TEACHERS' GUIDE

Grades 5-Adult

The Crabs, The Birds, The Bay

The Story of Delaware Bay's Great Annual Gathering

BULLFROG FILMS

the 19 minute video

The Crabs, the Birds, the Bay

is available from

Bullfrog Films
PO Box 149 Oley PA 19547
(800) 543-FROG
(610) 779-8226

For visiting information and educational opportunities, in New Jersey contact the Cape May Bird Observatory (New Jersey Audubon Society) at 609-861-0700 or the Nature Center of Cape May (also NJAS) at 609-898-8848. In Delaware, contact the Seaside Nature Center, Cape Henlopen State Park at 302-645-6852.

Horseshoe Crabs & Shorebirds
Teaching guide

Authored by Christopher Bennett

There are four living species of horseshoe crabs. Three species inhabit the Pacific coast of Asia, from Japan and Korea south to the East Indies. The species that inhabits the waters around Japan is endangered and is revered as a national treasure. A fourth species, the American horseshoe crab, is fairly common along the Atlantic and Gulf coasts from Nova Scotia to the Yucatan Peninsula in Mexico. The largest population of horseshoe crabs in the world, comprised of an estimated two to four million animals, is found along the mid-Atlantic coast of the United States. This population was much larger in the past. During the late 1800s four million horseshoe crabs were harvested annually from the Delaware Bay.

Since they first appeared over 300 million years ago horseshoe crabs have remained virtually unchanged. Scientists often refer to them as living fossils. Horseshoe crabs get their name from the hoof-like shape of the shell. Horseshoe crabs are arthropods. Arthropods have segmented bodies, jointed appendages, and an exoskeleton composed of chitin. Adult horseshoe crabs are relatively large. Females can reach lengths of twenty-four inches. Males are about one third smaller. The dark brown body is divided into three sections, the cephalothorax, the abdomen and telson. The eyes are located along three ridges on the upper surface of the cephalothorax. Near the center of each outer ridge is a small compound eye. They resemble the compound eyes of insects but are not as well developed. Horseshoe crabs are able to discern shapes and movement but

not detailed images. A pair of tiny simple eyes lie at the forward end of the central ridge. These tiny eyes are only capable of detecting changes in light intensity.

The underside of the cephalothorax bears six pairs of appendages. The first pair, the chelicerae, are used to manipulate food into the mouth. The next four pairs of appendages are similar in appearance in females and immature males. Each of these jointed legs ends in a weak pincher. These legs are used for pulling the crab along, digging and moving food toward the mouth. In adult males the first pair of legs, called pedipalps, are tipped with round bulbs armed with hooks. The hooks are used to grasp and hold on to a female during mating. In both males and females the sixth pair of appendages bear a set of four leaf-shaped blades. These legs are used for pushing the crab along and cleaning the gills. The base of the each leg is covered with stout bristle-like spines. These spines grind food as it is passed to the mouth, which is located between the first pair of legs. These feeding structures are called gnathobases. Small, cream-colored flatworms often squirm about between the bristles of the gnathobases and over the legs of live horseshoe crabs. They feed on scraps of food trapped in the bristles. A horseshoe crab may be host to hundreds of these worms and suffer no harm.

There is a fleshy muscular hinge where the cephalothorax and abdomen meet. Along both sides of the abdomen are six moveable spines. Five leathery flaps on the underside of the abdomen conceal the gills. Each flap protects about 150 leaf-like folds which provide a surface for oxygen exchange. They are called ”book gills“ because they are arranged like the pages of a book. Horseshoe crabs also use their gills as paddles when swimming. Swimming is most

often done by small individuals, but large horseshoe crabs can occasionally be seen backstroking across the surface of Delaware Bay. A long pointed, spike-like tail called the telson is attached to the rear of the abdomen. The telson is not a defensive weapon. It is used for turning rightside-up when accidentally over-turned and as an aid in moving across beaches or exposed mudflats.

The diet of horseshoe crabs includes a variety of marine invertebrates and other food items. They prefer small clams but also eat worms, other bottom animals and algae. Horseshoe crabs are also known to scavenge and in captivity they readily eat fish and squid. Males occasionally eat eggs of their own kind.

