the fish actually is or how much it weighs. This particular fish weighed in at 200 kilos and was 2.5 meters long.

Engage the students with a discussion using the following questions: How big do freshwater fish, like the Mekong giant catfish, grow? What would they eat? How much food would they require on a daily basis to survive? How many species of giant freshwater fish exist? Where could they live, considering their size? What are some of the challenges to their survival?

Explain to students that more than two dozen freshwater fish can grow to more than 2 meters long or weigh more than 100 kilos. Students may be familiar with some of these fish such as giant catfish, carp and sturgeon. Other types of fish may be unfamiliar to students because they exist in different regions of the world, such as the giant perch in Africa, air-breathing pirarucu in South America and massive freshwater whipray in Asia.



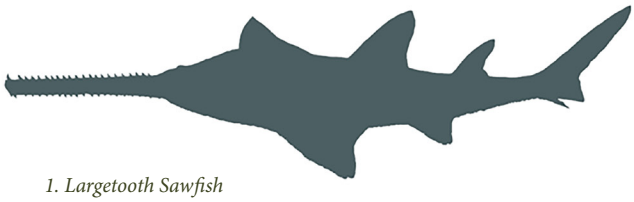
Pirarucu

To bring closure to this discussion, explain that throughout their range, this diverse group of fish has much in common: All are large, many are long-lived, and most are slow to mature. As the biggest fish, most require large, healthy lakes and rivers to thrive, and some make regular cyclical movements (migrations). They are usually an important source of food to the local people, and they are threatened with extinction.

Freshwater Stingray

Fish Scales!

Just how big are the world's largest freshwater fish?
Compare the size of these monster fish with that of Zeb Hogan, Ph.D.
Can you estimate the size of each fish?



1. Largetooth Sawfish

2. Pirarucu

3. Freshwater Stingray

4. Piraiba

5. Giant Barb

6. Golden Mahseer

7. Alligator Gar

8. Mekong Giant Catfish

9. American Paddlefish

10. Lake Sturgeon

11. Taimen

12. Goonch

13. Murray Cod

Zeb Hogan, Ph.D.
6 feet tall / 182.88 cm

NATIONAL GEOGRAPHIC MUSEUM

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Khone Falls

Locate the Major Rivers of the World and Meet the Monster Fish Team (Activity)

Introduction: "Monster Fish," large freshwater fish, are found in large lakes and rivers around the world. In order to help you gain an appreciation for many of the areas where Zeb Hogan has conducted research, this activity will help you track his travels. Hogan has worked with more than 100 scientists, fishermen, photographers and filmmakers to develop the material presented in the exhibition.

- Using a world map, point out to students the six different continents where Hogan and his research team have traveled to study monster fish: North America, South America, Asia, Australia, Europe and Africa.
- Using the same map, have students locate the largest rivers on each of those continents: the Mississippi, Amazon, Danube, Nile, Yangtze, Mekong and Murray-Darling.
- Hogan conducts much research to find rivers in different regions of the world that can sustain large fish. Part of his research focuses on climate, topography, sustainability and accessibility.

Activity: Divide your class into six research teams (one per continent) and have them identify the largest river on that continent (Mississippi, Amazon, Danube, Nile, Yangtze, Mekong or Murray-Darling). Then research the following questions: a) What Biome(s) are represented in the ecological region of the river? b) What is the climate like? c) What is the landscape (topography) surrounding the river in the region? d) How long is the river? e) What typical flora and fauna are found in that region? f) What are some of the endemic fish in that area, and which species have been recorded as the largest in the area?

Caption needed

Not only does Hogan research the science and geography of particular regions, he must also be sensitive to local customs, traditions and laws. Reconvene the research teams to answer a) what languages are spoken by the people living along the banks of the river? b) What cultures are present along the rivers and what geopolitical information is available from that region? c) Do the monster fish in that region have any cultural significance for local populations? d) Do the monster fish have any religious significance in the region?

