Horseshoe Crab Program

Limulus polyphemus

Grades 3-8 Version

	Graphic Aids & Materials --DVD—have teacher set it up and ready to go before you start the presentation --Horseshoe Crab Model --Blood/LAL sample --Laminated shorebird migration poster Put up at beginning. --Quadrats and laminated survey sheets --Pieces for Tic Tac Toe

Objectives: After participating in the program, students will be able to:

- Explain how the horseshoe crab is important to three groups: shorebirds, watermen, and other humans: Birds, Bait, and Blood!
- Name some adaptations the HSC has that enable it to survive and reproduce in its habitat—e.g., ten eyes, lights sensors, exoskeleton…

Note: Info in orange is what students need to know for the Tic-Tac-Toe Game.

Engage

Volunteer: Today we are going to talk about an amazing marine creature, which is a very important resource for three different groups.

- Ask the students to define a natural resource.
- Ask students if anyone has seen HSCs on the beach.

Tell students that they are going to learn what a remarkable creature the HSC is because of: its life history and their importance as a resource for three groups: shorebirds, watermen, and humans. Birds, Bait, and Blood. Tell them that the presentation will include a video; an activity where they'll be doing something that citizen scientists do in the field; and a Tic Tac Toe game at the end to see what they've learned.

Explore/Explain *(Go through very quickly. Can use Appendix B instead.)*

Life History

Props are the HSC model. Take out at this time and hold up to class.

> HSCs are called **living fossils**. They lived more than 450 million years ago, before the dinosaurs! Since that time, they have changed little. They are excellent survivors. The American HSC is known by its scientific name: *Limulus polyphemus.*

♦ Not true crabs (like our blue crab). Show model. How is this HSC model different from a blue crab? True crabs have one pair of claws, antennae or feelers, and jaws. Horseshoe Crabs are Arthropods but they don't have jaws, antennae or claws. They are more closely related to spiders, ticks, and scorpions. They look scary, but their rounded shape helps them from getting flipped around too much in rough surf and their thick shell protects them.

♦ *Limulus polyphemus* lives in the Gulf of Mexico and along the Atlantic coast up to Maine. There are three other species, which are found in Asia.

♦ Reaches **adulthood** from 9-11 years. Lifespan is 20 years or more.

♦ Show them **bookgills** and tell them that is how they breathe. The bookgills must always stay wet or damp; they cannot dry out. (This is info for later use in talking about why telson is important.)

♦ They live on the ocean floor near the continental shelf (not the deep, deep ocean) and only come up on the shores once a year to spawn—lay eggs. Because they are bottom dwellers, they need to sense the tides, the moon, and what is going on above them. So they have many light sensors on their bodies—they have **10 "eyes,"** many of which are just for sensing ultra-violet light and setting their inner "clocks." Their tail, called a **telson**, is covered with sensors so we count it as one of their "eyes." Each compound eye has 1,000 lenses or photoreceptors. It helps them see all around them too. Scientists study these large, compound eyes. Some insects have compound eyes.

♦ The **telson** has other purposes: They use it to flip over when they are on the beach on their backs or in the water and have been tossed around by the

waves (can demonstrate this and mention the hinge). And they use it to steer. Remember, it's also an eye. Never pick up a crab by its tail if you are going to handle it. The muscle that holds it is not strong, so it may come off. *Native Americans used the telson as a spear*, although it is not a stinger.
Turn and Talk Question: How would not having this tail make their survival more difficult? *Remember the bookgills.* (Some answers to look for: It would make survival more difficult because it is harder for the animal to swim, and more importantly, much harder for the animal to right itself if it should happen to be flipped over onto its back. This is dangerous if the HSC is stranded on its back out of the water. The gills will dry out if it is on its back and exposed to the sun. In addition, a HSC in this position is vulnerable to predators such as gulls, which will eat parts such as gills and legs.

♦ Show them where the **mouth** is. Mention that they do not bite. They have no teeth. Since they live on the bottom, they are bottom feeders. They eat mollusks, like clams, and worms, and small shrimp, and just about anything they can find. Also, their curved shell allows a HSC to plow through the undersea mud, muck, and sand in search of buried food.

