Native Fish in the Classroom

Teacher Guide

American Paddlefish (Polyodon spathula)

Louisiana Department of Wildlife and Fisheries and Louisiana Sea Grant College Program
2020 Update Edition

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TABLE OF CONTENTS

Acknowledgements vi

Introduction vii

SECTION 1: Background Information

Biology of the Paddlefish 1
Spawning 4
Feeding 6
Range 7
Habitat 8
Causes of Population Decline 9
Caviar Industry 10
Conservation 12

The Case of the Chinese Paddlefish 16

Aquatic Invasive Species 17

Fisheries Management and Hatcheries 19
What is a Hatchery? 19
Why are Hatcheries Important? 19
Booker Fowler Fish Hatchery 20

Paddlefish Quick Facts 22

SECTION 2: Aquarium Setup and Maintenance

Equipment for Aquarium Setup and Maintenance 23
Aquarium Setup 24
Logbook 25
Water Quality Monitoring 25
Aquatic Nitrogen Cycle 26
Ammonia/Ammonium-pH Curve 27
How to Change the Water 28
Vacuuming 28
Incubation Jar Setup 29
Fry Basket/Nursery Setup 31
Feeding 33
How to Use an Automatic Feeder 33
Daphnia spp. Setup 34
Problem Solving 35

SECTION 3: Appendices **42**

APPENDIX I:
LESSON PLANS
Water Quality
My Fish Ride a (Nitrogen) Cycle *A1*
Do You Believe in pH Magic? *A11*

General Paddlefish information
Snagging Paddlefish Information *A24*
Critical Conditions for Paddlefish Spawning *A32*
How Old is that Fish? *A44*

Effects on Paddlefish Populations
Extirpated? Don't you Mean Extinct? *A56*
What a Nuisance! *A67*
Do Dams Affect the Paddlefish Population? *A73*

Paddlefish Growth, Development and Behavior
How Fast Do Paddlefish Grow? *A83*
Comparing Eggs and Embryos *A95*
Life Cycles of the Wet and Wiggly *A102*
Pass the Water Fleas, Please *A110*

APPENDIX II:
References and Resources **A118**

APPENDIX III:
Louisiana State Science Standard **A130**
6th Grade *A132*
7th Grade *A137*
8th Grade *A142*
High School *A149*

APPENDIX IV:
Glossary **A163**

APPENDIX V:
Paddlefish Status Chart, Fry Diagram, Aquatic Hours Sheet and Water Quality Monitoring Log **A167**

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INTRODUCTION

Native Fish in the Classroom is a multidisciplinary, classroom-based project developed primarily for middle and high school students. The overall goal of the project is to create an active learning environment to assist students in developing an attitude of stewardship toward natural resources and an appreciation for fisheries management practices through the process of rearing Paddlefish.

The following objectives support this goal:

1) Provide students with background information on fisheries management, fish biology, protected species, and aquatic natural resources.
2) Maintain a classroom-based nursery aquarium in which students rear Paddlefish from eggs to fingerlings and learn about the components necessary for fish survival.
3) Learn about freshwater ecological systems by understanding the role of fisheries management and how it benefits the whole freshwater system.

Why Paddlefish?

The Paddlefish is an ideal species to use for studying fish growth and development in the classroom because its life cycle parallels the academic year. Paddlefish fry can grow about 1 inch per week in ideal environmental conditions, and often reach about 4 inches in less than two months. This rapid growth allows students to observe three distinct life stages of the Paddlefish.

Timeline

The project is expected to occupy class time from early March through mid-May. A teacher training workshop is scheduled in the summer for teachers new to the project. Additionally, a January meeting covering the Paddlefish spawn ensures successful preparation for receiving Paddlefish eggs in the spring. In early March, teachers are invited to bring their students to assist with the artificial spawning process at the Booker Fowler Fish Hatchery and bring eggs back to their classrooms.

Once hatched, fry will be reared to fingerling stage by the students in their classroom nursery tank. At the end of the school year, students will join their teacher to release their (hopefully!) 4-6-inch fingerling Paddlefish into a pre-approved public stream, with the required supervision/approval of an LDWF biologist. The hatchery will also have a reserve of Paddlefish fingerlings that will be released into Louisiana streams to help sustain a healthy Paddlefish population, in addition to being used to replace any classroom fingerlings that may die during the school year. The fingerlings raised in the hatchery often grow up to 6 inches or more before being released into the wild.

Expected Benefits

Louisiana students will obtain hands-on, real-science knowledge of the state's native aquatic resources, and ideally will develop a sense of stewardship towards all of Louisiana's natural resources.

Louisiana teachers will gain access to the state's Booker Fowler Fish Hatchery as an outdoor classroom. *Native Fish in the Classroom* will also provide hands-on classroom lessons unique to Louisiana.

Section 1

Background Information

BIOLOGY OF THE PADDLEFISH

American Paddlefish (*Polyodon spathula*) are large, gray to bluish freshwater fish. Adults usually reach about 5 feet in body length (excluding the rostrum) and weigh up to 60 pounds, but can be much larger in some areas. The largest ever recorded Paddlefish was caught in 1916 in Iowa, and was 7 feet, 1 inch long! Here in Louisiana, adult Paddlefish reach an average of about **2.5 feet** in body length and weigh from **10 to 15 pounds**.

As its common (or species) name ***spathula*** suggests, the Paddlefish has a long paddle-shaped snout or **rostrum** equivalent to one-third of the fish's total body length. On the rostrum you'll find 2 small **barbels** (like a catfish's "whiskers") as well as tiny pores called electroreceptors that help the Paddlefish locate it's food, which we will learn more about in a later section. The adult Paddlefish has a large, **toothless** mouth on the underside of its head and the fish is scaleless, except for a small patch near the caudal (tail) fin.

Paddlefish Taxonomy

Kingdom - *Animalia*

Phylum - *Chordata*

Superclass - *Osteichthyes*

Class - *Actinopterygii*

Subclass - *Chondrostei*

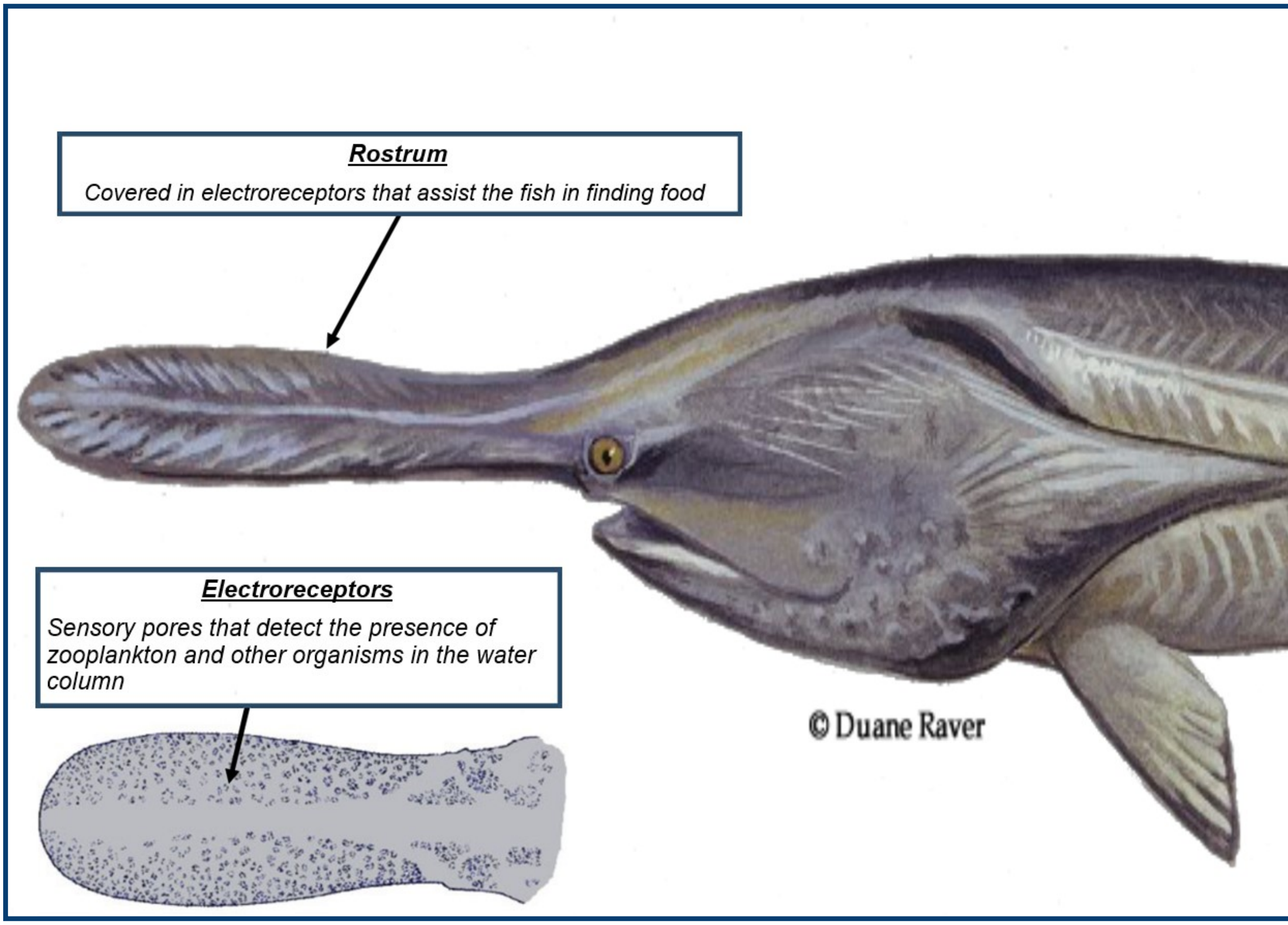
Order - *Acipenseriformes*

Family - *Polyodontidae*

Genus - *Polyodon*

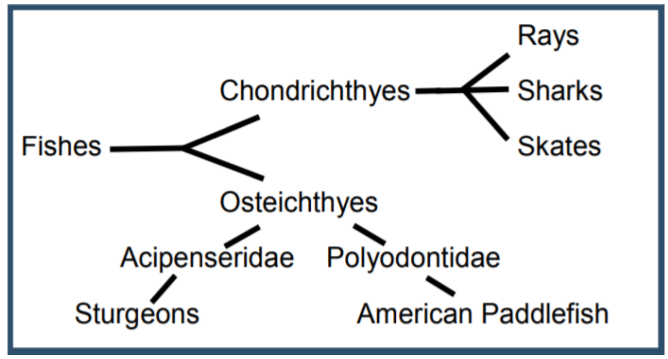
Species - *spathula*

Taxonomy of the American Paddlefish



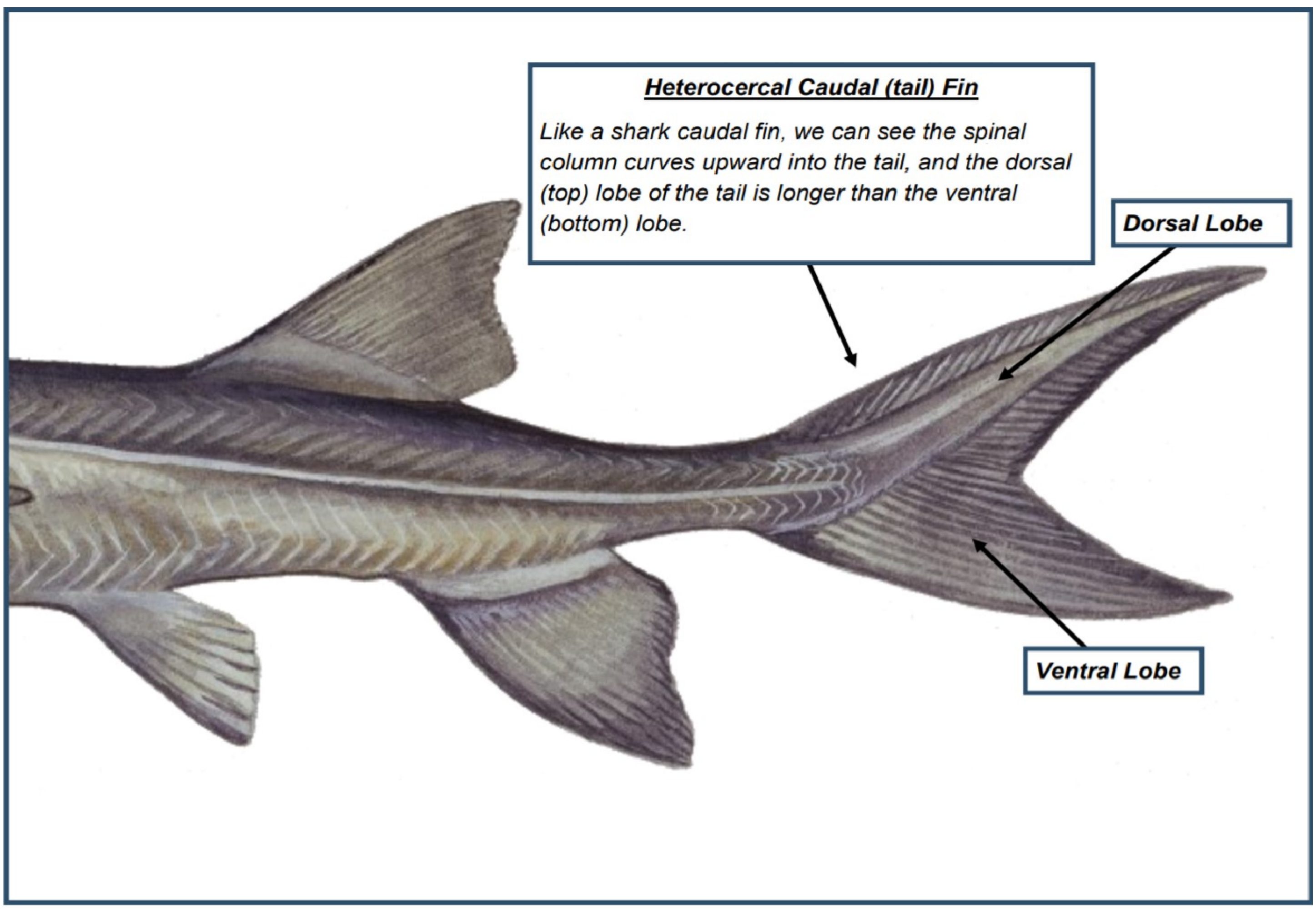
BIOLOGY OF THE PADDLEFISH

Paddlefish caudal fins are **heterocercal**, like that of a shark. This means that the dorsal (top) lobe, with the vertebral (spinal) column extending into it, is longer than the ventral (lower) lobe. The skeleton of the Paddlefish is mostly **cartilaginous**, with the exceptions of bone-like material found in the dentary (jaw) region and **ossified** (turned into bony tissue) skull structures found in mature Paddlefish.



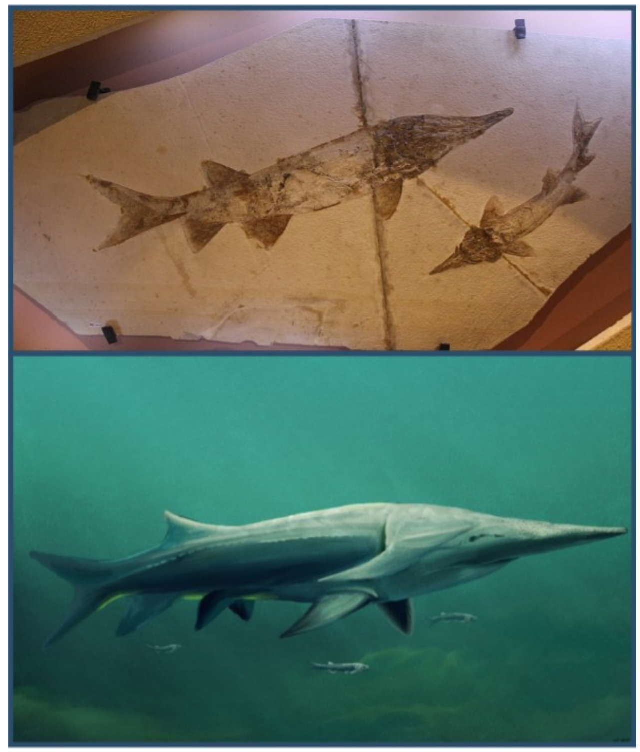
Simple phylogenetic tree showing evolutionary relationship of Paddlefish and other fish species

The Paddlefish looks like it is related to sharks, and was often mistaken as one when the species was first discovered and documented. In 1797, French naturalist ***Bernard Germain de Lacepede*** was one of the first scientists to disagree with the notion that Paddlefish were a species of shark. Bernard established the genus ***Polyodon*** for Paddlefish, of which the American Paddlefish is now the only living member. The German naturalist ***Johann Julius Walbaum*** had given the Paddlefish their species name *spathula* in 1792, five years before Lacepede, and thus is given credit for first scientifically naming the Paddlefish. Modern genetic analysis has proven that Paddlefish are more closely related to sturgeon, gar, bowfin, and other ray-finned fishes as opposed to sharks.



BIOLOGY OF THE PADDLEFISH

American Paddlefish are one of the largest freshwater fish in the world and can potentially live for **50 years** or more. It is the last remaining living species of Paddlefish in the world, with the Chinese Paddlefish (*Psephurus gladius)* being officially declared extinct in 2019. Unlike the American Paddlefish, the Chinese Paddlefish fed on other fish, had a sword-like mouth and could reach lengths of 9-10 feet or more!

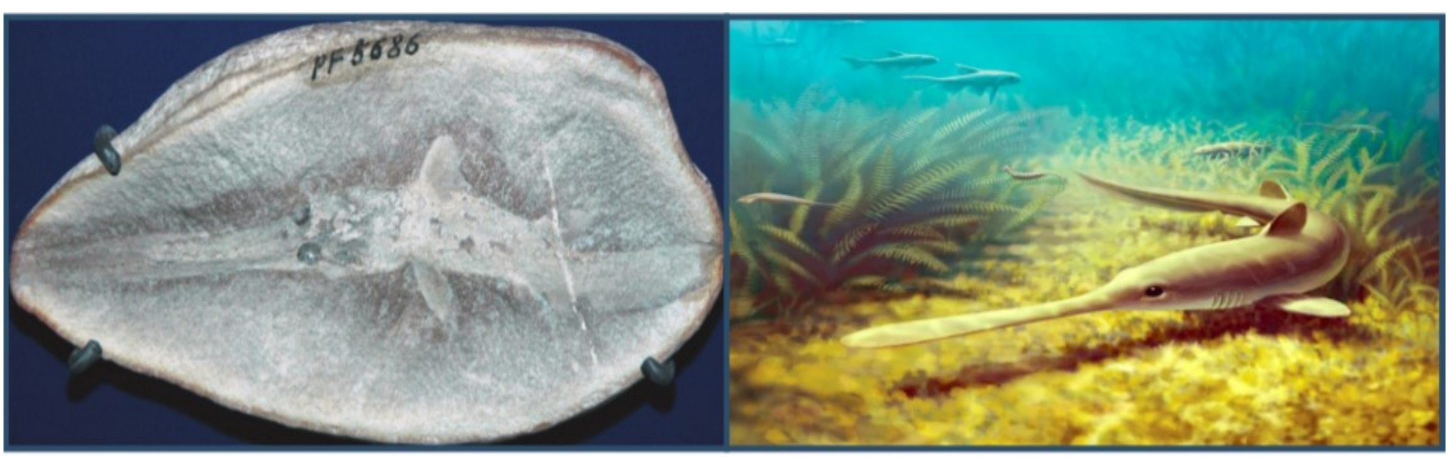


*125 million year old fossilized remains of extinct Paddlefish species "**Protopsephurus liui**" alongside artists recreation of what the fish may have looked like.*

Paddlefish in general are also one of the oldest living groups of fish. The oldest known Paddlefish fossils date back to the early Cretaceous period about **125 million years ago**, 60 million years before the extinction of the dinosaurs! Paddlefish are considered to be a **primitive species**, meaning they are physically similar to their ancestor species and show little evolution (change) over millions of years. Like its extinct relatives, the Paddlefish has a simple body and organ structure, a mostly cartilaginous skeleton, and few scales.

If we look even further back in the fossil record, we can find species that, while not members of the Paddlefish family (***Polyodontidae***), share a striking resemblance to our modern day Paddlefish. One such species is ***Bandringa rayi,*** a primitive species of shark found as far back as 350 million years in the fossil record, which is 100 million years before the first dinosaurs! It's fossil, seen below, looks much like a Paddlefish and very different from what we normally think of when we picture a shark. *Bandringa rayi* not only looks like a Paddlefish, but scientists believe it behaved like one as well, with their rostrums also containing the same electroreceptors that our Paddlefish use to find food today.

This phenomenon, when similar features evolve in independent species, is called **Convergent Evolution** and is one of the many fascinating aspects of the evolution of fish and of life in general. Another example of this is the fish-like body shape evolving not only in fish, but in mammals (Dolphins), reptiles (the now extinct Ichthyosaurs) and even some birds (Puffins) as well.



300+ million year old fossilized remains of extinct primitive shark species "Bandringa rayi" alongside artists recreation of what the fish may have looked like.

PADDLEFISH SPAWNING

Spawning is the release of eggs and sperm into the water for the purpose of reproduction. Paddlefish spawn only under specific environmental conditions and if all these conditions are not present, the fish will not reproduce. These necessary environmental factors include an increase in the time/length of daylight (**photoperiod**), a **temperature rise**, a significant increase of water flows (**flood pulse**), and **firm substrate** (coarse sand, gravel, cobble, mussel beds, or rip-rap) clean of silt. These conditions typically occur in Louisiana from **late February through March**. In more northern latitudes, such as Montana, they may not occur until May or June.

Males may spawn every year, but females do not. Once females reach maturity, it takes **2 or more years** for a female to produce mature eggs. When ready, a female can produce up to 10-12 pounds of eggs which can equate to as many as **500,000 eggs** or more per female! Once a female has enough eggs, she still may not spawn if the environmental conditions listed above are not favorable.

