ONE FISH TWO FISH **REDFISH** YOU FISH!

A biological and mathematical exploration of human impacts on a recreational fishery

Katherine White, Maryellen Timmons, and Paul Medders

Many students fish recreationally, but how many consider the impact this has on the fishery? Fisheries science is a broad topic that can be difficult to cover in high school classrooms, where time and curriculum constraints are felt by most teachers. However, many high school curricula call for increased focus on environmental science and sustainability. In response, educators seek innovative ways to present complicated environmental topics at appropriate levels for their students.

The recreational fishing activity presented in this article, "One Fish, Two Fish, Redfish, You Fish!" provides a hands-on, problem-based experience for students; it unites biology, math, economics, environmental policy, and population dynamics concepts. The activity can be completed in one or two class periods with inexpensive, readily accessible materials, and provides adaptive learning opportunities for students.

Further, the One Fish, Two Fish activity allows students to shape environmental policy in a realistic setting and evaluate their peers' work. By focusing on recreational—rather than commercial—fisheries, the activity drives home the connection between students and natural resources and makes an abstract topic more personal.

Common property resources

Fish are both natural resources (i.e., material goods provided by the environment) and renewable resources (i.e., material goods that can replenish their numbers over time). They are also a common property resource. In his essay, "The Tragedy of the Commons," ecologist Garrett Hardin defines this type of resource as one that is owned by no one but used by everyone (1968). His essay states that without restrictions on behavior, people using common property resources will ultimately overharvest (or exhaust) them in what he terms a "tragedy of the commons."

In a tragedy of the commons, multiple individuals acting independently and rationally and considering only their own self-interest will deplete a shared resource even though it is not in anyone's long-term interest. The rationale is that to the individual, in the short term, it makes sense to continue harvesting a common property resource because the negative consequences of doing so are spread among the entire user population in the long term.

FIGURE 1

Materials for Games 1, 2, and 3.

- one writing utensil per student
- one medium-strength magnet per student (circular, plastic-coated ones work best)
- 110 paper clips per group of three to five students
- tape
- bag of extra paper clips
- one calculator per group
- one pencil or craftstick per student (for "fishing pole")
- fishing line or yarn
- management tools paper slips
- coastal development scenarios paper slips
- one sheet of large, blue construction paper per group
- fishing game data sheet (one per group; see "On the web")
- safety goggles (for each student)

This concept can be applied to fish. To an individual fisherman, for example, the benefit of taking one more fish exceeds the negative consequences he or she feels from doing so (i.e., having less fish to catch) because these consequences are spread among all fishermen. Though the fisherman will gain a net benefit from harvesting that fish, the user group as a whole will experience a net loss as the fish population declines.

One reason environmental management proves so challenging is that many natural resources are also common property resources (e.g., fish, clean air, clean water), and managing this type of resource involves the collective expertise of economists, biologists, mathematicians, and sociologists alike. The One Fish, Two Fish activity allows students to gain familiarity with common property resources using fish as a model. Acting as environmental managers, they explore ways to prevent a tragedy of the commons from occurring.

The redfish craze

In this activity, red drum (*Sciaenops ocellatus*), or redfish, provides a concrete example and helps tailor the exercise to students' locations and experiences. We teach in Georgia, where red drum is recreationally and ecologically important, as it is in many southeastern Atlantic and Gulf States. This activity can be modified to better fit another location by selecting a fish species of local importance (see your local Fish and Wildlife Service or State Natural Resources Department for more information).

Casting the line

Prior to the One Fish, Two Fish activity, teachers gather the necessary materials (Figure 1). They create students' fishing poles by attaching a doubled up 13 cm (5 in.) strand of fishing line or yarn to a magnet with tape, and taping the wire or yarn to a pencil or craftstick "fishing pole" (see photo, p. 33). Teachers also print and cut out paper slips that list the fisheries management tools and coastal development scenarios used in Games 2 and 3, respectively. The template for these slips is available online (see "On the web").

Teachers spend the first 5–10 minutes of the activity introducing students to the fish species chosen for this activity and the various types of resources (e.g., natural, renewable, nonrenewable, common property). This provides context for the activity and allows students to begin brainstorming the many ways humans interact with fish.

Game 1: Free recreational harvest

In Game 1, students fish for paper clip red drum from a common body of water (i.e., blue construction paper) using their magnetic fishing rods. They do not follow harvest regulations at this point, since the first game is meant to illustrate a tragedy of the commons.

FIGURE 2

Game 1 procedure.

Free recreational harvest of red drum fish (20 minutes).