Food is passed with the legs and chelicerae to the gnathobases where it is "chewed." It is passed into the mouth, through the esophagus and crop to a muscular gizzard. In the gizzard the food is ground further and indigestible particles are regurgitated. The remaining material is passed to the stomach and intestine where it is digested. Waste is passed through the anus which is located on the bottom of the abdomen in front of the telson.

Horseshoe crabs possess a well developed circulatory system. A long tubular heart pumps blood to the appendages and gills through a system of arteries and sinuses. By slowly waving their book gills horseshoe crabs pump blood into and out of the gills. This action also creates a flow of water across the gill filaments. Oxygen moves across the gill membranes into the blood and carbon dioxide passes out. Horse-shoe crab blood cells contain copper instead of iron and, when oxygenated, the blood is blue. The blood also provides powerful protection from infection. When a horseshoe crab's exoskeleton is punctured

blood oozes from the wound. When it comes in contact with air or water it congeals into a gel-like mass sealing the wound. The blood also contains potent antibiotic properties. Many strong, healthy horseshoe crabs bear scars from ghastly wounds that have completely healed.

Along the Atlantic and Gulf coasts, lengthening days and mild temperatures accompanying the arrival of spring stir in horseshoe crabs the urge to move. In April male horseshoe crabs move up from the deep channels of Delaware Bay and the adjacent Atlantic where they have spent the winter. They restlessly patrol the shallow waters close to shore. As spring progresses more crabs, including females, arrive to begin mating. The nesting season lasts from the beginning of May until at least the end of July. Egg laying peaks around the spring tides of May and early June.

In the waters just offshore males pursue females in an attempt to grab hold of their abdomens with the pedipalps. When the tide is high the female, with an attached male, drags herself to the edge of the surf in search of a site to lay her eggs. The eggs must be laid in sand where life-giving oxygen can reach the developing eggs. The majority of the Bay shoreline however is fringed with salt marsh. Marsh sod is unsuitable for nesting because it lacks oxygen. Small sandy beaches line the shore in only a few scattered locations. Horseshoe crabs throng to these beaches. During peak egg laying periods these beaches are literally crawling with horseshoe crabs. In the Delaware Bay male crabs outnumber females at most nesting beaches by at least two to one. On some beaches there may be as many as five males battling for each female. At the water's edge unmated males often crowd around mated pairs in an attempt to

dislodge the attached male. On one beach along the Bay, at the height of the nesting season, male crabs may form a nearly solid mass five feet wide and a mile long.

Once at the water's edge the female digs into the sand to lay her eggs.. Three thousand or more bluish-green eggs, each about 1.5 mm in diameter, are deposited in clumps mixed with sand and pebbles. Five to seven clumps may be deposited in each nest 2 to 8 inches beneath the surface of the sand. The male fertilizes the eggs as they are deposited. When egg laying is complete the female covers the nest and drags her suitor back into the Bay with the retreating tide. The female and her attached mate will return to the beach on several high tides and deposit up to 80,000 eggs during the nesting season.

Egg laying can be a perilous undertaking. Many horseshoe crabs are over-turned in the surf. Thousands, unable to right themselves, die when their gills dry and cease functioning or their soft underparts are eaten by hungry gulls. As many as 200,000 horseshoe crabs succumb to these hazards along the Delaware Bay each year. The retreating tide leaves thousands of horseshoe crabs high and dry on Bay beaches. On sloping beaches most of these unfortunate creatures are able to crawl back to the water. On flat beaches stranded individuals have a harder time finding their way back to the water. These animals often walk in circles in a vain attempt to reach the water. They eventually dig into wet sand to await the next high tide. As long as its book gills are kept moist a horseshoe crab can survive out of water for many days. On the next high tide the crab will emerge and return to the water.

In shallow nests above the normal high tide line eggs hatch in about two weeks. In deeper nests

closer to the tide line where sands are cool, the eggs may take up to ten weeks to hatch. Under optimal conditions, the egg swells and the dark-green outer covering is shed about six days after fertilization. The developing embryo can be seen rotating within the transparent egg membrane. The embryo undergoes its first molt at this time. In the next eight days the embryo molts three more times. Two weeks after fertilization when the next spring tide inundates the nest, the egg bursts and the embryo emerges. Newly hatched horseshoe crabs have no telson. They are called ”trilobite“ larvae because they resemble trilobites, an extinct group of arthropods. They struggle to the surface and spend the next few days swimming about before settling to the bottom and assuming a normal horseshoe crab lifestyle.