Exoskeleton
You have a spine (backbone). Therefore, you are a vertebrate. HSCs have an exoskeleton (exo means "on the outside.") *So HSCs are invertebrates—they don't have a spine.* They have a shell, made of **chitin** (KY-tin), the same material that shrimp and crab shells are made of. It is very hard. In fact, their natural predators in the ocean are only a few—*Sharks and Loggerheads turtles, which both have strong jaws.*

How do you think HSCs grow? They molt! Snakes shed their skins, but crabs molt. HSCs will **molt** up to 18 times before they reach adulthood (*which is around what age?*). Show them on the model where the opening is to molt (in the front). They leave behind a complete copy of themselves. After that, they no longer molt, so they are full-sized and ready to reproduce. *Pass around molts and tell them that after they molt, it takes a few days for the shell to harden, which makes them easy prey for many marine creatures, especially if they are still very small.*
Are you beginning to see why HSCs are unique?

Explain
Special Characteristics

Male and Female

The female grows much larger than the males, about a third larger.
Question: Why do you think the female needs to be larger? This model represents an adult female. ***(***Take a few answers. Show them the eggs. Wow factor!) Quickly show them brain, digestive track, and gizzard.

Spawning

As the ocean and bay waters begin to warm in the spring as the days get longer, HSCs begin to move to the beaches to spawn. *(***Ask them to remember what spawning means**.) During the full moon phases in May and June, when the spring tides are the highest, the females drag the males onto the sandy beach to lay thousands of green eggs (*show them the Styrofoam eggs*). Many males will attach to her and even to other males in order to have a chance to fertilize the eggs. Males have a different set of front pincers, which look a little like boxing gloves *(show picture in book, p. 16)*. That's what they use to hold on to the female. She digs the nests 5-6" deep, lays her eggs, and then still carrying all those males, drags them across the nest to fertilize the eggs. *She lays about 4,000 eggs in each nest.* She will lay at least 15,000 eggs in a night (four to five nests).
A female will lay up to 100,000 eggs each spring! *In the Mid-Atlantic (Delaware Bay and Chesapeake Bay) region, this occurs during the high tides in May and June.*

That's a lot of eggs! And only about 1% of those eggs survive to adulthood! They are tiny and are food for other marine creatures when they start their life in the ocean.

Turn and Talk Question: Do you remember what they eat and what eats them (their prey and their predators)? What would happen if 50% of the HSCs survived instead of 1%, keeping in mind the answers you just recalled? How might that affect the HSCs' predators? How might that affect the HSCs' prey? Some answers to look for: we would be overrun with HSCs; the predators would not be able to eat all those crabs and the creatures the HSCs eat would need to increase as well. So our food chain or food web would be affected, wouldn't it?

Now let's see how they are so important to those three groups we mentioned.

HSCs and Shorebirds
Map of North and South America

Migrating shorebirds fly each spring from their winter grounds *(from the tip of South America) to the Arctic to nest. The Red Knot and Ruddy Turnstone are two such examples.*
(Show Map. You can also show the pictures in the book of the birds.)

Option to mention: The main cause of migration from their winter grounds is to follow their food sources and to find nesting sites (breeding grounds). Changes in weather or temperature in their winter grounds (S. America) are not the main cause of migration. Migration is normally triggered by changes in daylight and availability of food sources. When temperatures change, days become longer or shorter and food sources are not as available, so the birds migrate to find food for themselves and for their young when they hatch. There are millions of hatching insects for the birds in the Arctic in the summer.

By the time the birds arrive in the vicinity of the Chesapeake and Delaware Bays, they have flown almost 6,500 miles and they are exhausted and starved. They usually arrive in May and early June. What is happening with the HSCs in May and June when the birds arrive? (They are laying eggs.) This is not a coincidence that this timing is perfect for the shorebirds.