Have students share their findings with the rest of the class. After each group has shared, conduct a discussion on the similarities and differences among each of the rivers and regions. Note that there is little overlap between the fish found in each of these rivers. Additionally, the total number of freshwater fish species (fish diversity) that exist in each river varies from river to river and continent to continent. Can you find out how many freshwater fish inhabit in each river? Which rivers have the highest freshwater fish diversity?

Plan an Expedition / Mission to Visit One of the Areas (Activity):

Introduction: Many monster fish live in remote areas, requiring researchers and filmmakers to make long, difficult trips to find them. To travel to remote rivers in tropical Guyana, for example, Hogan and his team spent three weeks on the river. The team traveled by boat, using 18-foot canoes and small outboards to navigate the shallow, dry-season waters of the Essequibo and Rewa rivers. The team camped out on sandy beaches, stayed dry under tarps and slept in hammocks. In Mongolia, biologists studying taimen, the world's largest trout, spent months in the field each year tagging and tracking fish. The taimen team stayed in gers, traditional Mongolian tents, and traveled by jeep, jet boats, and rafts. Cold temperatures are the challenge here and the team must prepare everything needed for weeks or months in harsh conditions.

Activity: Now that you have conducted some basic research into different regions of the world, the next step is to plan an expedition to explore and conduct research in that area. Break the class into expedition teams with four-six members in each group. Have each group plan an expedition to a remote river location by researching the following questions:

- How would they get to the site?
- How long would they spend at each site?
- How long would the whole expedition take?
- What would they bring with them?

Mongolian House and Expedition Vehicle

Guyana Rewa River Group Expedition

Ask the students to plan the details of the trip, reminding them that the expedition will probably include travel by plane, car and boat. How much time will each leg of the journey take? Where will they stay while they are in the field? What types of gear are the most important? Hint: The major categories for monster fish expeditions usually include groups of items like transport, fuel/oil, tool box, camp equipment, personal equipment, kitchen, food, fishing gear, filming gear and science gear. What items fit in each category? Ask the students to dedicate extra time to learning about the equipment and supplies biologists use to study fish.

Have the students share their expedition plans and information with the rest of the class.

Giant Pangasius

Visiting the Exhibition:
Give the Students Their Mission

Tell the students that they are about to go on a journey — not to a river or lake — but to an exhibition about the world's largest freshwater fish and their habitats. While at the exhibition, the students' mission is to learn about giant fish (a.k.a. monster fish), the many forms they take, the rivers and lakes where they live, ways biologists study them, their importance to humans, the threats they face, and what we can do to protect them. Remind students that these "monster fish" are representative of freshwater fish worldwide — of all sizes — that we refer to collectively as freshwater fish biodiversity.

Collecting Information at the Exhibition:

While at the exhibition, the teacher may ask the students to keep a notebook to collect some observational information that can be used for classroom discussion after the visit to the Monster Fish Exhibition.

A sample notebook table could include the following:

5 Favorite Fish Scientific Name	Common Name and Nickname*	Fish Habitat	Fish Behavior	Fish Diet
1				
2				
3				
4				
5				

** For example, Cambodians call the Mekong giant catfish the "royal fish" because of its position as the largest fish in a vast underwater realm (the Mekong River).*

Additional information to be collected on the fish may be:

- How big is the river where the fish are found?
- What's unusual or surprising about its behavior?
- Where does the fish fit in the food chain?
- Which was your favorite fish? Why?

After Visiting the Exhibition: Discuss the Students' Impressions of the Monster Fish Exhibition

Ask the students what they thought about the exhibition and what interested them most. How did their impressions of monster fish change as a result of visiting the exhibition? Remind them that their overall mission was to learn about monster fish, the many forms they take, the rivers and lakes they inhabit, ways biologists study them, their importance to humans, the threats they face, and what we can do to protect them. Ask them to recall the sculptures and share their impressions. Do they think that fish like those presented as sculptures really exist?

If you had your students collect information in their notebooks, this is a great time to have them share that information and compare their favorite fish with other students or with the entire class. Wrap up the discussion with a statement that it is our stewardship (as humans) to help these ecosystems remain sustainable and healthy. Ask your students what they can do to contribute to the longevity of freshwater ecosystems so that future generations will also have monster fish to observe and learn about.