A horseshoe crab’s exoskeleton does not grow. In order for an individual to get larger it must shed, or molt, its exoskeleton. Horseshoe crabs molt in the summer. When it is time to molt, they burrow into the mud below the low tide line. The exoskeleton ruptures along the front edge of the cephalothorax and the crab crawls out of its old shell. This process may take several hours. The newly emerged crab’s shell is soft, wrinkled and pleated. The horseshoe crab absorbs water through its gills and the shell expands, becoming smooth and hard. Horseshoe crabs molt five times during their first year. They molt twice in their second and third years and then once each year thereafter. Male crabs take nine years to reach maturity. Females reach maturity in their tenth year. Horseshoe crabs may live two or three years after reaching maturity.

Horseshoe crab eggs and young are food for a host of animals. Sand shrimp, amphipods, fiddler crabs, several species of fish, and birds feed upon the

eggs and larvae. Young horseshoe crabs are eaten by a number of true crabs, fish and birds. Even the heavily armored adults fall prey to loggerhead sea turtles and some sharks. When they emerge to nest, horseshoe crabs are sometimes attacked by gulls, which turn the crabs over to eat the vulnerable soft parts. Humans are also counted among the horseshoe crab's predators. Horseshoe crabs were once harvested in large numbers for use as fertilizer and livestock feed. Today they are collected for use as eel and whelk bait.

Each spring when horseshoe crabs begin to stir in the Bay, birds thousands of miles away are responding to the same drive to reproduce. Red knots on the Atlantic coast of Argentina, ruddy turnstones flipping stones on beaches in Brazil, sanderlings chasing waves in Venezuela, and semipalmated sandpipers probing mudflats in Surinam are fueling up for their migration to high Arctic nesting grounds. The fat they store will not take them all the way to the Arctic. They must stop along the way to refuel. Unfortunately, timing is critical. When they arrive in the Arctic, the birds have only a few weeks to mate, lay eggs, and raise young during the brief Arctic summer. The birds cannot afford to waste precious time and energy searching for food. The locations where they stop to refuel must provide large concentrations of easily accessible food in a relatively small area. Scientists call these sites staging areas. There are several major shorebird staging areas in North and South America.

The Delaware Bay is by far the most important shorebird staging area in North America. Northbound shorebirds find abundant food just beneath the surface of the Bay's beaches. By mid-May the Bay's sandy beaches harbor millions of horseshoe crab eggs.

Around the beginning of May shorebirds arrive in a trickle. By mid-month they flow onto the beaches in waves. After non-stop flights lasting several days, and covering up to two or three thousand miles, they need food, and lots of it. Horseshoe crab eggs provide energy that will fuel the last leg of the shorebirds' migration to Arctic nesting grounds. In mid-May there may be tens of thousands of shorebirds greedily feeding on the bounty hidden in the sand.

Many species of shorebirds feed on horseshoe crab eggs along the Delaware Bay. However, four species comprise the majority of these birds. The red knot is the largest of these four species. Red knots can be up to ten inches in length, about the size of an American robin. In breeding plumage the breast and belly are reddish-brown and the upperparts are a mosaic of black, reddish brown and white. The ruddy turnstone is slightly smaller than the red knot. They can be up to nine inches in length. The head is white with a black collar and bib. The belly is white, the back is reddish brown and black and the legs are bright orange. The sanderling can be up to eight inches in length. In winter plumage they are gray and white. When they arrive along the shores of the Delaware Bay most are in the process of molting into their more colorful breeding plumage. When they leave for the arctic all sanderlings have a rusty head and breast, white belly and brown back. Semipalmated sandpipers are the smallest of the four species. They are about six inches in length, the size of a sparrow. They are brown above and white below.

Red knots, sanderlings, and semipalmated sandpipers probe into the sand in search of horseshoe crab eggs. The depth to which they probe for eggs is limited by the length of their bills. The majority of eggs are well beyond their reach. Ruddy Turnstones

dig two to four inch deep holes with their bills, exposing entire nests. They vigorously defend their excavations, chasing all other shorebirds from their holes. They often seem to spend more time fighting than feeding. Eventually the hole is abandoned by its defender and red knots, sanderlings and semipalmated sandpipers move in quickly to devour any remaining eggs.

