Welcome

to the Scientific Models in Adaptive Management edition of *Natural Inquirer*!

In this journal, you will learn about two important processes used to improve the condition of our natural environment. One of these processes, scientific modeling, involves a variety of techniques that help scientists understand or predict things that they cannot actually observe. You will learn about scientific modeling as you read the articles in this journal. Scientific modeling is used in medical, **marine**, space, and environmental science, among other fields. Scientific modeling helps scientists understand how things work now and how they might work in the future. Adaptive management, the second process, is improved by scientific modeling. In this journal, you will learn how scientific modeling helps environmental managers adapt to a changing environment.

Glossary words appear in **bold** and are defined on page 8.

Adaptive Management

Adaptive management is a term used in **natural resource management**. Adaptive management is a process managers use to identify problems and take action. Adaptive management also involves using information and evaluating it. Using these processes, adaptive managers make decisions about future action. Adaptive management is a continual process of learning and adapting. Such management is a way to make the best decisions possible and take the best actions possible about natural resources. Adaptive management is about planning for and acting in an uncertain future.

Because managers must deal with an uncertain future, scientists often use models to help them predict what might happen in the future. Scientists also help managers collect information and evaluate the effect of managers' actions.

A model is a simple representation of a system. Models can be mathematical and include numbers and symbols, or they can be drawings, maps, or illustrations. Another type of model is a physical model, such as a model airplane. Managers often use models to practice adaptive management (**figures 1a–1d**).

Compare and contrast the models on page 5. What is similar about them? First, you may have noticed that all the models are described using a circle. Adaptive management does not have an end point. Adaptive management is like your own learning process. Both adaptive management and your learning process use past learning to try out new things. Other similarities you may have noticed in these adaptive management models include the following:

(a) A design phase in which plans are made.
(b) An **implementation** phase in which action is taken.
(c) An evaluation phase in which what happened following the action is **monitored** and assessed.

Based on these four models, write at least two questions you have about adaptive management. After you have read this journal, have your questions been answered? If not, do additional research to answer your questions.

Figures 1a-d. Four models used to describe and help practice adaptive management. Illustrations adapted from the originals by Stephanie Pfeiffer.

Figure 1a. U.S. Geological Survey model of adaptive management.

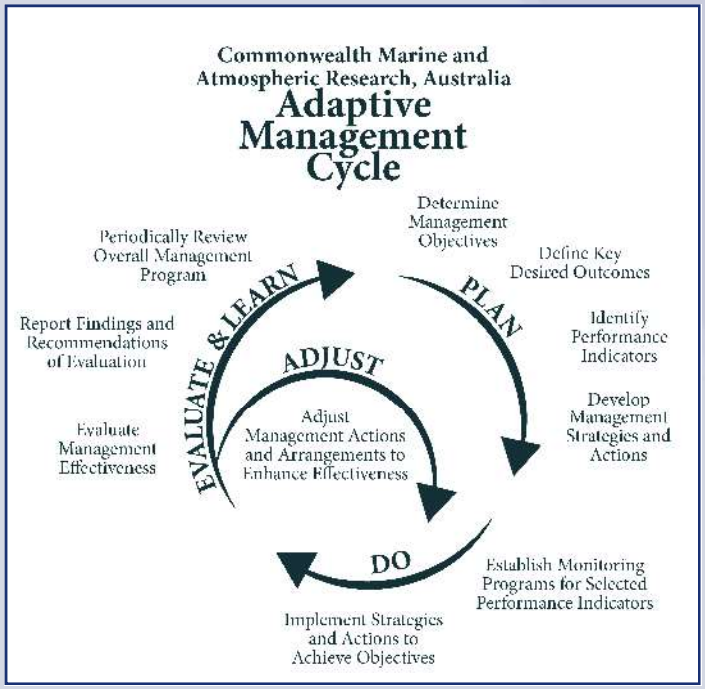

Figure 1c. Commonwealth Marine and Atmospheric Research model of adaptive management.

