Tying the Knot

How Do Horseshoe Crab and Red Knot Populations Affect Each Other?

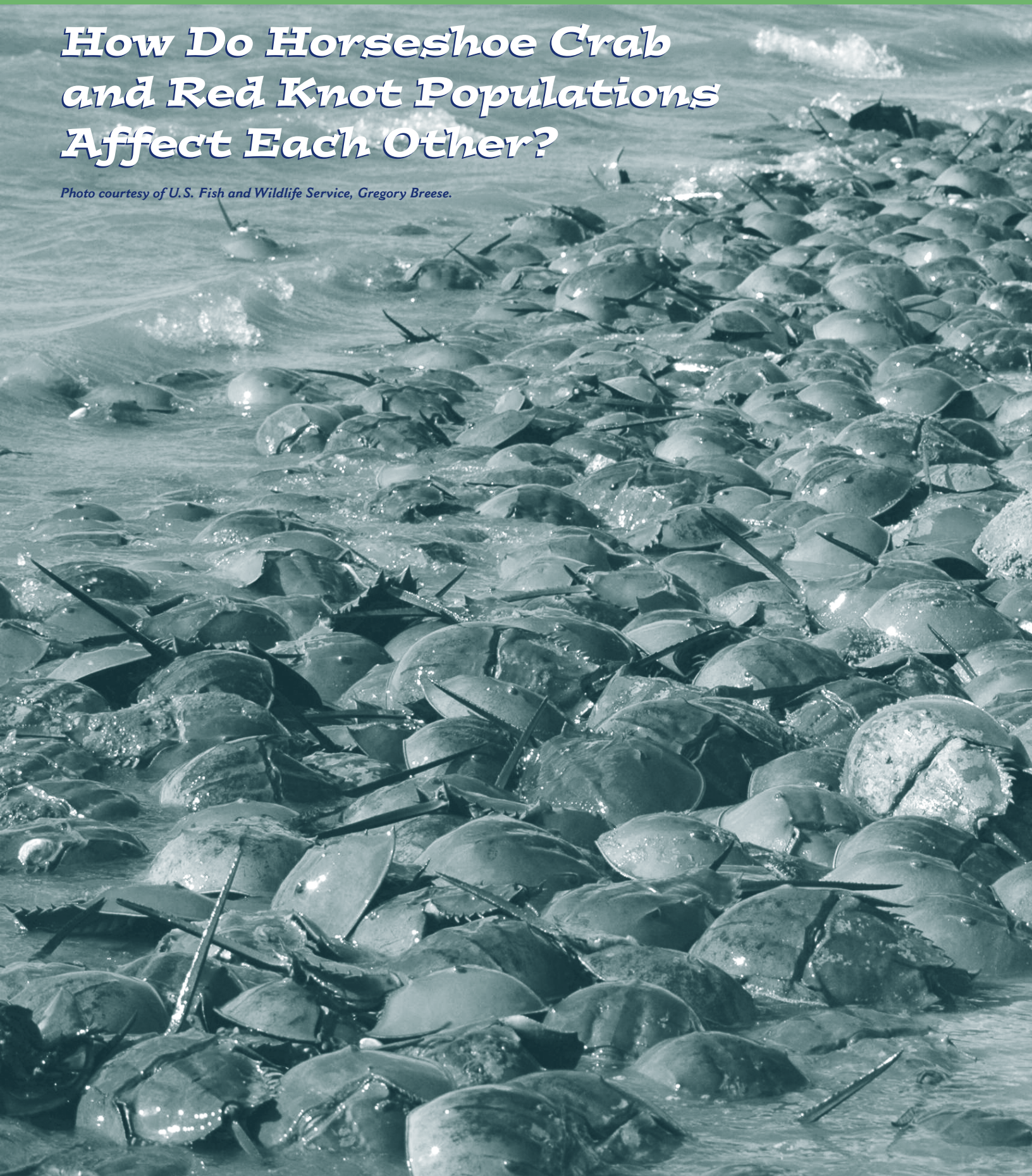
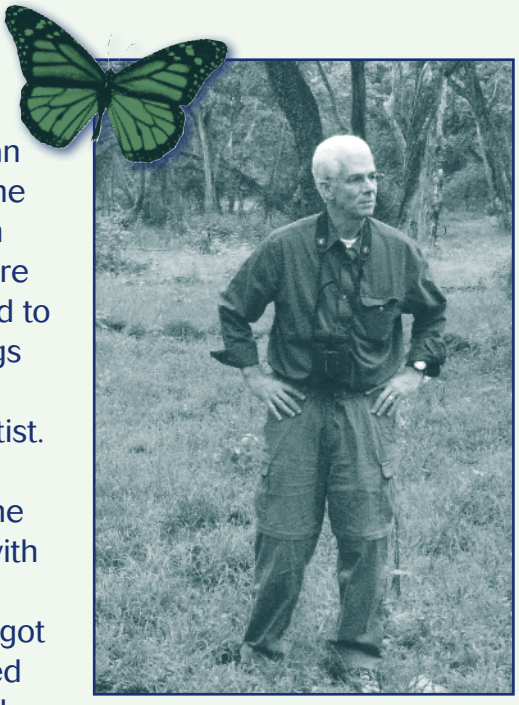


Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Meet the Scientists

◀ **Dr. Conor McGowan**, Population Ecologist: My favorite science experiences always involve being out in the field with the animals I am studying. The best one has to be when I trapped and banded waved albatross in the Galapagos Islands as an undergraduate student. The Galapagos Islands are such a beautiful, amazing place, and the waved albatross are such powerful, awesome birds.



▶ **Dr. Jim Nichols**, Population Ecologist: Science experiences can sometimes be scary. One time, I was working with other scientists who were studying Weddell seals in Antarctica. To do our study, we had to place plastic identification tags on the seals' flippers. The tags enable scientists to track the activities of individual seals.

I was out on the sea ice tagging seals with another scientist. We came upon a large female without a tag. She probably weighed about 1,000 pounds (453 kilograms). I was given the task of "catching" her, which involved throwing a cloth bag with rope handles over her head and jumping on her back. Then, holding on to the rope handles, I rode on her back until she got tired. She was tired in less than 2 minutes. When she stopped moving, I remained on her back and held the bag in place. The other scientist moved behind her to apply the tags to her rear flippers.

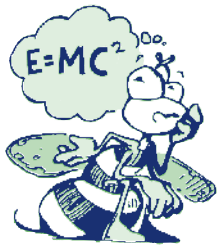
Suddenly, the seal began to roll to one side. I tried to pull my leg up so it would not be crushed by her rolling motion. I discovered that my crampons (metal spikes on the bottoms of my boots) were stuck in the ice. My leg was so far under the seal that I could not pull it loose. I yelled to my partner, who quickly moved to the front of the seal. He distracted her in the opposite direction of her roll, causing her to roll back to the other side. This movement gave me room to remove my leg. So thanks to the quick thinking of my partner, my leg was not crushed. I made sure in future captures that my leg did not get stuck again.

What Kind of Scientist Did This Research?

population ecologist: This scientist studies the populations of different species and how the population interacts with its environment.

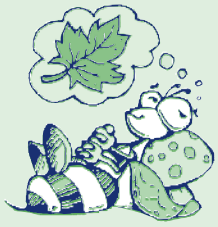
Glossary words are **bold** and are defined on page 44.

Thinking About Science



Land managers and other natural resource professionals are skilled individuals who take care of the land and natural resources. Every day, land managers and natural resource professionals must make decisions about how best to maintain the resources that are in their care. To help managers make the most informed decisions possible, scientists sometimes work with these professionals. In this case, science is used to help solve identified problems and meet objectives. In this study, scientists and managers worked together. The scientists designed models to help managers make good decisions about a population of horseshoe crabs and a certain type of **migratory** shorebird called the red knot.

Thinking About the Environment



Some birds **migrate** during winter months and then return to summer habitats for **breeding**. In this study, the red knot is a bird species that migrates south from its breeding grounds in the Canadian Arctic to southern South America. The one-way migratory journey for these birds can be up to 14,000 kilometers. The birds must stop frequently to rest and refuel to complete this journey. Certain locations are ideal stopover areas for these migratory birds because of food availability. The three areas are Tierra del Fuego (Argentina and Chile), northern Brazil, and the Mid-Atlantic United States (**figure 1**). Red knots spend November through February in these wintering areas and then migrate back to Canada in time for

