HORSESHOE CRABS: PRETTY AS A PICTURE?

The Crab Chix, LLC in conjunction with ERDG Associates are pleased to present the art and environmental education curriculum “Horseshoe Crabs: Pretty as a Picture?” While written for grades 3-6, all lesson plans can be modified for use with any grade level. It is our hope that through participation in these activities, students will gain a greater understanding of these unique animals, their role in their environment and our lives as well as their overall art ‘worthiness’!

While the following lesson plans were meant to be used together as part of a larger science and art curriculum, each is able to stand alone to better meet educator/learner needs. If possible, it is recommended that the “Living the Life of Limulus” background information be reviewed prior to using the other lesson plans.

This curriculum would not have been possible without the assistance of several individuals and organizations including the Barnegat Bay National Estuary Program (www.bbnep.org), Toms River, NJ who provided the necessary funding through their annual mini grant program and ERDG, Lewes, DE who generously allowed us to work with them in creating these lesson plans and provided support both personal and professional.

The Crab Chix, Trish Schuster and Beth Huch labored long and hard in providing a three day Horseshoe Crab Art and Science Camp in August and a Professional Development Workshop in October for educators. The following lesson plans reflect the topics covered and the art projects developed for both sessions. Many thanks to our campers and teachers who piloted these projects.

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LESSON TITLE: HORSESHOE CRABS AND ASIAN ART

LESSON TITLE: HORSESHOE CRABS: LIVING THE LIFE OF LIMULUS

LESSON TITLE: SHOREBIRDS AND HORSESHOE CRABS

LESSON TITLE: HORSESHOE CRAB 'CAVE ART'

LESSION TITLE: GYOTAKU JAPANESE FISH PRINTING

LESSION TITLE: HORSESHOE CRABS: PRETTY AS A PICTURE?

LESSON TITLE: HORSESHOE CRABS AND ASIAN ART

WRITTEN BY: The Crab Chix, LLC Trish Schuster and Beth Huch

OBJECTIVE(S):
1. Students will be able to discuss the concept of ink and wash paintings
2. Students will create their own piece of ink and wash art.
3. Students will be able to identify the four species of horseshoe crabs and their worldwide distribution.
4. Students will be able to discuss the relationship between culture and conservation.

NJCCCS:
Science: 5.1 B, 5.5 A, B, 5:10 A, B
Language Arts: 3.1, F, G, H, 3:2 A, B, 3:3: A, 3:4 B
Social Studies: 6:1 A, 6:6 A, B
Visual Arts: 1:1 A, B, 1:2 D, 1:5 A, B

MATERIALS: Access to the Internet, images of the four horseshoe crab species for comparison, newsprint paper and/or, paintbrushes (regular and/or sumi brushes), sumi ink or black paint, water, horseshoe crab shells.

PREPARATION: Review background information, prepare art supplies and other materials. Use *Living the Life of Limulus* for additional background information.

BACKGROUND: Four species of horseshoe crab have survived the last 360 million years. One species, known as the North American horseshoe crab (*Limulus polyphemus*) is found from Maine to Florida and the Yucatan Peninsula, Mexico. The three other species are found in Asia from Japan to India. Although there is an obvious "family resemblance", they all differ in size and other more subtle ways.

The Japanese horseshoe crab **(***Tachypleus tridentatus***)** is slightly larger than the North American species. It ranges from the Philippines to the South West Seas of Japan. Male *tridentatus* possess two sets of 'boxing glove' claws. Unlike the North American horseshoe crab, *tridentatus* spawns in shallow water and monogamous pairs mate for life. **Larval** *tridentatus* do not leave their nests after hatching and usually overwinter in them. They remain near their **natal beaches** the following spring/summer. In Taiwan, this animal is known as the 'learned hou' ("how") or crab. It is also called 'two parents-in-law' due to its mating habits and the 'three-puncture hou'.

Tachypleus gigas, also called the Chinese, Indian, serrated tail or coastal horseshoe crab, is found from the South China Sea to India. Roughly the size of a dinner plate, it has a serrated, triangular shaped tail or **telson**. *T. gigas* spawns in freshwater mangrove mud flats.

The Mangrove horseshoe crab (*Carcinoscorpius rotundacauda*), also called the king crab, is the smallest of the three Asian species. Approximately the size of a man's palm,

it is found from the South China Seas to India and overlaps its range with *T. gigas*. Like *gigas*, it also spawns in freshwater mangrove mud flats.

It is interesting to note how different cultures view horseshoe crabs. In the United States, particularly in NJ, DE and MD, they have been the focus of conservation, legislation and controversy due to the link between shorebirds and horseshoe crab eggs for many years (see 'Shorebirds and Horseshoe Crabs' curriculum for additional information). Since the late 1990's, several states have enacted moratoriums to limit or eliminate the horseshoe crab harvest. The Carl N. Shuster National Horseshoe Crab Reserve extending from MD to NJ and into the Delaware Bay was created to help protect the North American species.

Though data is insufficient, all three Asian species are included on the 'red list'-a list of threatened animal species created by the World Conservation Union. Research is being carried out and preserves have been established in/around the countries where the other Asian species are found. Unfortunately, just as in America and the rest of the developed world, people like to live at the beach. Development and the resulting loss of habitat, beach dredging and replenishment, rapid industrialization and pollution (particularly heavy metals and oil spills) and overharvesting have severely impacted these three species.

Japan leads the way in reverence for horseshoe crabs and considers *Tachypleus tridentatus* a national treasure. There is a wonderful legend regarding the Japanese horseshoe crab, or heikigani, as they are known in Japan. 'Gani' is the Japanese word for crab and 'heiki' is a reference to the Heiki clan or family. During the Japanese Civil War of the 12th century, the Heiki clan was nearly wiped out during a maritime battle. Folklore holds that those samurai who died bravely in the battle were reincarnated as horseshoe crabs or heikigani. They were identified by a marking on the back of their shell that resembled the Japanese character for 'man'.

Modern day biologists wondered what purpose these markings could serve. Unlike birds with their colorful plumage, horseshoe crabs do not rely on markings to attract mates. What purpose or evolutionary advantage could these markings serve? Biologists found that over the centuries Japanese fishermen created a breeding stock by throwing back any heikigani with strong markings for fear of harvesting someone's' relative.

Despite this reverence however, the population of horseshoe crabs in Kasaoka Bay may be as few as 40-50 pairs. In the Kasaoka Municipal Horseshoe Crab Museum, Japanese horesehoe crabs are being raised and released into the bay to help remedy the situation.

Because the Mangrove horseshoe crab mates for life and the males cling to the females, it is used as a symbol of marital fidelity in countries where they are found.

China is believed to have the largest population of Japanese horseshoe crabs. They have somewhat differing views regarding horseshoe crabs, however. There they are called 'hai guai' which means 'sea monster'.

Asian horseshoe crabs are harvested by the millions for food and are served in a number of ways. The females are served on a bed of greens so the eggs can be eaten. The eggs are a main ingredient in a soup that also includes coconut and pineapple. The legs are also eaten. In China, Hong Kong and Viet Nam, the Mangrove and Japanese species are considered delicacies. They are harvested by local fishermen or imported from China where they are prized for their eggs and meat. In the US, a large female horseshoe crab is worth only one to two dollars for bait. A pre-cooked female in a Hong Kong specialty shop by contrast may sell for as much as $25-$50 US dollars.

It is important to remember that some of the countries where horseshoe crabs are found are still developing nations. Imagine how hard it must be to convince a person living in a Third World country who may lack sufficient housing, electricity, running water, healthcare and/or food that this brown pointy animal may be in jeopardy!

For this reason, organizations like ERDG are partnering with communities where horseshoe crabs are found to create sanctuaries. Funds are used to create village infrastructure, such as clean drinking water while providing education and protection for threatened horseshoe crabs.

ASIAN ART

China has the oldest continuous civilization in the world-almost 5,000 years! Therefore, it has one of the oldest continuous art traditions known as Chinese ink and wash painting. In China, this type of painting is known as '**Mo shui'**. It was originally done only with black ink in varied concentrations to create different shades from black to light gray. An old Chinese saying holds that "When you have ink, you have color". This means that a great variety of colors can be created with black ink combined with varying degrees of water. It would not be until the Tang Dynasty (618-907 AD) that color was introduced.

