Horseshoe Crabs for Kids
An Educational Video

An Interactive Qualifying Project Report
Submitted to the Faculty
of the
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the
Degree of Bachelor of Science
By

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Approved by:

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Abstract

This project was performed to develop and implement a strategy for educating children about horseshoe crabs and conservation. Various children's books were read and analyzed to determine appropriate and understandable material to cover. Power Point presentations were given at local schools to gather more information on what children would like to learn and the best method of delivery. A DVD and CD-ROM were made using AVS Media's Video ReMaker 2.3 and TechSmith's Camtasia Studio 4.0 MenuMaker.

Acknowledgements

First and foremost, I would like to thank Dr. Daniel Gibson for his guidance, help, and advice throughout the course of this project. His enthusiasm for the horseshoe crab transformed this from just another requirement into a truly unforgettable experience, and was key to this project's success. I would also like to thank the administration and students from Heard Street School, North Falmouth Elementary, and Proctor School for allowing me to present during school hours. My thanks to the Committee for Conservation of Horseshoe Crabs invited me to a meeting where I was able to talk with Frank Germano of the Division of Marine Fisheries and Mick Dawson of Associates of Cape Cod meeting. Their perspectives on this animal were quite different, yet both regard it as a resource that needs to be conserved, and I thank them for giving me their unique viewpoints. As a fisherman's daughter, I have known about horseshoe crabs all my life, but this project provided me with the opportunity to help kids who have heard bad and scary things about horseshoe crabs to change the way they perceive them and to learn about conservation and ecological relationships at the same time.

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Introduction

With today's ever changing politics, talk of global warming, and unstable environment the future of all of Earth's species is uncertain. As seen from past generations, many adults are set in their ways and unwilling to change, particularly for such a nebulous concept. What they don't realize is that preserving our natural environment and ecology is the only way to ensure that life will continue as it has for the last 3.8 billion years. It is important to get children interested in the environment and meaningful issues now, so they will be fueled to make changes and be involved in beneficial efforts when they are older. The only way we can reach and educate future generations is through the youngest generation we have now.

Limulus polyphemus' ancient genes make them extremely interesting to scientists and they have become a vital research tool. The mechanisms of human vision were first discovered by studying the extra large optic nerves of horseshoe crabs. Their muscles and hearts have also been useful in research. Their ability to regenerate limbs is another feature that has kept horseshoes in the forefront of scientific research for over 50 years. Their dissected parts retain their functions for days if kept in seawater (Gibson, Gibson, 1983a). Most importantly, their blood is a necessity to the medical and pharmaceutical industries, and to human health. At Marine Biological Laboratory in Woods Hole, Massachusetts, Drs. Jack Levin and Fred Bang studied the clotting of horseshoe crab blood in the presence of bacteria, and down the street at the Woods Hole Oceanographic Institution, Dr. Stanley Watson discovered that horseshoe crab blood can be freeze-dried and used for diagnostic testing. The test performed is called a *Limulus* Amebocyte Lysate (LAL) test and can be used to instantaneously detect bacterial blood infections. LAL is most commonly used to test intravenous medications for contamination from

bacterial endotoxins (Gibson and Gibson, 1983a). This demand for horseshoe crabs could threaten them and easily lead to overharvesting, but the LAL industry truly uses the animals as a renewable resource by taking a non-lethal amount of blood and releasing the crabs back into the ocean. There is another harvest going on simultaneously, for bait for conch and eel pots, and none of those crabs survive. Getting people to realize that we need to protect this species for our health and survival is just the first step. Getting people to understand that they are priceless, because of the implications that come with their 450 million year old genes and their unique role in an intricate food chain will be more difficult. Getting people to understand that this ancient species has the right to survive as long as people do will be another story with many chapters.