By the end of May shorebirds hit the beaches like a tidal wave. One quarter to half a million shorebirds feed along the bayshore at this time. More than half of the entire Western Hemisphere population of red knots may be present along the bay at one time. While shorebirds are present along the bayshore in large numbers for more than a month, individual birds are present for only about two weeks before they continue their migration. While on the Bayshore shorebirds spend their day feeding, resting, and preening. Many birds nearly double their weight during their stay on the bayshore. A single sanderling may eat as many as 135,000 eggs during its stay on the Bayshore, or one egg every five seconds. Fifty thousand sanderlings could consume six billion eggs, or twenty-seven tons. At dusk, for reasons yet unknown, the shorebirds leave the Bay to spend the night along the Atlantic shore. Sanderlings roost in large groups on the few remaining undeveloped beaches. Knots, turnstones and semipalmated sandpipers gather instead around shallow salt marsh ponds. When high spring tides flood the marsh these birds join the sanderlings on the beach.

During the first two weeks of June shorebird numbers dwindle. Except for the remains of horseshoe crabs scattered along Bay beaches, a visitor to the bayshore in mid-June would find little evidence of the spectacle that had taken place. By this time

shorebirds are well on their way to Arctic nesting grounds. All four species nest on the Arctic tundra from Labrador to Alaska. Sanderlings, red knots and ruddy turnstones also nest in Greenland.

When they reach their nesting grounds male shorebirds establish territories. They call and use a variety of displays to defend their territories from other males and to attract a potential mate. Red knots, ruddy turnstones and semipalmated sandpipers are monogamous. Males and females mate with a single partner and usually share the job of incubating eggs and protecting the young. Sanderlings may be monogamous or females may mate with two or more males. This mating system is called polyandry. The female lays and abandons a clutch of eggs after each mating. Her mates incubate the eggs and care for the young. She may lay one clutch of eggs that she will care for herself. Eggs of each species hatch in about three weeks. When the young hatch their eyes are open and they are completely covered with down. They are up and running only a few hours after hatching. The young birds are led to feeding areas by their parents but must find their own food. Young shorebirds fly for the first time, or fledge, about three weeks after they hatch. Adult birds usually begin their southward migration before their young. The first adult shorebirds arrive in the Delaware Bay area in late June. Most adults have moved through the area by the end of August. In late July, juveniles on their first southward migration begin to arrive in the Bay area. By the end of October most shorebirds have moved further south except for some sanderlings and ruddy turnstones which spend the winter in the Delaware Bay region.

Migration is the most perilous time in the life of a bird. Foul weather and hungry predators are just

a few of the dangers a migrant may encounter. Man-made structures also take a toll on migrating birds. Hundreds of thousands of birds die annually as a result of flying into buildings, windows, powerlines and large radio antennas. Birds that successfully negotiate these hazards must then find suitable food and habitat along the route. Why then do birds undertake such hazardous journeys? Scientists believe that the benefits shorebirds gain by breeding in the arctic outweigh the risks of getting there. The sun shines nearly twenty-four hours a day during the brief arctic summer. The growing season is short, but constant sunlight fuels an impressive production of food energy by plants and plankton. These organisms support enormous numbers of small invertebrates and insects that serve as an abundant source of food for shorebirds and their developing young. In essence, shorebirds that can survive migration find abundant resources required to produce relatively large numbers of offspring in a short period of time.

Shorebirds aren't the only birds that visit the shores of Delaware Bay to feast on horseshoe crab eggs. Glossy ibis, crows and boat-tailed grackles all may be seen probing the sand for eggs. By far the most conspicuous is the laughing gull. Laughing gulls are much larger, bolder and certainly noisier than shorebirds. Laughing gulls winter from South Carolina to Central and South America. In April they return to southern New Jersey where they nest in large colonies in nearby salt marshes along the Atlantic coast. Laughing gulls are opportunistic feeders that eat insects, earthworms, spiders, marine invertebrates, fish, fruit, carrion and edible items found in landfills, dumpsters and parking lots. In May and June they head for the bayshore at dawn to gorge on horseshoe crab eggs. They probe into the sand with their bills like shorebirds, wade in the surf eating

eggs washed out of nests, and grab whole clumps of eggs as they are laid by female horseshoe crabs. On some beaches tens of thousands of gulls line the shore, even standing on mating crabs, snatching any eggs that come their way. On the beaches they intimidate and bully shorebirds. Even the aggressive turnstones give way to the gulls. At dusk the gulls return to their nesting colonies in a seemingly unending stream.