In 1701, a Chinese book called, "The Mustard Seed Garden Manual of Painting" was brought to Japan by Buddhist monks. It was essentially a 'how to' manual of Mo shui. Beginners were advised to paint four things: bamboo, plum, orchid and chrysanthemum. Known as **'The Four Gentlemen'**, it was believed that if one could master painting these four plants then one could paint anything as they contained all basic Mo shui strokes. In addition to being models for painting, each plant holds an important place in Asian culture.

Japan closed its borders to the outside world in the 17th century. They would remain closed for the next 150 years. During this time, Mo shui became uniquely Japanese and the technique we now know as **sumi-e** painting was developed.

The supplies for ink and wash/sumi-e are known as the **"Four Treasures":**

1. The brush is made of bamboo with different types of animal hair depending on its use. Regardless of the size of the brush, it always comes to a fine point.
2. The ink (sumi) is made from densely packed charcoal ash form bamboo or pine soot combined with glue from fish bones and formed into a rectangle. A dried ink stick

was easy to preserve and transport. A few drops of water are all that is needed to get smooth, black ink.
3. The ink stone (suzuri) is a mortar used to grind and hold the ink. They vary in size and can be as much as three feet long.
4. The paper is the final treasure. In China, the paper was traditionally made of silk while the Japanese favored rice paper.

In Asian art the process of getting ready to paint is just as important as actually painting. The artist begins by placing some water in the well of the suzuri, filling it halfway. The sumi is then dipped into the water and placed vertically on the flat surface of the suzuri. It is rubbed in a circular motion slowly and with easy pressure. Traditionally, the sumi would be ground for two to three minutes while the artist meditates and calms him/herself while mentally composing the painting.

The next step is to test the strength of the ink. If it is too light, more ink should be ground. If it is too dark, water can be added. When shades of gray are desired, black ink should be poured into a shallow dish and diluting it to the desired shade.

Mo shui and sumi-e are technically demanding media because once a stroke is made, it can't be erased or 'fixed' as it can in watercolor. The brush is not held like a pencil as Western artists do, but is instead held vertically. The thumb and forefinger hold the brush in an upright position while the palm has a distinct hollow. The ring finger is placed under the brush for support. Fingers should not touch the palm. The back should be straight but not tense. The entire arm from hand to wrist to elbow to shoulder is should be moved as one unit. Try to use only a single stroke to create an image. It definitely takes practice! Please note: This technique will most likely be awkward (and tiring!) to students.

Before painting, the artist should dip the brush in clean water and gently wipe off any excess. Too wet a brush results in a halo effect ("**nijimi")** of water around the image. The brush should be wet but not dripping. Next, dip just the tip of the brush into the ink. There are two basic strokes: one using only the tip of the brush and one that uses the side of the brush to create an image with one sharp and one soft edge. To load the brush, add water to the black paint and dip one third of the brush into it. To add more color, since it can't be layered on the paper, dip the other side of the brush into a different color (or hue if only using black).

To finish, add a 'chop' in red or black paint/ink. Asian artists traditionally use a chop of the characters of their name to sign documents and/or artwork. Students can create their own version by writing their monogram and enclosing it inside a rectangle or square.

ACTIVITIES:
1. Review background information with students and discuss. Teachers may opt to review science information first followed by art information vs. tackling all at once.

2. Can the name of something reveal how people feel about it? Is it easier to convince people to protect a 'learned' or smart animal than one that is a 'monster'? Ask students to cite other examples.
3. Visit various websites to access images of Asian horseshoe crab species. Compare and contrast w/each other and North American horseshoe crab. Visit **www.horseshoecrab.org** to see sumi-e horseshoe crab paintings.
4. Explore the concept of conservation in various countries. How does a country's status as 'developed' or 'Third World' impact this view? Using the Internet, research preserves/refuges in Asian countries that are trying to preserve horseshoe crabs.
5. Distribute art supplies and review sumi-painting information. Remind students of proper position of the brush and arm. Encourage students to experiment w/sumi-e techniques. Using horseshoe crab shells/images, instruct students to paint horseshoe crabs.
6. After several practices, students should compose a sumi-painting, using images of sumi-e paintings as references for composition. If available, distribute rice paper and instruct students to create a final sumi-e image. If desired, students could design and add their own chop to the painting. Research chops using the Internet.

VOCABULARY

Four Gentlemen: The four plants used as a basis for all sumi-e painting strokes including: bamboo, plum, orchid and chrysanthemum.
Four Treasures: The four supplies necessary for sumi-e painting including: the brush, ink or sumi, the ink stone or suzuri and the paper.
Larval: An early stage of arthropod development.
Mo shui: The Chinese name for ink and wash painting.
Natal beaches: The beach where horseshoe crabs hatched and where they instinctively return as adults to spawn.
Nijimi-a halo effect created by using a brush that is too wet when doing sumi-e painting.
Sumi-e: The Japanese name for ink and wash painting.
Telson: The correct name for a horseshoe crab 'tail'.

RESOURCES

www.horseshoecrab.org
www.lanhaidao.com (Asian species)
http://biodiv.sinica.edu.tw/~coconutcrab/web/images (Asian species)
geocities.com/…/chekjawa/horseshoe.htm (Asian species)
www./sc.usgs.gov/isschc07/links.html (2007 International Conference)
www.dinosaur.net/cn/fossil/200351022220606.jpg
www.dnr.state.med./…worldmap.html
www3.familie.ne.jp
www.galathea3.dk/…materiale/Thailand4.jpg (horseshoe crab on the half shell)
www.sakura.ce.tsukuba.ac.jp (Asian species)
www/.newib.ne.jp (Asian species)

LESSON TITLE: HORSESHOE CRABS: LIVING THE LIFE OF LIMULUS

BACKGROUND:
Are they crabs or spiders? Horseshoe Crabs are **arthropods** like true crabs, sharing some characteristics such as an **exoskeleton** that is shed in order to grow larger. They are also **invertebrates** and have jointed legs and claws – though the horseshoe crabs legs are designed to stir up food and not for defending itself.

Horseshoe crabs are more closely related to spiders, ticks and scorpions than to true crabs. They have eight legs and small claws found in front of the mouth (called chelicerae) like their **arachnid** cousins. They also have book gills while spiders have book lungs.

But horseshoe crabs are literally in a class all by themselves: **Merostomata** meaning "legs attached to the mouth". Only four species of horseshoe crab exist today. Three species are found in Asia and only one in North America along the Atlantic coast. All four species are similar in appearance.

Anatomy
Horseshoe crabs are invertebrates, meaning they have no backbone. Instead of an internal skeleton, the soft body parts are protected by a hard exoskeleton. The carapace (shell) is made of a material called **chitin**. The front half that resembles a helmet is called the **prosoma**. The back half is called the **opisthosoma**. A hinge of connective tissue keeps the two halves of the carapace together. This hinge enables the animal to fold up into a defensive 'V' position when on its back, thereby protecting the vulnerable gills and legs.

The tail or **telson** is not a weapon, but acts as a lever to right the animal should it be flipped on its back. If you find a horseshoe crab stranded on the beach, do not use the telson as a handle! If the muscle connecting the telson to the body is damaged, the animal is doomed.

The horseshoe crab has ten eyes! The large **compound eyes** are easily recognizable on either side of the prosoma. These are similar to compound eyes found in other arthropods such as flies, bees, butterflies and other insects. This type of eye provides multiple views of the same image. These eyes contain 1,000 **photoreceptors** (light sensitive cells) while our eyes contain over 100 million. The result is a vision of gray shades that is pixilated much like a digital image. The compound eyes allow the animal to see all around them with a range of about three feet. These eyes have a unique ability of powering up to one million times their normal sensitivity at night and powering down in the morning.

Two **rudimentary eyes** are found behind the compound eyes. Two **median eyes** are found on the front of the carapace along with a single rudimentary eye. These three eyes are often mistaken for nostrils. These 'eyes' perceive ultraviolet light from the sun and reflected light from the moon. This allows the crab to follow a lunar cycle. Two eyes are found between the chelicerae on the underside of the horseshoe crab. The final two eyes are found at the base of the telson.