1. Demonstrate the fishing game activity for students.
   a. Give one data sheet (see "On the web") to each group so students can follow along under the "example" column (each group works from one data sheet).
   b. Place blue construction paper in the center of the workspace to represent water and dump 110 paper clip "red drum" onto it.
   c. Explain that each student will use a pencil or craftstick "fishing pole" to fish for red drum over six seasons, each of which are five seconds long.
   d. Demonstrate the proper fishing technique: Gently dip the magnet up and down without dragging it through the clips.
   e. Explain the rows of the data sheet:
      - The "total population" is the number of red drum in each group's water at the beginning of each season.
      - The "number caught" is how many red drum each group catches per season.
      - The "spawning population" is the red drum that are having offspring.
      - The "young-of-the-year" (YOY) are the new offspring added to the population.
   f. Add the spawning population to the YOY from the previous season to get the starting total population. Have all students fill in "110" under "total population" for Season 1 in the example section.
   g. Count five seconds as you fish for one season.
   h. Count how many fish were removed and have students write this under "number caught" within the example column on their data sheets.
   i. Set these harvested fish aside.
   j. Instruct students to subtract the "number caught" from the original population to get the new "spawning population," the adult fish that are left after harvest.
   k. For every 10 fish in the spawning population, add 1 fish to represent new births for that season (e.g., if there are 33 fish in the spawning population, add 3 back to the population). Place this number in the YOY row on the datasheet.
   l. Add the appropriate number of paper clips back to your population to account for births (YOY).
   m. Instruct students to add the spawning population (adults that were not caught) to the YOY (new births) to get the total population for the next season.
   n. Repeat for one to two more seasons until students understand the concept.
   o. Ask several students to predict what they think will happen to the red drum population over time.
2. Divide students into groups of three to five.
3. Have one student per group come up and receive his or her group's materials: 1 sheet of blue construction paper, 110 paper clips, fishing poles, safety goggles, and a calculator.
4. Students fish for six seasons, or until all the fish are gone.

The teacher begins by demonstrating the logistics of the game (Figure 2). The purpose of this demonstration is to illustrate the "fishing" technique and show students how to properly fill out their data sheets. Students then "fish" within small groups for six seasons, and witness a tragedy of the commons as they overharvest their fish. (**Note:** The number of fish in the population each year is equal to the original population, plus new offspring, minus the number of fish caught.)

Before moving on to Game 2, the teacher leads a class discussion about the main points of Game 1 using the questions listed below (suggested answers are available online [see "On the web"]):

- What happened to groups' red drum populations over time? Did trends match our predictions?
- Why did the red drum population decrease?
- What does *sustainable* mean?
- How could we have harvested sustainably? How many fish could each group have taken per season and maintained the total population at a constant number?

- From an individual's perspective, why did we overharvest the red drum, even though we saw that our actions were causing the population to decrease?
- What can we do to prevent a tragedy of the commons?

Game 2: Management tools

In Game 2, students' goal is to maintain or increase their fish population over time. Each group receives a paper slip listing one type of fisheries management tool and then decides how to use it to best achieve their goal (Figure 3; slips are available online [see "On the web"]).

After groups have implemented their tools and finished fishing, the teacher brings the class together for a 10-minute discussion. (**Note:** If the teacher plans to complete the optional poster session after Game 3, this discussion should be brief, as groups will present specifics during their oral presentations.) He or she draws a table on the board listing each group, its management tool, how the group implemented this tool, and the final red drum population count. Ultimately, students should understand how management tools vary in effectiveness, and compare their management tools to those used by their state.

Keywords: Overfishing
at *www.scilinks.org*
Enter code: TST021101

Using the groups' results, the teacher then discusses the pros and cons of each type of management tool, emphasizing real-life feasibility. At the end of the discussion, the state's fishery management plan is discussed, using the following questions as a guide (suggested answers are available online [see "On the web"]):

FIGURE 3

Game 2 procedure.

Maintaining or increasing your red drum population (10 minutes).

1. Use the same game pieces and procedure as in Game 1.
2. Tell students that the purpose of Game 2 is to maintain or increase their red drum population.
3. Give each group a paper slip containing one of the following management tools (see "On the web" for cut-out slips):

   - *Bag or creel limits:* Each person can only catch ___ fish per season.
   - *Open or closed seasons:* Everyone can fish every ___ season(s).
   - *Access quotas:* Only ___ people in your group can fish each season.
   - *Stocking:* Add ___ extra hatchery-reared fish to your population at the end of each season (maximum of 10 extra per season).

   Groups choose how to specifically implement their tool. The same tool must be implemented for the full six seasons, and students should not mix methods.
4. Student groups fish for six seasons.

Addressing the Standards.

This activity addresses both the National Science Education Standards (NRC 1996) and the Essential Principles of Ocean Literacy (NGS and NOAA 2006).