The following activities will enable you to continue the study of monster fish with your students. These activities are not in any specific order, but are simply ways to extend the learning experience from the Monster Fish Exhibition.

Monster in Your Backyard? (Activity)

Students may not realize that they have monster fish living near them. Students may be able to visit a local river or lake (with appropriate adult supervision) to investigate the fish that live in their local aquatic systems and to explore whether any of those fish could grow to be very large (monster fish). Typically, there are local records kept about the kind of fish and sizes of fish caught in local areas. Try to find information on the fish records that exist for your local area. Big fish may be closer than you think!

Specific questions could include:

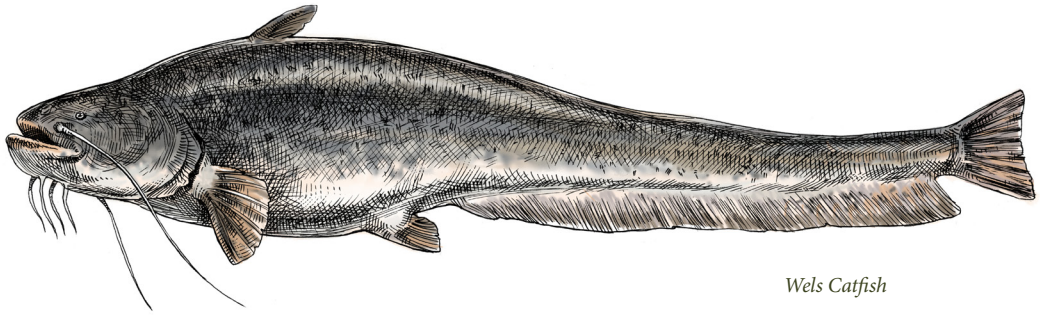
- What are the local rivers and lakes closest to where you live?
- What are the species of fish that live in your local freshwater sources?
- What do the local fish eat?
- What importance is the local freshwater source to the people that live near it?
- Are there any threats to your local freshwater sources including management/ challenges (water shortage, sewage management, pollution, dams, invasive species, overfishing, etc.)?

Visit a Fish Market (Activity)

When Zeb Hogan visits the Mekong River in Cambodia, one of his first stops is to the morning market. Local fish markets can provide valuable clues about the varieties of fish and health of the rivers in the region. Before or after your visit to the Monster Fish Exhibition, visit a local grocery store and observe the different kinds of fish being displayed. Pick your favorite three fish, draw a sketch of the fish, and take estimated measurements of the weight, length, width and height of the fish that you observe. Try to determine if those fish are specific to your area and naturally occurring (endemic), caught in your area but are not naturally occurring (invasive), or were not caught locally but were brought into your area from other areas (imported). Ask the store clerk if these fish were caught locally or if they were shipped to the store. Additionally, ask the clerk if these fish were caught in the wild or if they were farm raised fish (aquaculture). A visit to several local markets or ethnic stores may show a greater variety of fish that are endemic, invasive or transported to the local area.

Scenes from a Fish Market in Thailand

Imperiled Giants



Wels Catfish

Background

Populations of many giant freshwater fish species have declined significantly in recent years, leading them to be classified as endangered. An endangered species is an animal or plant that is at risk of disappearing — scientists call this phenomenon extinction. While extinction is a natural process (numerous animals and plants have gone extinct since life began on Earth nearly 4 billion years ago) the rate of extinction has increased recently as a result of human activity. The rate of decline for many freshwater animals has led scientists to consider the present-day disappearance of aquatic animals a freshwater extinction crisis. Approximately 70 percent of monster fish species are considered threatened. In North America overall, nearly 40 percent of freshwater fish are threatened, and 61 species are presumed extinct. The major threats to freshwater fish include: overfishing (overharvest), habitat degradation, dams, invasive species, pollution and climate change, all of which negatively impact populations of many species. In the majority of cases, fish are subject to more than one of these stressors.