The horseshoe crab has eight legs! There are four pairs of walking legs that are tipped with flat-tipped claws. As a horseshoe crab moves along the sandy bottom, it uses these claws to stir up food and work it towards the mouth. The claws are weak and cannot pinch you like a Blue Crab. The small claws found in front of the mouth are called **chelicerae**. These sensitive appendages discover food by touch and then, acting like small forks, place the food in the mouth. The last pair of legs resembling flower petals and are used to push off the bottom and to burrow. Males have a set of clasper claws in place of the first set of walking legs. These look like boxing gloves with large thumbs and are used for grasping the female's shell during spawning.

At the base of the legs are stiff bristles or spikes. These surround the mouth. As the animal grasps food and directs it toward this area, it continues walking. The bristles assist in breaking down the food before it makes its way into the mouth. This is important as horseshoe crab lack teeth. Horseshoe crabs are opportunistic eaters feeding on whatever is available – **detritus**, seed clams, small crabs and worms, as well as scavenging dead marine life.

Like fish, horseshoe crabs remove oxygen from the water using **gills**. Their **book gills** are unique. The first visible flaps are the **operculum** and protect the sensitive gills beneath. The operculum act like "tab dividers" in a notebook and between each divider are 100 pages of thin gill plates. Horseshoe crabs breathe by pulsating their gills. The gills can also help them swim upside down for brief periods. As long as the gills are in contact with damp sand, horseshoe crabs can survive out of the water for 24 hours. This is important as crabs can become stranded by the changing tide while spawning.

Every spring, usually from mid-May through mid-June in NJ, an amazing spectacle occurs – the **spawning** of the largest horseshoe crab population in North America. Millions of horseshoe crabs gather along the shores of the Delaware Bay to lay their eggs. During the spring tides (higher than usual high tides) smaller males seek out large females, most likely following scent clues.

Typically males of most species are larger than their female counterparts. Large size is an advantage in staking out and defending territory and competing with other males. Horseshoe crabs do none of these things. Speed, not size, matters. Females can attain a length of 2 feet and weigh 10 pounds. They need to be larger to carry the thousands of eggs that she will deposit in a season. Males are approximately 1/3 the size of females.

Males await the arrival of the females along the shore. Males will clasp hold of the female and other males may add to the chain. Several males may cling one behind the other as the large female makes her way to the beach. It is not uncommon to see other males gathering around them to fertilize at least some of the eggs. The female bulldozes into the sand and pushes out a depression depositing 5,000-30,000 eggs, all the size of a pinhead. She then pulls the male across the nest to fertilize them. This ritual will be repeated several times, with the female laying a total of 90,000 eggs per season.

Not all these eggs survive. Some will be swept out to sea to become fish food. Others will be uncovered by other horseshoe crabs. Many will be gulped by hungry birds.
The eggs hatch in two weeks and the babies burrow down in the mud to avoid being eaten. Only two of 90,000 eggs laid will reach adulthood.

While all this spawning is occurring, hungry migrating **shorebirds** are looking for a protein rich meal and there is nothing better than some freshly laid horseshoe crab eggs. About a dozen species of shorebirds rely on these eggs. Red knots, ruddy turnstones, as well as other shorebirds migrate from Central and South America. Approximately 50% of the world's population of red knots stop at the Delaware Bay to rest and restore fat supplies. These small shorebirds feed voraciously on the eggs, consuming as many as 9,000 per day. The abundant eggs, up to 100 tons, allow the birds to double their weight in less than two weeks and fly on to their breeding grounds in the Arctic.

There is much concern over this small shorebird. There has been a dramatic drop in the red knots and there is a true concern that these birds are on the fast track to **extinction**. Birds arriving late to the feast will likely not be able to continue the journey north or if they make it they may not have viable nests. The breeding schedule is very tight and the birds and they are winging their way back through this area in eight short weeks. The horseshoe crab eggs are the magnet that have drawn these birds to the Delaware Bay, probably for millennia. It is no coincidence that horseshoe crab spawning coincides with the shorebird migration.

Horseshoe crabs **molt** periodically as they grow larger- each time increasing their size by approximately 25%. Horseshoe crabs molt four times in their egg (although they are tailless). Once hatched, they will molt five to six times. Molting will continue until the animals are sexually mature – for males around 9 years old and females about 10 years. They will have molted some 17 times by the time they are adults.

Young horseshoe crabs crawl farther out to sea each year, spreading up and down the coast. Horseshoe crabs hatched in the Delaware Bay can be found anywhere from NJ to VA. While many over winter burrowed into the bottom muck of local bays, others migrate to the **Continental Shelf**. It is estimated that horseshoe crabs live 20 years in the wild.

Once horseshoe crabs stop molting, many smaller organisms take hold on the carapace. Since the crab tends to be slow moving, it is easy for animals to 'hitch a ride'. Slipper shells are often seen on both sides of the horseshoe crab. Other hitch hikers include barnacles, algae, oyster spat, and limulus leeches.

The only predators an adult horseshoe crab has are the leopard shark and loggerhead sea turtle. These appear to be the only animals that can crunch through the hard shell.

History
Native Americans in North Carolina used horseshoe crab telsons as spear points for fishing as early as the 1500's. Others used the shells as containers, boat bailers, or as

hand hoes. They also ate the lump meat in the legs and abdomen. Native people most likely taught settlers to use the horseshoe crab as fertilizer. By the 1860's, the horseshoe crab fertilizer industry was booming.

The animals were collected from the beach, dried in the sun and taken to factories for grinding. They were also harvested as pig and chicken feed until these animals developed a bad taste. By the late 1800's, over 4 million crabs were killed each year around the Delaware Bay. By the 1950's, the industry was fading. Neighbors of the fertilizer factories complained about the smell and chemical fertilizers had been developed.

In the 1980's harvests began to increase for use as bait for eels and whelks (conch). Around 1990, more and more people in Europe and Japan had developed a taste for whelks and American eels. Horseshoe crabs were harvested by hand, trawls and dredges during the spring spawning season. Reported landings steadily increased from less than 500,000 to over 1.3 million animals in 1997.

Horseshoe crabs are among the most studied invertebrates in the world. More than anything else, horseshoe Crabs are valued for their blood. These animals are true "blue bloods". High levels of copper in their blood create this rich color.

In the 1950's, researcher Frederick Bang found that horseshoe crab blood would clot in the presence of **endotoxins** – gram negative bacteria that can cause high fevers, seizures and even death in humans. As a result, horseshoe crabs are collected by labs in Delaware, Massachusetts and Virginia and safely 'bled'. A catheter is inserted into the heart through the muscle joining the carapace. The animals then bled 'donate approximately 10 ounces of blood (approximately 1/3 of their blood volume). They are then returned to the bay alive.

The blood is then sent to labs to be spun out in a **centrifuge**. The spun out white blood cells are then ruptured to release a protein, which is mixed with other ingredients to create the freeze-dried product known as Limulus Amebocyte Lystate (LAL). Since 1987 anything that is injected or implanted into the human body must be tested with LAL. It is also used for hemophilia, cancer and AIDS research. Every year, approximately 300,000 of these incredible animals save countless human lives.

In the 1920's, horseshoe crab eyes were studied, resulting in most of what we know about the human visual process. These scientists were awarded the Nobel Prize in 1967 for their research. It is the only animal for which we understand its complete **neural code**.

In Japan, doctors have found that the chitin coated suture material from the horseshoe crab shell is better for suturing wounds than silk. A paste made form the shell is also used to fill the cracks in broken bones and chitin is also used to treat burn dressings. Chitin is hypoallergenic and actually promotes healing by 50%.

The Future

There has been little research done on horseshoe crab populations in the past. One reason may be that these animals have fallen through the cracks of fisheries and shellfisheries departments because they are neither fish nor shellfish. One conservative estimate places the number at 2.3 to 4.5 million horseshoes on the Atlantic Coast between New Jersey and Virginia; other studies believe the number to be higher.