How long have horseshoe crabs and shorebirds been playing out there drama along the shores of Delaware Bay? No one is really sure. Twenty thousand years ago at the height of the last ice age the Delaware Bay did not exist. Tundra habitat covered much of the northern United States just south of the glacier's edge. The northward journey of shorebirds was much shorter. At some time in the last few thousand years, as the glaciers receded and migratory routes lengthened, shorebirds discovered the abundant food resources of the Delaware Bay and have been stopping there ever since.

Early ornithologists made no note of shorebirds feeding in large numbers along the bayshore. In the mid-nineteenth century, however, shorebirds were so numerous that a million or more shorebirds along the bayshore may not have seemed out of the ordinary. Ornithologists were not the only people interested in shorebirds. During the nineteenth century wild animals of all kinds were hunted unmercifully by market gunners to supply meat for big city markets and restaurants. By the early twentieth century, most shorebird populations were severely reduced. Likewise, horseshoe crabs did not escape persecution. In the nineteenth century horseshoe crabs were harvested for use in fertilizer and livestock feed. In the 1870s, four million horseshoe crabs were

harvested each year from the Delaware Bay. This industry declined as horseshoe crab numbers decreased and cheaper sources of fertilizers were discovered. By the 1960s horseshoe crab harvests declined to only one percent of historic levels. Today horseshoe crabs are harvested for use as eel and whelk bait. Crabs are also collected for use by the pharmaceutical industry. A compound in the blood of horseshoe crabs is used to test for toxins in drugs. The crabs are bled, held for a short period and then returned alive to the waters of Delaware Bay. This process seems to do little harm to horseshoe crabs; ninety percent of bled crabs survive.

In 1918 the United States and Great Britain (on behalf of Canada) signed the Migratory Bird Treaty, in response to alarm about declining bird populations. This ended the legal hunting off all but a few species of North American birds. Most shorebird populations have slowly rebounded, but will probably never return to the impressive numbers that once filled our skies. Horseshoe crabs, however, never received such strong protection. Recently, the states of New Jersey and Delaware have attempted to regulate the harvest of horseshoe crabs. In New Jersey horseshoe crabs can be harvested only at night during certain times of the month.

Human impacts on horseshoe crab and shorebird populations go beyond out-right killing. Habitat destruction is by far the most important threat to these species. Development of the Bayshore endangers the phenomenon that occurs on the beaches of Delaware Bay. Bulkheads, sea walls and jetties intended to protect beachfront property instead increase beach erosion and reduce areas where horseshoe crabs can spawn. The degradation of even one of the few sandy beaches along the Bay

could have a large impact on both horseshoe crab and shorebird populations. Danger lies offshore as well. Every day during the spawning season ships travel up the Bay carrying oil to refineries in Philadelphia and Wilmington. An oil spill during the peak of spawning season could prove catastrophic to both horseshoe crab and shorebird populations. Oil on the beaches could smother developing horseshoe crab eggs. With more than half of the new world population of red knots present along the bayshore at the peak of the season an oil spill could decimate this population.

In the 1980s, after a decade and a half of research, scientists announced a drastic decline had occurred in the populations of several species of shorebirds. Sanderling populations had decreased by eighty percent. It was believed that habitat loss along migration routes and in wintering areas was probably responsible for the declines. In 1984 several conservation groups, including the World Wildlife Fund, the Academy of Natural Sciences, and New Jersey's Division of Fish, Game and Wildlife, joined forces to protect the unique ecological phenomenon in the Delaware Bay. One year later the governors of New Jersey and Delaware declared the Delaware Bay a reserve for the conservation of shorebirds. It marked the beginning of the Western Hemisphere Shorebird Reserve Network, a program designed to identify and preserve important areas used by shorebirds in North, Central and South America. An international effort of this magnitude is essential if shorebird populations are to be protected. If just one staging area is lost or degraded to the point that it cannot support large populations, these shorebirds could disappear forever.