Shorebirds depend on the HSC eggs for nutrition and replenishment. They lose half their body weight during their long journey, and then gain it back over a two-week period gorging on the eggs, because the eggs are high in protein and fat.

Every year for eons the birds have been stopping over in the Delaware Bay and on Maryland beaches in May to mid-June to refuel. The birds' beaks are not long enough to get to the eggs in the nests that the crabs leave behind at night after spawning. The eggs the shorebirds eat are those that are either washed to the surface or those that other female HSCs expose when they are digging a nest to lay their own eggs.

These processes and timings are fragile. Warming waters from rising temperatures in our climate may move Horseshoe Crabs to spawn earlier, because the warming waters trigger their journey from the ocean to the bays' shores. If this happens, then when the shorebirds arrive at their usual time, there may not be enough eggs and they will not survive their journey to the Arctic. While the HSC is a strong survivor, the shorebirds that depend on them may not be. Scientists have been monitoring this timing.
Emphasize: Now you know why the HSC is important to the migrating shorebirds.

Since there is such an important connection between shorebirds and HSCs, we'll are going to do an activity that scientists use to count the number of HSCs on the beaches in the Delaware and Chesapeake Bays in May and June. These are surveys that are done in the middle of the night when the moon is full and the HSCs are covering the beaches. You will be using similar equipment and processes.

Activity 1

Scientists and volunteers doing these surveys use instruments called **quadrats,** which are one square meter. We have smaller ones that you will be using. The volunteers and scientists use the quadrats to randomly sample areas along a line on the beach so they can count the number of crabs within a quadrat each time they throw it down. Hundreds of crabs are crowding the shoreline at this point. (They are not counting every single crab on the beach. That would take all night! They do random sampling.)

Today, we will give you a "beach" and you're going to count the females crabs that are on your beach. Then we will do some math to determine the number of eggs that the HSCs in each quadrat section are going to lay. We can then determine if there will be enough eggs on your "beach" to provide enough fuel for the shorebirds to make the journey to the Arctic. See **Appendix A** for complete instructions and some real-world information.

Materials:
1. Laminated "beaches" with crab on them. 3 per set. Notice A, B, and C on each set and do not mix up. These sets represent either 15, 20, 30 or 40 crabs total in each set.
2. Quadrats
3. Four groups of students with desks together so you can lay out "beach" and a sheet of paper to do the math.

4. Picture of real survey being done. Pass this around.

Pass out the materials. See Appendix A at end for the specific instructions.

Use the different numbers they come up with to determine if each group has enough to support what the birds need. Write these numbers on the board (if board available). If not enough, this could be an indicator that the number of HSCs might not support the shorebirds that are feeding. *(See Appendix A for specific discussions on why a beach might not be good.)*

Citizen scientists do this every May and June to determine whether spawning females' numbers are going up or down. This helps scientists in monitoring the HSC population and the shorebird situation as well.

Watermen Connection
(Prop is whelk shell)

Watermen have been harvesting HSCs for decades as bait to catch conch (whelk) and eel. Historically, they were caught and ground up to be used as fertilizer for crops, but this is no longer done. Watermen are the people who catch, or harvest, the seafood that we eat.

HSCs are excellent bait for catching whelk, a large sea snail that is considered a delicacy in many areas of the world, or eel, also eaten by many Asian cultures. Watermen catch different fish or shellfish depending on the season and state regulations. The watermen catch the HSC as bait for conch and eel to supplement their income when other fish or shellfish aren't available.
Emphasize: So you see how the HSC is also important to the watermen. When you've seen a HSC on the beach, did you ever think it was so valuable?

Copper-based Blood
Props are the vial of LAL and the vial of HSC blood.