Shorebird researchers have provided anecdotal reports of fewer and fewer horseshoe crabs every year. Some scientists blame over harvesting of the crabs for bait as a cause. Loss of habitat in the form of nesting beaches also threatens the animals. There are still plenty who don't believe any of the scientific reports and insist there shouldn't be any limits.

Just as birds return to the same beaches to feed year after year, the horseshoe crabs return to the same beaches to nest. This is called **natal philapatry.** Many beach communities have built seawalls or piled up rocks to prevent erosion. The horseshoe crabs just keep on trying to nest and end up trapped on the rocks.

Pollution along the Atlantic Coast also plays a role. Horseshoe crabs are found just offshore of cities such as New York. Sewage, factory waste, street runoff, etc. kills the animals the crab relies on for food and may kill or weaken crab eggs and larvae. Mosquito spraying may also impact the horseshoe crab. Mosquitoes like the horseshoe are arthropods and the chemicals used to inhibit mosquito larvae from hatching may also effect the hatching horseshoe crab eggs.

Climactic change is also a concern. As the climate becomes warmer, there is concern that increases in water temperature will cause horseshoe crabs to nest earlier in the year, thereby breaking the link in the shorebird food chain. While the horseshoe crabs are flexible, the birds are not.

In 1991, Eastern Seaboard states passed legislation to limit the horseshoe crab catch. The FDA is setting stricter rules for the bleeding of the animals. More effective bait bags used by conchers have proven to be successful. Some fishermen have experimented with with menhaden laced with cast off horseshoe crab plasma from the biomedical field vs horseshoe crabs alone as bait. This has not been embraced by the conchers and eels to date.

In 2001, President Bush signed legislation that created a 1,500 square mile sanctuary for horseshoe crabs. The newly named Carl N. Shuster, Jr. Horseshoe Crab Reserve stretches approximately from Ocean City, MD to Ocean City, NJ and nearly 50 miles offshore at its widest point. It is named for the renowned horseshoe crab researcher. In 2006, NJ placed a 2-year moratorium on horseshoe crab harvesting. This was met with outrage from the fisherman who rely on the crab for bait.

Economic studies reveal the fishing industry can't compete with the eco-tourism boom that the nesting crabs and migrating shorebirds have created. The 1996 regional

economic impact resulting from expenditures by wildlife watchers in New Jersey and Delaware was the creation of 15,127 jobs and the generation of a total household income of $399 million dollars!

The horseshoe crab's highly developed sensitivity to endotoxins, has been seized upon by another industry that worries about bacteria: NASA. NASA's Planetary Protection Program has discovered the value of the Limulus Amebocyte Lysate (LAL) test in maintaining a sterile environment for its Mars missions. The results of horseshoe crab research has had and will continue to have a profound effect on man!

Ecological Research & Development Group of Lewes, DE, hosts an art contest each year for young people featuring the horseshoe crab. The winning entries then travel the East Coast & Japan as an exhibit. It is their hope that if the horseshoe crab is seen as being worthy of art, then it is surely worthy of conservation. ERDG is also working with communities here and in Asia to create community based horseshoe crab sanctuaries.

VOCABULARY

Arachnids-The class of animals that includes spiders, scorpions, ticks and mites
Arthropods-A large phylum of animals that includes insects, arachnids and crustaceans. All possess hard-shelled, segmented bodies
Book Gills-The specialized type of gills possessed by horseshoe crabs characterized by gill tissue covered by a series of protective flaps
Carapace-A hard covering or shell of an animal such as crabs
Centrifuge-A machine that whirls a mixture to separate its ingredients
Chelicerae-The small claws used to direct food into the horseshoe crabs mouth.
Chitin-The hard material that makes up the shell of true crabs and horseshoe crabs
Compound Eyes-The large, lateral eyes found on the prosoma of horseshoe crabs
Continental Shelf-A submerged border of a continent that slopes gradually and extends to a point of steeper decent to the ocean floor
Detritus-Disintegrated matter and debris from organic decomposition; marsh mud
Endotoxins-Poisons made be some bacteria which may cause illness or death of they enter the bloodstream
Exoskeleton- A hard, protective outer covering found on all arthropods
Generalists-Animals with diverse dietary and/or habit needs
Invertebrates-Animals lacking backbones
Median Eyes-The two small eyes on the front of the prosoma that are often mistaken for nostrils
Merostomata-The class of animals to which horseshoe crabs belong
Natal Philopatry-Returns to the place where one is born
Neural Code-The manner in which the nervous system functions
Operculum-Protective flaps covering the horseshoe crabs gills
Opisthosoma-The back half of a horseshoe crabs shell housing the gills.
Photoreceptors-Sensory organs able to sense light and dark
Prosoma-The front half of a horseshoe crabs shell.
Rudimentary Eye-Eye that acts as a photoreceptor
Shorebirds-Small, migratory birds found along beaches, rivers, and lakes
Spawning-To deposit eggs
Specialists-Animals with a highly specialized dietary and/or habitat needs
Telson-The long, pointy segment of the horseshoe crab incorrectly identified as a tail

RESOURCES

Websites

http://wpni01.auroraquanta.com/pv/biohorse?
http://nationalzoo.si.edu
http://mangrove.nus.edu.sg
www.afcd.gov.hk/conservation
www.brookdale.cc.nj.us/staff/sandyhook/dgrant/field/limulus.htm
www.delawareestuary.org
www.hku.hk/ecology
www.horsehosecrab.org
www.k12.de.us/warner/horseshoecrab
www.ocean.udel.edu/horseshoecrab

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Video/DVD

Winged Migration, Sony Pictures (2003).

LESSON TITLE: SHOREBIRDS AND HORSESHOE CRABS

AUTHORS: The Crab Chix, LLC: Trish Schuster & Beth Huch

OBJECTIVE(S):

1. Students will create one shorebird silhouette decoy.
2. Students will be able to identify the four major migration flyways.
3. Students will be able to identify at least one major staging area of the Atlantic Flyway.
4. Students will be able to explain the connection between shorebirds and horseshoe crabs.

NJCCCS

Visual Arts: 1.2 D
Language Arts: 3.1 H, 3.2 A, B, D; 3.3 A, B, D, 3.4 A, B, 3.5 A, B C
Social Studies: 6.1 A, 6.2 A, E; 6.5 A, 6.6 A, B, C, E
Science: 5.2 A, B; 5.5 A, B; 5.8 B, 5.10 A, B

MATERIALS

Decoys cut from 1" plywood with ¼" holes drilled in bottom
¼" dowels cut into 9" lengths
Sandpaper
Bases: 4" wooden blocks with ¼" holes drilled in center
Acrylic pain: white, black, burnt sienna
Foam brushes
Detail brushes
Large map of North and South America

PREPARATION

Cut decoys for each student. Drill holes for the dowels in bottom of each decoy as indicated on pattern and secure with a drop of glue. Review background material. Use *Living the Life of Limulus* for further background information.

BACKGROUND

At any given time during the year birds are on the move in the Western Hemisphere. It is thought that about half of the world's bird species migrate. The reasons for **migration** include changes in **climate**, which result in the loss of food due to seasonal changes, and following food sources such as insects and fish. The shortening and lengthening of days tells birds when it is time to migrate. Through **instinct,** birds such as waterfowl and shorebirds migrate from one region to another using **flyways**. The Atlantic, Mississippi, Central and Pacific flyways are the four major migration routes in North America that act like super highways for birds. South Jersey is part of this migration route. Other birds such as raptors and songbirds do not necessarily follow these same routes.

Birds prepare for the long journeys by adding fat to their diets. Birds must add fat reserves for use as fuel on their long treks. Fat reserves are increased within the body

cavity and underneath their skin. Flight efficiency depends on the quality of a bird's flight feathers, which in turn is affected by the quality of their food. The **range** of each species varies. Most species make stops along their migration to rest and refuel. These stopover points are called **staging areas,** as thousands of birds use them before the next leg of the journey.

The spawning of horseshoe crabs along the Delaware Bay in May and June coincides with the migration of many shorebirds. As the hungry migrants land in this area, the horseshoe crabs are laying hundreds of thousands of protein-rich eggs. It is thought that some quarter million horseshoe crabs will lay more than 100 tons of eggs attracting one of the largest gatherings of shorebirds in the country. Each bird doubles its weight in about two weeks by consuming some 9,000 eggs each day. Many of these palm sized birds have flown from the southern tip of Argentina and are headed to their breeding grounds on the Arctic Tundra.

