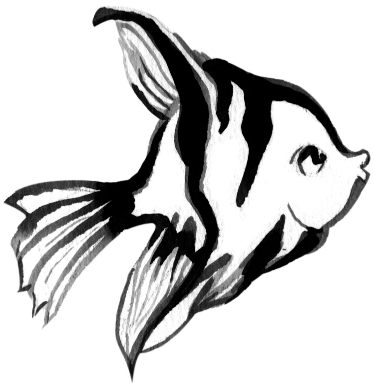

One Fish, Two Fish

Balancing Economy with Ecology as a Fishery Manager

Paul H. Dunn
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Abstract. The ocean provides humanity with many services and goods, including clean air, minerals, and food. Sustainable use and management of our marine resources are important to ensure that these resources are available for future generations. The turn-based activity presented in this article teaches students the challenges of managing a sustainable fishery, including the difficult task of accurately estimating population sizes. It also shows students that finding a balance between the environment and economic gain is possible but takes cooperation and work.

Keywords: fishery, natural resources, population, sustainability

Humans are heavily dependent on ocean resources. More than half of the people in the world live within 100 km of a coastline and rely on the ocean for food, jobs, and many other resources (Vitousek et al. 1997). Commercial fishing is an important part of the economy of communities in every coastal nation of the world (Pew Oceans Commission 2003). In the United States alone, fisheries contributed $28.6 billion to the gross national product in 2001 (ibid.). Although humans living near the coast rely more directly on ocean resources, those living inland also depend on the goods that the ocean provides, including clean water and air, as well as minerals, medicines, energy, and food (National Geographic Society et al. 2007). However, our dependence on the ocean as a source of food and income has led to the overfishing of many populations of marine organisms (Vitousek et al. 1997). This overfishing has caused the extinction or near extinction of many marine species, such as Steller's sea cow (*Hydrodamalis gigas*; Carlton et al. 1999), the Caribbean monk seal (*Monachus tropicalis*; ibid. 1999), and the white abalone (*Haliotis sorenseni*; Tegner, Basch, and Dayton 1996). Tragic stories like these underscore the importance of learning how to manage populations of living animals and of passing on knowledge to the next generation. Sustainable use of current ocean resources is essential to guaranteeing that the resources humans need and the jobs they provide are available in the future.

This activity introduces students to challenging questions such as the following: How do we best manage our natural resources and achieve sustainability? Can we strike a balance between the livelihood of people (i.e., fishers) and the natural balance of the seas (i.e., healthy fish populations)? The math, graphing, critical thinking, and reasoning skills required for this lesson make it ideal for older elementary and middle school students (grades 4–8). Although this activity does not require supplemental information, it could be enhanced by including the concepts and ideas presented in this article in a unit on conservation and resource management.

Objectives

Students learn (1) the importance and challenges of sustainability when taking resources, (2) what random sampling is and how it can be used to estimate animal population sizes, and (3) the importance of a healthy environment to the economy.

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Materials

- Several different dry food items, such as macaroni (16 oz bag), beans (24 oz bag), rice (14 oz bag), or crackers (8 oz box), representing animals in the kelp forest
- One large bag of small, hard-shelled candies, such as Skittles (16 oz), representing candyfish
- One tablespoon measure per group
- One small paper bag per group
- One copy per group of the worksheet for recording results (see the Appendix)

Procedure

1. Place 1 cup (16 tablespoons) of a mixture of food items, including both dry items and candy, into each of the paper bags prior to the beginning of the activity. Start with about 30 pieces of candy per bag, and record the exact number of candies in each bag.

2. At the beginning of the activity, write the goal of the game on the board: to have a healthy fishery and earn the most fishing points of all the fisheries in the class. Then present the rules to the students, drawing on the sample introduction below:

> Many renewable natural resources are important for our culture and our economy. However, if we remove too many of these resources, we may run out forever. In our activity today, you will be in charge of a candyfish fishery in the imaginary city of Kelptown. The candyfish is a highly prized species of fish found in the underwater kelp forests. It is known for its sweet insides and colorful exterior. Each candyfish reproduces and makes one baby candyfish every round of the game.
>
> Your job is to carefully manage this fishery to make sure the fish population survives. People and our economy need to harvest some fish to survive. If they do not get the fish they need, the government and citizens of the city will be unhappy. Because the kelp forest is limited in size, there is also a limit on how many candyfish can live there. However, if too many candyfish are removed from the kelp forest, you could harm your fishery so badly that the candyfish may never come back.

3. Divide the class into groups of four. Assign the roles of sampler, counter, grapher, and recorder to the members of each group. It may work best to rotate these roles within the group so each student has the opportunity to experience each task. Give each group a worksheet to record the results of the activity (see the Appendix).