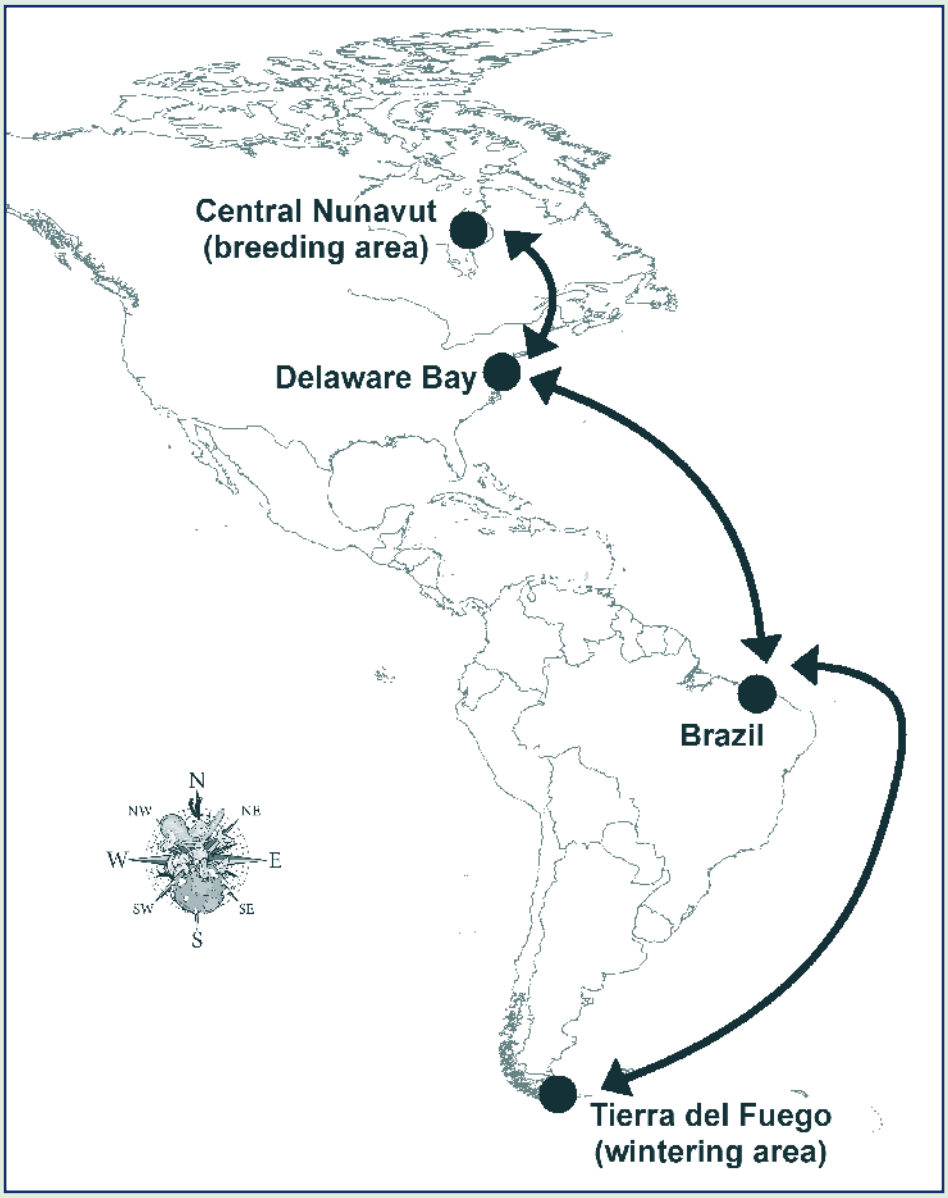


Figure 1. Stopover points for migrating red knots that spend the winter in three locations: Tierra del Fuego, northern Brazil, and the Mid-Atlantic United States. Map by Lindsay Gnann.