In the past, migration was important to hunters who took advantage of the natural resource winging into their bays, creeks, and marshes every year. In fact, **market gunners** made their living harvesting huge quantities of shorebirds and ducks that were hunted for their meat, while wading birds were harvested for their long plumed feathers that were used to decorate ladies hats. With the use of decoys, hunters were able to lure the birds closer to them.

Decoys have been used for over 2,000 years. Native Americans were the first to use decoys. They were made of reeds or the actual bird skins and stuffed with plant fibers. Carved decoys became North America's first true art form and have transformed through the years from simple "blind" decoys to elaborately painted decorative carvings. Today, such works are declared **'folk art'**. Carvings by old time masters now command high prices at auctions.

Bird populations began to decline drastically as hunters became more proficient. The federal government stepped in and passed the **Migratory Bird Treaty Act** in 1918. This made the sale of migratory birds illegal and banned market gunning. The federal government established hunting seasons and only four shorebirds could be taken (black-bellied and golden plovers and greater and lesser yellowlegs). All shorebird hunting ended in 1928.

Shorebirds are defined as any of the wildfowl that feed along beaches, tidal flats or marshes. Shorebird decoys are generally **"stick ups"**, since they are mounted on sticks and stuck in the ground. These decoys were then placed where shorebirds tend to feed. The **silhouette** or '**flattie**' decoys were relatively inexpensive and lightweight and therefore easy to carry. They were made from a thick slab of wood and painted only to resemble a specific species of waterfowl. Hunters could create a small flock and lure the unsuspecting shorebirds in for the kill.

Silhouettes are still in use today, though computer technology has provided manufacturers with the ability to silkscreen actual photographs onto vinyl, which is then applied to the form. The result is a very realistic decoy.

Warm Up
Introduce migration with students including discussion of flyways and staging areas. Introduce the shorebird connection to horseshoe crabs and to decoys.

ACTIVITIES

1. Discuss reasons for hunting shorebirds and waterfowl. Why was market gunning banned?
2. Have students research a migratory bird and provide a presentation to the class.
3. Discuss migration demonstrating some of the long flights of certain species. This discussion should include flyways, methods of migrations, staging areas, etc.
4. Discuss the importance of horseshoe crabs to the shorebird migration.
5. Paint a Ruddy Turnstone Decoy (See attachment)

a. Pass out flatties to students along with a piece of sandpaper. Have students sand rough edges and smooth flat surfaces. Use blackboard or flip chart to demonstrate.
b. Using white paint and sponge brushes, have students paint the entire decoy. Discourage use of heavy paint as it takes longer to dry. Light coats may be applied as needed.
c. Using small brushes (detail) and black paint, instruct students to paint bill, making sure to paint the top and bottom.
d. Once bill is complete, instruct them to paint a half circle on the lower cheek, making sure to paint the connecting line on the bottom as well.
e. Next paint the collar, wing line and tail feathers connecting across top and bottom. (Heavy lines in attachment 1)
f. Allow paint to dry.
g. Using the burnt sienna paint fill in the wing, making sure to paint the top as well. (Thin diagonal lines in attachment 1)
h. Allow paint to dry.
i. Using the black paint, paint the three wing ‘feathers’.
j. Allow to dry.
k. Using the white paint, paint the white wing feathers next to black as directed.
l. Allow to thoroughly dry.
m. Finishing touches:
    a. Students may “age” their decoys by lightly sanding the edges and sides.
    b. Brush with paper towel to remove sawdust.

6. Create a classroom diorama using the flattie decoys

VOCABULARY

climate: the customary pattern of weather for any specific locality.
flattie: a flat decoy of the stick up variety (See Silhouette Decoy).
flyways: four major migration routes in North America for waterfowl and shorebirds.
folk art: the traditional artisitic expressions of a culture.
instinct: an inborn tendency to act or respond in a particular way.
market gunners: one of the traditional jobs of watermen and baymen that involved shooting large numbers of birds for city restaurants in the 19th and 20th centuries.
Migration: the periodic movement of animals from one region or latitude to another
Migratory Bird Treaty Act: Law passed in 1918 closing down the market gunners and creating bag limits and hunting seasons.
range: the area over which anything moves or is distributed.
staging areas: locations along migratory routes where birds tend to stop and rest and feed.
stick ups: the traditional stylke of shorebird decoys whereby the birds were mounted on dowels and set into the ground.
silhouette decoy: A flat decoy of the stick up variety (see Flattie)

RESOURCES

www.horseshoecrab.org
www.migratorybirds.fws.gov

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ERDG 2012 South Bay Shore Drive, Milton, DE 19968 (brochure)

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Reiger, George (1983). Humble masterpieces: decoys. National Geographic, November 639-661.

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Shourds, H.V. & Hillman, A (1982). Carving Shorebirds. Minneola, NY:Dover Publications.

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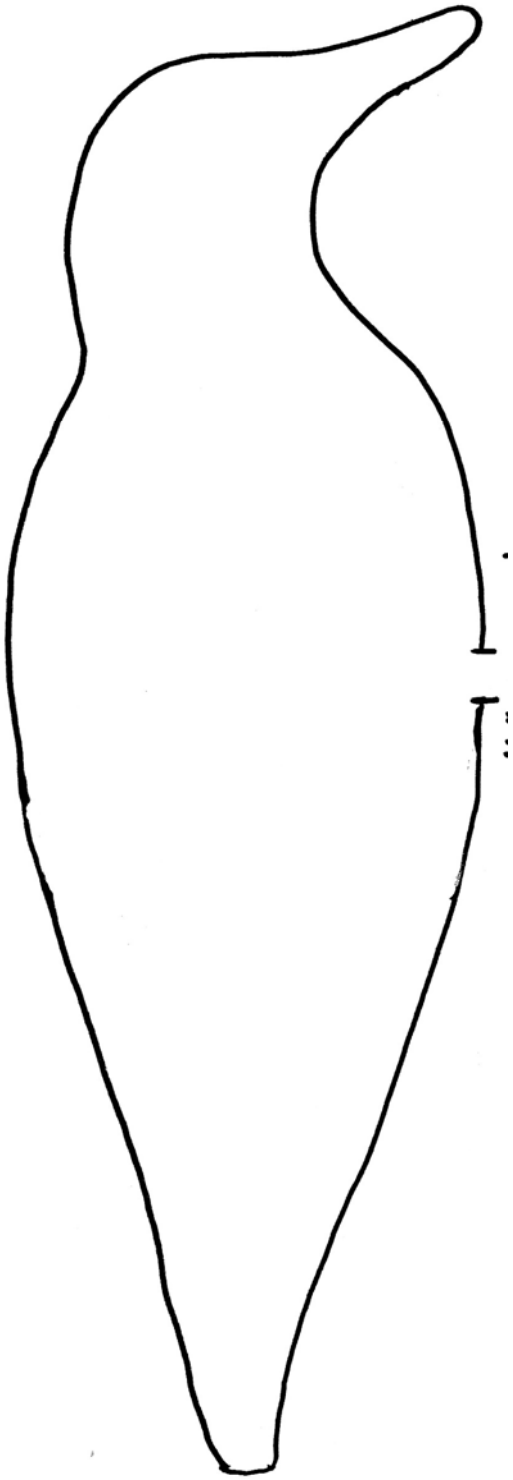
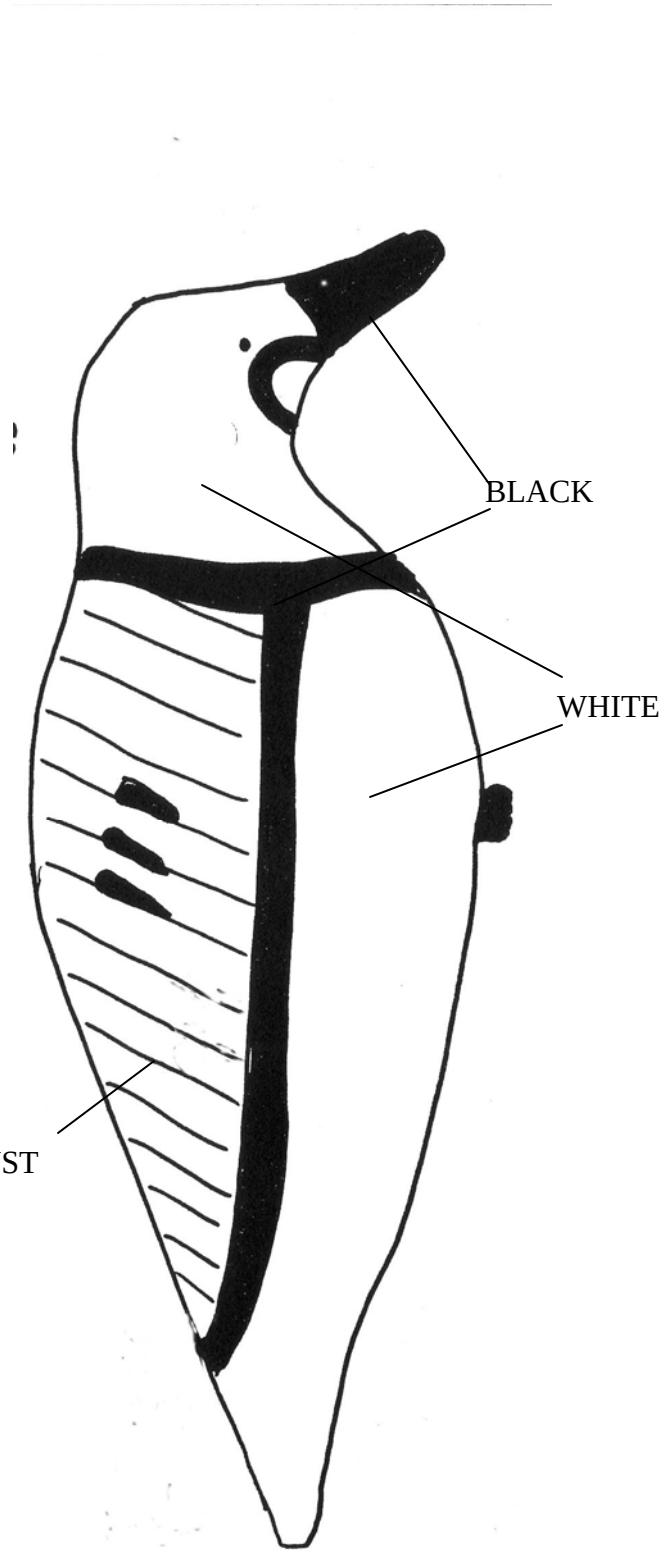
Video: *Winged Migration*, Sony Pictures (2003)