Recently hatched Paddlefish fry
Source: USFWS

During spawning, a large female accompanied by several smaller males will swim over selected suitable substrates, where males release milt (sperm) and females release eggs in the water simultaneously. Scientists call this spawning method **Broadcast Spawning**. In Louisiana, Paddlefish have adapted to spawn over hard substrates such as logjams and mussel beds because there are few gravel bars left in the state. The **naturally sticky** fertilized eggs adhere to the substrate, and are not washed away in river currents. The swift current keeps the eggs well oxygenated, and prevents debris and silt from covering them. Without these adaptations, the eggs would not be able to survive. If all goes well, the eggs will hatch in **about a week** and the larval fish are then swept downstream to quieter waters.

When first hatched, baby fish are called **fry**. The very beginnings of the fry stage in fish is called the **sac fry** stage. The name sac fry refers to the **yolk sac** that is still attached to the baby fish after it hatches (much like the yellow yolk of a chicken egg you would eat.) The fry uses this yolk sac as sustenance (food) until it is fully absorbed and the fry have grown large enough to begin feeding on zooplankton. After the fry stage, Paddlefish move on to the **fingerling** stage where they begin developing features more similar to their adult form.

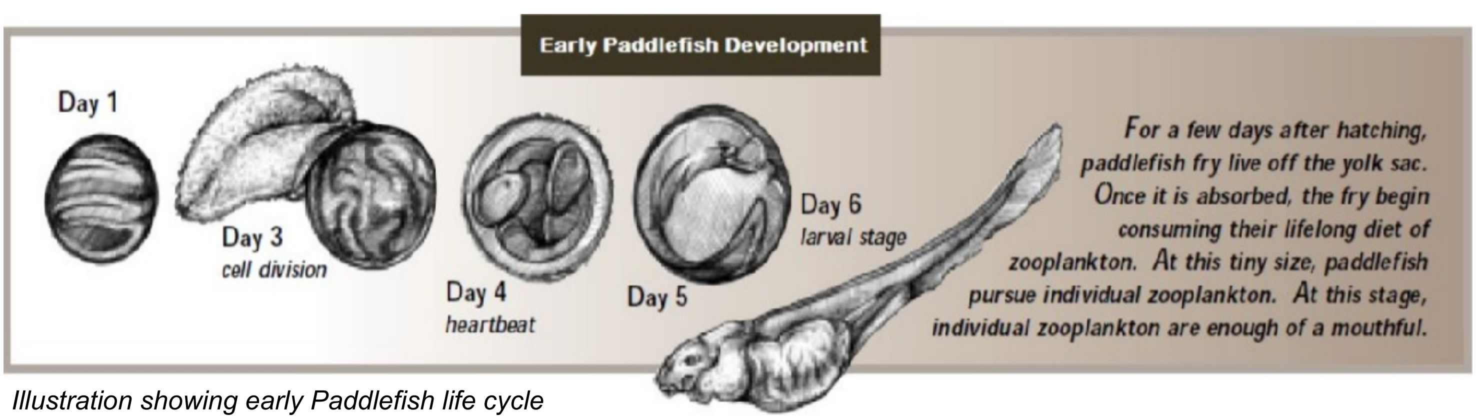


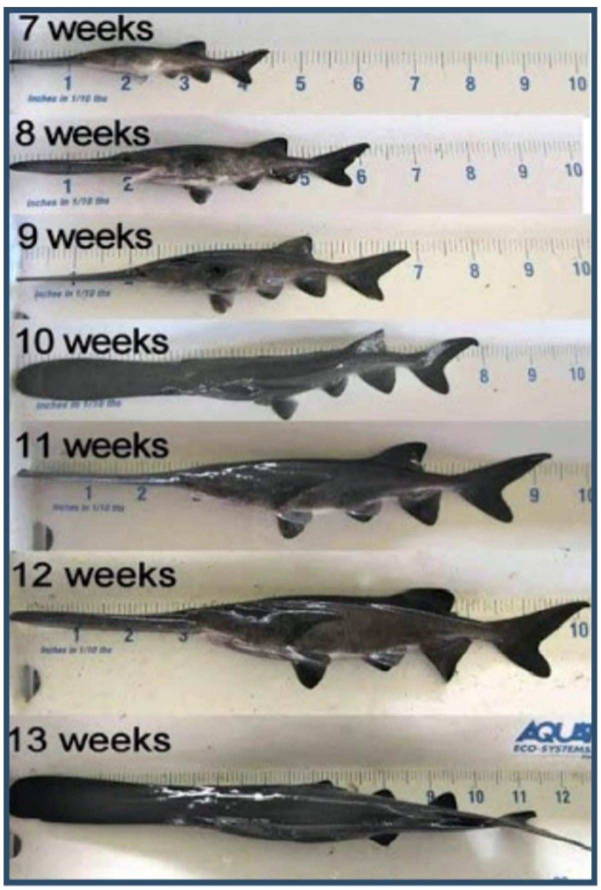
Illustration showing early Paddlefish life cycle
Source: Pennsylvania Angler & Boater

PADDLEFISH SPAWNING

Paddlefish hatch without their distinctive paddle-shaped rostrum, which begins to develop at the end of their fry stage. In fact, Paddlefish fry are actually **born with teeth**! This is why Paddlefish have the genus name ***Polyodon***, which means “many teeth” in Greek. They use these teeth to feed on individual zooplankton in the water column, which they will continue to do until they reach a large enough size to filter out many zooplankton at a time.

Example of variation in growth rates of Paddlefish fingerlings (all fingerlings shown are 30 days old)
Source: Garrison Dam National Fish Hatchery

By now you might be wondering, what is zooplankton? The term **plankton** refers to organisms that live in the water column and cannot swim against the currents, they just float. **Zooplankton** specifically refers to animal plankton (zoo meaning animal in Greek), as opposed to plant plankton which is called **phytoplankton**. Zooplankton usually comes in the form of microscopic crustaceans, however some zooplankton can be seen with the naked eye, such as certain species of Jellyfish.



Example of quick growth of a Paddlefish fingerling
Source: Southeastern Outdoors

Despite their ability to grow rapidly, Paddlefish mature late in life. Males reach sexual maturity between **7 and 9 years** of age, or at one-fourth of their expected life span. Females mature between **10 and 12 years** of age, or at one-third of their expected life span. Because of this, they are a particularly sensitive species when it comes to damage to their population. If the individuals of spawning age are somehow removed from a population, it could be years before new Paddlefish fry are spawned!

The Paddlefish at Booker Fowler Fish Hatchery will be **artificially spawned**, in a process that will be detailed in another section, and the eggs will then be taken back to the classroom by the teachers and their students and placed in an **incubation jar** until hatching

PADDLEFISH FEEDING

With its large size, most people would probably guess that the Paddlefish is a predator who pursues large prey. However, as we've learned so far the Paddlefish is actually a **filter feeder**, feeding on zooplankton and aquatic insects. Daphnia spp**.** (water fleas), copepods, and ostracods comprise the majority of the Paddlefish's diet, while they sometimes also feed on small-prey items such as larval fish. The mouth of the Paddlefish has numerous gill arches containing filaments called **gill rakers**, which are comb-like filaments that allow the Paddlefish to filter zooplankton out of the water.

Photo of Paddlefish gill rakers

Scientists once believed that the Paddlefish used its rostrum to dig into the sediment for food, it wasn't until more recently that we discovered that their rostrums are covered in sensory pores called **electroreceptors** (see illustration on pg1). These electroreceptors can detect weak electrical fields, allowing Paddlefish to use their rostrum like an antenna to find zooplankton and other organisms in the water near them. The receptors are so sensitive, that not only do they detect the presence of zooplankton, but the individual feeding and swimming movements of the zooplankton's appendages as well! These sensory pores extend from the rostrum to the top of the head and to the tips of the **operculum** (gill flaps) and take up nearly half the skin surface of the fish. Paddlefish have to rely on their electroreceptors to find food because they have **poorly developed eyes**. If the rostrum is damaged, a Paddlefish will still be able to locate food items because of electroreceptors located on the head region. Therefore, the rostrum is not the sole means of food detection but an important tool nonetheless.

As we discussed before, feeding habits of young Paddlefish differ from those of adults. Fingerlings less than 7 to 8 inches long do not have well developed gill rakers and are unable to strain zooplankton from the water. At this stage they are **selective feeders**, capturing zooplankton one at a time. Some young Paddlefish will selectively feed for up to one year or until they reach a total length of about 1ft.

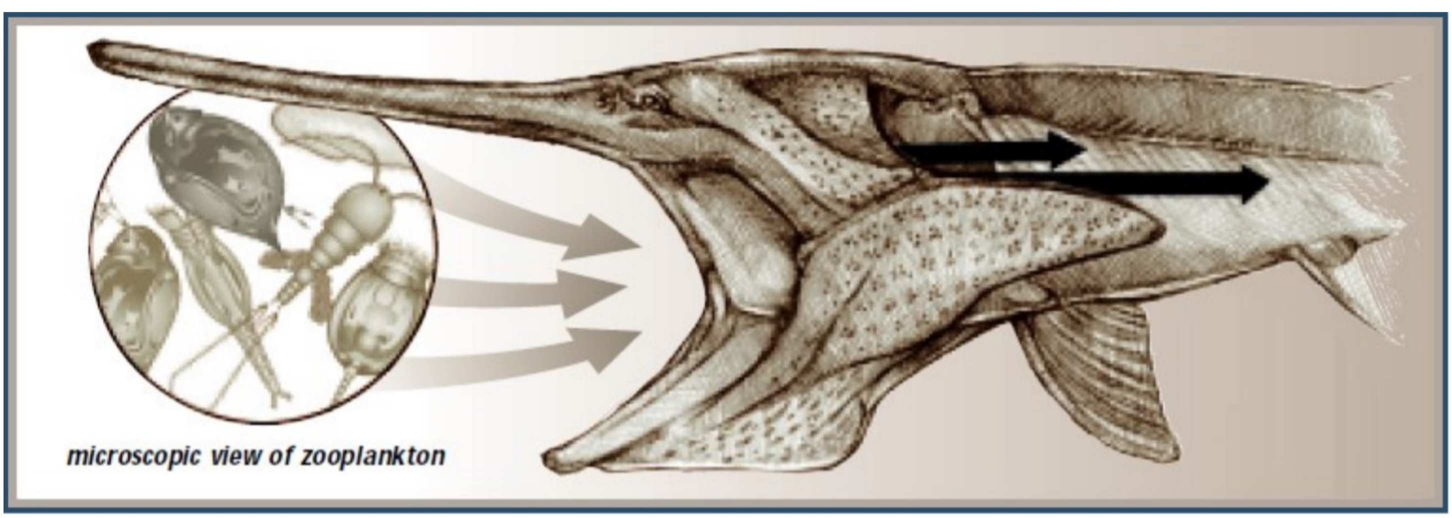
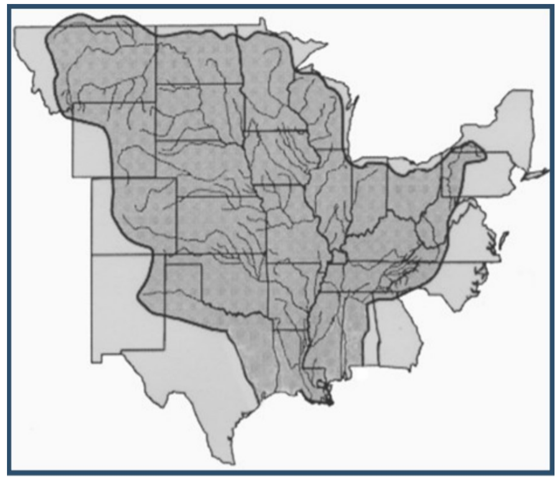


Illustration showing Paddlefish filter feeding
Source: Pennsylvania Angler & Boater

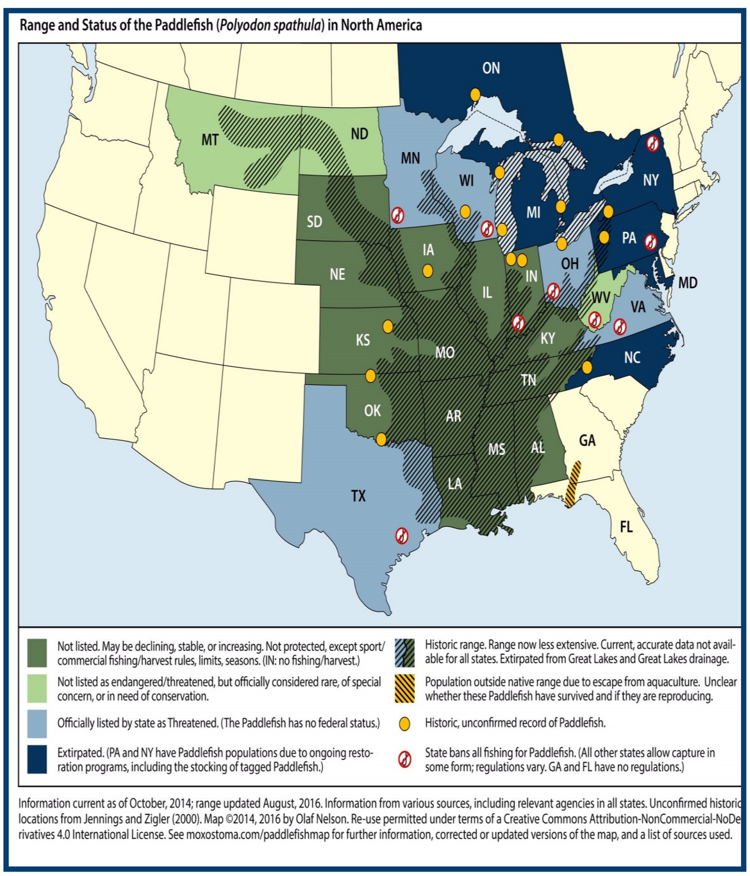
PADDLEFISH RANGE



Historic range of Paddlefish
Modified from Williamson 2003

It's often suggested that Spanish explorer **Hernando de Soto** was the first European to document Paddlefish when he traversed the Mississippi River in 1542. However, the first published European description of Paddlefish actually came from one of De Soto's crew members years later in 1557. Referred to as **A Gentleman from Elvas** (identity unknown), the Portuguese soldier described fishes caught by local Native Americans using nets in the Wabash River. Called **piexe pall** (shovel fish), they described the fish as "having a snout a cubit in length with the tip of it's upper lip being shaped like a shovel."

At that time, Paddlefish were found throughout the **Mississippi River drainage basin**, including the Great Lakes and rivers in Ontario, Canada. As of 2020, Paddlefish populations are now officially **extirpated** (naturally occurring populations no longer exist) in Canada, Pennsylvania, Maryland, New York, Michigan and North Carolina and their population range has been reduced to the Mississippi and Missouri rivers and tributaries, the Mobile Bay drainage basin, and Southwest Louisiana. Small Paddlefish populations do exist in Pennsylvania and New York thanks to ongoing recovery programs, however they are not yet self sustaining enough to officially say Paddlefish have returned in those states.



See Appendix V for larger image of map

In some parts of its current range, Paddlefish form stable populations and are **harvested** commercially and as sportfish by recreational anglers. The meat is eaten and is considered flavorful. More desirable than the meat are the **unfertilized** eggs, called **roe**. Paddlefish roe, like sturgeon caviar, is considered a delicacy. Harvesting of their roe has made the Paddlefish an economically valuable species, but has also had negative impacts on the species overall population.

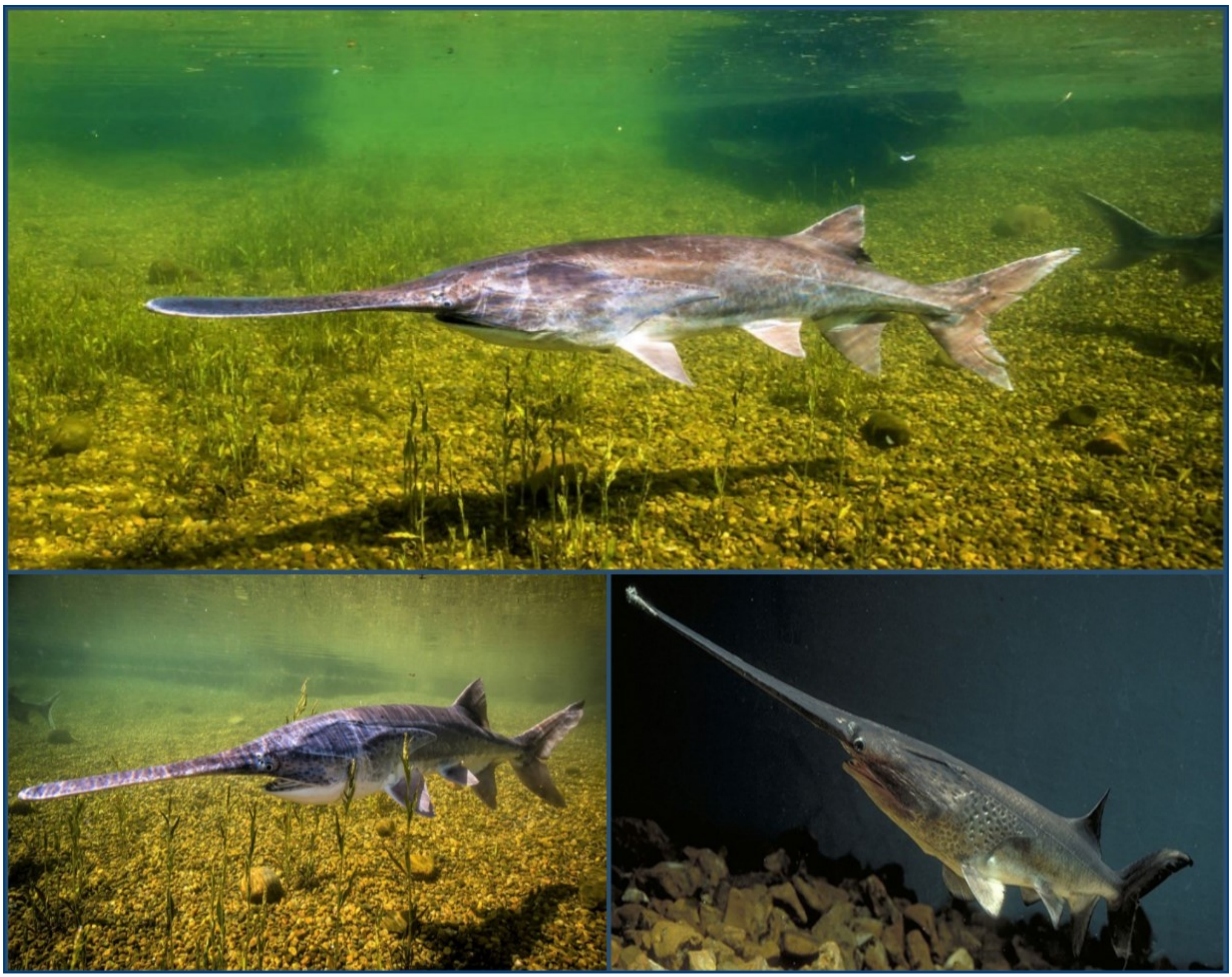
Outside of its naturally occurring range, there were also **non-indigenous** (not naturally occurring) populations of Paddlefish in Georgia which spread to Florida, although it is unknown whether or not these individuals have reproduced. They were accidentally released from an aquaculture facility along the Flint River in Georgia during Tropical Storm Alberto in July of 1994.

PADDLEFISH HABITAT

Paddlefish are found in many types of **riverine habitats** within the Mississippi River drainage basin. Many find homes in deeper, low-current areas of river systems. Some of these areas include side channels, backwaters, oxbow lakes, natural lakes, reservoirs, and tail waters below dams. For spawning habitat, as we discussed before, they prefer to have river systems with firm substrate (coarse sand, gravel, cobble, mussel beds, or rip-rap) clean of silt.

In Louisiana, Paddlefish are found in numerous rivers, lakes, and bayous, and are in **every river basin in the state**. Though primarily a freshwater fish, Paddlefish can also be found in more saline/brackish (salty) waters such as the estuarine systems of Lake Pontchartrain and Grand Lake where salt and freshwater mix.

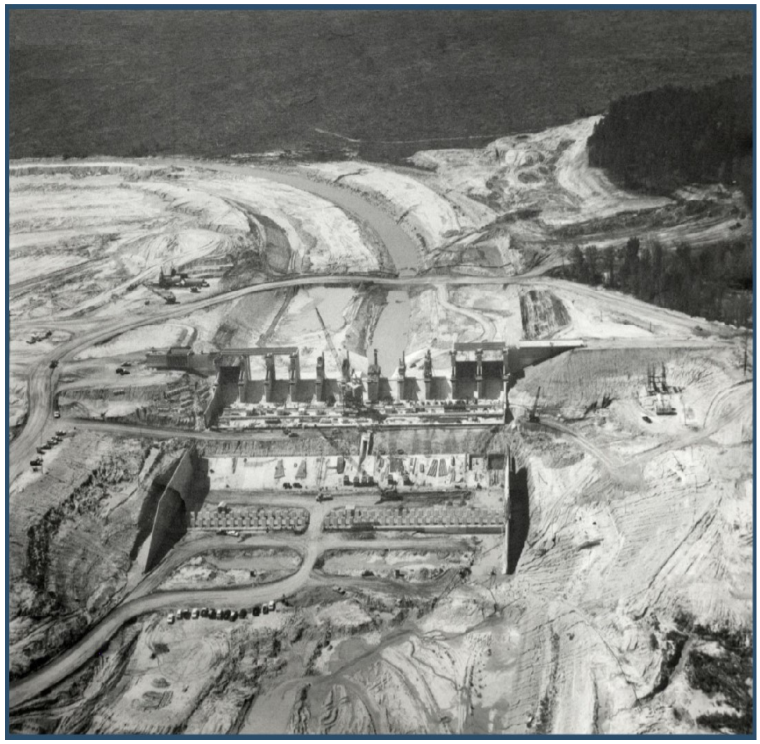
The fish are highly migratory and can travel up to **2,000 miles** in a river system, typically swimming near the surface, with tagged fish from Oklahoma being recaptured as far away as Tennessee for example.



Paddlefish in their natural habitat
Source: USFWS

CAUSES OF POPULATION DECLINE

Paddlefish are found in only **22 states** as of 2020 (excluding small recovery populations in Pennsylvania and New York). In some of the states where Paddlefish are found, the populations are protected under federal or state laws due to **severe population decline** in the past, although populations have successfully rebounded in some areas. As of 2020, **15 states** allow commercial and/or sport fishing for Paddlefish.