Reflection

To get an idea of the conservation efforts already being employed to help protect horseshoe crabs, I attended a meeting of the Committee for Conservation of Horseshoe Crabs at the Massachusetts Audubon Preserve at Long Pasture, in Yarmouth, MA. Here we met with members of the Massachusetts Division of Marine Fisheries and discussed more strict regulations that should be implemented to limit the amount of horseshoes that can be harvested from the shores of Cape Cod. Also discussed was illegal night poaching of horseshoe crabs. In some towns this goes unnoticed or even encouraged by shellfish wardens. Shellfish wardens would rather see less of the horseshoe crab because this means clam populations can grow uninhibited, and there is a big market for calms in this area. They don't realize that if too many clams are eaten, natural checks and balances will come into play. If the horseshoe crab population gets too large and consumes most of its food resources, it will then begin to die off, allowing the clam population to re-grow. This is a natural cycle that continues until one of the

species is removed. If the horseshoe crab was removed from this cycle, the clam populations would continue to grow, possibly so large that they would become unhealthy and spread diseases.

Throughout the course of the IQP, Power Point presentations were given at different local schools. Before presentations were given, childrens' books about horseshoe crabs were read to get an idea for the level of material to be covered. Presentations were given to fifth and sixth graders at Heard Street School in Worcester and to fifth graders at Proctor School in Northboro. Presentations were also given at North Falmouth Elementary to third graders and kindergarteners. The kindergarteners loved playing with the crabs, releasing one into the ocean, and enjoyed digging in the sand in search of the tiny green eggs. At their age a more hands-on approach was key to keeping their attention. They didn't ask many questions or offer much advice on how they would like to learn about horseshoe crabs. But, they loved their picnic on the beach, and their continuous squeals of delight offered all the information needed to decide on an effective way to go about teaching them and sparking their interest for this invaluable organism. The fifth and sixth graders were really interested and extremely excited for the horseshoe crab populations. At this level they were learning about insect anatomy, food chains, and even some genetics. The older kids also enjoyed seeing the horseshoes for themselves and investigating them in the class room. Teachers found the horseshoe crab presentations very beneficial because they coincided and embellished on the lesson plans that they were already implementing.

Students were asked if they'd rather hear a story about horseshoe crabs or more factual information. The general consensus was facts, facts, facts, with plenty of interesting pictures and videos. In the new world of hand held video games, iPods, and computers children love

technology. One of my favorite memories was when Dr. Dan was explaining the difference between red human blood and blue horseshoe crab blood. He asked the students what component of our blood made it red. After many incorrect answers he gave a hint. "It's a red metal." A boy in the front row jumped up out of his seat and threw his hand up in the air. Dr. Dan called on him and the boy exclaimed, "RED METAL?" This was not the correct answer but it was nice to see him so enthusiastic about learning something new. Another time, a young female student came aside to me after a presentation and shyly said, "So, I was thinking about being a scientist when I grow up too." This was the most gratifying moment of the entire project. After all, I am just a student as well, in pursuit of a degree in the rapidly moving scientific world of evolutionary physiology and genomics.

Editing and Creating Media

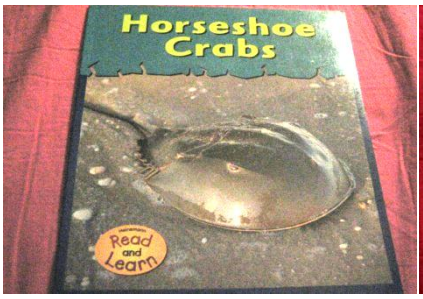
After presentations were given it was decided to produce an informational DVD and a CD-ROM. Some sections were filmed, while others were narrated to pictures. Windows Movie Maker was used to string pictures and videos together and add narration. It was also used to edit film clips and add them to the narrated strings of pictures and video. All chapters and a full length film were "Published." AVS Video Converter 5.6 was initially used to convert filmed media from IFO File format to a useable Video Clip (.avi) file. But, it was also used to convert files from Windows Media Audio/Video (.wmv) to Movie Clip (.mpg) form, so they would be compatible for use with TechSmith's Camtasia Studio 4 MenuMaker program available on campus lab computers. These files were added to a MenuMaker Project and used to create CD-ROM . AVS Media's Video Tools program was also employed to create a DVD with a scene selection menu. It was not anticipated that so many files would have to be converted for use

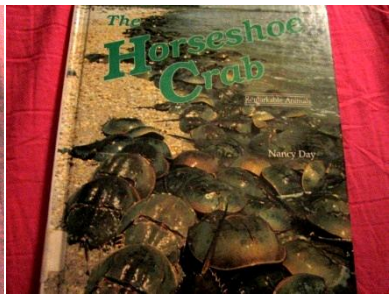
with different programs and converting all the different types of files ended up being much more time consuming than originally thought.