Attachment 1





LESSON TITLE: HORSESHOE CRAB 'CAVE ART'

WRITTEN BY: The Crab Chix, LLC Trish Schuster and Beth Huch

OBJECTIVE(S):
1. Students will be able to describe Paleolithic cave art in their own words.
2. Students will be able to describe horseshoe crab evolution and explain why they are called "living fossils".
3. Students will create their own horseshoe crab 'cave art'

NEW JERSEY CORE CURRICULUM CONTENT STANDARDS:
Science: 5.1 B, 5.5 A, B, 5.10 A, B
Language Arts: 3.4 A, B; 3.5 A,B
Social Studies: 6.1 A, 6.3 A, 6.6 A, B
Visual Arts: 1.1 A, B; 1.2 D; 1.3 D; 1.4 A, B; 1.5 A, B

MATERIALS: Paper, pencils, paint (red, burnt sienna, yellow ochre, black and violet), slate or stone (river rocks work well) and/or colored drawing paper, access to the Internet (http:/www.culture.gouv.fr/culture/arcnat/lascaux/en) and/or examples of Paleolithic cave art.

PREPARATION: Visit the above website and virtually tour the cave at Lascaux and/or study still photographs of Paleolithic cave art, provide paper and pencils, slate/stone and/or colored drawing paper, review background material, use *Living the Life of Limulus* for further background information.

BACKGROUND:
Long before the first human left their footprint in the sand and even before dinosaurs roamed the earth, there were horseshoe crabs. These ancient animals have been around for approximately 360 million years. They are the last in a long line of diverse marine animals called *Xiphosura,* which means 'sword-tailed animals'.

Though there were once many species of this group, only four are still in existence today. Of the four species of horseshoe crab worldwide, Limulus polyphemus (*Limulus* meaning 'odd' or 'off' and *polyphemus* after the giant Cyclops of Greek mythology) is the only species found in North America. The other three species are found on the southeastern shores of Asia.

Horseshoe crabs look much the same today as when they first appeared on the earth. In fact, juvenile horseshoe crabs are often called 'trilobite larva', a reference to a distant fossil cousin, the trilobite. For this reason, they are often called 'living fossils'. They have successfully survived ice ages, mass extinctions, continental shifts and the evolution of man. They are considered **generalists** because of this time-tested hardiness that is the reason for their success. It is also the reason for few evolutionary changes. By comparison, specialists are more vulnerable to extinction. Natural selection tends to create more species that flourish in the short run. Extinction keeps them in check. In the

long run, generalists survive while specialists are replaced by other specialists as evolutionary changes take place.

As generalists, horseshoe crabs are able to survive a wide range of conditions both natural and manmade. When some bays become badly polluted, most species of marine life die or leave. Horseshoe crabs are among the last to leave. They also tolerate a wide range of fluctuations in salinity, exposure to air, temperature and oxygen levels. Finally, horseshoe crabs are not picky eaters. In addition to feeding on small crustaceans, worms, mollusks and detritus they also scavenge.

These unique animals have survived over 360 million years of earth's history. Faced with manmade challenges today, it is our responsibility to preserve them for future generations. One way to do that is to change people's attitudes regarding horseshoe crabs. If this unusual animal can be seen as 'art worthy', then perhaps they will not frighten those unfamiliar with them.

CAVE ART

Humans have a strong desire for self-expression. Whether we sing, write, draw, paint, sculpt or dance, we need to express ourselves. This is as true for us today as it was for our ancestors. We often picture our ancient ancestors as hairy guys in animal skins sitting around the fire grunting to each other. Certainly such unsophisticated creatures could never create art! We know of course, that this not accurate. In fact, ancient art is surprisingly beautiful and demonstrates mastery of drawing, painting, engraving and sculpture.

There are many examples of ancient art from all over the world, but some of the best known and most spectacular ancient masterpieces are found in caves that date back to the Paleolithic period in Europe. The Paleolithic period is a prehistoric era that began 2.5 million years ago and ended in 10,000 AD. It was what we sometimes call 'the Stone Age'.

The most well-known cave art is found in Lascaux, in southwest France. In 1940, four teenagers were digging around by a hole created when some trees fell over. They widened the entrance and tumbled down the opening. Imagine their surprise when the passageway widened and they saw enormous paintings of various animal species on the walls and ceilings. After WWII, the opening of the cave was enlarged and opened to the public as well as scientists. Approximately 1200 people visited the caves every day to view paintings that were dated back some 15,000 years!

By 1955 however, signs of deterioration were noticed. Excess carbon dioxide from visitors breathing was to blame. Although the caves were closely monitored, the Ministry of Cultural Affairs decided to close the caves to the public in 1963. Once closed, the caves quickly returned to their earlier state. Today, the caves are monitored daily for changes in temperature, dampness and carbon dioxide pressure. Because of the great interest in the caves of Lascaux, a life size replica of the two most representative sections was opened to the public in 1983.

The majority of the images are realistically rendered animals typical of Paleolithic Europe. The animals stand out from the cave walls, in large part because they are painted on a grand scale. One bull in *The Cave of the Bulls* section is 17 feet long! The majority of the animals depicted are horses though aurochs (an extinct species of ox), stags, bears, big cats and a few fish and birds can be found. The animals are always in profile and look alert and energetic. Many are also engraved. They always stand alone with no vegetation or background.