Toledo Bend spillway construction
Source: Toledo Bend Lake Country

One of the primary causes of the decline in Paddlefish populations are the human activities that have led to widespread **habitat alteration, degradation,** and **loss**. There are several well-known limiting factors that affect Paddlefish populations, either by directly harming the fish or damaging habitat critical for the species' survival. These include **dam construction**, **pollution**, and **overharvesting**.

Spawning areas are degraded mainly by human efforts to improve flood control and navigation, including **dredging of rivers** and **construction of levees**, **locks**, and **dams**. Dams significantly alter the surrounding environment, affecting all forms of life in the local vicinity in two ways. First, dams form reservoirs with deep, open water and slow currents that may inundate areas that were once ideal Paddlefish spawning areas. Secondly, dams reduce water flow downstream, which will increase the release of sediment into the water covering clean gravel bars Paddlefish prefer for spawning. Dams also affect Paddlefish populations by creating barriers that prevent migration to spawning grounds and migration up and down the waterway for food. **Pollution** from industry, municipalities, and agriculture also further degrades water quality and Paddlefish habitat.

A good example of dam construction that impacted Louisiana's Paddlefish population specifically would be the **Toledo Bend Dam and Generating Complex**, built on the Sabine River. The purpose of this dam is to produce electricity, to maintain water supply, and to support recreation (especially for sport fishing). **The Toledo Bend Reservoir** covers 185,000 acres of land and is 65 miles long and 15 miles wide, making it the largest human-made body of water in the south. Unfortunately, this dam was constructed over critical spawning habitat (clean gravel bars) for the Paddlefish in that area, so currently fingerlings released there that move below the dam are unlikely to ever spawn due to the **lack of suitable habitat**. Lack of spawning habitat will eventually cause **drastic declines** in populations over time, as older fish start to die off without being replaced by new ones. This was the result of an **oversight** by the biological surveys conducted in the summer months pre-dam construction, which showed no signs of Paddlefish spawning since they only spawn during the **spring months** in Louisiana.
Since 1990, Louisiana Department of Wildlife and Fisheries and Texas Parks and Wildlife have worked jointly to restore the Paddlefish populations **above the dam**, and because of those restoration programs the Paddlefish populations above the dam have been restored to **healthy levels**.

CAVIAR INDUSTRY

Overharvesting for roe (unfertilized eggs) is another cause of additional stress to imperiled Paddlefish populations. This stress becomes more of a concern as sturgeon stocks rapidly decline worldwide and Paddlefish, a close relative with similarly sized roe, is sought as a replacement.

Image of Paddlefish "caviar"

Sturgeon species from the Black and Caspian Sea basins are the most common/sought after species harvested for their roe. Sturgeon species are the only fish to legally have their roe labeled simply as caviar under the Food and Drug Administration's (FDA) food labeling regulations, **21 CFR Part 101**. If the roe of another species is placed in a container labeled caviar, it must also include the name of the fish it was taken from with the font of the words the same size and prominence (**FDA warning letter 2002**). Trade of meat and roe harvest from sturgeon species listed as endangered is regulated under the **Convention on International Trade in Endangered Species of Wild Fauna and Flora** (CITES), which we will learn more about in another section.

Overfishing, poaching, and industrial pollution have greatly diminished populations of sturgeon species. As of 2020, all Caspian sturgeon species are listed as critically endangered by the **International Union for Conservation of Nature** (IUCN). Overall, sturgeon are one of the most critically threatened groups of animal in the world, with 85% of sturgeon species being at risk for extinction (63% listed as critically endangered).

Image of Beluga Sturgeon, the Caspian sturgeon species most commonly harvested for its roe for caviar (caviar shown on the right)

CAVIAR INDUSTRY

In more recent years, sturgeon **aquaculture farms** have been gaining popularity and are resulting in a resurgence of sorts for the global sturgeon caviar industry, especially when it comes to roe from the critically endangered **Beluga Sturgeon**. While still heavily regulated and restricted, this has allowed for the sale of caviar from **captive bred** Beluga Sturgeon without impacting wild populations, and in some cases the aquaculture farms also contribute to efforts to restore those wild populations. In the United States, **Sturgeon AquaFarms** in Bascom, Florida was the first facility to be granted an exemption from caviar trade laws on June 15th, 2016. The exemption was granted with the agreement that Sturgeon AquaFarms would commit to aiding in the **restoration** of wild Beluga Sturgeon **populations** and **habitat**, in addition to other agreed upon conditions. The exemption allows Beluga Sturgeon born and raised at the aquaculture farm to be harvested for meat and roe and to be traded in interstate commerce.

Beluga Sturgeon from Sturgeon AquaFarms aquaculture facility in Florida

Source: Merkle Photography

Roe harvested from Paddlefish

Source: Bobby Reed, LDWF

Because of the declining wild sturgeon populations and increased restrictions on the sale of their roe, other species such as the Paddlefish have been sought as replacements, as we've discussed. With its gray color and nutty flavor, Paddlefish roe is very similar in color, size and taste to caviar from Sevruga Sturgeon (*Acipenser stellatus*) from the Caspian Sea. In the United States, Paddlefish roe can yield fishers roughly **$260 per kilogram** ($120 per pound) and retail at **$810 per kilogram** ($192 per pound). Hopefully, aquaculture facilities like Sturgeon AquaFarms will soon be able to sufficiently supply the sturgeon caviar trade, ideally decreasing the need/desire for alternative sources of roe such as Paddlefish.

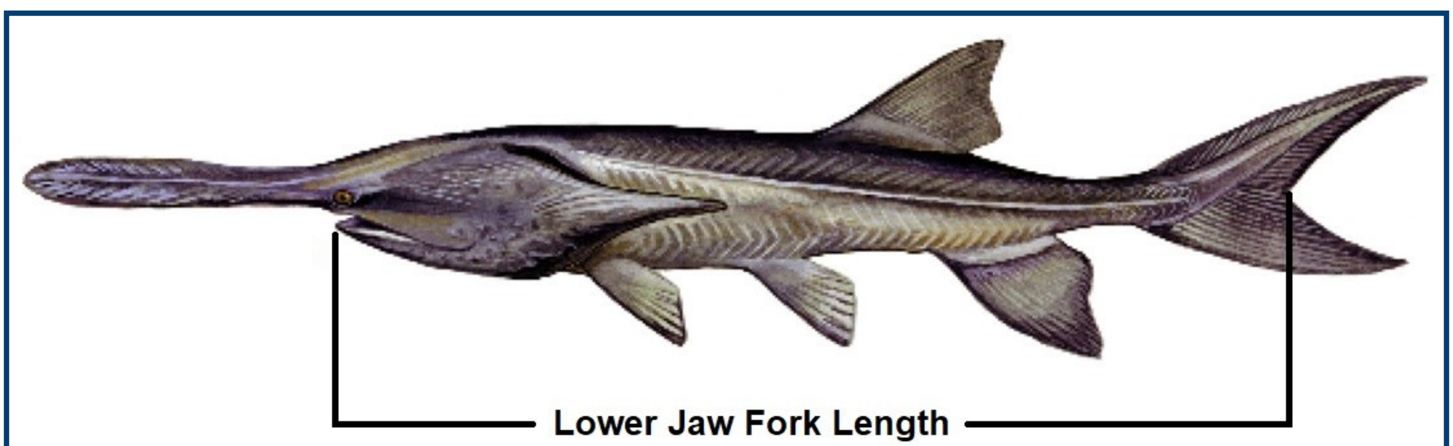
PADDLEFISH CONSERVATION

Depending on the state and the health of the specific population in question, the status of Paddlefish populations varies from federally protected and/or state-protected to unprotected. In 1992, the Paddlefish was listed in **Appendix II** of the **Convention on International Trade in Endangered Species of Wild Fauna and Flora** (CITES). CITES is an agreement among governments to ensure that international trade of a species will not threaten the species' survival. Species that are listed in Appendix II are not necessarily threatened with extinction, but the trade of these species is regulated. For the specimen to be exported, the exporter must show that they have a permit that certifies the specimen was <u>legally obtained</u>, that the specimen will face <u>minimal risk of injury</u> during transport, and that the trade of the specimen <u>will not be detrimental to the survival of the species.</u>

In 1991, 28 state natural resources management agencies formed a Mississippi River basin-wide conservation effort called the **Mississippi Interstate Cooperative Resource Association** (MICRA) to improve inter-jurisdictional management of aquatic resources. MICRA established the **Paddlefish/ Sturgeon Subcommittee** whose mission is to provide information and recommendations to conserve and manage Paddlefish through inter-jurisdictional coordination, communication, and assessment.

In Louisiana, Paddlefish are still considered protected though the population is stable. As of 2020, recreational anglers are allowed to take **two Paddlefish per day** with a **maximum lower jaw-fork length of 30 inches** (example shown below). This is meant to protect large mature females from harvest because, as we discussed earlier, Paddlefish take quite some time to reach the age of sexual reproduction (up to 10-12 years for females). Commercial fishing for Paddlefish however is **illegal in Louisiana**. Other states with sustainable Paddlefish populations that can support commercial and/or sport (recreational) fishing are Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Mississippi, Missouri, Montana, North Dakota, Oklahoma, South Dakota and Tennessee. Commercial fishing in Alabama was brought back in 2013, however due to declining quality of reports from Paddlefish fisherman, which caused the state to start suspecting illegal sales, commercial Paddlefish fishing was again closed indefinitely in 2018.

Throughout the Paddlefish's natural range, there are many programs to help restore populations to healthy, sustainable levels. In addition to crucial habitat conservation, restoration, and improvement efforts, fish hatcheries also play a very important role in this process by artificially spawning Paddlefish and releasing new fingerlings into the wild. **Programs**, **regulations**, and **facilities** like the ones we've discussed are extremely important to the conservation and preservation of Paddlefish, and as we'll see in the next section detailing the story of the Chinese Paddlefish, the absence of such efforts can lead to gross misuse and abuse of natural resources that can cause potentially irreversible damage to wildlife species and the ecosystems they live in.



PADDLEFISH CONSERVATION

Conservation Status

When discussing/researching the conservation of any species, you're likely to come across terms such as threatened, protected, endangered, etc. You might be wondering, what do these terms mean and where do they come from? Terms like these are known as a species **conservation status** or conservation status level and are used by numerous global, national, and statewide agencies/organizations to categorize species based on their conservation needs. In other words, assigning a conservation status for a species lets you assess which species are in the most dire need of **assistance** and **management**. The exact definitions of these terms will change depending on the particular source you're looking at, but they tend to have very similar definitions.

The most popular and common list of conservation statuses was established in 1964 by The International Union for Conservation of Nature and is called the **IUCN Red List of Threatened Species**. The IUCN Red List is currently the worlds most comprehensive information source for the global conservation status of animal, fungi and plant species. It created **9 categories** which species can be grouped into (all detailed in a table on page 14). In most cases, these terms do not come with any legal backing to them as they're often created by non-government conservation organizations. However, conservation statuses outlined by state and federal agencies do have legal backing to them and are used to enforce those laws and guide species management.

Endangered Species Act

The most well known conservation law in the United States is the **Endangered Species Act** (ESA). Passed in 1973, the ESA created 2 potential listings for species: **Endangered**, which means a species is in danger of extinction throughout all/most of its natural range without proper management, and **Threatened,** which means a species is likely to become endangered in the immediate future without proper management. Species listed as either Endangered or Threatened under the ESA will have federal protections with legal ramifications for individuals who disturb these species. In addition to the ESA, each state also has their own conservation legislation and laws governing protections for species that compliment the federal laws.

Louisiana State Conservation Statuses

State statuses for Louisiana can be found in **Title 56 of the Louisiana Revised Statutes** as well as relevant rules and regulations adopted by the Louisiana Wildlife and Fisheries commission and the Secretary of the Louisiana Department of Wildlife and Fisheries. Louisiana generally uses 5 categories for the conservation status of species: **Endangered**, **Threatened/Endangered**, **Threatened**, **Prohibited** and **Restricted Harvest** (all detailed in a table on page 14*).* As of 2020, Paddlefish are still protected in Louisiana and fall under the **Restricted Harvest** status.

In addition to these conservation statuses, Louisiana (as well as all other states) also has a population ranking system further detailing the status of a species' population in the state, containing **12 possible rankings** (all detailed in a table on page 15*).* These rankings differ from the more well known conservation statuses in that they strictly deal with the health of a population within the state as opposed to it's legal or management conservation status. One way to think about it, is that a species population rank can advise us on which conservation status it should receive. As of 2020, Paddlefish are given a rank of S4 in Louisiana, meaning their population is likely secure in the state.

PADDLEFISH CONSERVATION

IUNC Red List - Conservation Statuses	
Status:	*Definition:*
Extinct (EX)	No known living individuals
Extinct in the Wild (EW)	Known only to survive in captivity, or as a naturalized population outside it's historic range
Critically Endangered (CR)	Extremely high risk of extinction in the wild
Endangered (EN)	High risk of extinction in the wild
Vulnerable (VU)	High risk of endangerment in the wild
Near Threatened (NT)	Likely to become endangered in the future
Least Concern (LC)	Lowest risk; does not qualify for a higher risk category
Data Deficient (DD)	Not enough data to make an assessment
Not Evaluated (NE)	Has not yet been evaluated against the criteria

Table detailing the IUNC Red List conservation statuses and definitions of each

Louisiana State Conservation Statuses	
Status:	*Definition:*
Endangered	Species at risk of extirpation or extinction. Take or harassment of these species is a violation of state and federal laws.
Threatened/ Endangered	Imperiled species with populations of conflicting protection status. Take or harassment of these species is a violation of state and federal laws.
Threatened	Species at risk of becoming endangered. Take or harassment of these species is a violation of state and federal laws.
Prohibited	Possession of these species is prohibited; no legal harvest or possession allowed without valid Scientific Research and Collecting Permit issued by LDWF.
Restricted Harvest	Restrictions regarding the take and possession of these species.

Table detailing the Louisiana state conservation statuses and definitions of each

Louisiana State Population Rankings	
Ranking:	*Definition:*
S1	Critically imperiled in Louisiana because of extreme rarity (5 or fewer known extant populations) or because of some factor(s) making it especially vulnerable to extirpation
S2	Imperiled in Louisiana because of rarity (6 to 20 known extant populations) or because of some factor(s) making it very vulnerable to extirpation
S3	Rare and local throughout the state or found locally (even abundantly at some of its locations) in a restricted region of the state, or because of other factors making it vulnerable to extirpation (21 to 100 known extant populations)
S4	Apparently secure in Louisiana with many occurrences (100 to 1000 known extant populations)
S5	Demonstrably secure in Louisiana (1000+ known extant populations)
B or N	May be used as qualifier of numeric ranks indicating whether the occurrence is breeding (B) or nonbreeding (N)
SA	Accidental in Louisiana, including species (usually birds or butterflies) recorded once or twice or only at great intervals hundreds or even thousands of miles outside their usual range
SH	Historical occurrence in Louisiana, but no recent records verified within the last 20 years; formerly part of the established biota, possibly still persisting
SR	Reported from Louisiana, but without conclusive evidence to accept or reject the report
SU	Possibly in peril in Louisiana, but status uncertain; need more information
SX	Believed to be extirpated from Louisiana
SZ	Transient species in which no specific consistent area of occurrence is identifiable

Table detailing the Louisiana state population ranks and definitions of each

THE CASE OF THE CHINESE PADDLEFISH

When discussing the conservation of our American Paddlefish (*Polyodon spathula*), it's important to compare with the fate of the recently extinct **Chinese Paddlefish** (*Psephurus gladius*). At one time this fish joined the American Paddlefish as one of the only 2 living species of Paddlefish in the world and could be found primarily throughout the **Yangtze River** in China. However, the Chinese Paddlefish was officially declared extinct in a 2019 paper published by scientists from the Yangtze River Fisheries Research Institute in China who estimated the species went extinct sometime around 2005-2010, and was likely **functionally extinct** (no more reproducing individuals of the species) by 1993.

As it's species name gladius suggests (gladius is the Latin term for sword), this Paddlefish differed from the American Paddlefish in that it's rostrum was pointed and sword-like. They were a much bigger species of Paddlefish, averaging around 3 meters (9.8ft), and unlike their filter-feeding relatives, the Chinese Paddlefish ate larger prey, primarily fish and crustaceans. The Chinese Paddlefish also differed from it's American counterpart in that it was an **anadromous** fish, meaning it spent part of it's life cycle in salt water. The fish would spend part of their life in the lower, brackish portions of the Yangtze River but would migrate further upstream to spawn.

The main causes of population decline and ultimately extinction for this species were a combination of **dam building** (primarily the construction of the Gezhouba and Three Gorges dams), which fragmented the population and prevented the fish from migrating to their spawning locations, and **overfishing.** Fishing of Chinese Paddlefish has a history dating back centuries. By the 1970s, harvests were reaching near **25 tons per year**. The Chinese Paddlefish was listed as critically endangered by the IUCN in the 1990's, and was last seen alive around 2003. The fate of this species is an important case study in how policy/regulations, conservation programs, and in many ways public sentiment, play an invaluable role in preserving our wildlife and natural resources and can be the difference between species going extinct, like the Chinese Paddlefish, and species rebounding and in some cases thriving, like the American Paddlefish.

One of the only known photos of the Chinese Paddlefish in existence

Source: Unknown

AQUATIC INVASIVE SPECIES

Plants and animals living outside their natural geographic boundaries can be called by many names: **exotic**, **introduced**, **nonindigenous**, **invasive**, **non-native**, and **nuisance**. Some of these organisms have been intentionally introduced by humans for reasons such as use in agriculture, the pet industry, and fish and wildlife management. Others have entered accidentally in ships' ballast waters, in packing materials, as hitchhikers on other plants and animals, or even in hurricanes. Because of its mild climate and geographical location, Louisiana is **very susceptible** to the introduction of a variety of non-native plants and animals.

When non-native species make their way into natural ecosystems, they can threaten native habitats and the organisms that live there. Once established, non-native species can displace native plants and animals, alter ecosystems, cause disease, and interfere with industry, agriculture, and recreation. Once a non-native species begins negatively impacting the native environment, they're referred to as **invasive species**.

A great example of an invasive species in Louisiana are the **Asian Carp**, which is a group of freshwater invasive fish species from China and other parts of East Asia. Included in this group are many species that people across the US have grown familiar with in recent years, such as the **Bighead Carp** (*Hypophthalmichthys nobilis*), **Grass Carp** (*Ctenopharyngodon idella*), **Silver Carp** (*Hypophthalmichthys molitrix*), and **Black Carp** (*Mylopharyngodon piceus*).

These invasive carp species affect Paddlefish in several ways, especially the Bighead Carp and Silver Carp. Both of these species **feed on zooplankton**, which we've learned is the Paddlefish's primary source of food. By competing with Paddlefish for the same food sources, these carp can have significant negative impacts on Paddlefish populations in Louisiana by limiting the amount of resources available to sustain the Paddlefish population. The Silver and Bighead Carp also encroach on Paddlefish habitat, adding another layer of negative impacts onto the already significant **resource depletion** caused by sharing a food source.

BIGHEAD CARP

Source: US Fish and Wildlife Service

The adult Bighead Carp reaches **51 centimeters** (20 inches) in length and can weigh about **9 kilograms** (19 pounds). It has irregular black blotches on its body as well as small scales. The body shape is distinctive with a short body length and large head. It is a filter feeder that eats plankton throughout the water column.

SILVER CARP

Source: US Fish and Wildlife Service

The adult Silver Carp reaches **120 centimeters** (47 inches) in length and can weigh about **9 kilograms** (19 pounds). It is a silver-colored fish with a toothless, upturned mouth that has fused and sponge-like gill rakers. This fish feeds on plankton in the upper portion of the water column and prefers to inhabit impoundments or backwaters of large rivers.

AQUATIC INVASIVE SPECIES

Grass Carp

Source: US Fish and Wildlife Survey

The adult Grass Carp reaches a length of **127 centimeters** (50 inches) and can weigh about **27 kilograms** (60 pounds). Its coloring is dark bronze on the back with a silver belly. The scales are darkly colored on the edges, giving the fish a cross-hatched appearance. Grass carp feed on soft aquatic vegetation.

Black Carp

Source: USGS

The Black Carp reaches **132 centimeters** (52 inches) in length and weighs up to **68 kilograms** (150 pounds). It is brownish-black in color with black-gray fins. The body shape is long and thin, and it has a mouth full of teeth made to crush prey. Found in large rivers and lakes, this fish prefers to inhabit the bottom portion of the water column, closer to its prey. The black carp eats snails, mussels, aquatic insects and crustaceans. It closely resembles the grass carp, but is darker in color.

Zebra Mussel

Source: USGS

Another aquatic invasive species that can have a negative effect on the Paddlefish's food source is the **Zebra Mussel** (*Dreissena polymorpha*). Zebra Mussels are small **filter feeders** that live in freshwater and have alternating dark and light bands on their 2-inch-long shell. They are known to take more food out of the water column than they can actually use, which affects all other filter feeders in the area by decreasing the amount of plankton in the water column. While primarily a lake mussel, they can have serious impacts on river ecosystems as well.

Invasive species are a very serious issue all over the world, especially when it comes to their impacts on environmentally sensitive/threatened species such as the Paddlefish. A 2005 paper published on the economic impacts of invasive species calculated that invasive species cost the U.S. alone more than $120 billion in damages every year, in addition to the hundreds of million spent each year to try and mitigate the issues caused by invasive species.

FISHERIES MANAGEMENT AND HATCHERIES

Louisiana Department of Wildlife and Fisheries (LDWF) is the lead agency in the state to conserve and protect living renewable resources for present and future generations of Louisiana citizens. The mission of the **Office of Fisheries** is to conserve and protect aquatic resources by controlling the harvest and replenishing of aquatic species, and enhancing fishery stocks and habitat. The Office of Fisheries manages fish populations and habitats for the conservation and improvement of recreational and commercial fishing. These aquatic resources are managed to provide for the needs of consumptive and non-consumptive users, to maintain environmental health, and protect imperiled species. This is accomplished by setting fishing seasons, size and possession limits, gear restrictions, or other means of protecting key resources including replenishing species and conserving, restoring, and enhancing their habitats. Ongoing research provides insight into the proper functioning of natural systems, and public education programs promote the wise use of these resources.

ROLE OF HATCHERIES

What is a hatchery?