Book Review

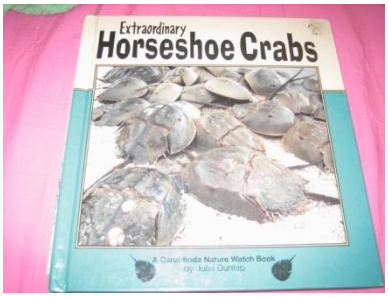
Educational Books

Horseshoe Crabs, by Lola Schaefer, is a great book for young kids, especially those just learning how to read. It is not too detailed, has large print, and clearly labeled pictures. It even includes a little quiz on the last page to help review what you've just learned. *The Horseshoe Crab*, by Nancy Day, is a very informative book. It was written in conjunction with Carl Shuster, one of the world's leading experts on horseshoe crabs.



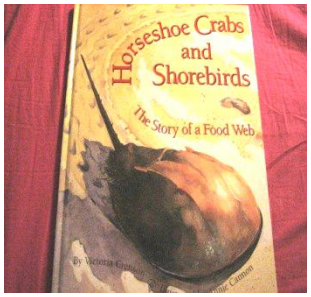


Extraordinary Horseshoe Crabs, by Julie Dunlap was published a bit later so it had all the same information as Day's book and was a little more up to date. Julie Dunlap also used Carl Shuster for her book along with Robert Barlow, another horseshoe crab researcher. Medical uses and experiments with horseshoe crabs were discussed a little more in depth. This is likely to attract and help mold future scientists. Dunlap includes more amazing pictures that really capture your attention. For these reasons, I chose it as my top pick for educational content.



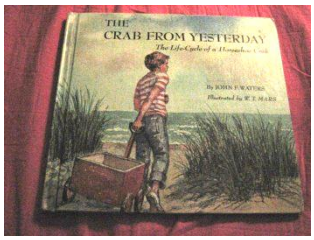
Story Books

Horseshoe Crabs and Shorebirds the Story of a Food Web, by Victoria Crenson, is an



excellent book. It is not too detail, but really emphasizes the importance of one animal for the survival of many other species. It has beautiful illustrations and would be great to spark the interest of kids before they are old enough to get into more detailed scientific information. This was my favorite book because it taught the importance of horseshoe crabs from a more ecological perspective.

The Crab from Yesterday, by John F. Waters, was the second story book analyzed. Also



written with the help of Carl Shuster, the information was almost too similar to that in Day's book. However, it was a good story with a moral too.

Script

Getting to Know the Horseshoe Crab

Horseshoe crabs have been on this planet for over 450 million years!! Throughout this time dinosaurs have come and gone, mass extinctions have occurred, and countless other species have evolved, but horseshoe crabs have remained the same. Looking at a horseshoe crab today is like looking at a living fossil. Horseshoe crabs are a member of the arthropod family. Arthropods are invertebrates, meaning they don't have a back bone like humans. They are characterized by crunchy outer shells called exoskeletons, made of chitin, and lots of jointed legs. This Pair, shaped sort of like fans, is used to dig and push sand aside.

The oldest arthropod is the trilobite and it has been extinct for over 400 million years. As you can see from these trilobite fossils, they look similar to horseshoe crabs. Today there are only four species of horseshoe crabs left, and only one lives in our neck of the woods. This species, *Limulus polyphemus,* lives along the eastern seaboard from Maine to Florida and along the Yucatan peninsula. The first thing that comes to mind when talking about horseshoe crabs is, well, crabs. But as a matter of fact horseshoe crabs aren't even crabs at all. Their closest living relatives are spiders, ticks and scorpions. When a horseshoe crab's helmet shell is removed you can see how similar they look to spiders. They are descendants of extinct sea scorpions called Eurypterids. All of these animals have a special feature in common. None of these animals have jaws so they can't "chew" their food. They are the only living animals with chelicerae. In ticks and spiders the chelicerae act like fangs. While, a horseshoe crab's are just a specialized pair of pinchers used to push food into their mouth. Their mouth is a bristlely opening in the center of their legs and they use their shoulders to chew, well, mush up their food!