Many solutions that have been proposed for preserving healthy ecosystems and aquatic populations focus on industrial development, water use and harvest/fishing practices that are sustainable, meaning that the practices are environmentally responsible and do not harm the long-term probability of the persistence of a population or species. As consumers, humans can practice sustainable living in a number of different ways: by making educated choices about how and from where we get our energy, what we eat, how much water we use, and which fish we choose to eat or catch.

Activity 1

Share with students the above information regarding threats to freshwater fish. Ask students to consider possible conservation solutions to the problem of declining freshwater fish populations. What are some solutions that have been proposed for marine fish? Are these solutions appropriate for freshwater fish? Why or why not?

To begin the next part of the activity, split the class into two research groups. Ask the first group of students to research the water supply in the local area. Have students identify where the local water is supplied from. Possible sources include nearby lakes and streams, snowpack, ground water, wells, etc. Are these water sources renewable (do they replenish themselves each year)? Ask the students to come up with some solutions for what could be done to help protect and preserve these water sources.

Have the other groups of students investigate where the major sources of local energy come from. Is the energy source renewable (wind, solar, geothermal, hydro) or non-renewable (coal, natural gas)? Using hydropower as an example, ask students what could be done to make hydropower less damaging to fish stocks. For example, the location of a dam is important when assessing the environmental impact. These types of impacts can be better understood by conducting a holistic survey of socio-economic, cultural and human-health costs and benefits associated with a proposed project. This process is known as an environmental impact assessment (EIA).

Have students report back to the rest of the class about their findings and possible solutions to maintain healthy and sustainable aquatic ecosystems for freshwater fish.

Activity 2

Ask students to find a sustainable seafood guide online. Most sustainable seafood guides focus on marine fish and advise consumers about food choices based on the conservation status (i.e. level of sustainability) of the fish stock in question. Have students identify whether the fish should be avoided or eaten in moderation, and/or which fish would be considered a best choice for eating according to the sustainable seafood guide based on the conservation status of the fish. Here is a link to the world Wildlife Fund (WWF) sustainable seafood guide (and links to other sustainable seafood guides): http://wwf.panda.org/what_we_do/how_we_work/conservation/marine/sustainable_fishing/sustainable_seafood/seafood_guides/

	Avoid Eating	Eat in Moderation	Best Choice for Eating
Mekong giant catfish			
Colorado pikeminnow			
Farmed-raised catfish			
Wild caught Pacific salmon			
American paddlefish			
Wels catfish			
Piraiba			
Giant Siamese carp			
Nile perch			
Farm-raised pirarucu			

Zeb Hogan, Ph.D., with a Giant Euransian Trout

Have students justify their answers, keeping in mind that farm-raised fish are usually a sustainable alternative to eating wild caught fish with poor conservation status.

Ask the students to explain the difference between commercial fishing, subsistence fishing and recreational angling. All three types of fishing can be sustainable if harvesting is kept to sustainable levels. Commercial fishing is usually regulated by monitoring the total number of fish that are removed from a river or lake. Subsistence fishing is often managed by laws regulating access, equipment, fishing season and catch. Recreational fishing, or sport fishing, can be managed in a variety of ways including regulating access, equipment, fishing season and catch, as well as by encouraging catch-and-release fishing.

Catch-and-release fishing is particularly beneficial for large-bodied, long-lived "trophy" fish, because the largest fish usually have the highest reproductive potential. Ask students if they participated in the "Fishin' Decision" interactive portion of the Monster Fish Exhibition. What lessons did students learn about catch-and-release fishing?