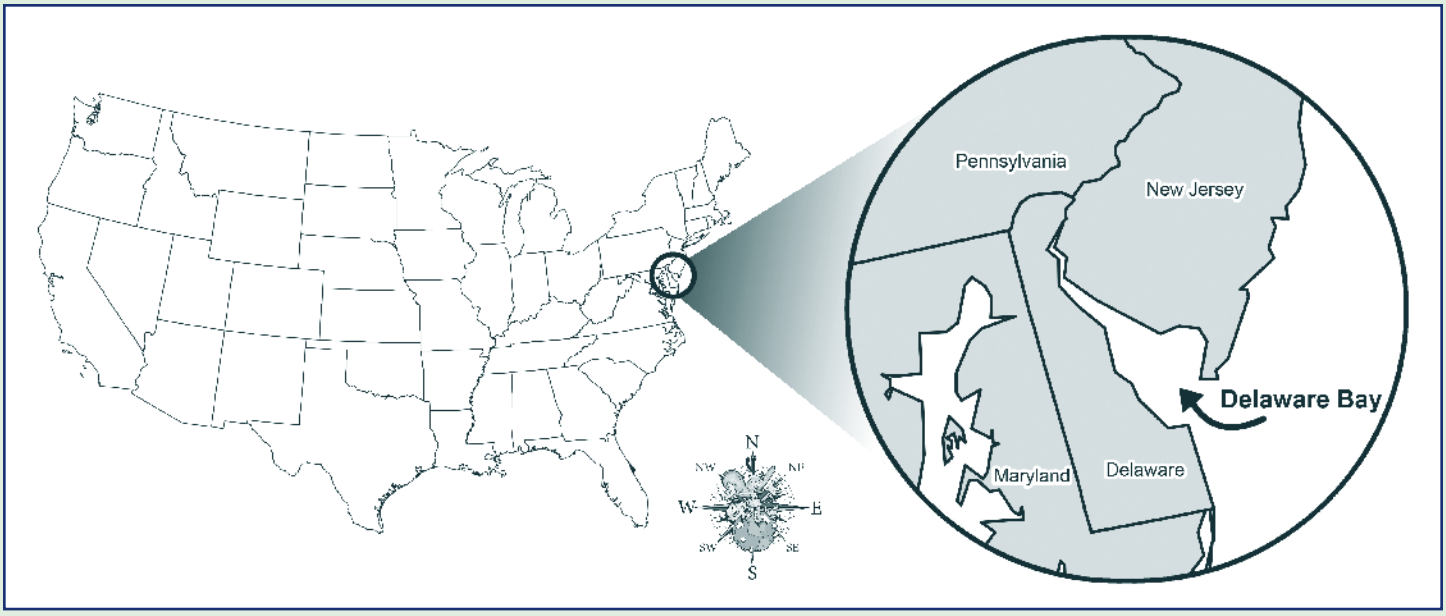


Figure 2. Delaware Bay is located in the Mid-Atlantic United States. Map by Lindsay Gnann.

summer. Delaware Bay in the Mid-Atlantic United States is a perfect stopover location for the birds (**figure 2**).

Delaware Bay is an **estuary** (**figure 3**). Because estuaries are transition zones between the ocean and freshwater areas, the mix of ocean water and fresh water provides a lot of nutrients in the area. For red knots, the big draw is horseshoe crab eggs. In this study, you will learn how the horseshoe crab population may affect the red knot population.

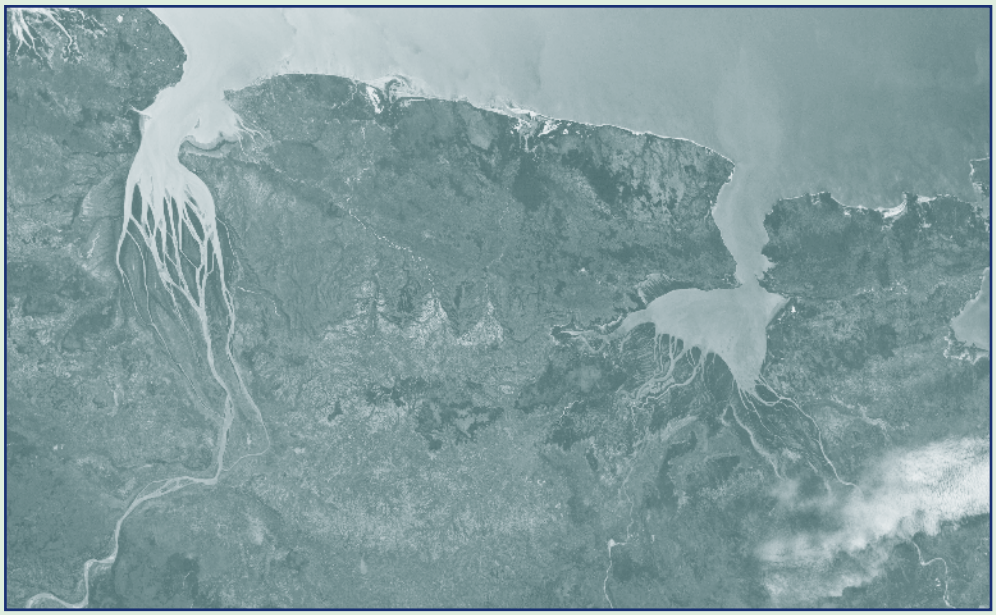


Figure 3. Two estuaries on the northwestern coast of Madagascar. The Republic of Madagascar is located off the southeastern coast of Africa, in the Indian Ocean. This photo was taken by an Expedition 28 crew member on the International Space Station. Photo courtesy of the National Aeronautics and Space Administration.

Number Crunch

How many miles is a one-way migratory trip for the red knot? (Hint: 1 km= 0.621 miles)

Introduction

In this study, the scientists used a **structured** decisionmaking process called adaptive management (see page 4 for more information about adaptive management). Structured decisionmaking is a process where managers first define management **objectives**. After managers have defined their objectives, scientists use models to predict results of different possible actions managers could take. Then managers select one of the actions. Next, people monitor the ecosystem and see if the objectives are achieved by the action that was chosen. Then managers adjust the next action based on the new information they learned.