Anatomy

Now with all this talk of a mouth in the center of their legs and shoulders that chew food, I bet you're a little confused. So here's some basic anatomy of a horseshoe crab. **A** is pointing to the helmet shaped portion of their shell, the prosoma. This is technically their front or head. **B** is pointing to their tail. Many people think that horseshoes use it a weapon, but it will only hurt you if you step on it. But when walking along the beach, horseshoe crabs are HARD to miss!! Be careful not to poke yourself in the eye with the tail if you pick up a horseshoe. There is a joint connecting the tail to the shell that can be damaged or dislocated just like humans, so you shouldn't pick up a horseshoe crab by its tail. Instead, hold it by its sides. **C** points to their two lateral compound eyes. **D** marks their gills. Adult horseshoe crabs have 5 books of gills, with about 200 leaflets each. **E** points to their five pairs of jointed legs and **F** to their pair of chelicerae. **G** points to the centrally located mouth.

Recent History

Now that we know a little bit about the history and basic anatomy of the horseshoe crab, let's get into some more interesting stuff. As many of you know horseshoe crabs have the rare ability to regenerate lost limbs, which not many animals can do. This makes them extremely important for research. Most people don't know how important they are, not just humans but to countless other species as well. But before we get into all the reasons why they are so important, let's get to know the horseshoe crab a little better first.

Over the past one hundred years humans have made it really tough for horseshoe crabs. In the late 1800's and early 1900's horseshoe crabs were considered pests and millions of them were ground up and used as fertilizer. Some towns even offered cash rewards for horseshoe

crabs! This led to a drastic decline in their populations. Increases in coastal development and illegal runoff of waste water and chemicals, has started to deteriorate the unique environment necessary to the horseshoe crabs' survival. Additionally they are used as bait for conch and eel traps. However, many conservation efforts have been passed to limit the number of horseshoe crabs that can be used as bait and to close shorelines during mating and egg lying. As a matter of fact the entire coast of Delaware Bay has been closed to harvesting because so many horseshoe crab eggs are laid on these beaches, and many bird species depend on them for food

Juveniles and Molting

A young horseshoe crab is often referred to as a juvenile. Juvenile crabs spend most of their time in the safety of salt marshes, nestled in the sand for protection from other hungry sea creatures. Food is also abundant and easily accessed in these shallow coastal estuaries. Juvenile Horseshoe crabs eat bits of algae, small clams and sea worms. When horseshoe crabs feed they stir up a lot of sand and microscopic sea creatures, which other fish like to feed on. Here you see a symbiotic relationship between a couple of little fish and a horseshoe crab. They follow as he feeds to get the leftovers. A juvenile crab will molt numerous times per year for the first few years, then it will molt less frequently. After 7-10 years the horseshoe crab is an adult. Molting occurs as a horseshoe crab grows bigger. A horseshoe crab grows a new soft shell underneath, then the old shell splits and the horseshoe crab walks out head first. Then it sucks up a whole lot of water, expanding its shell so that it is more than one-third longer, and wider than it was. At first the shell is soft but hardens quickly to restore its protective armor. Common crabs also molt their shells, but back out rather than coming out the front.

Adults and Reproduction

Horseshoe crabs are believed to live up to 18 years. Really old horseshoe crabs have mussels, barnacles, lady slippers, or even seaweed that grows on their shells. Horseshoe crabs are just like a moving rock providing a nice place for these small sea creatures to live. There are many differences between adult female and adult male crabs. The most obvious difference is their size. Female horseshoes are bigger than the males! Females also do most of the work; pulling the male around and dragging him up onto the beach while laying eggs. Sometimes multiple males will hook on to a single female. Males even have a special set of claws to help them hold on. When a female reaches adulthood the first set of claws remain the same, while the males' turn into special claspers that look like boxing gloves. These claspers are only used to hook onto the underside of a female's shell. Males also have another feature that makes their ride easier. A male's shell is more curved, where their forehead would be, while a females' is rather straight. This allows them to overlap the female's shell and makes the pair more stable. Another less noticeable difference is hidden underneath the 1st flap of the book gills. This is where the eggs are released from a female and sperm released from a male (Gibson and Gibson, 1983b).