The Standards	Ocean literacy principles
Unifying Concepts and Processes (p. 104) • Evidence, models, and explanation **Life Science** (p. 181) • Populations and ecosystems • Interdependence of organisms **Science in Personal and Social Perspectives** (p. 193) • Populations, resources, and environments • Natural resources • Science and technology in local, national, and global challenges	• The ocean supports a great diversity of life and ecosystems. (Essential principle 5) • The ocean and humans are inextricably interconnected. (Essential principle 6)

FIGURE 4

Game 3 procedure.

Coastal development scenario (10 minutes).

1. Use the same game pieces and procedure as in Games 1 and 2.
2. Tell students that the purpose of Game 3 is to create their own management plan in response to a coastal development issue. Define coastal development as "the phenomenon of people moving to the coast and altering its environment."
3. Give each group a paper slip with a coastal development scenario. Each slip contains details about one of the following scenarios (these can be modified to better fit students' geographic location):
   - Increased fishing pressure due to increased size of angler population
   - Increased fishing pressure due to a revival of the blackened redfish recipe (a popular dish from the 1980s that scientists were concerned would greatly deplete the red drum population in the Gulf of Mexico)
   - Fish kill due to toxic algal bloom caused by increases in nonpoint-source pollution from an expanding coastal human population (e.g., farms, lawn fertilizers, human waste)
   - Fish kill due to factory toxins (point-source pollution from a new factory)
   - Fish nursery habitat destruction in advance of a new neighborhood, decreasing young-of-the-year survival

   Groups create a plan to address their scenario and implement this plan for the full six seasons.

- Which management tool was most effective? Why?
- Would you be able to implement your tool in the same manner in real life? Why or why not?

Game 3: Coastal development scenarios

In the third and final fishing game, students explore how coastal development can affect a recreational fishery. *Coastal development* is a term used to describe the phenomenon of people moving to the coast and altering its environment. It can also encompass human development at any land-water interface, such as lakes, streams, and rivers (for more information, see "On the web"). Each group receives a paper slip with one development scenario and then decides which management tool to use in this situation (Figure 4).

Optional group poster and presentation

At the teacher's discretion, student groups can prepare a virtual poster using Microsoft PowerPoint or a similar program and present it to the class (see "On the web"). Students graph and interpret their data from Games 1, 2, and 3, and summarize the main points of this exercise.

The poster requires that students conduct research on a real-life example of their coastal development scenario and critically compare it to their group's management plan from Game 3. Students in the audience take notes and critically evaluate the presenting group's management plan, using a peer-evaluation prompt that is available online (see "On the web").

Reeling it in

As students conclude the One Fish, Two Fish activity, they should be able to express how it illustrates a tragedy of the commons and list various measures used to prevent this from occurring. They should also be able to connect their real-life fishing activities with fish population numbers. The following questions can be used to guide a 10-minute wrap-up discussion (suggested answers are available online [see "On the web"]):

- Summarize how this activity illustrates a tragedy of the commons. Specifically, what was the common property resource and why? What were the costs and benefits to each fisherman?
- Summarize how this activity illustrates a solution to the tragedy of the commons.
- When you go fishing, can you keep each fish you catch?
- What can *you* do to help stabilize the red drum (or other fish species) population?

Catch and release

Fisheries and fisheries management are increasingly pertinent topics in today's high school classrooms, as water-related concerns move to the forefront of our collective environmental conscience. Through hands-on engagement and problem-based learning techniques, this activity allows students to exercise critical-thinking skills and gain a better understanding of how their actions can reverberate through natural systems. Students have the opportunity to model a real biological system—they can physically "fish" and see the results, cementing in their minds humans' impact on the natural world.

Students also gain exposure to other anthropogenic influences on aquatic habitats, such as habitat destruction, eutrophication, and toxic pollution. They are encouraged to problem solve and devise their own management plans in the face of negative environmental issues. By working through this planning process, comparing their work to that of professional scientists, presenting their findings, and writing peer-evaluations, students learn to think critically about what it takes to make reasoned decisions about