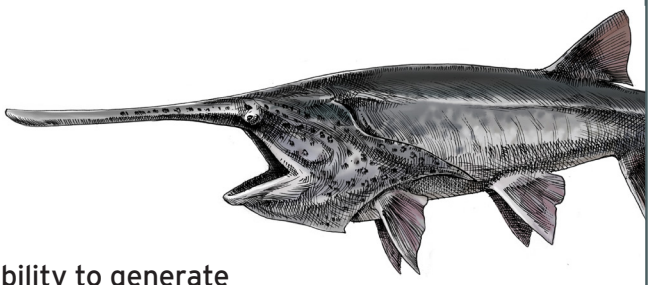
Robot Fish / Design Your Own Fish

Background

Engineers have designed robot fish to accomplish a variety of tasks, from cleaning toilets to spying or assisting in scientific exploration. Ask your students to design a robot fish. What are the main characteristics of a fish? What purpose do they serve? Fish come in many different shapes and sizes from the snakelike eel, to the flattened stingray, to the streamlined taimen. What does body shape tell us about a fish? Why would an eel be shaped like a snake? Why are stingrays flat? The variety of body shapes is astounding and can vary even within one group like catfish. For example, the tiny pencil catfish measures less than 1 centimeter at maturity while the largest catfish, the Mekong giant catfish, measures three meters in length and can weigh up to 300 kilograms.

While humans are comparatively awkward in water (we swim slowly, our senses of sight and sound are dulled, and we can only hold our breath for a few minutes), fish have many adaptations that make them at home in the water. Many fish have fins positioned on the top, sides, bottom and back. What is the name of each of these fins? What purposes do they serve? What special characteristics or behaviors do some freshwater fish have that other fish do not? Do these characteristics or behaviors benefit these fish? How?

Explain to students that fish use their senses to assimilate to their environments. Examples include a lateral line, which fish use to detect water particle displacement, eyes that may function in both bright and low light, ears that are sensitive to distant sounds and pressure oscillations, nares (nostrils) that can detect waterborne chemicals, and organs capable of sensing electromagnetic fields.



Paddlefish

Ask students to think about what other attributes might be important to a fish. The size and shape of teeth often dictate what and how fish eat. Students also may want to give their fish special tools, like the ability to generate an electric shock (the electric eel can generate a strong shock of up to 700 volts), a long snout or rostrum to detect or debilitate prey (both the American paddlefish and freshwater sawfish have specialized rostrums), or a toxic spine to ward off potential predators (the giant rays of Asia, South America and Australia all possess toxic barbs, which can grow to 15 centimeters).

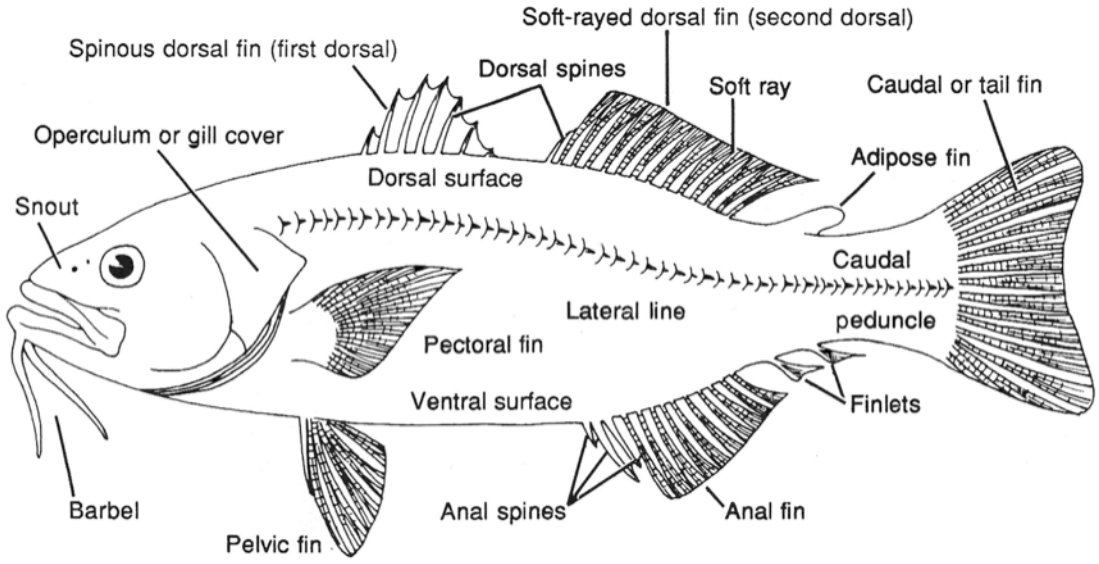


Figure 1 General Fish Physiology. Gene Helfman, University of Georgia. Used with permission.