Ancient artists made them appear three dimensional through a variety of techniques. Overlapping animals have **reserves** around parts of their bodies. A reserve is an area of the picture left the natural color of the background. Thus, by leaving a reserve around the hindquarters of a horse, it is naturally separated from the horse behind it. The artists also included more detail in potentially confusing sections like the legs and hooves. The forequarters of the animals are often disproportionately large making them appear more powerful. Finally, the artists took advantage of the shape of the cave walls, painting larger body sections on bulges and curves.

Human figures are unusual in cave paintings and Lascaux has only one. The obviously male figure is lying down w/a bison or bull next to it. The animals' head is lowered as though it is going to or has just gored the man. Interestingly, the human figure has the head of a bird. The section this painting is found in is logically referred to as *The Hall of the Dead Man*. Signs or symbols are also found in cave paintings and fit into two categories. The first are elaborate geometric shapes. The second are dots or lines. One researcher has suggested that the dots are maps of the night sky since the patterns relate to various constellations. Some cave paintings are also marked with handprints. It seems we have a need to sign our work!

Ancient artists didn't paint the outer openings of caves. Instead, they traveled deep inside, often having to crawl or erect scaffolds to complete their work. They overcame the darkness by burning animal fat in carved out stones. Lacking brushes, these they used mats of moss or hair to paint, along with hollowed out bones or reeds to blow pigment out like a Stone Age airbrush. They had a limited color palette and used red, yellow, black, brown and violet from minerals such as red and yellow ochre, magnetite and magnesium. Charcoal was used to outline all or part of the images.

The purpose of these paintings is unknown. Due to the distance from the cave opening and the lack of any signs of human habitation, it has been suggested that the paintings served some ceremonial or religious purpose. Regardless of the reason, their simple yet elegant beauty has inspired countless artists and serves to remind us of our need for self-expression.

ACTIVITIES:

1. Review background information with students.
2. Discuss the difference between generalists and specialists and generate lists of more well known species. Discussion should include food sources, habitat, range, etc.

Using pictures of animal species found in Lascaux, discuss which species are still in existence today. Students should hypothesize as to why some survived while others did not.

3. Instruct students to create a horseshoe crab timeline. Use the Living the Life of Limulus background material and/or visit www.horseshoecrab.org to discover past and present day uses of horseshoe crabs to include in the timeline.
4. Inform students that they are going to create their own version of cave art using horseshoe crabs as the subject. Pass out paper, pencils and slate/stones (or paper if stone is not being used).
5. Instruct students to trace their stone so they can better plan the size of their painting. Using pencils, students are to create a sketch of a horseshoe crab that fits within the outline of their stone. Students may also wish to include other appropriate animal forms such as shorebirds, gulls, etc. but should stick with the basic principles of cave art (i.e., no vegetation, background, profiles only, etc.).
6. Once students are satisfied with their sketch, they should transfer it to the stone. Instruct students to apply only light pressure with the pencil to avoid pencil lines showing through the painting.
7. Provide students with a paintbrush and a limited color palette (brown, black, red, yellow and violet). Students should mix brown with the red and yellow creating red and yellow ochre.
8. Instruct students to paint their stones keeping the look soft and appropriate to the Paleolithic period. When complete, the painting may be partially outlined with black. Posting pictures of cave art around the room will help students achieve the right 'look'.

VOCABULARY

Generalists: Species able to withstand a wide range of conditions such as changes to habitat, food sources, etc.

Paleolithic- A prehistoric era that began 2.5 million years ago and ended in 10,000 AD; sometimes called 'the Stone Age'.

Reserve- An area of a picture left the natural color of the background that allows that section to stand out.

Specialists: Species unable to tolerate changes to habitat, food sources, etc.

RESOURCES

Eldridge, N. Fossils: The Evolution and Extinction of Species. Princeton University Press: Princeton, NJ.

http:/www.europreart.net

http:/www.culture.gouv.fr/culture/arcnat/lascaux/en

http://www.metmuseum.org

www.horseshoecrab.org

www.paleos.com (horseshoe crab ancestors)

fr.wikipedia.org/wiki/merostomata (French wikipedia-good images)

LESSION TITLE: GYOTAKU JAPANESE FISH PRINTING

WRITTEN: The Crab Chix, LLC: Trish Schuster & Beth Huch

MATERIALS: Vinyl fish replicas, paint, material to be printed (i.e., fabric, tee shirts, rice paper, paper towels, etc.), foam brushes, newspaper, drying rack (optional), smocks (optional),

NJCCCS
Visual Arts: 1.2 D, 1.3 D, 1.5 A, B
Language Arts: 3.1 H, 3.2 A, B, D, 3.3 A, B, D, 3.4 A, B, 3.5 A, B, C
Science: 5.2 A, B, 5.5 A, B, 5.8 B, 5.10 A, B
Social Studies: 6.1 A, 6.6 A, B, C, E

OBJECTIVE (S):
1. Students will be able to identify basic fish anatomy
2. Students will complete at least one gyotaku print
3. Students will be able to identify at least 5 species of fish found in Eastern Seaboard Bays (i.e. Delaware, Barnegat, etc.)

PREPARATION:
Prepare workstations, review background information, copy work sheets

BACKGROUND/OVERVIEW:
Many people of all ages today have participated in some type of printmaking process; whether they used rubber stamps, vegetable stamps, block printing, silk screens etc. These popular projects often have historical roots going back centuries. One technique that few people are familiar with is **gyotaku** ("gee-ooh-tah-koo") or Japanese fish printing.

Before the invention of cameras, Japanese fishermen recorded large or unusual specimens by making ink block reproductions of their catch. Although not used for its original purpose today, gyotaku provides us with a beautiful and useful technique for studying other cultures and marine life.

Professional gyotaku artists today use real (dead) fish. Thanks to the creation of lifelike vinyl replicas cast from molds taken from real fish, prints can be made over and over without harming any animals.

The media used varies. If desired, students can use tee shirts or canvas bags. Fabric paint or latex house paint can be used to create wearable art. Fabric paint can also be used on squares of muslin. Rice paper can be used with acrylic paint.

In addition to providing insight to another culture, gyotaku is an excellent way to learn about a variety of marine life without harming any animals. Over 1,000 species of fish are found along the Atlantic Coast of North America and new species continue to be

found, especially as we explore the deeper reaches of the world's oceans. Approximately 300 species can be found in New Jersey waters.

New Jersey's waters are home to a great variety of marine life. Many of these fish spend only part of the year here while migrating up and down the coast or back and forth from estuaries and the ocean. Other species can be found here year round. Bays or **estuaries,** such as Barnegat Bay, are areas where salt water from the ocean and fresh water from mainland creeks and streams meet to form **brackish** water. Estuaries have been described as 'cradles of the sea'. Some fish, like winter flounder and killifish are born in estuaries. The young fry of other species like bluefish and striped bass rely on estuaries as their nurseries. These and other species depend on the nutrient rich water that washes in from **tidal marshes** during changing tides. Larger animals feed on smaller species creating complex food webs. Approximately 70 % of our nation's commercially important fish and shellfish spend at least part of their lives in estuaries. Without healthy estuaries, commercial fisheries could not exist.

This abundant resource has provided a livelihood for commercial fishermen in New Jersey for over 300 years. Approximately 3,000 commercial fishermen harvest seafood in the garden state from six major commercial fishing ports: Cape May, Atlantic City, Point Pleasant, Belford, Port Norris and Barnegat Light. In fact, a full 10% of our nations' seafood comes from Viking Village in Barnegat Light. Over 100 species of marine life are harvested from New Jersey waters and shipped to seafood markets all over the world. As a side note, it is important for students to realize that commercial fishing is one of the most dangerous occupations in the world and every year, fishermen are lost (many students may have seen "The Perfect Storm").

State and Federal regulations, such as the amount of fish harvested, the size of the nets used, the number of boats involved in a specific fishery and fishing locations, try to ensure that our natural resources are protected and remain a renewable resource. Even recreational fishermen are expected to adhere to state limits regarding the legal seasons, size and/or quantity of fish harvested. This was not always the case and many species have experienced a decline due to overharvesting.

Striped Bass have been the mainstay of New Jersey's fisheries from the time of the Colonial period. Population declines in the 70's and early 80's resulted in new legislation that reduced both recreational and commercial harvests. The striped bass recovery is a success story. Most recreational fishermen today participate in catch and release programs where the animals are caught, sometimes tagged, and then released. This is just one story, however. Swordfish and other species continue to decline in number, though many restaurant menus would suggest otherwise.