A hatchery is a place where fish species such as bass, catfish, and sunfish are hatched, raised, and then stocked in waterways to enhance natural populations. LDWF operates four fish hatcheries; **Beechwood Fish Hatchery**, **Monroe Fish Hatchery**, **Lacombe Fish Hatchery** and **Booker Fowler Fish Hatchery**. The Beechwood, Monroe and Lacombe Hatcheries are older facilities constructed in the 1920s and 1930s and the newer Booker Fowler Fish Hatchery began fish production in the spring of 1997.

Why are hatcheries important?

Resource managers nationwide acknowledge hatcheries as valuable tools for the preservation of our nation’s fish resources. Fish are stocked for several reasons. Some are stocked to **enhance** recreational fishing, others to **restore** native species to waters they formerly occupied.

The LDWF fish hatchery system has a rich history of fish production and research. Much of the technology used in modern catfish and Striped Bass aquaculture practices was developed at the department’s hatchery facilities. Historically, the hatchery system functioned primarily as support for technical assistance to pond and small lake owners and for stocking new and renovated lakes with native species, predominately Largemouth Bass and Bluegill. Today, Louisiana’s hatcheries produce fish for bodies of water that have been damaged by habitat destruction or overuse, as well as stocking select lakes with popular sport fish, primarily the Florida subspecies of the **Largemouth Bass** (*Micropterus salmoides floridanus*).

Why stock Florida Largemouth Bass?

The primary reason to stock **Florida Largemouth Bass** is that the Florida subspecies of Largemouth Bass grow larger than our native bass, and thus are more enjoyable for anglers to catch. By stocking the Florida subspecies, we can enhance the genetic makeup of our native Largemouth Bass through **cross breeding**, which will naturally occur in the wild. This will lead to an overall increase in the average size of our native Largemouth Bass, a trend we have seen successfully taking place since the first introduction of the Florida subspecies in the 1980’s as state weight records for the species have been increasing ever since.

BOOKER FOWLER FISH HATCHERY

The **Booker Fowler Fish Hatchery** was built with federal disaster relief funds that were allocated to Louisiana due to damage to the Atchafalaya Basin in 1992 by Hurricane Andrew. Paddlefish populations were decimated; 100,000 fish were lost to this storm. The total cost to build this state-of-the-art facility was $13 million. It is the **largest fish hatchery** in Louisiana, and has been designated as the department's primary fish production facility. The hatchery produces all fry and provides most of the fingerling production for the state of Louisiana.

Hatcheries can be warm-, cool- or cold-water facilities. Booker Fowler Fish Hatchery is a warm-water station involved in spawning, hatching, and rearing young fish (fingerlings). Fingerlings are raised to a size and age that provides them the best chance of survival in the wild. Louisiana's hatchery system supports the management plans implemented by LDWF's Inland Fisheries biologists, providing them with healthy sportfish fingerlings to stock into Louisiana's public waters.

Overhead view of retention ponds at Booker Fowler Fish Hatchery, used to raise fish for stocking

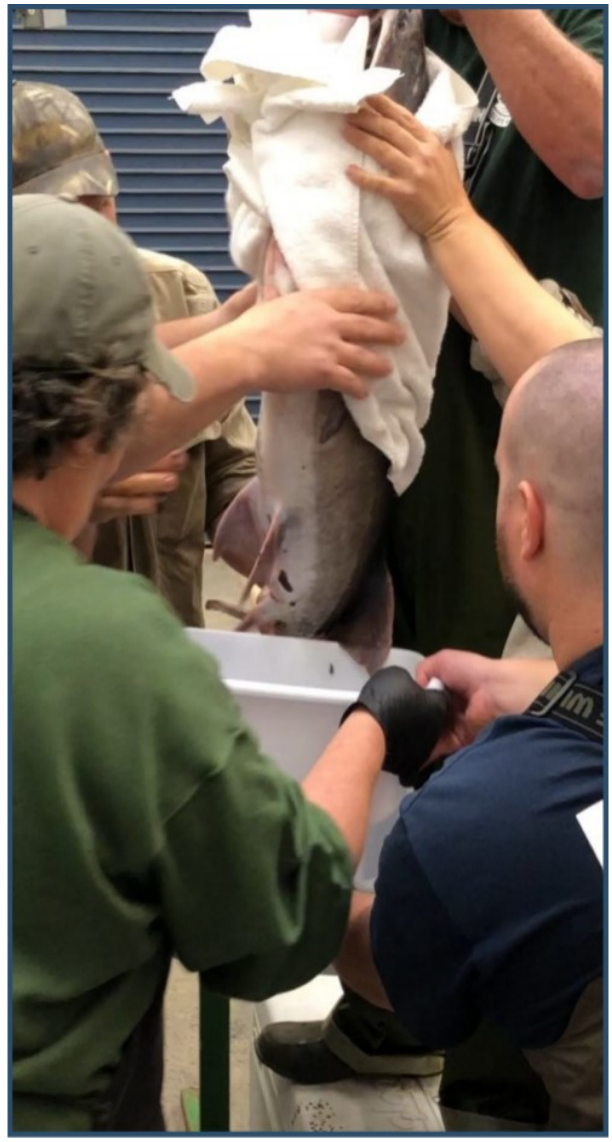
Booker Fowler Fish Hatchery has spawned Paddlefish since 1997 and has since produced millions of fry and fingerlings. The hatchery cannot provide Paddlefish with all the environmental factors required to spawn naturally (see spawning section), therefore, Paddlefish are **artificially spawned** in the hatchery. Wild Paddlefish stock are collected because they are river inhabitants and do not respond well to living in hatchery ponds. In Louisiana, mature fish are collected from flooded tributaries in February. Once collected, Paddlefish are transported in hauling trucks.

Outdoor "raceways" used to house adult Largemouth Bass for spawning

At the hatchery, the fish are sexed, weighed, and tagged. Next, the fish are injected with the **LHRHa hormone** (luteinizing hormone releasing hormone analog), which stimulates spawning. The female is given **two injections**, one 24 hours and one 12 hours prior to spawning to help the eggs ripen (become ready to be spawned). Males are given **one injection** about 24 hours prior to spawning to increase milt (sperm) production. The following morning, female Paddlefish are examined for softened abdomens, which is a sign that eggs are mature. When eggs begin to flow from the vent of the female, artificial spawning begins.

BOOKER FOWLER FISH HATCHERY

Eggs can be removed from the female Paddlefish in two ways: the female may undergo a **Caesarean section**, or she can be stripped of her eggs. During the Caesarean section procedure, the female is placed on a stretcher on her dorsal side (belly up) and kept irrigated via water running across her gills. A small incision is made on her abdomen, and the eggs are quickly removed. The incision is sutured; an antibiotic is administered, then the female is returned to the holding tank to recover. The advantage of this procedure is that more eggs are collected from the female. During the **stripping procedure**, the female is placed on the stretcher while a small incision is made near the **urogenital opening**. Then the female is held by her rostrum while pressure is applied to the female's abdomen to force eggs out, and eggs are collected. The female is then stitched up and returned to her holding tank. After artificial propagation, females are usually held for about **21 days** to allow for withdrawal from the hormone and to ensure survival before returning them to their collection site.



Booker Fowler Fish Hatchery staff removing eggs from female Paddlefish by stripping

Through both procedures, eggs are handled in the same manner. They are collected in plastic tubs and kept moist, but relatively dry. Each egg has a small pore (**ovipore**) located on its surface, which will begin to close once it is inundated with water. Likewise, a sperm does not become active unless it comes in contact with water. Once all the eggs are collected from one particular female, milt is collected from several males in a separate container by applying pressure to their abdomens. Eggs and sperm are then ready to be mixed. Adding water **activates the sperm**, which is then poured over the eggs, and fertilization begins when eggs start to clump together.

As mentioned previously, Paddlefish eggs are naturally sticky and will spread out and adhere to substrate when the fish spawn in the wild. At the hatchery however, a clay mixture called **fuller's earth** is added to the fertilized eggs to prevent them from sticking together. This is critical, as clumping can cause **fungal growth** or **lack of oxygen** which could prevent eggs from hatching. The eggs are stirred continuously with a turkey feather for **30 minutes** to make sure they are adequately coated with the clay.

After sufficient mixing, eggs are rinsed free of the fuller's earth mixture and placed into incubation jars and **tumbled** against one another for aeration, where they will hatch in **5 to 7 days**. The newly hatched fry swim up and out of the incubation jars into collection tanks, where they are then transported to indoor "raceways", similar to the outdoor raceways we saw on the previous page.

PADDLEFISH QUICK FACTS

- The first written description of a Paddlefish from a European came from a member of Hernando De Soto’s crew, who described seeing Native Americans catching fish who's upper lips resembled shovels
- The American Paddlefish (*Polyodon spathula*) is the only extant (living) species of Paddlefish in the world
- Hurricane Andrew caused the death of 100,000 Paddlefish in the rivers and lakes of Louisiana. The majority of the loss occurred in the Atchafalaya River basin.
- Paddlefish are among the largest freshwater fish in the world, reaching lengths of over 5ft.
- Paddlefish sometimes travel 100 to 200 miles to find an ideal habitat for spawning.
- The Paddlefish is considered a living fossil, dating back to at least the Cretaceous period (65-125 million years ago)
- Similar to sharks, Paddlefish have mostly cartilaginous skeletons. However, they are still located within the taxonomic group of “Bony Fishes” (Osteichthyes)
- While the American Paddlefish are filter feeders, some other extinct Paddlefish species were more predatory, such as the Chinese Paddlefish
- Paddlefish have smooth skin and few scales, the skin feels like a wet tire
- The genus name for Paddlefish, Polyodon, is Greek for “many teeth” and refers to the Paddlefish’s many diamond-shaped teeth in its fry stage. The species name, spathula, is Latin for “spatula” or “blade” and refers to the paddle-shaped rostrum of the fish.
- Common names of the Paddlefish include: duckbill cat, Mississippi Paddlefish, spadefish, spoonbill cat, and spoonbill catfish.
- The largest American Paddlefish ever caught was taken with a spear in 1916 in Okoboji Lake, Iowa. It was 7ft 1in long and weighed 198lbs
- There are some reports of Chinese Paddlefish getting nearly 23ft long and over 1000lbs, though a more generally accepted max size was around 660lbs and 10-12ft.
- The Paddlefish have a "3rd eye" on the top of their skull, called a Parietal eye. It doesn't work the same as a normal eye, but it is photoreceptive and aids in regulating the organisms circadian rhythms and hormone production. Many other fishes, amphibians, and reptiles also have this "eye"

Section 2

Aquarium Setup and Maintenance

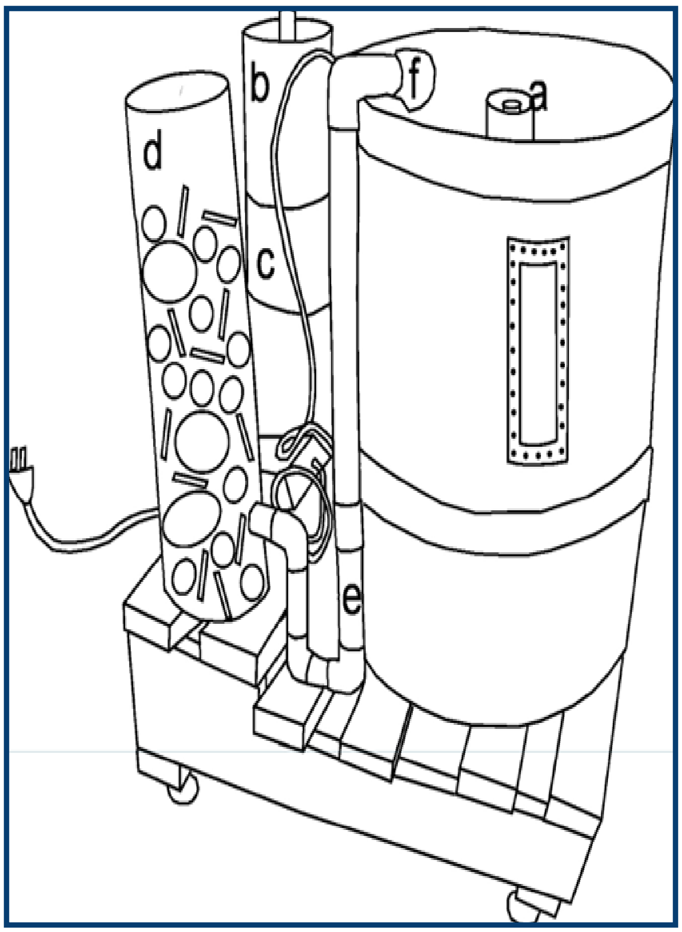
Equipment for Aquarium Setup and Maintenance

- **48-gallon circular Recirculating Aquaculture System** — Full setup of tank, recirculation system and bio-filtration system.
- **Biological filter material (biobeads)** – can be made from plastic pan scrubbers, cut up straws, whiffle balls, bottle caps, and/or anything plastic with a lot of surface area for bacteria to grow on. For this program, we use Biobeads that are provided to you.
- **Incubation jar** – used to incubate eggs until hatching. (See directions on Page 29)
- **Fry basket/nursery** – used to hold newly hatched fry until strong enough to swim throughout the tank. (See directions on Page 31)
- **Air stones** – oxygenate the water
- **Pipettes (Turkey Baster)** – for moving eggs and small hatchlings and removing dead or fungal eggs. Standard Turkey Basters are the best tool to use for this and could also be used for removing debris in the water (excess food, waste, etc.)
- **Nitrifying bacteria** – bacteria that feed on ammonia compounds (waste from food and fish). The presence of these bacteria clears water and reduces odor
- **Fish nets** – used to remove live fish from bucket or tank
- **Water quality test kits** – to test for ammonia compounds (NH_3 / NH_4), nitrates (NO_3), and nitrites (NO_2) and to measure pH levels. These water quality parameters need to be maintained at proper levels to prevent stress on fish. The test kit used is the API Freshwater Master Test Kit
- **Fish food** – high-protein crumble, brand name Rangen (provided by hatchery), or live *Daphnia* spp. The high-protein crumble must be kept frozen
- **Automatic feeder** – delivers the frequent feedings larval fish require. An automatic feeder such as the Intellifeed automatic fish feeder ensures fry and fingerling receive enough food
- **E6000** – a strong adhesive used to seal leaks in the aquarium setup
- ***Daphnia* setup** – (optional) used to rear a *Daphnia* spp. colony (See Page 34)
- **Aquarium vacuum** – (optional) a long tube siphon, used when necessary to remove excess debris and dirty water from the tank. Any device that will allow you to clean excess food/waste out of your tank will suffice.

Aquarium Setup

- The aquarium should be set up at the beginning of the school year in order to support larval fish in the spring, the tank must run for a few months before acquiring Paddlefish fry or eggs to allow time for nitrifying bacteria to establish.
- To check for leaks in your new tank or your empty tank that has been sitting over the summer months, fill the tank outdoors. Make sure that the lower ball valve is closed.
- If there is a leak, drain the tank, dry it, and apply E6000 as needed. This should be done outdoors or in a well-ventilated area. Allow adhesive to cure for 24 to 72 hours.
- If the tank is leak free, fill it in the classroom.
- Plug in the air pump and make sure the air stone is new.
- Run the tank for several days, then add native fish such as Mosquitofish (*Gambusia* spp.) or Bluegill to help establish good bacteria colonies in the tank. The Booker Fowler Fish Hatchery can provide fish for this purpose. **If using Mosquitofish, keep in mind you will need significantly more of them in your tank than you would a larger species such as bluegill.**
- In two to three weeks, a brown slime coat will begin to cover the filter material – this is bacteria.
- This tank takes longer to set up than most because the temperature needs to remain low, ranging from 15°C to 18°C (60°F to 65°F) to allow proper hatching of Paddlefish fry. When water temperatures are cooler, bacteria grow slower.

<u>The aquarium has several major features:</u>



- The tank is equipped with a double standpipe (a), which includes an internal and external standpipe. This allows water to be drawn from the bottom of the tank to the filters. To keep fry from entering the filter system, cover inner standpipe with a plastic canvas sleeve.
- In the first filter, water travels through the physical filter (b). Water comes in near the bottom of this filter, which traps large food particles or debris at the filter floss barrier (c).
- Water travels across to the second filter, the biological filter (d), where bacteria feed on organic compounds in the water, converting them to non-harmful compounds.
- Water then travels to the airlift (e), which pumps oxygenated water from the biological filter into the tank.
- The top of the airlift brings water back into the tank and should be angled (f) to encourage a circular flow of water.
- The process is then repeated. This is why it is called a recirculating tank.

Logbook

The logbook will be used to monitor the development of Paddlefish from eggs to fingerlings, water quality, and other physical features and anomalies. See Appendix # V for a sample log. Take daily readings of temperature, pH, nitrate, nitrite, ammonia compounds, and dissolved oxygen when the tank is first set up until water quality parameters do not fluctuate. Monitor water quality semiweekly (twice a week) after parameters become stable. Once eggs arrive, daily water quality testing should begin again. Continue daily monitoring through the first two weeks after the fry start feeding. Once minimal fluctuation of water quality parameters is observed, then semiweekly readings may resume.

Water Quality Monitoring

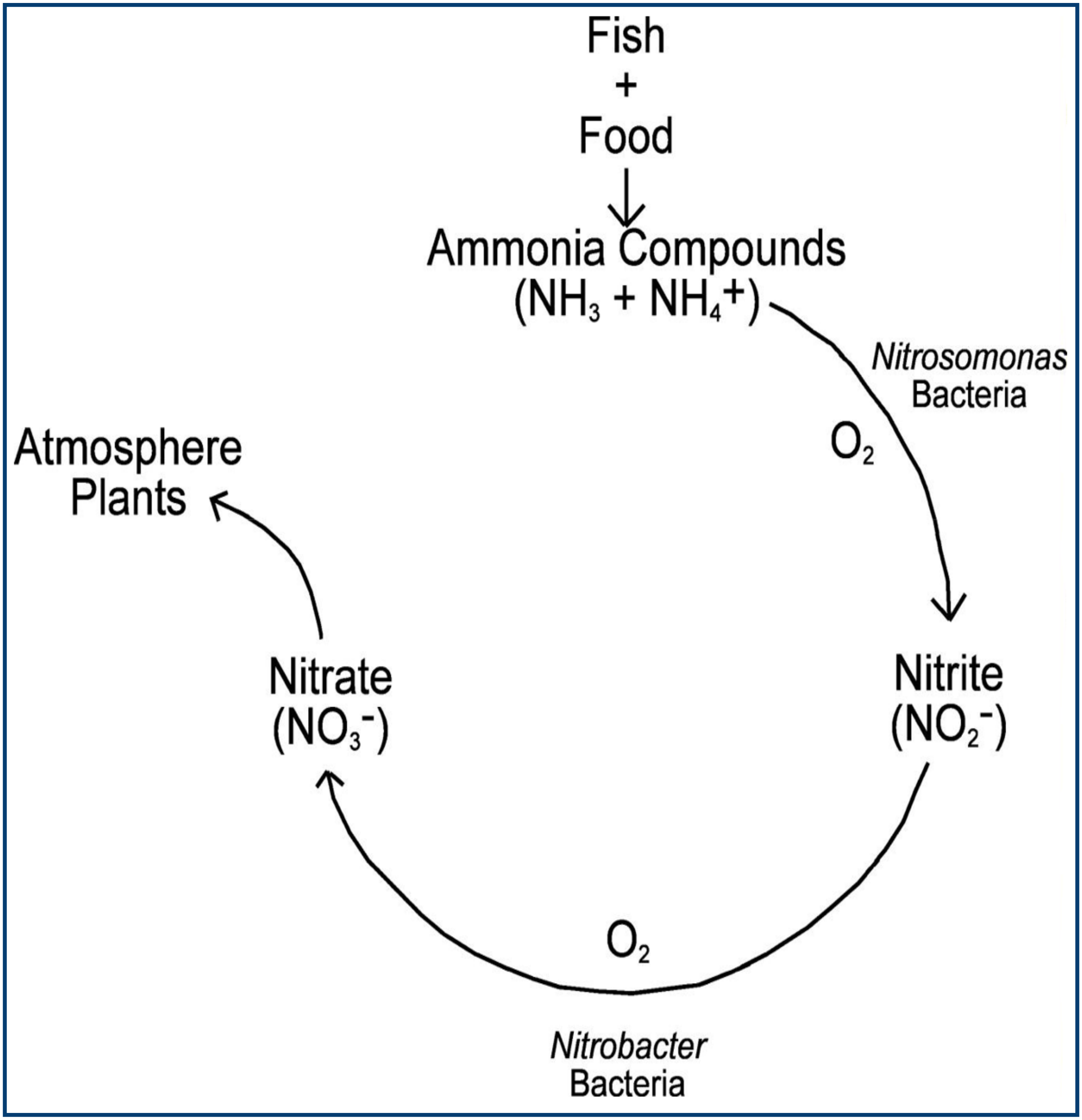
Water quality must be maintained in order for the fish to survive and grow properly. Water should be **<u>TESTED DAILY</u>** for temperature, dissolved oxygen (DO), ammonia compounds (NH_3 or NH_4^+), nitrates (NO_3), nitrites (NO_2), and pH. For any water changes or additions, water must be de-chlorinated before adding it to the tank.

One thing to keep in mind when managing your tank's water quality is the relationship between Ammonia/Ammonium and pH, as a spike in NH_3 or NH_4^+ could be caused simply from a change in pH (See the next 2 pages for a diagram of the Aquatic Nitrogen Cycle and Ammonia/ Ammonium-pH chart.)