The blood of the HSC is a creamy tan color until exposed to the air; then it becomes a *blue-green color.* **Question: What color is our blood when it comes out of us?** (Red) That's because our blood has iron. The HSC's blood contains a different mineral that transports oxygen. **Here's a clue: Think of a penny or the Statue of Liberty that turns bluish green when it is exposed to air for a long time.** (Copper!) Unlike our blood, which has

iron to transport oxygen, a *HSC's blood is copper-based to transport oxygen in the blood.*

This blood is then processed in a centrifuge to remove the fluids and a white powder is left. This is the white powder that is derived from the blood. (Show vial.) **Limulus Amoebocyte Lysate**. Or LAL. Scientists use this LAL test to check the sterility (meaning no germs) of drugs, vaccines, and other shots or fluids that are given with a needle—anything that goes directly into the bloodstream. They test in batches. When the powder is exposed to gram negative bacteria, or endotoxins (which are harmful to us), the LAL clots and engulf the toxins. They will discard that batch, knowing it is unsafe. If you've had a chicken pox, flu, polio, etc. vaccine, you've benefitted from this. Also, any human who has had an artificial knee, hip, or heart valve replacement has benefitted as well. These are all tested using the protein found in HSC blood. You can imagine that this is a multi-billion dollar industry!

Watermen collect the crabs for the laboratories that bleed the crabs (you'll see in video). This does not permanently harm the crabs. You will see in the DVD that they insert the needle in this muscle. *(Show them the muscle at the hinge.)*

Emphasize: In this way, HSCs are important to humans as a group.

Human Impact on HSCs

HSCs help us, the shorebirds, and watermen in many ways. However, there are things WE can do to help this creature. Remember what we said about flipping them over when needed. That's one way. We also said that HSCs' major natural predators are the loggerhead turtle and shark, but what WE do on and along our shorelines affects the HSC as well. *Development of beach front property and erecting rip-rap or bulkheads where they spawn can also affect its populations, and that would negatively affect the shorebirds*. (They will see these things in the video.) We must think about where we build our houses and what we do with our beachfronts. If there is no beach, there is no spawning. Leaving natural shorelines is best for many creatures, including the HSC. That's what some people at DNR work on. We talk to landowners about leaving their shorelines natural or to taking down their barriers and creating natural shorelines again and we help them accomplish this.

Get stickers ready during video for handing out at end.
Maryland Public TV Horseshoe Crab Video/CD

The students will now see a video clip on the horseshoe crab and the people that depend on them. This will provide the students with a visual representation of horseshoe crab basic life history, the connection with migratory shorebirds, and their importance to people. Tell them to watch and listen carefully because we will be playing a game of Tic Tac Toe next to see how much they learned. Tell them that many things we talked about are shown in the video.

Evaluate: Horseshoe Crab Tic-Tac-Toe Game

The students will participate in a basic Tic-Tac-Toe game using a horseshoe crab theme. Duration: 10 minutes

Materials:

1. Horseshoe crab question cards. Make sure all questions asked are covered somewhere in the lesson plan. [Please read all these questions beforehand to make sure you do cover all of them.]
2. Team symbol cards—Red Knot and HSC
3. Tic-Tac-Toe grid, which you will have drawn on the chalkboard or whiteboard.

Procedure*:* Draw a Tic-Tac-Toe grid on the board.

Divide the class into two groups. The groups compete against each other in the game. Pick one child from each team to be the leader. This student will consult with the team and give the answer. Assign one team as the Red Knots and one team as the Horseshoe Crabs.

The teams will take turns answering the questions chosen by the volunteer. Make sure to ask questions that you have covered in the class. When a team successfully answers the question, ask one child to come up and chose a square to be marked with their team symbol. Other team member can coach this student volunteer. The students' objective is to successfully answer the game questions to get Tic Tac Toe. When a team has done this, the game ends. Usually it is a tie.

At the end of the game, if there is time, ask the students if they now have a better understanding of the HSC. Answer any remaining questions the students might have.

For questions from students that you cannot answer, please direct them to the DNR website for Horseshoe Crabs. Go to www.dnr.maryland.gov (write this on board) and search Horseshoe Crabs. Or, go to www.horseshoecrab.org

Glossary

Arthropod: an invertebrate animal having an exoskeleton (external skeleton), a segmented body, and jointed appendages.

Prosoma: The anterior section of arachnids and many crustaceans, consisting of the fused head and thorax.