The numerous species of fish found in the world vary greatly in size, form, habitat and color. All fish, however share a number of traits in common: skeletons, gills and scales.

Scales developed from armored ancestors and are composed of keratin like our fingernails and hair. These thin, transparent plates overlap like roofing shingles and are

designed to protect the sensitive skin below. Many fish have a clear slime on the scales that allow the animal to glide more easily through the water. This slime also protects the fish by trapping bacteria and fungus before they can infect the animal.

Much like the rings of a tree, the age of a fish can be estimated by counting the growth rings on the scales. Counting the number of scale rows is also a means of accurate species identification as each has an unchangeable number of these rows. The rough sandpaper texture of shark scales (actually modified teeth called denticles) has been used for sandpaper and sword grips for centuries. Special amino acids in the scales reflect the light, resulting in the silvery flash and interplay of colors on the skins of living fish. Most species lose color rapidly after death.

Gills are used to remove oxygen from the water. Because water contains only about 5% of the oxygen found in air, a fish could expend 20% of its oxygen supply just to obtain more oxygen! Fortunately, gills are able to absorb oxygen more efficiently than lungs. Described simply, fish take in water through their mouths. This water then passes over special tissues called **lamellae** that absorb oxygen and release carbon dioxide and nitrogen. The water is then expelled through the gill openings.

The horizontal line that runs the length of many fish's body is known as a **lateral line**. This unique feature, found nowhere else in the animal kingdom, allows fish to sense changes in water pressure, low frequency vibrations, or turbulence in the water before they can see the cause of this change. Vibrations in the water pass through the scales and are interpreted by receptors in the lateral line. In water with poor visibility like the bay, fish swim in tight knit schools, using their lateral lines to sense and coordinate sudden turns. Schooling is a characteristic of many fish species that protects them from predators. We do not fully understand how fish maintain the same distance from one another while 'dancing' with ballet-like precision. The lateral line is visible on some species. Many possess whiskers or fleshy **barbels** on the chin that also act as sensory organs.

Fish also possess a highly developed sense of smell that permits them to sense chemicals in the water, allowing them to identify food and other fish. Most people are chillingly aware of a sharks' ability to sense one part of blood to one million parts of water.

The eyes of a fish are equipped with rods that are more sensitive and more numerous than in humans allowing them to see well in deep or murky water. As a result, most fish feed at dawn or dusk when there is less glare from the sun. Some fish, like striped bass, have extra rods that allow them to feed at night. This vision, while sensitive, is generally designed to detect light vs. detail. Because fish lack eyelids they can even spot potential predators while asleep!

The majority of fish are excellent swimmers, though some species rely on camouflage to avoid predation and/or capture food. The paired **pectoral, pelvic** and **anal fins** help a fish control its pitch, so that it can rise, dive or stay level. They also help to brake and change swimming angle. **Dorsal fins** on the top of the body allow the fish to maneuver and

prevent rolling. Changing combinations of fin angles allows the fish to 'steer'. Powered by the **caudal** or tail fin, many fish swim by wriggling their entire body to generate forward motion. Others, like seahorses or puffer fish, scull with their dorsal and anal fins. Others, like skates and stingrays, flap their pectoral fins, much like birds, 'flying' through the water.

As with all species, body shape is designed to fit specific needs. Streamlined, torpedo-shaped fish such as tuna are able to swim very quickly, but generally lack maneuverability while flattened fish like lookdowns are slow, but agile. Some flattened fish such as flounder are superbly designed for life on the bottom. These fish lack endurance, but are capable of lunging with great speed and accuracy.

PROCEDURE:

Warm Up: Introduce the topic, asking students if they have heard of gyotaku. Determine their level of experience with any type of block printing. Explain that gyotaku is similar to those techniques, although a fish is used instead of a stamp or linoleum block.

Review the background information and explain that vinyl replicas will be used so that live fish will not be harmed. In addition, the number of editions (prints) created with the replicas is far more than a real fish could produce.

ACTIVITIES

1. Break the class up into groups based on the total number of vinyl replicas. Distribute one replica/group and establish their work station.
    a. Ask each group of students to work cooperatively to identify the type of fish based on its physical characteristics. Visit http://en.wikipedia.org/wiki/fish_anatomy as a reference for anatomy. Each group of students should have a 'group print' of the fish to which correctly identified body parts can be attached using labels or index cards.
    b. Instruct students to measure the overall length and width of their replica. Measure the length of the head from the **snout** to the operculum or gill cover. Measure the height of the dorsal fin from its base to the longest ray. Repeat if there is a second set of dorsal fins. Count the number of rays, if any, in the dorsal fins. Does the dorsal fin appear as if it would be soft or erect with stiff rays? Measure the width of the caudal fin. Describe and illustrate the shape of this fin. Measure the length of the pectoral and anal fins. Record this information.
    c. Based on the measurements taken and other observations, ask students to draw conclusions re: the speed of their species, how they move, whether they were predators, prey or both, etc. The use of a field guide can be helpful in making these determinations.
2. Have students research different species of animals that live in a specific Atlantic Coast bay and present their findings to the class.

3. FISH PRINTING

Note: The teacher should have at least one example of a finished gyotaku print to show the class prior to demonstrating the technique.

a. Provide each station with at least 2 pieces of newspaper/student, water, paper towels for printing and clean up, paint, paper plates (paint palette), stampers or printmaking rollers.
b. Advise students that they will be making their own fish print and will need to be patient until it is their turn. Each student should have one piece of newspaper beneath the replica as they are applying the paint.
c. Paint can be applied with a printmaking roller or a stamp of some kind. Cosmetic sponges are ideal, inexpensive stampers. Paint should be applied in a thin layer so that scales and other details are not lost. It should not be smeared on the replica, again so that details are not lost.
d. Once the entire surface, including edges is covered, pick up the painted replica and replace the first piece of newspaper with a clean piece. Center the replica on the clean newspaper, making sure paint does not accidentally get on the paper. (If it does, it can be transferred to the final print).
e. Carefully place the fabric or paper on the replica taking care not to let it slide and thus smear the paint. Lightly anchor the fabric with one hand. Use the other hand to gently but firmly press the material into the paint. Do not use a rubbing motion or the paper can shift, smearing the paint.
f. Once the entire surface of the fabric has been pressed into the paint, carefully remove it and hang or lay flat to dry.
g. Rinse the replica thoroughly after each print and pat dry before applying more paint. Failure to do so will result in dried paint that will obscure fine details.

Wrap Up:
"Group prints" of each species could be displayed with identification markers or cut out and attached to an underwater scene background. Students could then share their findings to the class by reporting on the results found on their data sheets.

VOCABULARY

Anal Fin-Paired fins closer to the tail that are used to brake and prevent pitching.
Barbels-Fleshy sensory organs found on the chins and faces of some species of fish.
Brackish Water-The mix of salt and fresh water found in estuaries.
Caudal Fin-The tail fin used to create forward movement in many species.
Dorsal Fin-The top fin used to help fish maneuver through the water.
Estuaries-Where fresh water rivers and creeks meet salt water from the ocean, resulting in a unique habitat.
Gills-The breathing organs of fish.
Gyotaku-The Japanese technique of fish printing.
Lamellae-Specialized gill tissue that absorbs oxygen from the water and expels waste gases.
Pectoral Fin-Paired fins just behind the gills that are used to brake and prevent pitching.

Pelvic Fin-Paired fins closer to the head. As with other paired fins, they are used to brake and prevent pitching.
Lateral Line-A sensory device found on the sides of fish.
Scales-. Thin, transparent, overlapping plates that protect the skin of most fish.
Snout-The nose area.
Tidal Wetlands-Small islands found in the bay that provide critical habitat for a variety of marine species.

RESOURCES

Websites

www.cleanoceanaction
www.livingoceans @audubon.org
www.seafood.audubon.org (Seafood Wallet card listing 30 species of fish/shellfish according to their abundance and sustainability)
http://en.wikipedia.org/wiki/fish_anatomy

Books

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