Water Quality Parameter	**What It Measures**	**Desired Range**	**Danger Reading – How Fish are Affected**	**Remedies**
DO	Amount of oxygen in water	7 to 9 ppm	1 to 5 ppm causes respiratory stress. Zero ppm is an anoxic condition and fish will die.	1) Change air stone every two weeks. 2) Check that water level in biological filter is high enough to allow airlift to pump water sufficiently.
pH	Acidity or alkalinity of water	6.5 to 8.5	Less than 4.5 or higher than 11 is fatal to fish.	1) Change 50% of water. ($11<pH<4.5$) 2) Add ¼ cup baking soda. ($pH<4.5$)
NO_2	Partially decomposed material in water	0 to 1 ppm	Above 1 ppm leaves fish more susceptible to bacterial and viral infections.	1) Change 50% of water. 2) Add nitrifying bacteria. 3) Add zeolite or other ammonia reducer if levels do not decrease.
NO_3	Decomposed material in water	0 to 10 ppm	At above 10 ppm prolonged exposure will decrease fish's osmoregulation.	1) Change 50% of water. 2) Add nitrifying bacteria.
NH_3 or NH_4^+	Amount of waste in water	Less than 0.06 ppm	Increases as pH increases; 0.06 to 0.2 ppm damages gills, eventually killing fish.	1) Change 50% of water. 2) Add nitrifying bacteria. 3) Add zeolite or other ammonia reducer if levels do not decrease.
Temperature	Average amount of heat in water	Eggs: 15� C to 18� C (60� F to 65� F) Fry/fingerlings: 17� C to 22� C (63� to 72� F)	Eggs: above 18� C (65� F) fungus growth increases and hatching is premature. Fry: above 22� C (72� F) more susceptible to disease.	Prepare gallon jugs with dechlorinated water and place in freezer. If water is too warm, place frozen jugs in tank until water cools. Keep air temperature about 17� C (63� F).

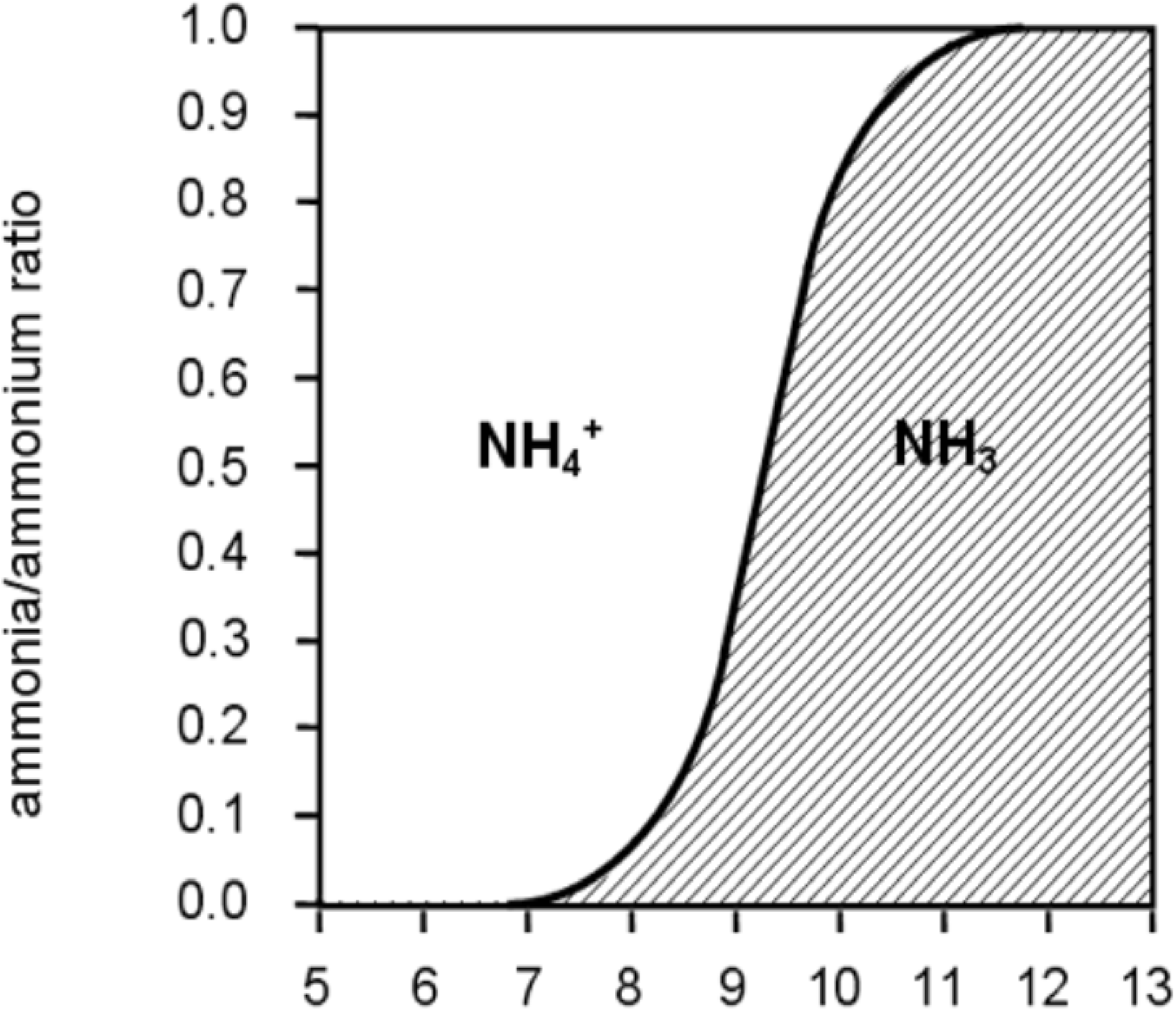
Parameter Ranges may be a little more conservative than necessary, but they are a good rule of thumb to follow as a general guideline.

Aquatic Nitrogen Cycle



Breaking down of fish food and waste produced by fish will lead to Ammonia (NH3-) and Ammonium (NH4+) in your tank. Bacteria will then process this into Nitrites and Nitrates, and in nature this would then be processed by plants, released into the atmosphere, etc.

Ammonia/Ammonium-pH Curve



How to read graph:

Graph shows the ratio of ammonia and ammonium in solution as it relates to pH. For example: at a pH of 8 Ammonia is at ~5% and Ammonium ~95%, at a pH of 9 Ammonia is at ~30% and Ammonium ~70%, etc.

As the pH increases (becomes more alkaline), the amount of Ammonium (NH4+) in the water decreases and the amount of Ammonia (NH3-) increases (Equilibrium at pH of ~9.25). If your tank is experiencing an increase in Ammonia, it could potentially be caused by an increase in the Alkalinity of your water. This is something to consider when managing your tank.

How to Change the Water

There is no need to change the water in the tank unless uneaten food is collecting on the bottom or water quality parameters are far outside the desired ranges. If these conditions occur, use the aquarium vacuum to remove water from the tank.

Vacuuming

- To vacuum the tank, fill the tube with water by submerging the wide end of the vacuum first. Slowly submerge the rest of the tubing, making sure there are no air bubbles in the tubing of the vacuum.
- While all the tubing is underwater, place your thumb over the small end of the tube to make a tight seal. With your other hand, grasp the large end so that its opening is near the bottom of the tank and away from the Paddlefish fry.
- Next, remove the small end of the tube from the water while holding your thumb tightly sealed over the opening and place this end into a bucket. Release your thumb. Water will now run from the tank into the bucket.
- Move the wide end of the tube along the bottom of the tank to vacuum food and dead fry.
- Once the bucket is almost filled with water, pull the wide end out of the tank and let the remaining water flow into the bucket.
- Fresh water must be de-chlorinated before adding it to the tank.

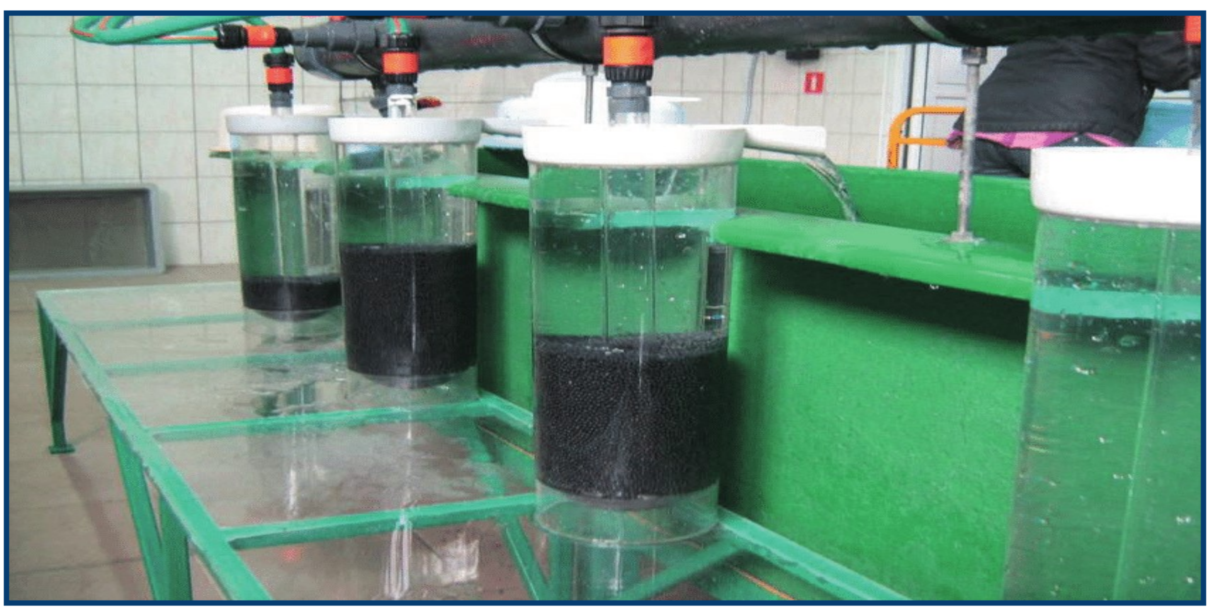
Incubation Jar Setup

***Note**: Before receiving Paddlefish eggs, remove any fish that were previously occupying the tank and place them in a separate aquarium.*

Most incubation jars will be designed to mimic the McDonald hatching jars used by state hatcheries, and depending on the specific manufacturer and model will have differing guidelines on usage to be aware of. In general, egg hatching systems will primarily include the hatching jar itself and a water or air pump with tubing to attached to jar, and depending on the make/model of jar you purchase it may come with other accessories such as a hanger to hang the jar from the outside of the tank or a suction hanger to adhere the jar to the inside of the tank. Examples of hatching jars are shown below and links to purchasing options will be provided.

To set up the incubation jar:

- Fill your jar with water **FROM YOUR TANK!**
- Depending on your specific hatching jar, you'll want to place the jar either over the side of the tank (it's recommended to position a piece of foam or wood between the pitcher and the outside of the tank to keep the pitcher from resting at an angle) or suctioned to the inside the tank.
- Attach the tubing to the water/air pump (make sure the tubing is the correct size and fits snug on your air/water pump).
- Next, place the water pump inside the biological filter or tank, about one foot from the top. If using a jar that requires an air pump, simply secure the air pump somewhere outside the tank.
- Plug in the water/air pump and water will begin to circulate in the pitcher.
- Gently pour eggs from the plastic bag (received at the hatchery Paddlefish spawn) and into your hatching jar.
- Make adjustments to the speed of your pump so eggs gently tumble. **If the eggs are whirling rapidly in the incubation jar, the larval fry developing inside the eggs may suffer spinal cord damage and die!**
- Remove the incubation jar once eggs are hatched and depending on your style of jar, you'll need to periodically gently pour the newly hatched fry out of the jar into your fry basket in your tank.



McDonald Hatching Jars

Incubation/Hatching Jar Examples

- Common type of hatching jar, meant to mimic the McDonald style hatching jars we saw earlier.
- This jar would use a water pump, would be affixed to either the inside or outside of the tank using a hanger and comes with a mesh screen to prevent the fry from being able to swim out the top of the jar.
- It could potentially be setup to allow the fry to swim out on their own (out of the lip you can see extended from the top of the jar) but you can also remove the fry yourself.

- Similar to the jar above, this is one of the more popular styles of hatching jar although they are becoming increasing difficult to obtain.
- It uses a water pump that you would connect to the black nozzle on the side of the jar.
- This jar would be on the outside of the tank, with the smaller vertical tube you see hanging off the side being placed inside the fry basket in your tank.
- Once the fry hatch, they would then swim up the jar, out that tube and down into the fry basket all on their own.

- This is the **Ziss Zet-80** fish egg tumbler/ hatching jar.
- Likely one of the cheaper and easier to find options.
- This jar requires an air pump instead of a water pump and will be suctioned to the inside wall of the tank instead of hung from the side like the others.
- Additionally, you will need to remove the lid for this jar and gently pour the fry into the fry basket yourself once they begin hatching.

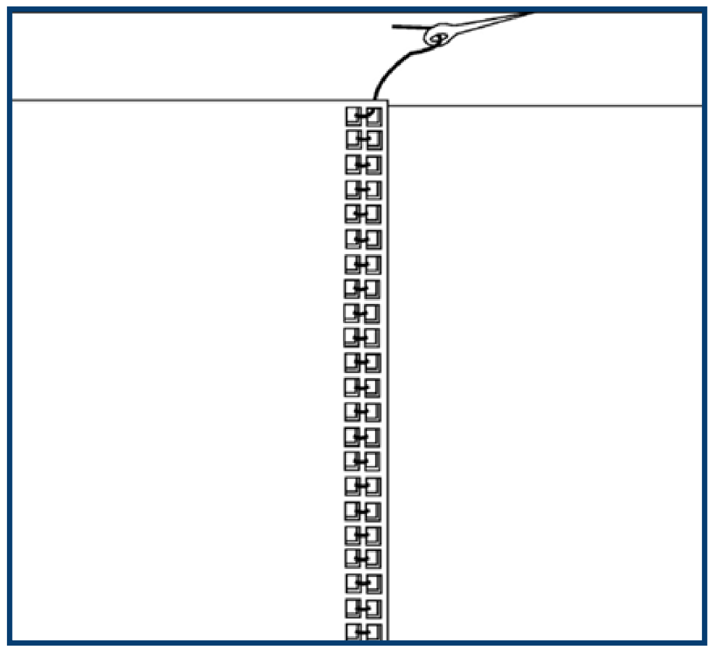
Fry Basket/Nursery Setup

The fry basket will be used for newly hatched fry. In some older hatching jars, the fry will be able to swim out of the spout of the incubation jar on their own and into the fry basket after hatching. If you're unable to locate a jar such as this (shown on previous page), you will need to gently pour your fry out of the incubation jar and into the fry basket yourself once they begin hatching.

Materials needed to build fry basket/nursery:

- 3 pieces of No.10-point mesh plastic canvas
- monofilament line
- Marker
- Scissors
- large embroidery needle
- E6000 adhesive

Step by Step Setup



1. Place two pieces of No.10-point mesh plastic canvas together so that they overlap by two rows of mesh holes. **(Any larger than this and the fry WILL escape through the holes in the mesh.)**

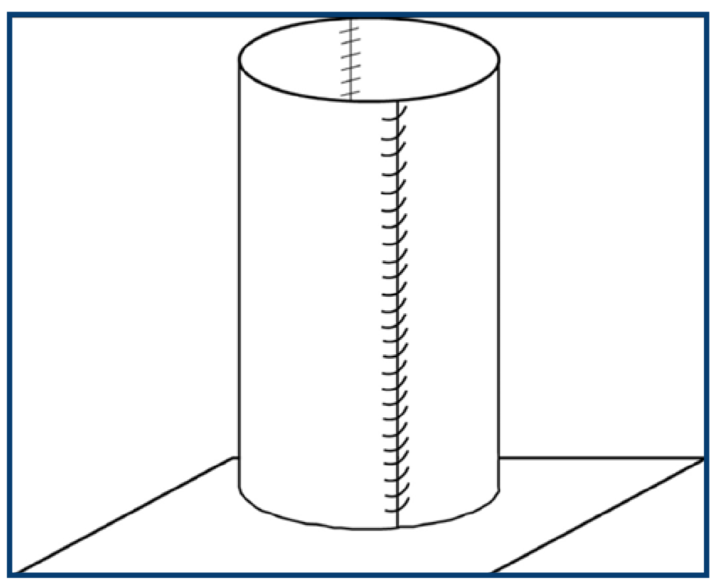
2. Thread the monofilament line through the embroidery needle and sew the pieces of plastic canvas together.

3. After the two pieces are sewn together, bend the ends towards each other to form a cylinder.

4. Repeat steps 1 and 2 on the open side of the cylinder.

5. Place the cylinder of plastic canvas on top of the third piece of plastic canvas.

6. Place a bead line of E6000 adhesive along the seam inside and outside of the plastic canvas base. Smooth out the bead line of adhesive. Place the cylinder of plastic canvas with the glued side up to dry.



Fry Basket/Nursery Setup

Step by Step Setup

7. Once the adhesive has dried, use scissors to cut away excess plastic canvas.

8. ***optional depending on jar model***

On the open end of the basket, cut a triangular-shaped notch to allow the basket/nursery to fit flush against the incubation jar.

9. Now the basket is ready to use.

10. Place a dowel or yardstick across the top of the tank.

11. Evenly attach four 1-foot lengths of monofilament to the open end of the basket. These pieces will be tied together and used to hang the basket/ nursery from the dowel or yardstick across the top of the tank.

12. Now, attach the monofilament line to the dowel or yardstick. The basket should be at the top of the water to ensure that the fry can't escape into the rest of the tank.

Quick Notes

- The fry will remain in the basket/nursery for more than a week. This will give the young fish time to learn to swim and absorb their yolk sacs.
- While fry are in the basket/nursery, food can be introduced. If food gets stuck in the mesh holes and starts to accumulate, gently move the basket up and down and the food will be released.
- The fry will be ready to be released from the basket/nursery when their yolk sacs are completely absorbed and they are swimming freely. Once the fry have been released from the nursery basket, remove the basket, clean it, and store the equipment for next year.

Feeding

Fry will be eating an artificial food source, Rangen, which is a hatchery fish food. The fish food contains 40 to 45 percent protein and is manufactured in several sizes (0 to 2). *Daphnia* spp. can be supplemented into the fishes' diet. (See section on maintaining a *Daphnia* spp. colony.)

Rangen is perishable and must be stored in a freezer. It should be discarded after three months. Never use food from the previous year. Old food has a significantly lower nutritional value and will leave fish susceptible to disease. For example, vitamin C in the feed will decrease by 80 percent in seven months.

Feeding

Feeding should start about 5 days after hatching. This is when the fry lose their gut plug and have used up their nourishing yolk sac. Carefully watch your newly hatched fry to look for any that have very little yolk sac left. Once the first few start to have a very small yolk sac, it is time to introduce food into the tank. When the fry start to eat, expect a large die off because some fry cannot adapt to the artificial food source.

When introducing food, sprinkle a pinch of crumble inside the nursery basket. A large salt shaker is an effective way to deliver smaller amounts of food evenly across the water surface. This can be done several times a day to introduce fry to the feed. Once fry feeding behavior is noticed, it is time to use the automatic feeder.

Start with the smallest crumble (size 0). When the fry are about 1 inch in length start mixing in the larger crumble (size 1). Once all fish have reached that length, use only size 1.

Automatic Feeders

There are a few options available for you to purchase, each with their own unique operating instructions. The option we recommend is the **Lifegard Intellifeed Aquarium Fish Feeder**. This feeder will attach to the side of your tank and runs on battery power, although a cheap power adaptor can be purchase to plug into an outlet. The Intellifeed feeder is much cheaper than most alternatives and is much easier to find (**$53 on Amazon as of 2020**).

https://www.amazon.com/IntelliFeed-Aquarium-Fish-Feeder/dp/B007AA2R54

TO GET THE REQUIRED AMOUNT OF FEEDINGS, YOU WILL NEED TO PURCHASE 2 INTELLIFEED FEEDERS! This is still a cheaper option than most alternatives.

Use the display pad to set your feeding times. For your tanks, you'll want to program your feeder(s) to **6 feedings per day in total** (*detailed instructions and tutorial video links on page 37*).

MAKE SURE THAT THE TIMER IS WORKING AND IS PROGRAMMED PROPERLY! (PAGE 37)

Tank with food dispenser on swivel apparatus
(Photo courtesy Kathleen Nichols)

Intelli-Feed automatic Feeder

Feeding

Double-check the settings on the timer to ensure that the proper amount of food is added to the tank. Excessive feeding will likely cause water quality problems in your tank.

If the power goes out or the timer is unplugged, the settings for feedings shouldn't be affected unless they are somehow deleted. The clock will go out and must be reset. **<u>ALWAYS MAKE SURE THE FEEDER IS FUNCTIONING PROPERLY AFTER A POWER OUTAGE!</u>**

<u>Tips to keep the automatic feeder functioning:</u>

- Ensure your feeder is properly secured, either on the side of your tank or wherever you have it located.
- When programming your feeder, always closely follow the instruction provided with your feeder. For the Intellifeed feeder, see **<u>page 37</u>** for a more detailed explanation and links to tutorial videos. **REMEMEBER TO PROGRAM BOTH FEEDERS TO GET A TOTAL OF 6 FEEDINGS PER DAY!** You can program one for 4 feedings and another for 2 or both for 3, either option will work.
- Set feedings every 4 hours
- Only use the Rangen fish feed from LDWF.

Daphnia spp. Setup (optional)

Daphnia spp. are small crustaceans that live in freshwater and are commonly known as "water fleas." *Daphnia* spp. live for about one month and will reproduce about every three days. It can be difficult to start a colony of *Daphnia* spp., but once a colony has formed, it is very easy to maintain.

<u>To start a *Daphnia* spp. colony you will need:</u>

- Culture of *Daphnia* spp. (See lesson entitled "Pass the Water Fleas, Please" for information on where to obtain *Daphnia* spp.)
- Hard water
- A Clean, clear container such as a 3-liter bottle or a small tank (5 to 10 gallons)
- High-protein fish food pellets
- A garbage can with a lid (great way to store extra water, in case of water changes)

1. Add water and a few pellets of food to the container and let it sit for at least 10 days.
2. Add *Daphnia* spp. and place the container in an area with indirect sunlight (near a window or light). *Daphnia* spp. need eight hours of light a day.
3. The container can be aerated, though *Daphnia* spp. will grow fine without extra air as long as they are not overfed.
4. For larger populations and more frequent feedings, aeration with large bubbles at a slow rate is best.
5. Place one pellet of high-protein fish food in the container. Once the pellet dissolves, add another. It may take up to one week for a pellet to dissolve.
6. Change water no more than once every three weeks. Up to 50 percent of the water can be changed at once. Use only aged (10-day-old) water. Remember, slightly dirty containers grow the best *Daphnia* spp.

Problem Solving

What to do if:

- **The aquarium water is cloudy and smelly.**

  The water may turn cloudy as nitrifying bacteria begin to multiply in the tank in response to an increased nutrient load. Once Paddlefish begin to feed, there will be increased waste from the fish and uneaten food that may start to decay. Bacteria will multiply to keep up with the demand, however, before they become sessile (attached to a substrate, such as biobeads), they will float, causing water in the tank to look cloudy. Once bacteria attach to a substrate, the water will clear up**. It is imperative that the tank is set up and running at the beginning of the school year.** This will allow for the biological filter to be seeded properly with nitrifying bacteria and prevent water quality problems once Paddlefish are introduced.