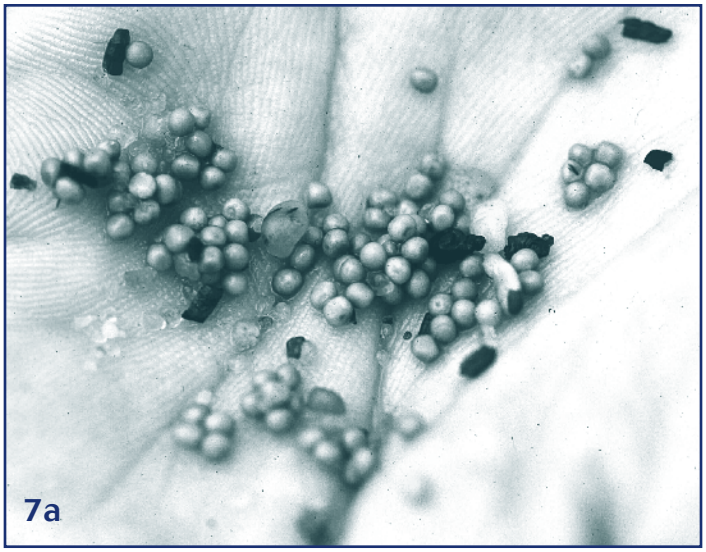
The cycle of taking action, monitoring results, and adjusting the next action is how managers learn more about the ecosystem. They can, therefore, make better decisions. It is important to design accurate models to help managers understand the ecosystem. This modeling also helps the managers make the most informed decisions possible about managing the ecosystem.

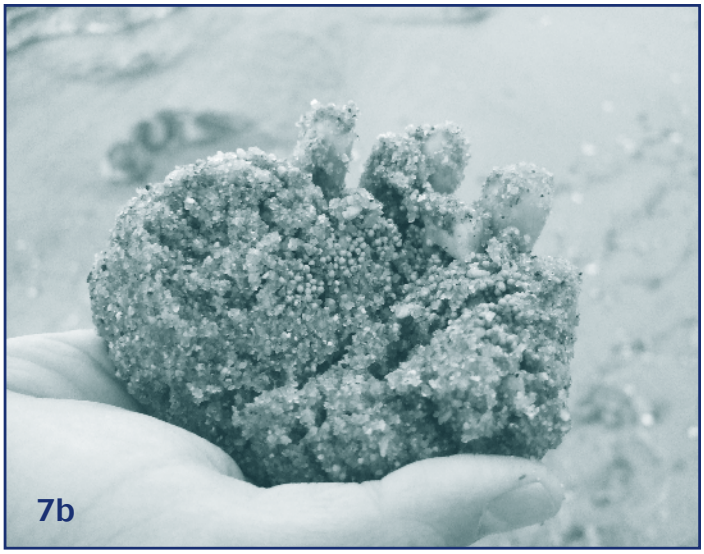
In this study, scientists wanted to examine how the **harvest** of horseshoe crabs in Delaware Bay affects the red knot (**figures 4 and 5**). The red knot is a migratory bird (**figure 6**). The red knot feeds primarily on the eggs of horseshoe crabs during its stopover in Delaware Bay (**figures 7a and 7b**). Thousands of shorebirds make the same stopover as the red knots and **gorge** themselves on food. Although the red knots eat a lot of horseshoe crab eggs, these eggs are mostly ones that would not have hatched. The eggs will not hatch because they are too close to the sand's surface. As red knots feed, they nearly double their weight in 2 weeks. This weight gain allows the birds to continue on their **strenuous** migratory journey north to the **Arctic** to breed during the summer months.

Figure 4. Thousands of horseshoe crabs come up onto the beaches in Delaware Bay to lay their eggs. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Figure 5. Red knots stop to eat in Delaware Bay. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Figure 6. Thousands of red knots fly to Delaware Bay and land there to refuel for their long migratory journey. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.





Figures 7a and 7b. These tiny horseshoe crab eggs are what red knots eat to store energy. Photo 7a courtesy of U.S. Fish and Wildlife Service, Gregory Breese. Photo 7b courtesy of Dr. Conor McGowan.

The population of red knots has declined from approximately 150,000 birds in the 1990s to 15,000 birds in 2008. Today's red knot population is low enough to be listed as a threatened species. A threatened species benefits from some protection under U.S. law. During this same time period, the harvest of horseshoe crabs has increased. Horseshoe crabs are harvested as bait for eels and whelk (**figure 8**).