Now that we know the basic differences between a male and a female, it makes sense that they travel around in pairs. From late May and into July horseshoe crab pairs begin to lay their eggs. Just look outside, if lilacs are in bloom, it is the perfect time to catch a glimpse of horseshoe crabs laying their eggs. On an incoming tide close to a full moon, a female crab crawls up to the water's edge, dragging a male behind her. Here, the female will burrow face first into the sand to create a nest and lay her eggs. The male will fertilize them by releasing

sperm over the eggs in the nest. Just one female can lay thousands of eggs! Adults make their nests on beaches, close to salt marshes, where their young will be safe and well fed.

Eggs and Development

Horseshoe crabs start out their life inside a tiny green egg. This is not just any ordinary egg, it changes color! The outer green shell, or chorion, is actually just one of its layers. The egg swells up with water and the green shell pops off to expose a delicate clear egg (Gibson and Gibson, 1983b). Now, you can watch the horseshoe crab embryo develop right in front of your eyes! The embryo will molt its soft shell four times during development, while it's still inside the egg. Before the third molt the embryo has tiny stump legs, and looks kind of like a zipper**.** After the third molt the embryos have longer legs and begin to move around inside their eggs. After the fourth molt, the embryos begin flapping their gills and resemble an adult's body plan more closely. After the embryo hatches it is called a larva. As larvae, horseshoe crabs usually swim, using their gills for propulsion. Their next task is to dig to the surface of the nest and join the juveniles hiding in the salt marshes nearby. Here they will also develop into juveniles and eventually adults crab capable of reproduction.

Research

Though little horseshoes are a tasty treat and the eggs are necessary for many species' survival, adult crabs don't have many predators. Birds are one of their only natural predators and they are only in danger when they are up on the beach laying their eggs. Sometimes mating horseshoe pairs get left behind on the beach as the tide recedes, or are flipped upside down by waves. When they are on their backs it is easy for birds to swoop down and pick at their soft underbody that their hard upper shell usually protects. Human activities actually pose the

biggest threat to their survival. But luckily a lot of scientists realize this and are doing everything they can to help. Scientists have also found medical applications for horseshoe crabs, and ensuring their survival will continue to help the human population and our health.

Because horseshoe crab eggs are transparent it makes them a perfect and very easy animal to research. Larvae and juveniles also look transparent when a light is shined on them. Here you can see the blood circulating through the heart and down to the tail of a juvenile crab. A large amount of medical research has been performed involving horseshoe crab development, regenerating nerves, and their eyes, heart and blood.

Eyes

Horseshoe crabs actually have 9 eyes (Shuster et al., 2003)! Two of these are on the bottom of a horseshoe crab's shell. Horseshoe crabs don't have balance organs (ours are in our ears) and it is thought that these two eyes on the bottom help let a horseshoe crab know if it is upside down. If these eyes aren't sensing light then the horseshoe crab knows it is right side up, if all of a sudden these eyes start to sense light, then the horseshoe crab will know it is upside down. Then, it can dig its tail into the sand to prop itself up and flip back over onto its belly (Schaefer, 2002). If you see a horseshoe stranded and attempting this on the beach, it is always nice to help him out and put him right side up at the water's edge. If they can't flip back over quickly enough they risk being dried out by the sun or nibbled on by a bird. Another eye, on the topside senses ultra violet light, which comes from the sun. At night this eye does not sense any UV light so it signals the two main eyes to become one million times more sensitive to light. This allows horseshoe crabs to see just as well as night as they do in the day! These two eyes are compound eyes, with thousands of different parts. And these eye parts are the largest of any

animal, which makes them easy to study. Dr. H. Keffer Hartline used horseshoe crab eyes to study and learn about how human vision works. He figured out so much about human vision and made so much progress by studying these large eyes that he won the Nobel Prize!