Activity

Organize your students into design teams of two-four people per team. Utilizing the Engineering Design Process (EDP), ask the students to design a robot fish that highlights a specialized design to survive in a competitive environment.

The first step in the EDP is to have students "Identify the Problem," in this case, designing a fish with a specialized characteristic that will help it to survive in a competitive environment. Part of this design step includes conducting research on different fish specializations. A separate part of this phase requires students to identify the constraints that they will have for this design project. In engineering, constraints are considered the limiting factors in the design process. There are typically three main constraints, including the cost of the project (materials budget), the time frame to complete the project, and the quality of the end product (minimum qualifications of the end product).

Note for Educators: For successful projects, the teacher should collect available materials and establish a chart of expenses to help students create a budget to work from. Teachers should also have a time frame in mind (number of class periods or hours that the project will run). Finally, a minimum standard should be developed in order to define the "success" of the end product. An example of a minimum standard might be whether the fish can adequately survive in its habitat. How effective was the characteristic that was developed for this survival strategy?

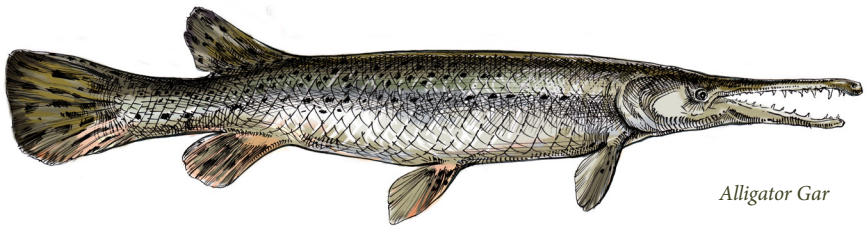
The second step in the EDP is for kids to "Brainstorm" as many solutions, or in this case, as many specialized characteristics as they can think of for fish survival and competitive nature. Creative, bizarre ideas are encouraged here as sometimes those ideas make the best design project. Once brainstorming is complete, the students then work through all the ideas to eventually settle on one idea that they will construct.

The third phase of the EDP is for students to "Make a Plan." This plan will become the blueprint of the project. Sketches and drawings are important because measuring and scaling the drawing will lead to more successful building. Students should pay attention to which materials are available for building their fish and then construct a budget that will support their plan, but fit within the budgetary constraints of the project. Before students move on to the next phase, it is strongly encouraged that the teacher review the plan with the students.

The fourth and fifth phase in the EDP is to "Build" and "Test" the design. Students should construct the fish with the materials they have selected. Building and testing become an iterative process, meaning that once you have a prototype, you test it to make sure that it works. If for some reason the prototype fails, this is an opportunity to redesign and rebuild the fish. The iterative process of build and test can go on for quite some time, so it is important that students pay attention to the time constraint. Whether hours or days, time goes by fast and students will need to plan accordingly so that they are able to finish the project with the quality that they need within the time given.

The last phase of the EDP is for students to "Implement the Solution." The project is complete and now the students may share their results or even market their fish design for competition. This is an opportunity for students not only to use engineering and science as the basis for the fish, but to also to utilize some simple mathematics for figuring out how much to sell their fish for, as well as for coming up with a marketing strategy to sell their fish. Have students create a presentation to present to the rest of the class "selling" the idea that their fish is best and showing why other students should buy it. Technology can be used here along with communication skills (writing and speaking) to make the project as a whole a well-rounded STEM project.

For further reading on the Engineering Design Process, the Engineering is Elementary (EiE) curriculum and Engineering Adventures curriculum from the Museum of Science in Boston are great resources for engineering activities for students in grades K-8. Visit http://eie.org/ for more information.