Opisthosoma: The abdomen section containing the gills.

Chitin: A nitrogen-containing polysaccharide that is a tough, protective, semitransparent substance and is the principal component of arthropod exoskeletons and the cell walls of certain fungi.

Exoskeleton: A hard outer structure, such as the shell of an insect or crustacean, that provides protection or support for an organism.

Limulus Amoebocyte Lysate: an extract of blood cells from the horseshoe crab (*Limulus polyphemus*). It is commonly used in a test to detect bacterial endotoxins.

Spawn: to deposit eggs

Appendix A

Instructions for Survey

Pass out the four sets (three cards in each set—one set for each of the four groups). For each group, students should line up the A, B, and C sections end to end ("landscape"). Explain that this is the "beach" where you will be laying their quadrats.

--Make sure they start in the left-hand corner along the bottom edge.

--Lay the quadrat down, count whole crabs and half crabs (less than a half doesn't count) in the first quadrat. Record. Turn the quadrat over to next section but SKIP that section (random sampling) and flip over to next section. Count and record. Should be able to get three samplings out of beach.

--As the students are working, have them keep track of the numbers.

--When they have run out of space, they will total the number of crabs they counted and divide that by number of quadrats sampled (three). This is taking an average.

--Then they will multiply their average number of females from above by the average number of eggs a female lays in a night *(ask them if they can remember the number 15,000 before you tell them)*.

Scientists know that over the two weeks the birds are eating the eggs, they need approximately 50,000 eggs per sq. meter to make their journey. So what does that tell you about your beach? *(Not right sand, not wide enough, too much wave activity, sand not oxygenated enough, too wet, too dry)* **Not all beaches are the same.**

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Appendix B—To speed along, use this in place of longer information:

Horseshoe Crabs are called living fossils. They have been around since before the dinosaurs. They do look prehistoric. They look scary but they are harmless.

They are arthropods, but are not true crabs. No antennae, claws, or jaws. They are related to spiders, ticks, and scorpions. They live on the ocean bottom and only come out of the water to spawn. Since they are bottom dwellers, they need to sense the tides and what is happening above them and to have their internal clock set, so they have many light sensors, or eyes, on their body. This tail, which is called a telson, serves like an eye because it has so many light sensors on it, but it also helps them flip over when they have been rolled around by the tides and stranded on their back. And they use it to steer. So they would not survive very long without their tail. Never pick a crab up by its tail if you are going to handle it. Native American used them as spears and bowls. **Ask Turn and Talk Question**

They eat anything on the bottom—mollusks like clams, shrimp and worms. They have a mouth but no teeth. Just bristles and legs that grind their food. Their claws do not pinch.

They are invertebrates. They carry around their skeleton (exoskeleton) and because of the hard shell, as an adult their only ocean predators are sharks and loggerhead turtles.

So they grow by molting. Not shedding, which snakes do. They crawl out of their shells (here) when they have outgrown it and develop a hardened shell within 24-36 hours, but are still vulnerable for awhile. They molt about 18 times before they reach adulthood at 9-11 years old. Then they do not molt anymore. They begin to reproduce!

Spawning
Females are larger than males. Why do you think that is. Explain differences. Open up crab. Explain when they spawn, how, and talk about eggs and numbers (this information is essential to Activity 1). 1% survive.
Do Turn and Talk Question on 50% surviving.

Shorebirds eat these eggs. Some coming all the way from S. America on their yearly migration to the Arctic, where they will lay their eggs. The shorebirds, like Red Knots and Ruddy Turnstones, leave their homes in S. America to find nesting grounds in the Arctic where there are millions of insects at the time they arrive. But that long journey (6,500miles)! They lose half their body weight by the time they've reached the Ches. and Del. Bays and they are exhausted. They need to refuel. Eggs high in fat and protein.

Talk about eggs being on beaches. Processes and timing are fragile. Talk about warming waters and earlier spawning and what that would mean for birds. Then go into activity. Then mention watermen. Then talk about blood. And show DVD.