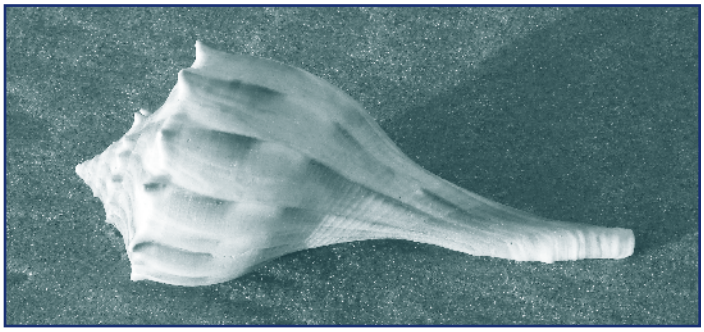


Figure 8. Horseshoe crabs are harvested as bait for whelk. Whelk is a word used for many species of sea snails. Photo courtesy of Jo O'Keefe: http://okeefes.org/Whelks/Whelks.htm.

What Is Adaptive Management?

Have you ever heard that experience is the best teacher? This idea is the foundation of adaptive management. Adaptive management is a way for land managers to deal with an unknown future and to learn from trying new things. When land managers try something new, the outcome is evaluated. Based on the evaluation, the managers try another approach to improve their management. The process continues, with managers continuing to learn and adapt.

Scientists often help managers by designing and implementing the evaluation process. As you can see, scientists are involved in some parts of the adaptive management process. Land managers, however, treat the entire adaptive management process as an experiment. What happens when you do an experiment? Hopefully, you learn from your experience!

The red knot population decline may be because of fewer horseshoe crab eggs in Delaware Bay. In addition, horseshoe crab blood is collected from live horseshoe crabs for **pharmaceutical** testing. This blood collection, however, is not believed to affect the horseshoe crab population. The scientists in this study wanted to figure out how to manage the harvest of horseshoe crabs in such a way that the populations of red knots and horseshoe crabs stopped declining.

Number Crunch

- What is the difference in the number of red knots stopping in Delaware Bay now compared with 15 years ago?

Reflection Section

- In your own words and in the form of a question, state what the scientists wanted to know.
- Do you think it is important for managers to define objectives for their management decisions? Why or why not?

What Are Horseshoe Crabs?

Horseshoe crabs are one of the world's oldest creatures. This type of animal is estimated to be at least 300 million years old. That's pretty old, especially when you consider that the beginning of the Age of Dinosaurs was 230 million years ago. Were horseshoe crabs living on Earth before the dinosaurs? How do you know?

The horseshoe crab is an **invertebrate**. The horseshoe crab belongs to the **arthropods**. It may look like a crab but it is more closely related to spiders and scorpions (**figure 9**). Horseshoe crabs lay their eggs during breeding season in sandy beach habitats. During spring breeding, millions of crabs crawl up the beaches of Delaware Bay. This breeding cycle occurs at the same time as the **lunar cycles**. Horseshoe crabs, in particular, like to lay their eggs during the full moon and **new moon** in May and June. Visit http://www.udel.edu/research/explore/loader.html to learn more about horseshoe crabs!

Figure 9. Horseshoe crabs may look like crabs, but they are more closely related to spiders and scorpions. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Methods

The scientists had to make a basic mathematical **model** to test different management practices. (Read about a mathematical model of a zombie attack on page 7.) The basic model had two parts. First, the scientists needed a horseshoe crab population model that looked at the effects of harvesting on both male and female horseshoe crabs. Second, the scientists needed a red knot population model that linked red knot survival to horseshoe crab breeding in Delaware Bay. After the scientists combined these two parts, they had a basic model in which they could run **simulations**.

Using this basic model, the scientists created two specific mathematical models to represent two competing **assumptions**. The first model assumes that the amount a bird weighed at the end of the stopover had large effects on its survival. The second model assumes that the amount a bird weighed at the end of the stopover had a small effect on its survival. The second model assumes that heavy and light birds, in general, have similar survival rates.

When the scientists were building the models, they needed to include certain types of data. For example, the scientists set initial population sizes at 1998 levels. They also included data about the number of horseshoe crabs coming onto the beaches for the period 1998–2008. These data included the number of horseshoe crabs harvested in Delaware Bay. The scientists then used the models to predict what might happen with eight different possible management actions (**figure 10**).