The future is uncertain. At least for now, horseshoe crabs continue to spawn on Delaware Bay beaches each spring and out of the skies rain shore-

birds by the thousands, alighting briefly before continuing on to their Arctic nesting grounds. Increased public education and awareness and continued commitment of government and conservation organizations is critical for the preservation of not only Delaware Bay but equally important habitats just a shorebird flight away.

Bibliography

Bent, A.C. 1962. *Life Histories of North American Shorebirds*. Dover Publications. New York.

Barnes, R.D. 1980. *Invertebrate Zoology*. Fourth ed. Holt, Rinehart and Winston. New York.

Bonaventura, J., C. Bonaventura and S. Tesh. 1982. *Physiology and Biology of Horseshoe Crabs*. Alan R. Liss, Inc`. New York.

Boyle, W.J., Jr. 1986. A Guide to Bird Finding in New Jersey. Rutgers University Press. New Brunswick, New Jersey.

Bryant, T.J. and J.R. Pennock, eds. 1988. *The Delaware Estuary: Rediscovering a Forgotten Resource*. University of Delaware Sea Grant College. Newark, Delaware.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. *The Birder's Handbook*. Simon and Schuster Inc. New York.

Harding, J.J. and J.J. Harding. 1980. *Birding the Delaware Valley Region*. Temple University Press. Philadelphia.

Hayman, P., J. Marchant and T. Prater. 1986. *Shorebirds: An Identification Guide to the Waders* of the World. Houghton Mifflin Co. Boston.

Hall, W.R. *The Horseshoe Carb - A Reminder of Delaware's Pas*t. MAS Bulletin. University of Delaware Sea Grant College. Newark, Delaware.

Myers, J.P. 1986. "Sex and Gluttony on Delaware Bay." *Natural History*. 95:68-77.

National Geographic Society. 1987. Second ed. *Field Guide to the Birds of North America*. National Geographic Society. Washington, D.C.

Pettingill, O.S., Jr. 1970. *Ornithology in Laboratory and Field*. Burgess Publishing Co. Minneapolis.

Stout, G.D., ed. 1967. *The Shorebirds of North America*. The Viking Press. New York.

Terres, J.K. 1980. *The Audubon Society Encyclopedia of North American Birds*. Alfred A. Knopf. New York.

Wood, M. 1973. *Birds of Pennsylvania: When and Where to Find Them*, Rev. ed. Pennsylvania State University Agricultural Experiment Station. University Park, Pennsylvania.

Visiting & Educational Opportunities

For visiting information and educational opportunities, in New Jersey contact the Cape May Bird Observatory (New Jersey Audubon Society) at 609-861-0700 or the Nature Center of Cape May (also NJAS) at 609-898-8848. In Delaware, contact the Seaside Nature Center, Cape Henlopen State Park at 302-645-6852.

Related Videos from Bullfrog Films:

Secrets of the Salt Marsh 20 min., Grades 7-adult. Overview of salt marsh ecology

Estuary 12 min Grades 7-Adult. Prizewinning under-water look at food chain in estuarine ecology.

The Intertidal Zone 17 min., Grades 5-Adult. Rich diversity in overlapping fresh and salt water ecology.

The Great Horseshoe Crab Field Trip 28 min., Grades 7-Adult. Master Science Teacher prepares and takes his Harlem biology class to apply scientific method in encounter with horseshoe crabs.

Where the Heron Finds Its Home 46 min. Grades 7-Adult. Great Blue Heron indicates health of wetlands.

Wasting of a Wetland 23 min., Grades 7-Adult. The Everglades at risk.

Troubled Waters: Plastics in the Marine Environment 29 min., Grades 7-Adult. Communities begin to cleanup and abide by MARPOL Treaty.

Keepers of the Coast 31 min., Grades 7-Adult. Surfers, "indicators" of our species, lead the effort to clean up beaches.

Arribada! The Olive Ridley Arrival 17 min., Grades P-7. Comical Kratt brothers encounter sea turtles.

A Celebration of Birds 54 min., Grades 6-Adult. Portrait of Roger Tory Peterson.

Sea of Slaughter 96 min., Grades 10-Adult. Farley Mowat documents devastation of marine wildlife.