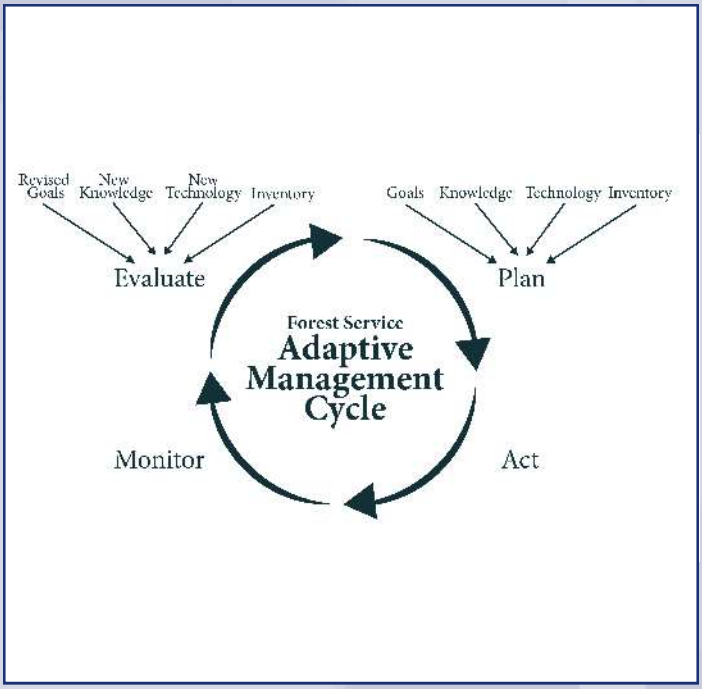

Figure 1b. Forest Service model of adaptive management.

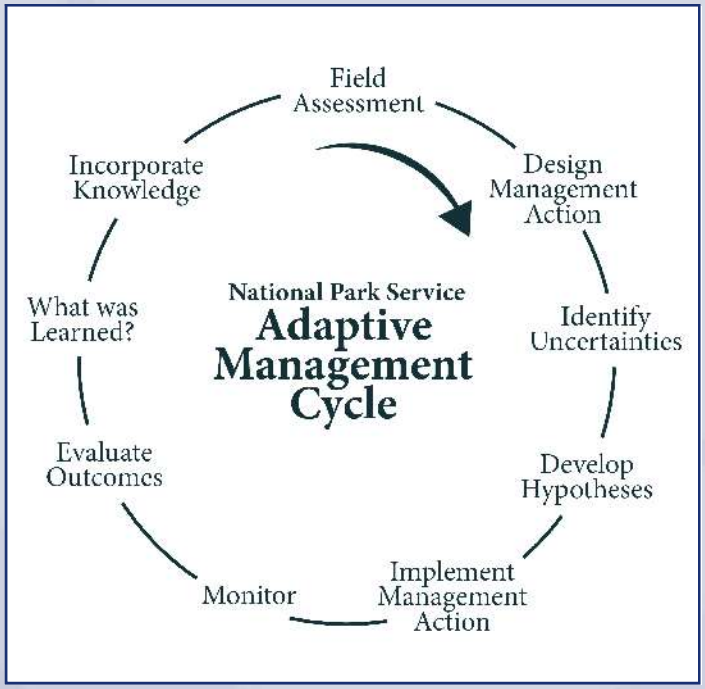

Figure 1d. National Park Service model of adaptive management.

All the models in **figure 1** either state or **imply** that learning through experience helps to make better decisions about management actions.

Examine the National Park Service model **(figure 1d)**. On the right-hand side, you see that adaptive management includes identifying uncertainties. Uncertainty involves being unsure about some things. We are uncertain, for example, about the **magnitude** of climate change. We may be uncertain whether an earthquake or flood will occur, or whether an insect pest will damage vegetation.

Other uncertainties involve human actions. We often do not know what humans will do in a situation. In adaptive management and the models that support it, identifying uncertainties is important.

Adaptive management is a tool that natural resource managers can use to improve the effectiveness of their management through learning. Using adaptive management, managers try something new. They evaluate and learn from the results, then make any necessary changes. After they make the changes, they evaluate again and learn from the results. Managers continue to make any necessary changes. This process continues without an endpoint.

During adaptive management, managers **monitor** and evaluate the results of actions. Monitoring and evaluating first involve identifying what one wants to know about a management action. Then, monitoring includes developing a research plan, followed by collecting, analyzing, and evaluating information. Often, scientists help managers with these parts of adaptive management.

In this journal, you will read about research that scientists have done that can help managers practice adaptive management. In each model in **figure 1**, identify where in the model scientists are most likely to work with managers.

Models

Ironically, one tool used for monitoring and evaluating is not shown in **figure 1**. This tool is the use of models to describe natural ecosystems. Sometimes these models also include human actions. In adaptive management, managers and scientists often use models like those in **figure 1** to describe systems. They also use maps and other illustrations to describe systems.

When working with managers doing adaptive management, scientists often use mathematical models to describe ecosystems. Mathematical models are equations. Mathematical models help scientists predict what might happen in the future (**figure 2**). The models enable predictions to be made by making **assumptions** about the identified uncertainties (See "When Zombies Attack!"). Using mathematical models, scientists help managers understand what might happen if they take various actions. After taking an action, managers monitor and evaluate the effects of that action. They compare the effects with the model's prediction. Where in **figures 1a–1d** would you place the use of models in adaptive management?