Reflection Section

- Why do you think the scientists wanted a population model for horseshoe crabs that looked at both male and female horseshoe crabs?
- Why did the scientists consider different possible management actions?
- Why did the scientists group the red knots into two weight categories?

Adaptive Management in Your Life

Do you have a butterfly garden in your schoolyard? If you do not, pretend that you do. Your class has decided to use adaptive management to improve the garden. First, you must identify the problem and your objective. Let's say that only one species of butterfly visits your garden. This lack of variety is the problem. Your objective is to have as many butterfly species as possible visiting the garden. Your class does research in the media center. You identify two additional flowering plants and plant them in the garden.

After 2 weeks, you observe and record the butterfly species in the garden. You identify two additional species. After evaluating your results, your class does more research. You discover that butterflies like shallow pools of water. You create a shallow pool, wait 2 more weeks, and observe and record the butterfly species. Another species is identified. After evaluating the results of your management, your class does more research. You discover that butterflies like to have shady as well as sunny spots to rest. What steps will you take next?

Action	Female Harvested	Males Harvested
1	0	0
2	0	200,000
3	0	400,000
4	100,000	200,000
5	200,000	400,000
6	300,000	300,000
7	300,000 – (Red knot threshold is 30,000)	300,000 – (Red knot threshold is 30,000)
8	300,000 – (Red knot threshold is 60,000)	300,000 – (Red knot threshold is 60,000)

Figure 10. Different management actions were based on different numbers of horseshoe crabs that could be harvested. In actions 7 and 8, no horseshoe crabs can be harvested when red knot **abundance** is less than the **threshold**.

Findings

The scientists found that both models were sensitive to changes in horseshoe crab egg survival rates and **juvenile** horseshoe crab survival rates. Heavy harvest of horseshoe crabs decreased red knot abundance in both models, but had a much greater effect in model 1. Recall that model 1 assumed that a bird's survival was related to its weight. Harvesting only male horseshoe crabs had little effect on red knot population numbers in both models.

Models 1 and 2 produced different predictions for the eight different possible management actions shown in **figure 10**. With no harvesting, for example, model 1 predicted that the median abundance of red knots 90 years in the future would be about 65,000 birds. Model 2, however, predicted a population of around 200,000 red knots. The management action that restricted horseshoe crab harvesting until a certain number of red knots was present improved population predictions for the red knot.

Reflection Section

- Why do you think harvesting only male horseshoe crabs had little effect on red knot abundance?
- If you were the scientist, would you recommend that horseshoe crab harvests be limited in the future? Why or why not?

You Are the Adaptive Manager!

In this article, you are learning about research and evaluation as a part of the adaptive management process. One important feature of adaptive management is its focus on an uncertain future. Scientists help managers by doing research. Scientists provide information that can be used to predict what might happen in the future. Pretend you are the manager of the area being studied in this research. How would you use the findings of this study? What management action would you take? After taking the action, what would you ask the scientists to monitor?

Discussion

The scientists in this study developed the first models for predicting effects of management actions on horseshoe crab and red knot populations in Delaware Bay. The two models showed different results. Model 2 showed faster red knot population growth.

What is the reason for using both models to make a management decision? Using two models helps scientists include things they are unsure about in the decisionmaking process. Let's say the manager's objective is to maximize the number of red knots. Using action 8 would be best even though scientists don't know for sure whether red knot weight is important for survival. If the manager's objective is to maximize the horseshoe crab harvest, however, action 7 would be the best. The models' results show that managers may be able to **conserve** the red knot population, while allowing some horseshoe crab harvesting.

The scientists suggested the best management strategy would be for managers to take actions based on what the models predicted. The best strategy would also take into account the current state of the ecosystem and management objectives. The scientists believed that additional data would help them decide which of the two models provides the best predictions. Additional data would also help create better models. Specifically, scientists suggested that more information is needed about the relationship between a red knot's weight gain and the availability of horseshoe crab eggs.

Reflection Section

- Do you think this model will be useful to managers and natural resource professionals? Why or why not?
- Should the scientists continue to estimate the populations of horseshoe crabs and red knots next year? Why or why not?

Glossary

abundance (ə **bən** dənt(s)): A degree of plentifulness.

Arctic (**ärk** tik): The Arctic Ocean and lands in and adjacent to it.

arthropod (**är** thrə päd): Any of a phylum of invertebrate animals (such as insects, arachnids, and crustaceans) having a segmented body, jointed limbs, and a shell of chitin that is shed periodically.

assumption (ə **səm(p)** shən): A fact or statement taken for granted.

breed (**brēd**): To produce offspring by sexual reproduction.

conserve (kən **sərv**): To avoid wasteful or destructive use of; to use carefully.

estuary (**es** chə **wer** ē): A passage where the tide meets a river current; especially: an arm of the sea at the lower end of a river.

gorge (gȯ(ə)rj): To eat in large amounts.

harvest (**här** vəst): To gather or collect.

invertebrate (in **vərt** ə brət): Lacking a backbone.

juvenile (**jü** və nīl): Showing incomplete development.

land manager (**land ma** ni jər): A skilled professional who takes care of the land.