  If the water turns cloudy when Paddlefish are introduced, make sure that all water quality parameters are within the normal range. If water testing shows normal levels, nothing further needs to be done, and the water should clear up in a few days. If water testing shows abnormal levels, see the water quality monitoring section (Page # 28) for remedies.

- **There is not enough water flow from the airlift.**

  The airlift may not be working for several reasons:

  A. The air stone may be broken or clogged with brown algae. Make sure that the air stone is replaced about every two weeks. A clogged air stone can be cleaned and reused. Throw away broken air stones.

  B. The tank does not have enough water in it. Water will evaporate from the tank. Check the water level in the tank by observing the level of water in the biological filter. If the biological filter is low on water, this will slow down the amount of water that the airlift is able to pump into the tank. Remember to add only dechlorinated water.

  C. The air pump may not be working properly and may need to be replaced. Remove the air pump, hook it up to another water source, and observe if it is aerating properly.

  D. If not working, replace the air pump.

- **The filters are turning brown. Should they be cleaned?**

  The filters will turn brown as food particles and other debris begin to collect in the physical and biological filter. There is no need to clean the filters unless water flow is impeded from one filter to the other. If there is an excessive buildup of debris in the physical filter, simply remove the floss pads and rinse with water. **NEVER WASH ANY FILTER MATERIALS WITH SOAP OR DETERGENTS OF ANY KIND. THIS WILL KILL FISH!** It is normal for the biological filter to turn brown as bacteria build up on the substrate, biobeads, or other materials in the filter. Never wash or rinse the substrate or biological filter materials. This will destroy beneficial bacteria that drive the nitrogen cycle in the tank.

Problem Solving

- **<u>What if the eggs start to grow fungus?</u>**

  There are several reasons why fungus may begin to grow on Paddlefish eggs:

  A. The water temperature is over 18°C (65°F). Increased water temperatures will encourage fungal growth and kill Paddlefish eggs.

  B. The eggs are dead. This occurs in the hatchery system, also. Eggs die and fungus begins to grow.

  C. Eggs are not tumbling enough in the incubation jar. Eggs that come in contact with each other may start to stick together. Contact promotes fungal growth.

  <u>Remember, eggs should gently tumble around in the incubation jar.</u>

  In all cases, eggs with fungus will likely not hatch, so remove them immediately from the tank to prevent a fungal egg from spreading fungus to a healthy egg.

- **<u>The ammonia level is above 0.06 ppm.</u>**

  Ammonia level is the most critical water quality parameter to monitor. Ammonia levels are safe below 0.06 parts per million (ppm). Larval fish are extremely susceptible to increased ammonia levels. Fish gills can be damaged when ammonia levels reach 0.1 ppm to 0.2 ppm. High ammonia levels are accompanied by high pH levels, due to the amount of hydroxide ions in the tank. So, if the pH is increasing, make sure that ammonia levels are monitored closely.

  **Increased ammonia levels are caused by insufficient numbers of nitrifying bacteria in the tank. Ammonia is a by-product of fish waste and uneaten, decaying fish food. Nitrifying bacteria consume waste products and keep ammonia levels at a normal level.*

  **Ammonia levels can also related to pH, see page 27 for Ammonia/Ammonium-pH curve*

  IMPORTANT: The tank must be set up early. If the tank is not allowed to run for a few months before acquiring Paddlefish fry, nitrifying bacteria will not have had enough time to become established in the tank.

  To decrease ammonia levels:

  1. Change 50 percent of the water, and then check the ammonia level.
  2. Add nitrifying bacteria to the tank. Remove filter floss in the physical filter for one day to prevent new bacteria from attaching to this substrate. Replace the filter floss the next day.
  3. If the ammonia level is still high, add zeolite (or another ammonia reducer) to the tank.
  4. More water changes may be necessary. Repeat steps above.

  TIP: If the tank is allowed to run for several months before Paddlefish eggs are acquired, water changes should not be necessary.

Problem Solving

- **<u>How do I know if I am overfeeding?</u>**

Overfeeding occurs when fish are given more food than they can eat. It can lead to increased ammonia levels. Signs of overfeeding include food accumulating on the bottom of the tank and fungal growth.

The amount of food released into the tank is directly proportional to the space where the food is shaken out of the automatic feeder. To decrease the volume of food dispensed you can decrease the number of rotations of the feeding drum per feeding (this may take some experimenting).

- **<u>How do I set my timer on the automatic feeder?</u>**

This will depend on the specific feeder you purchase. This section will detail info for the Intellifeed feeders as they are the cheapest and most available option. For other brand feeders, please contact the NFC program manager for assistance and guidance.

The Intellifeed feeders can handle up to 4 feedings per day, so you will need to program either one feeder for 4 feedings and the other for 2 or both for 3. **Links to tutorial videos detailing the programming of the Intellifeed feeders can be found below.**

<u>Setting the clock:</u>

When first turning on the Intellifeed feeders, you'll be prompted to set the time. To do this, choose the **Hour**, press **SET,** choose the **Minutes**, press **SET** again and you're done programming the clock.

<u>Setting automatic feeding events</u>:

1. Press and hold the **SET** button for `3 seconds, this will take you to the feeding cycle programming screen. You should be shown feeding cycle **1** when you first do this. The number on the **LEFT** is the **FEEDING CYCLE** and the number on the **RIGHT** is the **NUMBER OF FEEDING DRUM ROTATIONS PER FEEDING**.

2. Set the feeding cycles to **2 ROTATIONS** (adjust accordingly in future for fish needs), then press **SET** once more.

3. Next the device will have you set the time for that feeding cycle. Set the clock like in Step 1, but **FOR THE SPECIFIC TIME OF THAT FEEDING CYCLE** (e.g., 6:00am, 10:00am, 2:00pm, etc.)

4. Repeat the above step for 5 more feeding cycles to total 6 feedings (split across 2 feeders).

5. Since you're using 2 feeders for 6 feedings, you'll need to skip some feedings to get a total of 6. To do this, just **SET THE FEEDING DRUM ROTATIONS TO 0** for any feeding cycle you wish to skip.

6. **MONITOR WATER QUALITY AND FISH BEHAVIOR AND ADJUST DRUM ROTATIONS ACCORDINGLY!**

<u>Tutorial Video Links for Intellifeed feeders:</u>

https://www.youtube.com/watch?v=guFM6CxrGaY

https://www.youtube.com/watch?v=hVwpZ_r-J7M

Problem Solving

- **When should I start feeding the fish?**

Test your automatic feeder well in advance of receiving Paddlefish. This will allow you to become familiar with the apparatus and determine if the feeder is working properly. A broken feeder can lead to the starvation of fry. Start to introduce a small pinch of food to the nursery/fry basket when the first fry are about 3 days old. This will get the fish accustomed to the presence of food in the water.

Feeding behavior is easy to observe. Fry swim constantly, usually in a straight manner. When food is introduced, the fry will swim through the food, detect the food, turn and zigzag or swim in circles through the food. Once feeding behavior is noticed, the automatic feeder should be set up immediately and set for regular around-the-clock feedings.

- **What if the pH is too high (above 8.2) or too low (below 6.5)?**

The pH measurement is one of the most common water quality tests performed. Although pH indicates the sample's acidity or alkalinity, it is a measurement of the hydrogen and hydroxide ions found in a substance.

The pH scale ranges from a value of 0 to 14. A substance with pH lower than 7 is an acid and has a high concentration of hydrogen ions. A substance with pH higher than 7 is a base and has a high concentration of hydroxide ions.

An optimal pH range is 6.5 to 8.2 for most fish reproduction and development. Generally, fish cannot live in a pH below 4 or above 11. These extreme pH levels may affect body functions (physiology) of aquatic organisms making it very important to maintain pH levels in the aquarium. When troubleshooting water quality problems, such as pH, test the tap water. Hard tap water in some areas may be slightly alkaline because it may contain elevated levels of calcium carbonate and dissolved carbon dioxide. Because the pH of hard tap water ranges from 7.0 to 8.5 the water may need to be monitored more frequently.

The pH of a tank may decrease (become more acidic) due to fish, algae, and plants releasing carbon dioxide (CO_2). Another reason pH may decrease is from the release of hydrogen ions caused by the reduction of ammonia during the nitrogen cycle. If the pH in the tank is below 6.5, the pH can be corrected by adding baking soda (sodium bicarbonate). Baking soda contains pH-stabilizing carbonates. These carbonate molecules can freely give or take hydrogen ions.

Problem Solving

Increasing pH:

Begin by dissolving two teaspoons of baking soda in a large beaker filled with tank water. Pour this solution into the tank. Retest the water in two hours. If the pH is still low, wait 24 hours before adding more baking soda. Baking soda should be added in small amounts to increase pH because the fish are acclimated to the lower pH level. Most likely the pH gradually became more acidic; therefore, in order for the fish to safely acclimate, pH should be gradually raised no more than one pH unit per day.

The following day, test the pH again. If it still remains below 7.0, add more baking soda:

> **-** the exact amount is up to your discretion. For instance, if the pH is 6.5, adding two more teaspoons of baking soda will increase the pH too much. Therefore, baking soda may need to be added in smaller increments than a teaspoon. It may take several days to adjust the pH back to an optimal range.

Decreasing pH:

If the pH of the tank is too high (above 8.5), test the ammonia level in the tank. If the ammonia level is above 0.1 ppm to 0.2 ppm a water change will be required. Refer to the problem-solving section, “The Ammonia level is above 0.06 ppm.” on Page # 37 for details on how to change the water.

Appendices

I. Lesson Plans

Water Quality
My Fish Ride a (Nitrogen) Cycle………………………………………………………… A1
Do You Believe in pH Magic?.. A11

General Information on Paddlefish
Snagging Paddlefish Information……………………………………………………. A24
Critical Conditions for Paddlefish Spawning……………………………………….. A32
How Old is that Fish?.. A44

Effects on Paddlefish Populations
Extirpated? Don't you Mean Extinct?.. A56
What a Nuisance!.. A67
Do Dams Affect the Paddlefish Population?... A73

Paddlefish Growth, Development and Behavior
How Fast Do Paddlefish Grow?.. A83
Comparing Eggs and Embryos……………………………………………………… A95
Life Cycles of the Wet and Wiggly………………………………………………… A102
Pass the Water Fleas, Please……………………………………………………… A110

II. References and Resources..…………………………………………………………….. A118

III. Louisiana State Science Standards……………………………………………...…… A130
6th Grade……………………………………………………………………….….. A132
7th Grade………………………………………………………………………….... A137
8th Grade………………………………………………………………………….... A142
High School…………………………………………………………………………... A149

IV. Glossary……………………………………………………………………………………… A163

V. Paddlefish Status Map, Fry Diagram, Aquatic Hours Sheet
and Water Quality Monitoring Log……………………………………………………… A167

Appendix II - References and Resources

American caviar – Paddlefish caviar. 1-800-caviar.com.
https://www.1-800-caviar.com/nsearch.html?catalog=1-800-caviar&query=Paddlefish&x=0&y=0. Accessed December 7, 2020.
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PDF files with classroom activities on how to make a worm bin and bedding types.

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IUCN Red List. International Union for Conservation of Nature.
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https://gf.nd.gov/fishing/Paddlefish-snagging/faq. Accessed December 11, 2020.
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Full pH scale and examples of solutions at each pH level

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University Corporation for Atmospheric Research. *Tree Rings Simulation - Dendrochronology https://scied.ucar.edu/interactive/tree-ring. Accessed December 8, 2020.*
Cool interactive simulation that let's you virtually "grow" tree rings and adjust different environmental factors to see how those factors impact tree ring growth.

University of Colorado. *PhET: pH scale basics https://phet.colorado.edu/sims/html/ph-scale-basics/latest/ph-scale-basics_en.html Accessed December 7, 2020*
Very cool interactive simulation allowing students to mix water and other liquids to see effects on pH

University of Michigan Museum of Zoology. Animal Diversity Web. *Polyodon spathula. https://animaldiversity.org/accounts/Polyodon_spathula/. Accessed December 11, 2020.*
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Upper Midwest Environmental Sciences Center. *Paddlefish Study Project.* http://www.umesc.usgs.gov/aquatic/fish/Paddlefish/main.html. Accessed June 14, 2004. Information for restoring depleted Paddlefish populations. Also has a Paddlefish video that can be downloaded for viewing.

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Urban Worm Company. *Vermicomposting 101: 9 Awesome Choices for Worm Bedding.* https://urbanwormcompany.com/what-to-use-for-worm-bedding/
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Links to other invasive species related resources for teachers.

Vector Disease Control International. *Mosquito Biology - Understanding the Life Cycle of the Mosquito.*
http://www.vdci.net/mosquito-biology-101-life-cycle. Accessed December 14, 2020.
Info on mosquito life cycle with images of each stage.

Video Resources

Louisiana Department of Wildlife and Fisheries. Booker Fowler Fish Hatchery. *Paddlefish Spawn.* https://www.youtube.com/watch?v=HhJwH5mGRjM. Accessed December 7, 2020.
Video showing the Paddlefish Spawn at the Hatchery.

Moravek, Jessie. *The dam dilemma: how to balance hydropower, rivers & people (video).* YouTube - Tedx Talks.
https://www.youtube.com/watch?v=BmG5OzIW5_8. Accessed December 11, 2020.
Great short lecture on the affects of dams on river ecosystems and how to balance the pros and cons of dams.

National Geographic. *Invasive Species 101 / National Geographic.* YouTube.
https://www.youtube.com/watch?v=gYNAtw1c7hI. Accessed December 11, 2020
Good short overview of invasive species and why they cause problems.

North Dakota Game and Fish Department. Paddlefish Stocking.
https://www.youtube.com/watch?v=tQh-hPS1INs. Accessed December 7, 2020
Cool video showing process of raising Paddlefish in hatcheries then releasing them into the wild

Reid, Bruce. Lower Mississippi River Conservation Committee. Paddlefish: Anatomy of a Living Fossil.
https://www.youtube.com/watch?v=ZrEOOIlD3QM&t=2s. Accessed December 7, 2020.
Really good short video detailing basic overview of Paddlefish biology, ecology, behavior and conservation.

Texas Parks and Wildlife. Tracking Paddlefish.
https://www.youtube.com/watch?v=U4WSXXzjnbg. Accessed December 7, 2020.
Great video detailing some Paddlefish conservation efforts in Texas.

Wills, Betty. *The Paddlefish: An American Treasure* (video).
https://www.youtube.com/watch?v=FONx-LEly0k. Accessed December 7, 2020.
This video addresses all facets of the life of Paddlefish in the United States.
It's decades outdated but still worth watching. Released in 1995.

Appendix III – Louisiana State Science Standards

From: Louisiana Department of Education - Louisiana Student Standards for Science

The Louisiana Student Standards for Science were created by over eighty content experts and educators with input from parents and teachers from across the state. Educators envisioned what students should know and be able to do to compete in our communities and create standards that would allow students to do so. The LSSS provide appropriate content for all grades or courses, maintain high expectations, and create a logical connection of content across and within grades.

The LSSS represents the knowledge and skills needed for students to successfully transition to postsecondary educations and the workplace. The standards call for students to:

- Apply content knowledge
- Investigate, evaluate and reason scientifically
- Connect ideas across disciplines

The LSSS do not dictate curriculum or teaching methods. Decisions about how to teach these expectations are left to local districts, schools, and teachers.

Structure and Components of the Standards

The LSSS are arranged by grade levels from kindergarten to high school. The standards include:

- *Performance Expectations* – define what students should be able to do by the end of the year.

- *Science and Engineering Practices* – the practices that scientists and engineers use when investigating real -world phenomena and designing solutions to problems. There are eight science and engineering practices that apply to all grade levels and content areas.
    1. Asking questions and defining problems
    2. Developing and using models
    3. Planning and carrying out investigations
    4. Analyzing and interpreting data
    5. Using mathematical and computational thinking
    6. Constructing explanations and designing solutions
    7. Engaging in an argument with evidence
    8. Obtaining, evaluating and communicating information

- *Disciplinary Core Ideas* – the most essential ideas (content) in major science disciplines that students will learn. Disciplinary Core Ideas are grouped into 5 science domains.
    1. Physical Science (PS)
    2. Life Science (LS)
    3. Earth and Space Science (ESS)
    4. Environmental Science (EVS)
    5. Engineering, Technology and Applications of Science (ETS)

- *Crosscutting Concepts* – common themes that have applications across all disciplines of science and allow students to connect learning within and across grade levels or content areas. The 7 crosscutting concepts apply to all grade levels and content areas.
    1. Patterns
    2. Cause and effect
    3. Scale, proportion and quantity
    4. Systems and System Models
    5. Energy and matter
    6. Structure and function
    7. Stability and change
- *Clarification Statements* – provide examples or additional explanation to the performance expectation.

Overview of standards covered by NFC lesson plans

6th Grade

Physical Science (PS):

6-MS-PS1-1

Performance Expectation: Develop models to describe the atomic composition of simple molecules and extended structures.

Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include carbon dioxide and water. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular -level models could include drawings, 3-D models, or computer representations showing different molecules with different types of atoms.

Science and Engineering Practices:

2. Developing and using models: Develop and/or use a model to predict and/or describe phenomena. Modeling in 6-8 builds on K-5 and progresses to developing, using, and revising models to describe, test and predict more abstract phenomena and design systems.

Disciplinary Core Ideas:

Structure and Properties of Matter: Substances are made from different types of atoms, which combine with one another in various ways. Atoms from form molecules that range in size from two to thousands of atoms. Solids may be formed from molecules, or they may be extended structures with repeating subunits.

Crosscutting Concepts

Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Life Science (LS):

6-MS-LS1-1

Performance Expectation: Conduct an investigation to provide evidence that living things are made of cells, either one or many different numbers, and types.

Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and nonliving things, and understanding that living things may be made of one or many cells, including specialized cells. Examples could include animal cells (blood, muscle, skin, nerve, bone, or reproductive) or plant cells (root, leaf, or reproductive).

Science and Engineering Practices:

3*. Planning and carrying out investigation*s: Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meets the goals of the investigation. Planning and carrying out investigations to answer questions or test solutions to problems in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

Disciplinary Core Ideas:

Structure and Function: All living things are made up of cells, which are the smallest living unit. An organism may consist of one single cell (unicellular) or many different types/numbers of cells (multicellular).

Crosscutting Concepts

Scale, Proportion, and Quantity: Phenomena that can be observed at one scale may not be observable at another scale.

6-MS-LS2-1

Performance Expectation: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant or scarce resources.

Science and Engineering Practices:

4*. Analyzing and Interpreting Data*: Analyze and interpret data to provide evidence for phenomena. Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

Disciplinary Core Ideas:

Interdependent Relationships in Ecosystems: Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

6-MS-LS2-2

Performance Expectation: Construct an explanation that predicts patterns of interaction among organisms across multiple ecosystems.

Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems and relationships among and between biotic and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, mutually beneficial, or other symbiotic relationships.

Science and Engineering Practices:

6. *Constructing explanations and designing solutions*: Construct an explanation that includes qualitative or quantitative relationships between variables that predicts and/or describes phenomena. Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Interdependent Relationships in Ecosystems: Predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

Crosscutting Concepts

Patterns: Patterns can be used to identify cause and effect relationships.

6-MS-LS2-3

Performance Expectation: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.

Science and Engineering Practices:

2. Developing and using models: Develop and/or use a model to predict and/or describe phenomena. Modeling in 6-8 builds on K-5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

Disciplinary Core Ideas:

Cycle of Matter and Energy Transfer in Ecosystems: Food webs are models that demonstrate how matter and energy is are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment can occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Geochemical cycles include carbon, nitrogen, and the water cycle.

Crosscutting Concepts

Energy and Matter: The transfer of energy can be tracked as energy flows through a designed or natural system.

Earth and Space Science (ESS):

6-MS-ESS3-4

Performance Expectation: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Clarification Statement: Examples of evidence include grad-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, minerals, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions.

Science and Engineering Practices:

7. *Engaging in argument from evidence*: Construct, use and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

Disciplinary Core Ideas:

Human Impacts on Earth Systems: Typically, as human populations and

per-capita consumption of natural resources increases, so does the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Biogeology: Living organisms interact with Earth materials resulting in changes of the Earth.

Resource Management for Louisiana: Responsible management of Louisiana's natural resources promotes economic growth, a healthy environment, and vibrant productive ecosystems.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Overview of standards covered by NFC lesson plans

<u>7th Grade</u>

Physical Science (PS):

<u>7-MS-PS1-2</u>

Performance Expectation: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, or mixing zinc with hydrogen chloride. Examples of chemical and physical properties to analyze include density, melting point, boiling point, solubility, flammability, or odor.

Science and Engineering Practices:

4. *<u>Analyzing and Interpreting Data</u>*: Analyze and interpret data to determine similarities and differences in findings. Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

Disciplinary Core Ideas:

<u>Structure and Properties of Matter</u>: Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) under normal conditions that can be used to identify it.
<u>Chemical Reactions</u>: Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

Crosscutting Concepts

<u>Patterns</u>: Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

7-MS-PS3-4

Performance Expectation: Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in average kinetic energy of the particles as measured by the temperature of the sample.

Clarification Statement: Emphasis is on observing change in temperature as opposed to calculating total thermal energy transferred. Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.

Science and Engineering Practices:

3. *Planning and Carrying Out Investigations*: Plan an investigation individually and collaboratively, and in the design; identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many much data is are needed to support a claim. Planning and carrying out investigations to answer questions or test solutions to problems in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.

Disciplinary Core Ideas:

Definitions of Energy: Temperature is a measure of the average kinetic energy; the relationship between the temperature and the total energy of the system depends on the types, states, and amounts of matter present.
Conservation of Energy and Energy Transfer: The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the mass of the sample, and the environment. Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

Crosscutting Concepts

Scale, Proportion, and Quantity: Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Life Science (LS):

7-MS-LS1-3

Performance Expectation: Use an argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems. Systems could include circulatory, excretory, digestive, respiratory, muscular, endocrine, or nervous systems.

Science and Engineering Practices:

7. *Engaging in argument from evidence*: Construct, use and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

Disciplinary Core Ideas:

Structure and Function: In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions in order to maintain homeostasis.