Alligator Gar

Robot Fish Resource Links

http://machinedesign.com/technologies/navy-builds-robotic-fish-spy-missions (robot fish)

http://www.techlicious.com/blog/hexbug-aquabot-remote-control-angelfish-toy-fair-2015/ (robot fish)

http://www.euronews.com/2015/02/18/robot-cuttlefish-ready-for-underwater-action/ (robot fish)

Resources

Books (for children)

Books (for adults)

- *Philosopher Fish*
- *Cod*
- *Four Fish*
- *Your Inner Fish*
- *Carl Safina / Song for a Blue Ocean*

Professional Articles

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http://education.nationalgeographic.com/education/encyclopedia/sustainable-fishing/?ar_a=1

http://environment.nationalgeographic.com/environment/freshwater/aquatic-ecosystems/

Freshwater Ecosystems

http://kids.nceas.ucsb.edu/biomes/freshwater.html

http://www.kidzworld.com/article/1951-biomes-of-the-world-aquatic

http://www.neok12.com/Ecosystems.htm

Protecting Your Fresh Water

http://water.epa.gov/action/weatherchannel/whatyoucando.cfm

How Do Fish Get Big?

http://www.learn4good.com/games/online/play_fishy_online.htm

http://www.nationalgeographic.com/field/explorers/zeb-hogan.html

http://news.nationalgeographic.com/news/2007/11/071115-megafishes.html

http://environment.nationalgeographic.com/environment/freshwater

http://ngm.nationalgeographic.com/2010/04/table-of-contents

http://sanctuaries.noaa.gov/education/teachers/pdfs/sustain_seafood_lesson1.pdf

Go Fishing

http://takemefishing.org/fishing/family/fish-with-your-kids/

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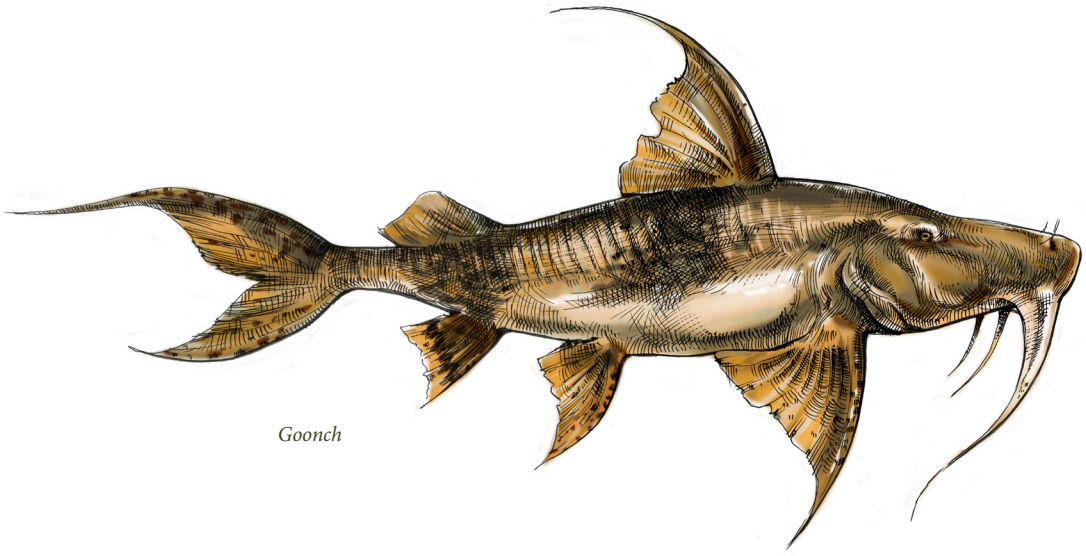
James, Paul; Magee, Liam; Scerri, Andy; Steger, Manfred B. (2015). *Urban Sustainability in Theory and Practice: Circles of Sustainability.* London: Routledge.

Krough, David (2011). *A Guide to the Natural World* (5th Edition). San Francisco, CA., Pearson Education Inc.



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