Adapted from McGowan, C.P.; Smith, D.R.; Sweka, J.A.; Martin, J.; Nichols, J.D.; Wong, R.; Lyons, J.E.; Niles, L.J.; Kalasz, K.; Brust, J.; Klopfer, M.; Spear, B. 2011. Multi-species modeling for adaptive management of horseshoe crabs and red knots in the Delaware Bay. Natural Resource Modeling. 24: 117–156. http://www.fws.gov/northeast/fisherycenter/pdfs/McGowanetal2011.pdf.

lunar cycle (**lū** nər **sī** kəl): The changing appearance of the moon as seen from Earth.

migrate (**mī** grāt): To pass from one region or climate to another usually on a regular schedule for feeding or breeding.

migratory (**mī** grə tōr ē): Having a way of life that includes migrations.

model (**mäd** əl): A simplified copy or representation of something to help human understanding.

new moon (**n(y)ü** mün): The moon's phase when its dark side is toward Earth.

objective (əb **jek** tiv): An aim or goal.

pharmaceutical (**fär** mə **süt** i kəl): Of, relating to, or involved in pharmacy or the manufacture and sale of medicinal drugs.

simulation (**sim** yə **lā** shən): The imitation by one system or process of the way in which another system or process works.

strenuous (**stren** yə wəs): Marked by or calling for strength or energy.

structured (**strək** chərd): Organized.

threshold (**thresh** hōld): A level, point, or value above which something will take place and below which it will not.

Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.

FACTivity

In this FACTivity, you will learn about the migration of the red knot and why different areas where the red knot stops are important for the red knots' survival. This journey is one of the longest migratory journeys, marking close to 9,000 miles or 14,000 kilometers!

Time Needed

Three 50-minute class periods

Materials

- A copy of the map for each student (see map on page 46)
- Pencils (one for each student)
- Books or Internet resources about stopover locations and the red knot
- Paper to make pamphlets
- Colored markers

Methods

1. First, take a map and locate each stop that the red knot makes on its migratory journey. Mark the Hudson Bay area, then the Delaware Bay area, Brazil, and finally Tierra Del Fuego.
2. After you have marked the areas on the map, draw lines in between the points to mark the entire length of the journey.
3. Learn a little bit about each area and why it is important for the red knot. To complete this activity, your teacher will divide the class into small groups. Each group will be assigned a migratory stop. (Note: If you have more than four groups, multiple groups can study the same stopover location).
4. Each group will pretend to be travel agents for the area assigned. You and other students are travel agents for red knot birds (not people). You will need to research your assigned stopover location and create a short presentation and pamphlet to entice the red knot to come and stop over at the assigned location. You will make a presentation to the class and can display your pamphlets on a bulletin board.
5. After you and the other students have shared your presentations, your teacher will facilitate a group discussion. This discussion will focus on the challenges of such a long journey and the importance of safe stopover locations.

Map by Lindsay Gnann.

Note to Educators: A rubric for this FACTivity can be found at http://www.naturalinquirer.org. After arriving at this Web site, click on educational resources and then lesson plans. Scroll down and you will see "Article Lesson Plans." The rubric will be listed here.

If you are a Project Learning Tree (PLT) educator, you may use "Habitat Pen Pals" and "Web of Life" as additional activities.

Web Resources

Shorebirds and Horseshoe Crabs
http://www.delawareestuary.org/publications/factsheets/Horsecra.pdf

All About Horseshoe Crabs
http://www.udel.edu/research/explore/loader.html

Smithsonian Migratory Bird Game
http://nationalzoo.si.edu/scbi/migratorybirds/Education/Kids_Stuff/Woth_game/default.cfm

Animal Planet Horseshoe Crab Information
http://animals.howstuffworks.com/arachnids/horseshoe-crab-info.htm

U.S. Fish and Wildlife Service Blog
http://www.fws.gov/news/blog/index.cfm/2011/5/3/Delaware-Betting-on-Survival-in-Delaware-Bay

PBS Video Series About Red Knots and Horseshoe Crabs
http://www.pbs.org/wnet/nature/episodes/crash-a-tale-of-two-species/introduction/592/