Information Processing: Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

Crosscutting Concepts

Systems and System Models: Subsystems may interact with other systems; they may have subsystems and be a part of larger complex systems.

7-MS-LS1-6

Performance Expectation: Construct a scientific explanation based on evidence for the role of photosynthesis and cellular respiration in the cycling of matter and flow of energy into and out of organisms.

Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.

Science and Engineering Practices:

2. Developing and using models: Develop a model to describe unobservable mechanisms. Modeling in 6-8 builds on K-5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

Disciplinary Core Ideas:

Organization for Matter and Energy Flow in Organisms: Within individual organisms, food (energy) moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth or to release energy through aerobic and anaerobic respiration. Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

Crosscutting Concepts

Energy and Matter: Matter is conserved because atoms are conserved in physical and chemical processes.

7-MS-LS2-4

Performance Expectation: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Clarification Statement: Emphasis is on recognizing patterns in data, making inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.

Science and Engineering Practices:

7. *Engaging in argument from evidence*: Construct, use and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

Disciplinary Core Ideas:

Ecosystem Dynamics, Functioning, and Resilience: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Crosscutting Concepts

Stability and Change: Small changes in one part of a system might cause large changes in another part.

7-MS-LS2-5

Performance Expectation: Undertake a design project that assists in maintaining diversity and ecosystem services.

Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, habitat conservation, or soil erosion mitigation. Examples of design solution constraints could include scientific, economic, or social considerations.

Science and Engineering Practices:

6. *Constructing explanations and designing solutions*: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Ecosystem Dynamics, Functioning, and Resilience: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Crosscutting Concepts

Stability and Change: Small changes in one part of a system might cause large changes in another part.

7-MS-LS3-2

Performance Expectation: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.

Science and Engineering Practices:

2. Developing and using models: Develop and/or use a model to predict and/or describe phenomena. Modeling in 6-8 builds on K-5 and progresses to developing, using and revising models to describe, test and predict more abstract phenomena and design systems

Disciplinary Core Ideas:

Growth and Development of Organisms: Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. Cells divide through the processes of mitosis and meiosis.

Inheritance of Traits: Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. In sexually reproducing organisms, each parent contributes to the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Overview of standards covered by NFC lesson plans

8th Grade

Physical Science (PS):

8-MS-PS1-1

Performance Expectation: Develop models to describe the atomic composition of simple molecules and extended structures.

Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of extended structures could include minerals such as but not limited to halite, agate, calcite, or sapphire. Examples of molecular-level models could include drawings, 3-D models, or computer representations showing different molecules with different types of atoms.

Science and Engineering Practices:

2. Developing and using models: Develop and/or use a model to predict and/or describe phenomena. Modeling in 6-8 builds on K-5 and progresses to developing, using and revising models to describe, test and predict more abstract phenomena and design systems

Disciplinary Core Ideas:

Structure and Properties of Matter: Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

Crosscutting Concepts

Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

8-MS-PS1-6

Performance Expectation: Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride, calcium chloride, or a citric acid and baking soda (sodium bicarbonate) reaction in order to warm or cool an object.

Science and Engineering Practices:

6. *Constructing explanations and designing solutions*: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Chemical Reactions: Some chemical reactions release energy (exothermic reactions), others store energy (endothermic reactions).
Optimizing the Design Solution: Although one design may not perform the best across all tests, identifying the characteristics of the design that performs best in each test can provide useful information for the redesign process-that is, some of those characteristics may be incorporated in to the new design.

Crosscutting Concepts

Energy and Matter: Flows, Cycles, and Conservation: The transfer of energy can be tracked as energy flows through a designed or natural system.

Life Science (LS):

8-MS-LS1-4

Performance Expectation: Construct and use arguments based on empirical and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of survival and successful reproduction of animals and plants respectively.

Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, or vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds or creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar, and odors that attract insects that transfer pollen or hard shells on nuts that squirrels bury.

Science and Engineering Practices:

7. *Engaging in argument from evidence*: Construct, use and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

Disciplinary Core Ideas:

Growth and Development of Organisms: Animals engage in characteristic behaviors that increase the odds of reproduction. Plants (flowering and non-flowering) reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

Crosscutting Concepts

Cause and Effect: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

8-MS-LS1-5

Performance Expectation: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

Clarification Statement: Examples of local environmental conditions could include the availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting the growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, or fish growing larger in large ponds than they do in small ponds.

Science and Engineering Practices:

6. *Constructing explanations and designing solutions*: Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Growth and Development of Organisms: Genetic factors, as well as local conditions, affect the growth of the adult plant.

Crosscutting Concepts

Cause and Effect: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

8-MS-LS4-1

Performance Expectation: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

Clarification Statement: Emphasis is on finding a pattern of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.

Science and Engineering Practices:

4. *Analyzing and interpreting data*: Analyze and interpret data to determine similarities and differences in findings. Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

Disciplinary Core Ideas:

Evidence of Common Ancestry and Diversity: The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.

Crosscutting Concepts

Patterns: Graphs, charts, and images can be used to identify patterns in data.

8-MS-LS4-2

Performance Expectation: Apply scientific ideas to construct and explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms.

Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.

Science and Engineering Practices:

5. Constructing explanations and designing solutions: Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events. Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Evidence of Common Ancestry and Diversity: Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.

Crosscutting Concepts

Patterns: Patterns can be used to identify cause and effect relationships.

8-MS-LS4-3

Performance Expectation: Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.

Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.

Science and Engineering Practices:

4. *Analyzing and interpreting data*: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

Disciplinary Core Ideas:

Evidence of Common Ancestry and Diversity: Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. A comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.

Crosscutting Concepts

Patterns: Graphs, charts, and images can be used to identify patterns in data.

8-MS-LS4-6

Performance Expectation: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations of species over time.

Clarification Statement: Emphasis is on using mathematical models, probability statements and proportional reasoning to support explanations of trends in changes to populations over time. Students should be able to explain trends in data for the number of individuals with specific traits changing over time.

Science and Engineering Practices:

5*. Using mathematics and computational thinking*: Use mathematical representations to describe and/or support scientific conclusions and design solutions. Mathematical and computational thinking in 6-8 builds on K-5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to spurt explanations and arguments.

Disciplinary Core Ideas:

Adaptation: Adaptation by natural selection acting over generations is one important process by which populations change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment tend to become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Crosscutting Concepts

Cause and Effect: Phenomena may have more than one cause and some cause and effect relationships in systems can only be described using probability.

Earth and Space Science (ESS):

8-MS-ESS3-3

Performance Expectation: Apply scientific principles to design a method for monitoring and minimizing human impact on the environment.

Clarification Statement: Examples of the design process may include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts may include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture or the removal of wetlands) and pollution (such as of the air, water or land).

Science and Engineering Practices:

6*. Constructing explanations and designing solutions*: Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events. Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Human Impacts on Earth's Ecosystems: Human activities, globally and locally, have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negatively and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Developing Possible Solutions: A solution needs to be tested to prove the validity of the design and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Models of all kinds are important for testing solutions.

Crosscutting Concepts

Cause and Effect: Relationships can be classified as casual or correlational and correlation does not necessarily imply causation.

Overview of standards covered by NFC lesson plans

High School

Physical Science (PS):

HS-PS1-1

Performance Expectation: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level and the composition of the nucleus of atoms.

Clarification Statement:

Physical Science: Examples of properties that could be predicted from patterns could include reactivity of metals, nonmetals, metalloids, number of valence electrons, types of bonds formed, or atomic mass. Emphasis is on the main group elements.

Chemistry: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, atomic radius, atomic mass, or reactions with oxygen. Emphasis is on main group elements and qualitative understanding of the relative trends of ionization energy and electronegativity.

Science and Engineering Practices:

2. *Developing and using models*: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems or between components of a system.

Disciplinary Core Ideas:

Structure and Properties of Matter: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

Types of Interactions: Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

Crosscutting Concepts

Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

HS-PS1-2

Performance Expectation: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

Clarification Statement:

Physical Science: Examples of chemical reactions could include the reaction of sodium and chlorine, carbon and oxygen or hydrogen, and oxygen. Reaction classification includes synthesis, decomposition, single displacement, double displacement, and acid-based.

Chemistry: Examples of chemical reactions could include the reaction of sodium and chlorine, carbon and oxygen, or carbon and hydrogen. Reaction classification includes synthesis, decomposition, single displacement, double displacement, and acid-based.

Science and Engineering Practices:

6. *Constructing explanations and designing solutions*: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Structure and Properties of Matter: The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

Chemical Reactions: The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Crosscutting Concepts

Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

HS-PS1-3

Performance Expectation: Plan and conduct an investigation to gather evidence to compare the structure of substances at the macroscale to infer the strength of electrical forces between particles.

Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole), Examples of particles could include ions, atoms, molecules and network solids (such as graphite). Examples of macro-properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.

Science and Engineering Practices:

3. *Planning and Carrying Out Investigations*: Plan and conduct an investigation individually and/or collaboratively to produce data to serve as the basis for evidence, and in the design; decide on types, how much and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time) and refine the design accordingly. Planning and carrying out investigations to answer questions or test solutions to problems in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Disciplinary Core Ideas:

Structure and Properties of Matter: The structure and interactions of matter at the macro scale are determined by electrical forces within and between atoms. *Types of Interactions:* Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

Crosscutting Concepts

Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

HS-PS1-4

Performance Expectation: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products and representations showing energy is conserved.

Science and Engineering Practices:

2. *Developing and using models*: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems or between components of a system.

Disciplinary Core Ideas:

Structure and Properties of Matter: A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
Chemical Reactions: Chemical processes, their rates and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms in to new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

Crosscutting Concepts

Energy and Matter: Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within a system.

HS-PS1-6

Performance Expectation: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining the designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.

Science and Engineering Practices:

6. *Constructing explanations and designing solutions*: Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Chemical Reactions: In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
Optimizing the Design Solution: Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

Crosscutting Concepts

Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

HS-PS3-1

Performance Expectation: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Clarification Statement:

Chemistry: Emphasis is on explaining the meaning of mathematical expressions used in the model. The focus is on basic algebraic expression or computations, systems of two or three components, and thermal energy.

Physics: Emphasis is on explaining the meaning of mathematical expressions used in the model. Focus is on basic algebraic expression or computations; systems of two or three components; and thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.

Science and Engineering Practices:

5. *Using mathematics and computational thinking*: Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions, including computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Disciplinary Core Ideas:

Definitions of Energy: Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

Conservation of Energy and Energy Transfer: Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. Mathematical expressions allow the concept of conservation of energy to be used to predict and describe system behavior. These expressions quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and velocity. The availability of energy limits what can occur in any system.

Crosscutting Concepts

Systems and System Models: Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Life Science (LS):

HS-LS1-3

Performance Expectation: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis in living organisms

Clarification Statement: Examples of investigations could include heart rate responses to exercise, stomate responses to moisture and temperature, root development in response to water levels or cell response to hypertonic and hypotonic environments.

Science and Engineering Practices:

3. *Planning and Carrying Out Investigations*: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design; decide on types, how much and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time) and refine the design accordingly. Planning and carrying out investigations to answer questions or test solutions to problems in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Disciplinary Core Ideas:

Structure and Function: Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing the organism to remain alive and functional even as external conditions change within some range. Feedback mechanisms can promote (through positive feedback) or inhibit (through negative feedback) activities within an organism to maintain homeostasis.

Crosscutting Concepts

Stability and Change: Feedback (negative and positive) can stabilize or destabilize a system.

HS-LS1-4

Performance Expectation: Use a model to illustrate the role of the cell cycle and differentiation in producing and maintaining complex organisms.

Clarification Statement: Emphasis is on conceptual understanding that mitosis passes on genetically identical materials via replication, not on the details of each phase in mitosis.

Science and Engineering Practices:

2. *Developing and using models*: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems or between components of a system.

Disciplinary Core Ideas:

Growth and Development of Organisms: In multicellular organisms, the cell cycle is necessary for growth, maintenance, and repair of multicellular organisms. Disruptions in the cell cycles of mitosis and meiosis can lead to diseases such as cancer. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation (stem cell) produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.

Crosscutting Concepts

Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales.

HS-LS2-1

Performance Expectation: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity, biodiversity, and populations of ecosystems at different scales.

Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and completion. Examples of mathematical comparisons could include graphs, charts, histograms, or population changes gathered from simulations or historical data sets.

Science and Engineering Practices:

5. *Using mathematics and computational thinking:* Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential, and logarithmic) and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Disciplinary Core Ideas:

Interdependent Relationships in Ecosystems: Ecosystems have carrying capacities, which are limits to the number of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges as predation, competition, and disease that affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. Human activity directly and indirectly affects biodiversity and ecosystem health (e.g., habitat fragmentation, introduction of nonnative or invasive species, overharvesting, pollution, and climate change).

Crosscutting Concepts

Scale, Proportion, and Quantity: The significance of a phenomenon is depending on the scale, proportion, and quantity at which it occurs.

HS-LS2-4

Performance Expectation: Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen, and nitrogen being conserved as they move through an ecosystem.

Science and Engineering Practices:

5*. Using mathematics and computational thinking:* Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential, and logarithmic) and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Disciplinary Core Ideas:

Cycles of Matter and Energy Transfer in Ecosystems: Energy is inefficiently transferred from one trophic level to another that affect the relative number of organisms that can be supported at each trophic level and necessitates a constant input of energy from sunlight or inorganic compounds from the environment. Photosynthesis, cellular respiration, decomposition, and combustion are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, hydrosphere, and geosphere through chemical, physical, geological and biological processes.

Crosscutting Concepts

Energy and Matter: Flows, Cycles, and Conservation: Energy cannot be created or destroyed – it only moves between one place and another place, between objects and/or fields or between systems.

HS-LS2-6

Performance Expectation: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood and extreme changes, such as volcanic eruption or sea -level rise. Emphasis should be on describing drivers of ecosystem stability and change, not on the organismal mechanisms or responses and interactions.

Science and Engineering Practices:

7. *Engaging in argument from evidence*: Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Disciplinary Core Ideas:

Ecosystem Dynamics, Functioning, and Resilience: The dynamic interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability and may result in new ecosystems.

Crosscutting Concepts

Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

HS-LS2-7

Performance Expectation: Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Clarification Statement: Examples of human activities can include urbanization, building dams, or dissemination of invasive species.

Science and Engineering Practices:

6. *Constructing explanations and designing solutions*: Design, evaluate and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas:

Ecosystem Dynamics, Functioning, and Resilience: Ecosystems with a greater biodiversity tend to have a greater resistance and resilience to change. Moreover, anthropogenic changes (induced by human activity) in the environment – including habitat destruction, pollution, the introduction of invasive species, overexploitation, and climate change – can disrupt an ecosystem and threaten the survival of some species.

Biodiversity and Humans: Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Humans depend on the living world for the resources and other benefits provided by biodiversity. Human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, the introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts.

Crosscutting Concepts

Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

Earth and Space Science (ESS):

HS-ESS2-5

Performance Expectation: Plan and conduct an investigation on the properties of water and its effects on Earth's materials and surface processes.

Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).

Science and Engineering Practices:

3. *Planning and Carrying Out Investigations*: Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations of phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. Planning and carrying out investigations to answer questions or test solutions to problems in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Disciplinary Core Ideas:

The Role of Water in Earth's Surface Processes: The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials and lower the viscosities and melting points of rocks.

Crosscutting Concepts

Structure and Function: The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

HS-ESS3-3

Performance Expectation: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations and biodiversity.

Clarification Statement: Examples of factors that affect the management of natural resources include costs of resources extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.

Science and Engineering Practices:

5. *Using mathematics and computational thinking:* Create a computational model or simulation of a phenomenon, designed device, process, or system. Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions (e.g., trigonometric, exponential, and logarithmic) and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Disciplinary Core Ideas:

Human Impacts on Earth Systems: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

Crosscutting Concepts

Stability and Change: Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Environmental Science (EVS):

<u>HS-EVS1-1</u>

Performance Expectation: Analyze and interpret data to identify the factors that affect sustainable development and natural resource management in Louisiana.

Clarification Statement: Evidence of Louisiana's natural resource wealth is found in understanding the functions and values of varied ecosystems and environments, the supply of non-renewable mining products, and profitable agricultural commodities. Examples of key natural resources include state waterways (such as rivers, lakes, and bayous) and the aquatic life found in them, regions of agriculture (pine forests, sugar cane, and rice fields), and high concentrations of minerals and fossil fuels on and off shore. Factors to consider in reviewing the management of natural resources include a review of historical practices, costs of resource extraction and waste management, consumption of natural resources, ongoing research, and the advancements in technology.

Science and Engineering Practices:

4. <u>Analyzing and interpreting data</u>: Analyze data using tools, technologies and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Disciplinary Core Ideas:

<u>Louisiana's Natural Resources</u>: Ecosystem capital can be characterized as goods (removable products) and services such as the functions and values of wetlands.

Crosscutting Concepts

<u>Stability and Change</u>: Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

HS-EVS1-3

Performance Expectation: Analyze and interpret data about the consequences of environmental decision to determine the risk-benefit values of actions and practices implemented for selected issues.

Clarification Statement: Examples could be taken from system interactions: (1) loss of ground vegetation causing an increase in water runoff and soil erosion. (2) dammed rivers increasing ground-water recharge, decreasing sediment transport, and increasing coastal erosion. (3) loss of wetlands reducing storm protection buffer zones allowing further wetland reduction. (4) hydrological modification such as levees providing protection to infrastructure at a cost to ecosystems.

Science and Engineering Practices:

4. Analyzing and interpreting data: Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Disciplinary Core Ideas:

Resource Management for Louisiana: Some changes to our natural environment such as the building of levees and hydrological modification have provided for economic and social development but have resulted in unintended negative impacts.

Crosscutting Concepts

Cause and Effect: Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is knows about smaller scale mechanisms within the system.

HS-EVS2-2

Performance Expectation: Use a model to predict the effects that pollution as a limiting factor has on an organism's population density.

Clarification Statement: The law of limiting factors is often illustrated as a graphic tolerance curve and can be used to infer the range of tolerance a species has for specific pollution hazards. When combined with real-world data such as field measurements of abiotic factors, these models can be used to help predict the suitability of an ecosystem for a particular species.

Science and Engineering Practices:

2. *Developing and using models*: Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solves problems. Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing and developing models to predict and show relationships among variables between systems and their components in the natural and designed-world(s).

Disciplinary Core Ideas:

Pollution and the Environment: Different organisms have unique tolerances to pollution hazards. Many of the organisms most tolerant of pollution are the least desirable to humans (e.g., for food, for recreation, for ecosystem services).

Crosscutting Concepts

Cause and Effect: Cause and effect relationships can be suggested and predicted for complex natural and humna0designed systems by examining what is knows about smaller scale mechanisms within the system.

HS-EVS2-3

Performance Expectation: Use multiple lines of evidence to construct an argument addressing the negative impacts that introduced organisms have on Louisiana's native species.

Clarification Statement: The exotic organisms introduce in Louisiana include plants such as Chinese tallow, kudzu and water hyacinth and animals including nutria, Asian tiger mosquitoes, and zebra mussels. These organisms can have impacts on scales ranging from the level of the individual (e.g., competition) to that of landscape (e.g., the destruction of coastal marches by nutria).

Science and Engineering Practices:

7*. Engaging in argument from evidence*: Construct, use and/or present an oral and written argument or counterarguments based on data and evidence. Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Disciplinary Core Ideas:

Ecosystem Change: The introduction of exotic/invasive species causes a disruption in natural ecosystems and can lead to the loss of native species (i.e. threatened/ endangered). Changes in ecosystems impact the availability of natural resources (e.g., sediment starvation, climate change).

Crosscutting Concepts

Cause and Effect: Cause and effect relationships can be suggested and predicted for complex natural and humna0designed systems by examining what is knows about smaller scale mechanisms within the system.

APPENDIX IV - GLOSSARY

Acid – a solution or substance having a pH lower than 7, indicating that it has a high concentration of hydrogen ions. One example of an acid is lemon juice.

Aerobic – a metabolic process that uses oxygen.

Alkaline – a substance having a pH greater than 7, indicating it has a low concentration of hydrogen ions. An alkaline substance is also called a base. Ammonia is an example of a base.

Ammonia (NH_3) – product of the decomposition of plant matter and human and animal waste in water. Some ammonia can be absorbed by aquatic plants, but most ammonia is broken down further into nitrite and nitrate by bacteria.

Ammonia compounds – includes ammonia (NH_3) and ammonium (NH_4^+).

Ammonium (NH_4+) – ionized form of ammonia.

Anaerobic – a metabolic process that does not use oxygen.

Aqueous – a solution that is mostly water.

Ballast water – water that is taken up into the ballast of the ship. The ballast is a compartment located between the outside and the inner hull used to balance the ship full of cargo. The water is released when the ship enters a port.

Base – See alkaline.

Broadcast spawn – simultaneous release of gametes (eggs and sperm) in the water column. Paddle-fish eggs are scattered over shoals of sand, gravel, boulders or mussel beds.

Brood – young of animals.

Brood stock – adult population of fish that spawn in a given year.

Cabbage water indicator – solution made from red cabbage that is used to measure the pH of a substance.

Cartilaginous – made of cartilage. Paddlefish are cartilaginous; their skeletons are made of cartilage not bone.

Cleavage – series of cell divisions in a fertilized egg.

Clitella – a saddle-like sac in the body wall of an earthworm that secretes a mucous layer during copulation. The mucous layer hardens into a tough, chitin-like band that forms a cocoon.

Compost – a mixture of decaying organic matter that has nutrients to improve the soil.

Conservation – actions to manage or improve the health of an ecosystem, ecotone, habitat, or species.

Convergent Evolution – When the same features evolve independently in different species.

Copepod – a small crustacean living in fresh and/or salt water. The body of the copepod is slender and segmented; its antennae allow it to drift in the water. There are 9,000 species of copepods. Most crawl or swim, but at least one-third live as parasites on fish and invertebrates.

Critical conditions – chemical, biological and physical conditions that must be met in order for some-thing to occur.

Critically imperiled – informal term for very small or rapidly declining population that is at risk of extinction.

***Daphnia* spp**. – small freshwater crustaceans commonly known as water fleas.

Dentary – the jawbone of a Paddlefish. It is the fish's only bony structure. Dentaries can be cross-sectioned, and the age of the fish can be determined by the growth rings.