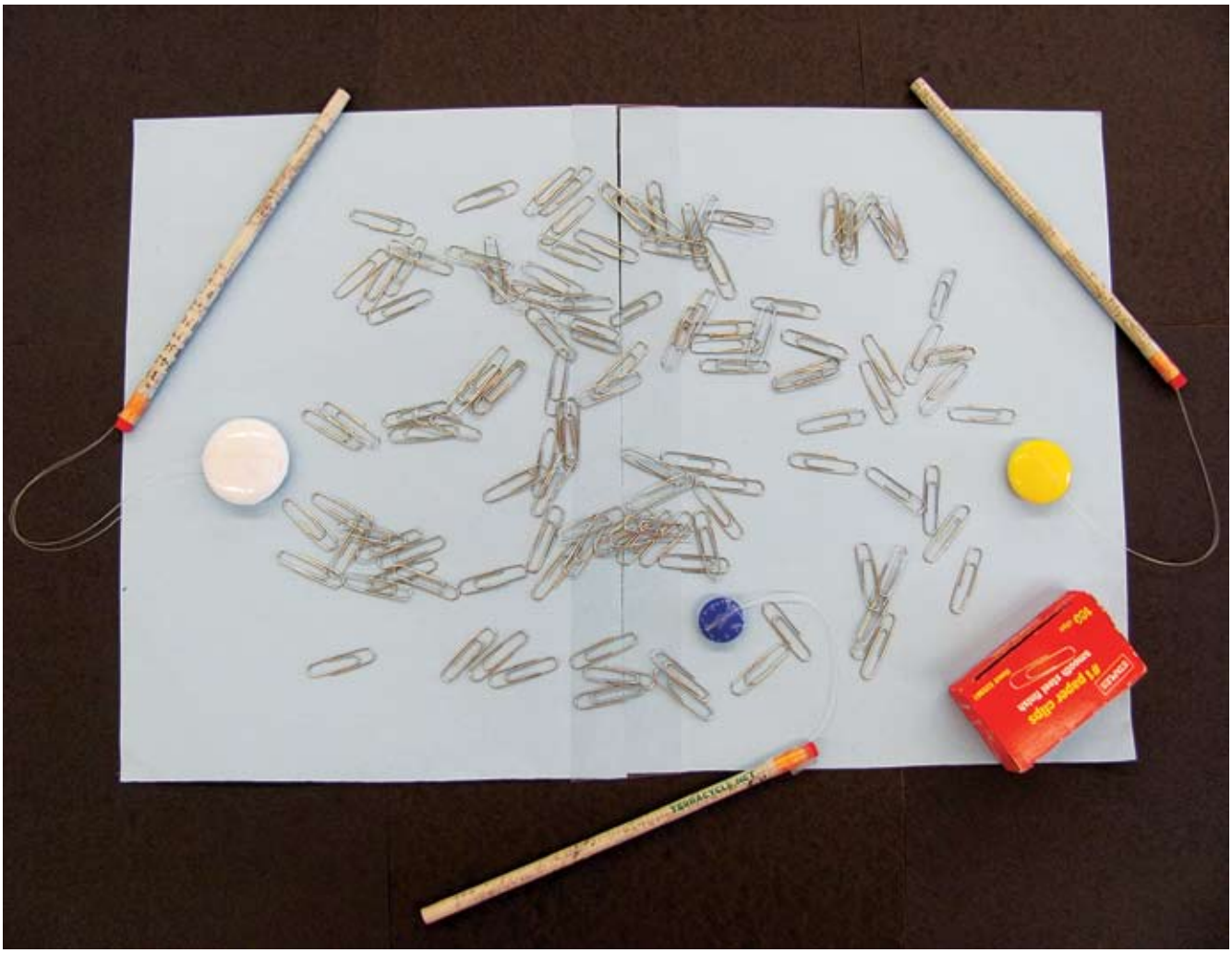

PHOTO COURTESY OF THE AUTHORS

Fish setup for Game 1.

our environment and how crucial it is for a productive, functioning citizen to understand environmental issues.

At the very least, this activity presents students with a way to have fun while learning; at best, it helps shape their awareness of environmental issues, influences some to become better stewards of our planet, and encourages others to seek innovative solutions that align human needs with those of the environment. ■

Katherine White (kew36@cornell.edu) *is a graduate student in education at Cornell University; Maryellen Timmons* (mare@uga.edu) *is a marine education specialist at the University of Georgia's Marine Education Center and Aquarium, a branch of the Marine Extension Service in Savannah; and Paul Medders* (paul.medders@dnr.state.ga.us) *is an angler education and public outreach specialist in the Coastal Resources Division of the Georgia Department of Natural Resources in Brunswick.*

Acknowledgments

This activity was developed as part of a grant awarded by the Georgia Sea Grant program in 2009 that funds four recently graduated college students for an 11-month teaching internship at the University of Georgia's Marine Education Center and Aquarium, a branch of the University's Marine Extension Service. Activity development funded by Georgia Sea Grant 2009-2010 E/EDU-1-Timmons.

On the web

Additional resources, slips, data sheet, suggested answers to discussion questions, and more: *www.nsta.org/highschool/connections.aspx*

References

Hardin, G. 1968. The tragedy of the commons. *Science* 162 (3859): 1243–1248.

National Geographic Society (NGS) and National Oceanic and Atmospheric Administration (NOAA). 2006. *Ocean literacy: The essential principles of ocean sciences K–12.* Washington, DC: NGS.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.