Using models in adaptive management helps managers make informed decisions when acting for an uncertain future. Adaptive management provides a way for natural resource managers to keep track of and learn from their actions. Learning is one of the most important elements in adaptive management. In this edition of *Natural Inquirer,* for example, you will read about Denali National Park in Alaska. Park managers at Denali have an important challenge that they face at the beginning of every hiking season. Managers want to open as many trails as possible to hikers. Managers also want to keep noise and disturbance away from nesting

Figure 2. Mathematical models of the average height of 18-year-olds based on their height at age 15. In this model, height at age 18 is uncertain. These models make assumptions about the number of inches boys and girls will grow from age 15 to 18. These assumptions are based on an average of the measured heights of many 15- to 18-year-olds.

$H_{B18} = H_{B15} + 6$
Where H_{B18} = height of boys in inches at age 18, H_{B15} = height of boys in inches at age 15

$H_{G18} = H_{G15} + 1.5$
Where H_{G18} = height of girls in inches at age 18, H_{G15} = height of girls in inches at age 15

If scientists assumed that boys would grow 7 inches between age 15 and 18, how would the first model change?

eagles. Managers, along with scientists, monitor the number and location of active eagle nests every year. They use this information in models. Based on monitoring and modeling results, managers continue to learn about the correct number of trails and which trails to open each year.

Many government agencies use adaptive management. Two of those agencies are the Forest Service and the U.S. Geological Survey (USGS). The Forest Service and the USGS developed this journal to describe their use of scientific models in adaptive management. You can read about these

WHEN ZOMBIES ATTACK!

Mathematical models and other types of models were used in the articles you will read in this journal. The following paragraph describes the development of a mathematical model. Because zombies are not real, the entire model was based on assumptions. The scientists who developed the model contributed the following paragraph.

> Zombies are trendy in popular culture and entertainment. In this paragraph, we describe how we modeled a zombie attack. We used biological assumptions based on popular zombie movies. We first introduce a model for a zombie infection. We illustrate the outcome using numerical solutions. We then change the model to introduce a period during which humans are infected, but not infectious, before becoming undead. We then update the model to include the effects of a possible cure. We examine the effect of regular reductions in the number of zombies. Finally, we develop conditions under which all zombies are removed. We show that only quick, aggressive attacks against zombies can stave off the doomsday scenario: the collapsing of society as zombies overtake us all.

Munz, P.; Hudea, I.; Imad, J.; Smith, R.J. 2009. When zombies attack! Mathematical modeling of an outbreak of zombie infection. In Tchuenche, J.M.; Chiyaka, C., eds. Infectious disease modeling research progress. Ottawa, Ontario, Canada: University of Ottawa: 133–150. This abstract was edited slightly for a middle school audience and approved by P. Munz.

agencies on the inside back cover of this journal. The scientists from these agencies work with natural resource managers and help them with part of the adaptive management process.

USGS scientists work with many groups. These groups include natural resource managers, landowners, State and local governments, Native American tribes, and citizens. Citizens, for example, may be interested in outdoor recreation such as boating, hiking, and wildlife and bird watching. USGS uses adaptive management to involve different groups with different viewpoints and interests in the process. Where in **figure 1a** do you see this part of the adaptive management process?

The Forest Service uses adaptive management to improve the condition of the nation's forests and grasslands. Managing wildland fire by using adaptive management is also an important job of the Forest Service.

In this journal, you will learn how people use scientific modeling in adaptive management to understand and manage the decline in numbers of shorebirds and horseshoe crabs. You will learn how resource managers could use scientific modeling to save cedar trees in Alaska. You will also learn how using models in adaptive management can help managers protect **ecosystems** into the future. If zombie attacks were possible, you would understand the importance of preparing for an attack. Adaptive management is helping managers prepare for an uncertain natural resource future. In a changing world, this preparation is important for everyone.

Glossary

assumption (ə **səm(p)** shən): A temporary belief that can be tested.

ecosystem (**ē** kō sis təm): A system made up of an ecological community of living things. interacting with their environment, especially under natural conditions.

implementation (**im** plə men **tā** shən): The act of carrying out. Accomplishing.

imply (im **plī**): To express indirectly.

ironically (ī **rän** ik lī): Related to irony; an inconsistency between what is expected and what has happened.

magnitude (**mag** nə tüd): The size or quantity of.

marine (mə **rēn**): Of or relating to the sea.

monitor (**mä** nə tər): To watch or keep track of.

natural resource management (**na** chə rəl **rē** sȯrs **ma** nij mənt): The conduct of activities within natural areas to achieve goals.

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