Deionized water – has a pH of 7, which is neutral. This means the level of hydrogen ions (H+) and hydroxide ions (OH-) in pure water are equal.

Drought – a long period of time without rainfall that negatively affects growing or living conditions.

Electroreceptors – specialized organs that sense mild electronic current. Tens of thousands are located on the rostrum, opercular flap, and head of the Paddlefish. The receptors respond to microvolt-scale electrical emissions of planktonic prey and are used to locate the plankton during feeding behavior.

Embryo – the fertilized egg of a vertebrate after cleavage.

Endangered – in great danger or at risk of ceasing to exist.

Exotic – See nonindigenous.

Extinct – no longer living anywhere on Earth.

Extirpated – a species that no longer exists in a specific geographic area it once inhabited.

Eye-fork length – the measurement from the eyespot to the fork of the tail. This measurement is used instead of total body length in Paddlefish because rostrums can be damaged and their lengths vary naturally.

Fecundity – capacity for producing offspring. In Paddlefish, it is a general term used to describe the number of eggs produced.

Filter feeder – an animal that uses gill rakers or other modified mouth parts to harvest tiny particles of food from the water column.

Fingerling – small, immature fish less than one year old.

Fish kill – any biological, chemical, or physical event that causes a large amount of fish to die.

Flex cam – See video microscope.

Free-living – nonparasitic, living independently of another organism.

Fry – recently hatched fish. It is still considered an embryo.

Functionally extinct – No reproducing individuals left of a species.

Gill raker – an arched structure that protects tender gill filaments. In Paddlefish, they are modified into numerous elongated structures that augment or increase efficiency in filtering plankton from the water.

Gravel bar – an area on the bottom of a waterbody covered by small rocks.

Habitat – a place where an animal or plant lives and obtains food, water, shelter and living space.

Hard substrate – any solid structure covering the bottom of a waterbody, e.g. logs, gravel and mollusk shells.

Heterocercal tail – a tail fin like that of a shark, with the upper lobe longer than the lower lobe.

Hydroxide – hydroxide ions (OH-). Concentration determines the alkalinity of a solution or substance.

Inference – a conclusion based on facts or evidence.

Ion – an atom with extra electrons or missing electrons that make it unstable and ready to react with another atom to form a neutral compound.

KWL chart – a learning tool: K – What do you know? W – What do you want to know? L – What did you learn?

Limiting factor – any physical, chemical, or biological condition that interferes with or prevents a population from thriving.

Logarithmic scale – scale in which one unit of change is a tenfold increase of the previous unit.

Metamorphosis – a change in form and often habits of an animal during normal development after the embryonic stage, such as egg to larva to pupa to adult.

Native species – animals or plants that occur naturally in an area.

Nitrate – a water-soluble inorganic form of nitrogen (NO_3) that is a common water pollutant. In the nitrogen cycle, nitrites are broken down into nitrate by bacteria.

Nitrify – a chemical reaction that results in nitrate formation from nitrite. This is usually done by bacteria.

Nitrite – a water-soluble inorganic form of nitrogen (NO_2) that is a common water pollutant. In the nitrogen cycle, ammonia is broken down into nitrite by bacteria.

***Nitrobacter* spp**. – beneficial bacteria that convert nitrite to nitrate.

***Nitrosomonas* spp**. – beneficial bacteria that convert ammonia to nitrite.

Nonindigenous species – plants and animals that live outside their natural geographic boundaries, also referred to as exotic, introduced, or non-native.

Non-native – See nonindigenous.

Notochord – a flexible, rod-like structure that forms the main support of the body in the lowest chordates; a primitive backbone.

Nuisance species – a nonindigenous plant or animal that out competes native species for food or habitat and alters the environment.

Occurrence – to exist or be present in a geographic area.

Osmoregulation – regulation of water potential in living cells that allows movement of water across the cell membrane to maintain optimal function.

Ostracod – a small crustacean enclosed in a bivalve carapace that resembles a tiny clam. There are 8,000 different species that live in both fresh and salt water. Most ostracods are benthic (live on the bottom) organisms.

Otolith – ear bone of a fish. When the otolith is cross-sectioned, the rings on the ear bone can be counted like tree rings to determine the age of a fish. Each ring represents one year of life.

pH – the potential of hydrogen. It is the measure of the concentration of hydrogen ions (H+) in solution. The pH will equal 7 for neutral solutions and increase to 14 with increasing alkalinity and decrease to zero with increasing acidity.

pH indicator – used to determine whether a solution is an acid or a base.

Phytoplankton – microscopic, free-floating aquatic plants.

Plankton – organisms that float or drift in fresh or salt water.

Poach – to kill, collect, or hunt an animal or a plant illegally.

Population – two or more individuals of the same kind occupying a specific area.

Predator – an animal that kills and eats other animals.

Prey – animals that are hunted by predators.

Propagation – multiply or increase by natural reproduction.

Protected – Limited in number, therefore, prevented by state laws from being disturbed.

Range – a geographical area in which a species of organisms lives.

Restoration – to return to a former state of existence.

Restricted – governed by laws and regulations that limit the use or harm of something.

Rostrum – a snout-like projection on the head.

Sample population – a small group that represents the characteristics of an entire population.

SOAR (Scope-on-a-Rope) – See video microscope.

Species – a group of organisms that can interbreed and produce more of their own kind.

Species of concern – Informal term indicating that the U.S. Fish and Wildlife Service has some concern for the future well-being of a species that does not receive and Endangered Species Act protection.

Stagnant water – water that is not moving or flowing.

Status – current state of a species' existence.

Threatened – an animal or plant that is likely to become endangered in the future throughout a significant part of its range.

Tree cookie – a cross-segment of a trunk of a tree that can be used to find information about the age and past physical environment of the tree.

Urogenital opening – a common passage that functions for both excretion and reproduction.

Venn diagram – an education tool used to show differences and similarities among objects.

Video microscope – a microscope that is attached to a TV/VCR or computer to examine and/or film magnified objects.

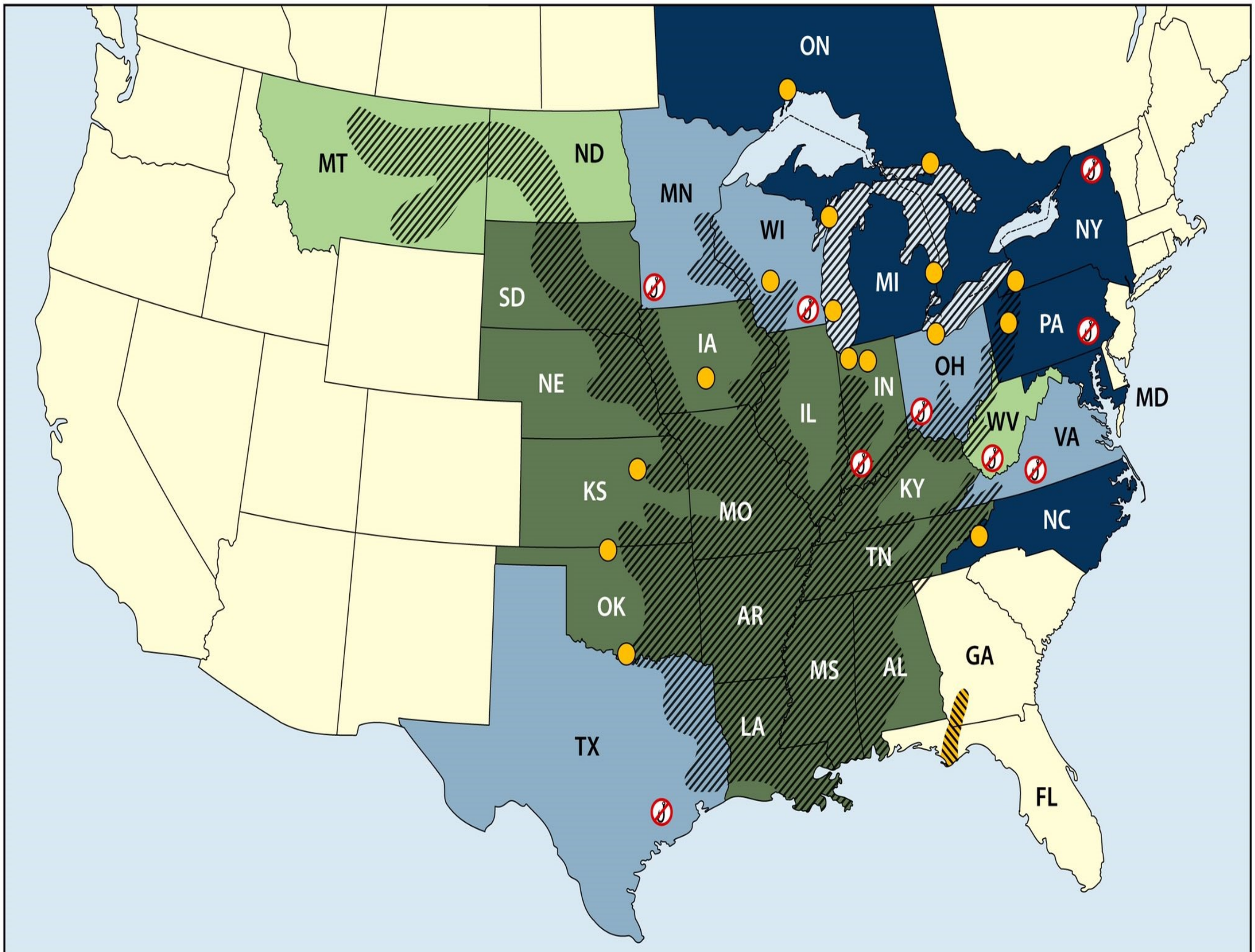
Yolk sac – a round sac on the belly that supplies food to the embryo.

Zooplankton – animals that float or drift in the water. Some, such as copepods, spend their entire lives as plankton, while others such as fish, mollusks and crustaceans are planktonic only during larval stages.

APPENDIX V -

PADDLEFISH STATUS MAP, FRY DIAGRAM, AQUATIC HOURS SHEET AND WATER QUALITY MONITORING LOG

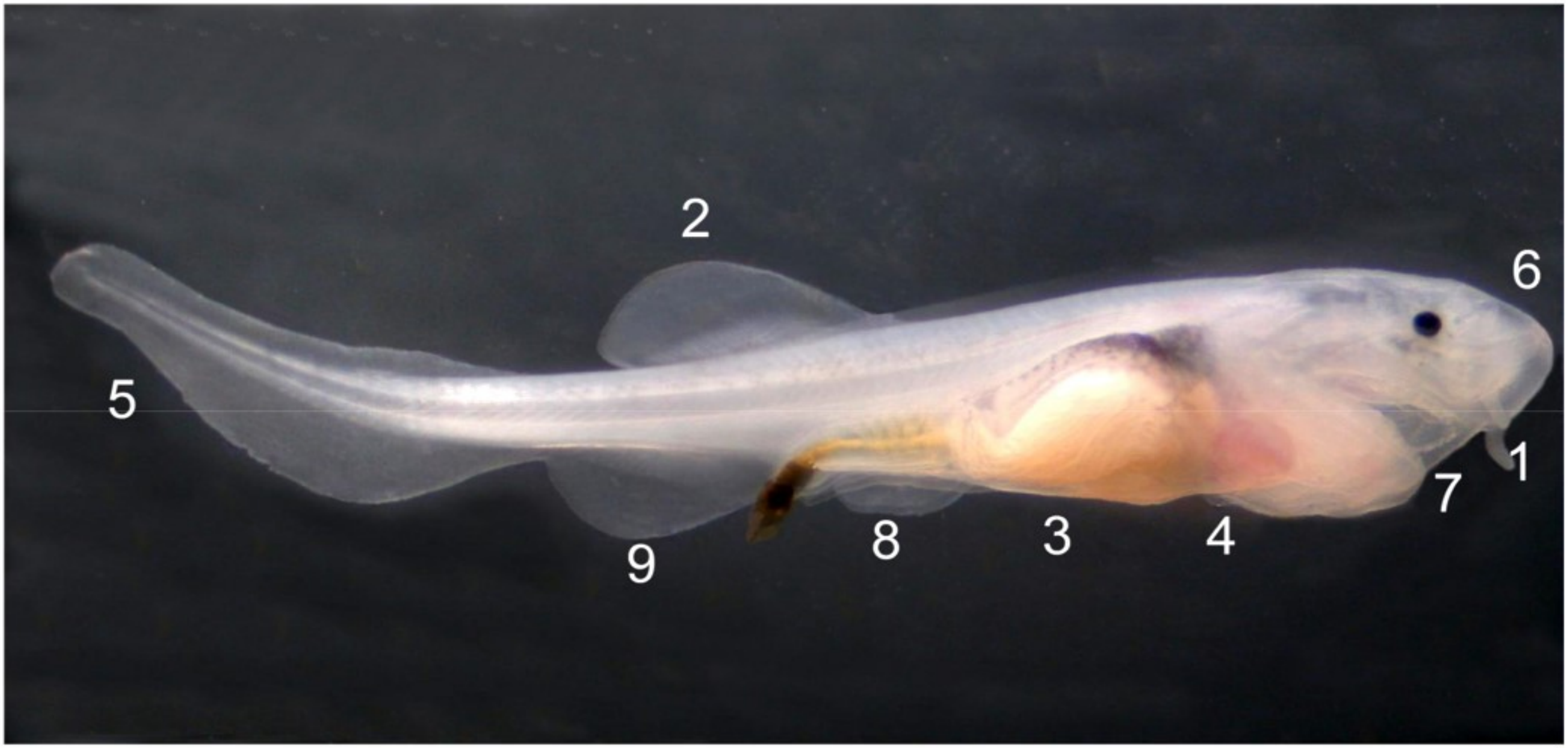
Range and Status of the Paddlefish (*Polyodon spathula*) in North America



Not listed. May be declining, stable, or increasing. Not protected, except sport/commercial fishing/harvest rules, limits, seasons. (IN: no fishing/harvest.)	Historic range. Range now less extensive. Current, accurate data not available for all states. Extirpated from Great Lakes and Great Lakes drainage.
Not listed as endangered/threatened, but officially considered rare, of special concern, or in need of conservation.	Population outside native range due to escape from aquaculture. Unclear whether these Paddlefish have survived and if they are reproducing.
Officially listed by state as Threatened. (The Paddlefish has no federal status.)	Historic, unconfirmed record of Paddlefish.
Extirpated. (PA and NY have Paddlefish populations due to ongoing restoration programs, including the stocking of tagged Paddlefish.)	State bans all fishing for Paddlefish. (All other states allow capture in some form; regulations vary. GA and FL have no regulations.)

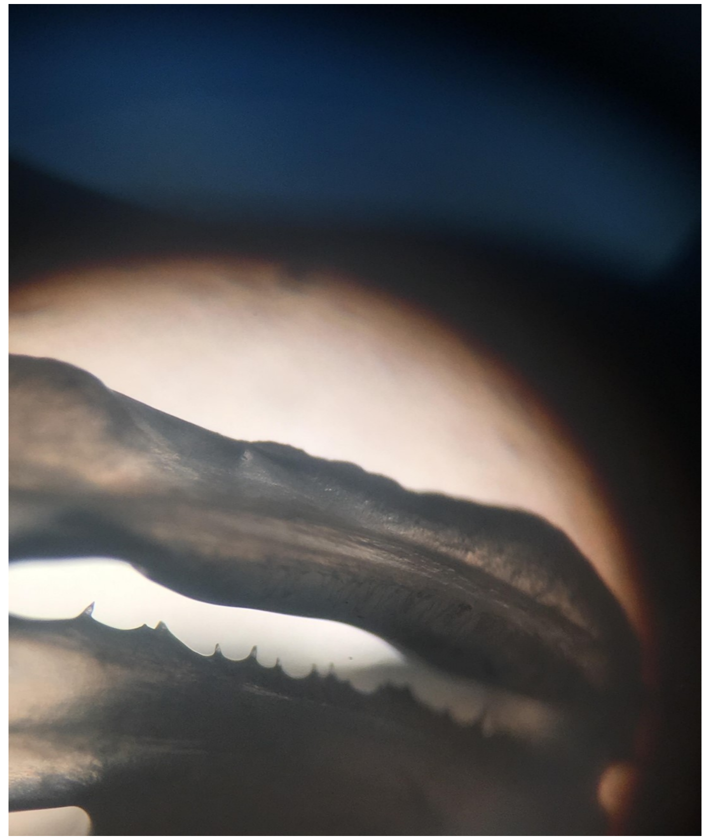
Information current as of October, 2014; range updated August, 2016. Information from various sources, including relevant agencies in all states. Unconfirmed historic locations from Jennings and Zigler (2000). See moxostoma.com/paddlefishmap for further information, corrected or updated versions of the map, and a list of sources used.

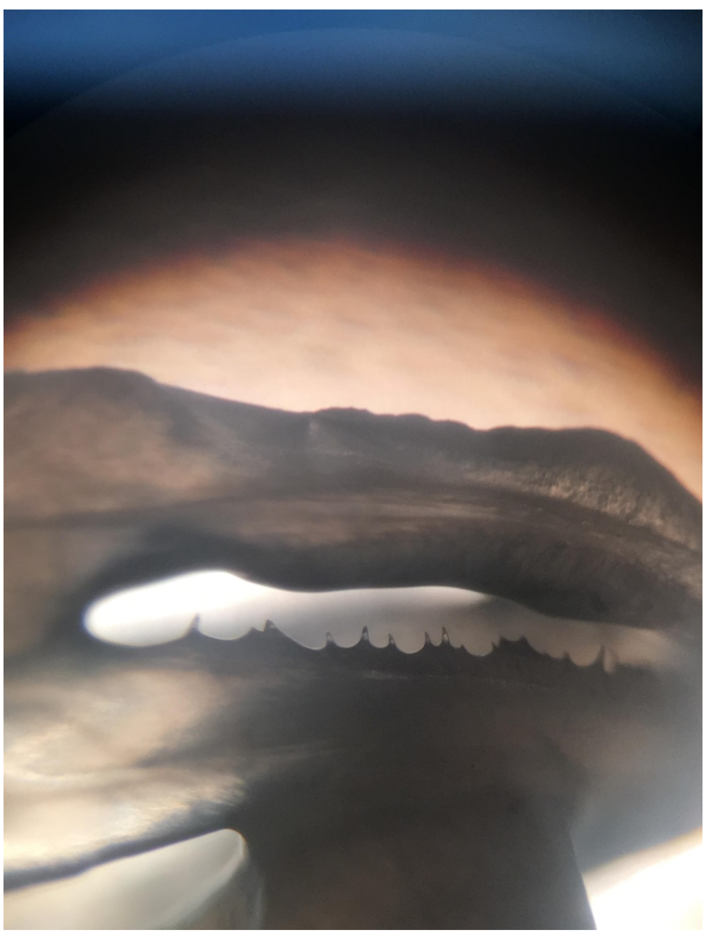
Paddlefish Fry

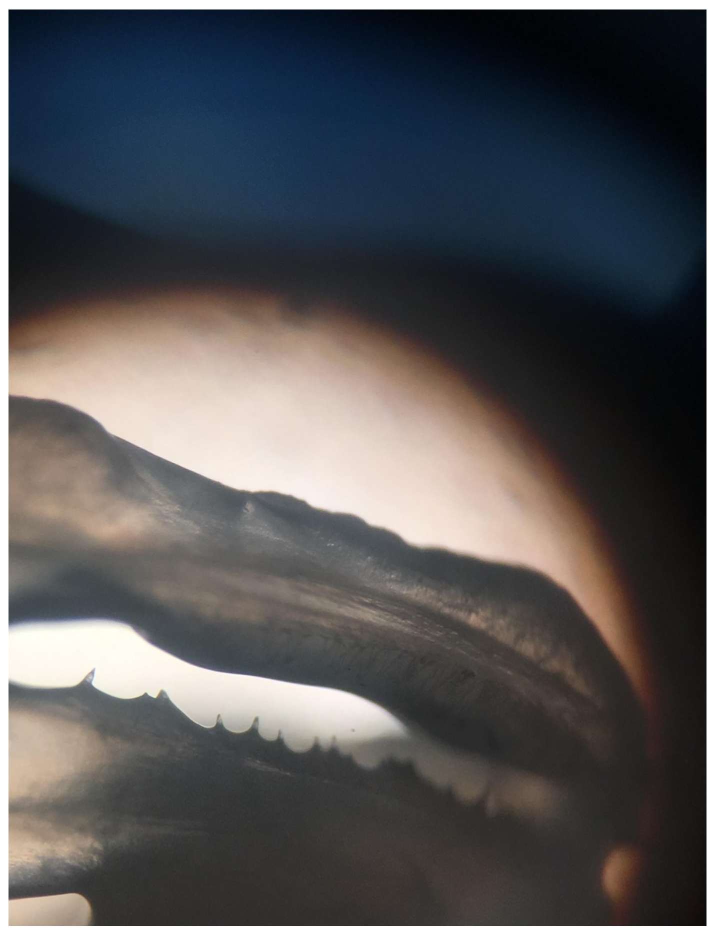


1. barbels
2. dorsal fin
3. digestive tract
4. heart
5. heterocercal caudal fin
6. rostrum
7. teeth
8. pelvic fins
9. anal fin

Paddlefish Fry Teeth







Louisiana Department of Wildlife and Fisheries

Volunteer Time & Activity Log

Location of Event: ____________________ (Site) ____________________ (City) Date(s) of Event: ____________

Event Title: ____________________ Organization/School Hosting: ____________________

Event Length (Hours): __________ Event Attendance: __________ Age Range/Grade Level: __________

**** If you are a certified VIP for LDWF then do not fill out this form. Log your hours on Galaxy Digital at lwff.galaxydigital.com ****

					30 min. Increments		Hours Volunteered
Date	**Name**	**Signature**	**E-Mail**	**Activity/Lesson**	**Start Time**	**End Time**	
					Total Hours		

Start time and end time should be in 30 minute increments (Ex. 6:30am-10:00am).

Fax completed form to: (225)765-2624 OR E-mail scanned copy to: hdavid@wlf.la.gov OR Mail to: LDWF, ATTN: Heather David, 2000 Quail Dr. Room 336, Baton Rouge, LA 70808

Native Fish in the Classroom

Water Quality Data Sheet

Date									
Air Temp.									
Water Temp.									
pH									
Ammonia									
Nitrite									
Nitrate									
Notes:									