Blue Bloods

Another unique property of horseshoe crabs is there blood. Humans have red blood because of an element named iron. But horseshoe crabs use copper so they have blue blood (Shuster et al., 2003). Besides the color, this blood is special for another reason. Here you see a horseshoe crab that has fallen off a truck and died. Next to the pool of blood, you can see a chunk of white goo zoom into goo. A special cell in horseshoe crab blood, called an amebocyte is responsible for this. Horseshoe crabs live in shallow water where there are lots of bacteria. So, if a horseshoe crab gets a cut it must start to heal quickly so bacteria can't get inside and make it sick. When a horseshoe is wounded the amebocytes travel to the cut and start to form a clot to block the bacteria from getting in! Researchers at Woods Hole Oceanographic Institution realized that you can freeze dry horseshoe crab blood and use it to be sure that drugs injected into humans don't contain any bacterial poisons called endotoxins. This test is called Limulus Amebocyte Lysate, LAL. Horseshoe crabs are collected so they can donate blood, then are returned to the ocean. If a flu shot is contaminated with an endotoxin, it can make you very sick or even kill you. So nowadays, every injectable drug in the United States has to be tested with LAL before it can be used. The test tube on the right shows an LAL test that is negative for endotoxins, the sample remains a liquid. The test tube on the left shows a sample that is contaminated with bacteria. When LAL is applied, the sample begins to form a clot and turn into a gel. This is an easy way to make sure prescription drugs are safe. Before, bunnies were used to test this. If a bunny got sick from an injection, scientists would know that the drug was not

safe. This was a cruel way to test drugs, and now with the help of horseshoe crabs it can be done without having to make an animal sick!

Regeneration

A protein that helps nerve grow and helps goldfish to remember tricks has recently been found in developing horseshoe crabs!!! Here is a close up picture from a microscope that shows where Ependymin is found in the nerves that a horseshoe crab uses as a brain. This is what a nerve cord looks like when it is dissected out of a horseshoe crab. This same 450 million year old gene is found in humans and goldfish today and is responsible for turning short term memories into long term memories. However, in horseshoe crabs we think it could be the key to regeneration. Humans and goldfish express this neurotrophic factor in their Central Nervous Systems, their brains and spinal cord. Like humans and goldfish, horseshoe crabs make this protein in their brains as the nervous system develops. But they ALSO express it in the nerves in their legs. Maybe this is why horseshoe crabs can regenerate their legs but humans can't.

Horseshoe Crabs and Shore Birds: A Complex Food Chain

Besides all the uses humans have found for horseshoe crabs, they have an even more important natural role to play. Red knots are a species of bird that migrate from the southernmost point of South America all the way to the arctic (Dunlap, 1999). After they leave South America and spend many days flying, they stop in Delaware Bay where they feed on the tiny green horseshoe crab eggs. In just two weeks, the birds double their weight just by eating these eggs. This stop is necessary for the red knots so they will get enough fuel and energy to

reach the arctic, make a nest, and lay their eggs. After they lay their eggs and it is time to return to South America, the red knots make a stop on Cape Cod's national seashore where they have another feast on horseshoe crab eggs. If all of a sudden there was a decline in the horseshoe crab population and therefore the amount of eggs being laid, the birds would still stop in Delaware Bay just like always. However, this time there wouldn't be enough food and the birds would not be able to reach the arctic or lay their eggs. This is one of the reasons why Delaware Bay and Cape Cod's national seashore were closed to harvesting of horseshoe crabs. And red knots aren't the only species that feed on the eggs, many of other birds and small fish do too. Small animals like raccoons also feed on horseshoe crab eggs. So by helping save horseshoe crabs you are assuring the survival of many other species as well.

Horseshoe crabs are a keystone in a food chain that many other species depend on for survival. This ancient species is not only extremely useful to human health and survival but it is also detrimental to countless other animal species. By eating razor clams, they stop the clam populations from getting out of hand. If horseshoe crabs weren't around the natural balance of things would be thrown completely out of whack. Shore birds wouldn't be able to migrate and would die out, clam populations would get to great and out of control, and humans would be set back years in terms of medical advances. Horseshoe crabs are intertwined in a complex food web that provides a feast necessary for migrating birds and food for many other species. They offer moving homes for barnacles, seaweed and other shellfish, and are highly beneficial to humans. The amount of knowledge that can be gained by studying this living fossil is never ending. Conservation of this species is very important and necessary, not only for the survival of humans but for countless other species as well. And to assure the survival of this species for future generations we're going to need your help.

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