4. Explain how each round of the game will proceed.

- *Sampling.* First, have each group sample its kelp forest (paper bag) to estimate how many candyfish are in the fishery. Explain that it is often impossible to count every living thing in an ocean habitat. Therefore, fishery managers take and count small random samples of fish instead. Then, the fishery managers can use math to estimate the total amount of fish on the basis of the number of fish they sampled and the size of the whole area. Tell students that the total amount of living things in the kelp forest is about 16 tablespoons, which includes animals other than candyfish. Each group's sampler will take a spoon and, without looking, remove four tablespoons of the mixture (or animals) from the bag. Remind students that they may not look to see exactly what is inside the bag because this would be impossible in a real kelp forest.
- *Counting.* Next, the counter in each group will determine how many candyfish were removed from the kelp forest in the 4 tablespoons removed by the sampler. The recorder should write down the number in the "sample total" column of the worksheet. All animals that were removed, including the candyfish, should now be returned to the bag.
- *Estimating.* To estimate the total number of candyfish in the kelp forest, we multiply the number of candyfish we counted in the sample by 4 because 4 out of 16 tablespoons (i.e., one-fourth of the total amount) of living things were sampled. For example, on the basis of a 4-tablespoon sample containing 6 candyfish, an estimate of the population for the entire kelp forest would be 24 candyfish. After each group calculates an estimate for its kelp forest, the recorder should write this number in the "population total" column of the worksheet.
- *Fishing.* The students in each group must now decide how many candyfish they will let the fishers remove during this turn. Ten candyfish per turn is the absolute minimum the fishers require. For each extra candyfish above 10 that the fishers remove, the group receives 1 fishing point. If the kelp forest does not contain enough candyfish for the fishers, they will become upset, and the group will lose 1 fishing point for each fish below 10. Once they have made their decision, students take turns fishing with the spoon until their limit is reached. The group's recorder should write down the number of candyfish removed in the "fish removed" column, figure out the estimated population of candyfish remaining in the kelp forest by subtracting the number of fish removed from the estimated total, and record this number in the "population after fishing" column.
- *Scoring.* Record how many fishing points each group earned during the round and remind students that the group with the most points at the end of the game will win. Collect the candyfish that were caught during the round and ask the students to replace all non-candyfish material in their kelp forests.
- *New fish.* Remind the students that each candyfish makes one baby per turn. Each group should receive one new candyfish for each candyfish remaining in their population according to the students' estimate. The recorder should write down the number of new fish in the "new fish" column of the worksheet and add this number to

the "population after fishing" number to come up with the "new population size" number. Add the new fish directly to each group's kelp forest, making sure not to let any group amass more than 50 candyfish at any one time. Make sure students understand that 50 candyfish is the kelp forest's carrying capacity (i.e., the maximum number of fish that can live there).

5. Tell the grapher in each group to plot the group's new candyfish population for that turn, including the babies, on the back of the worksheet (see the sample graph in Figure 1).

6. Continue to the next rounds, which are conducted the same way as the first. You can end the activity after any number of rounds. We have found that time, not attention, is most often the limiting factor. Remember that the more rounds you play, the more the conservative fishing strategies will pay off. We recommend at least five rounds to clearly demonstrate the lesson objectives.

7. Follow the activity with a class discussion about how each group fared in the fishery management world, using the groups' graphs to illustrate their results. Ask these questions: Which strategies were most effective? Which were least effective? Did the strategy change because of what had happened in earlier rounds? What factors could make the job of a fishery manager difficult (e.g., inaccurate sampling, overfishing, unhappy fishermen)? Why is it important to have good managers in charge of our fisheries? What would happen if we were all fishing from the same kelp forest? What would happen if a few fishermen did not follow the rules and took more than their share of fish?

Discussion and Findings

Through a series of activities, this lesson demonstrates the importance of conservation and sustainable practices for the environment and economy. Students use basic mathematical principles and critical thinking skills to agree on the best possible management practice for their fishery.

The first few rounds of the game go slowly until the students become comfortable with the different tasks and calculations. It is possible to do a few practice rounds as a class instead of explicitly presenting the rules before the activity begins. You must also decide how much help to give students with the math and calculations. In our experience, fourth graders needed quite a bit of guidance, but middle school students should pick up the math more easily.

Our students were highly engaged during this activity. There was clear excitement in every classroom as the students chose their management strategy and began to catch the candyfish. The teamwork element of the activity led to active involvement by most group members. Students were required to discuss problems and compromise to deal with differences in opinion—skills of vital importance not only in the game, but also in managing a real fishery.

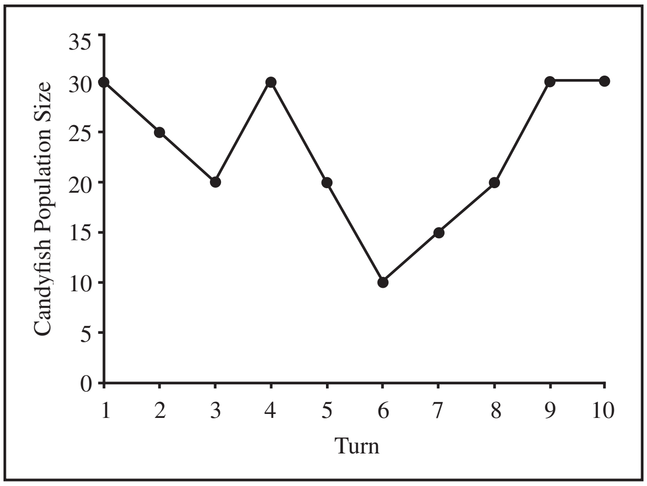

FIGURE 1. Sample graph of population size versus turn.

Although every class has its own personality and the lesson never goes exactly the same way every time, certain situations occur frequently. A scenario that repeats itself in almost every class is that at least one group will attempt to get ahead early by overfishing at the beginning. This group will quickly amass many more points than more conservative groups. However, as the game progresses, these fast-starting teams will remove all of their candyfish and crash their fishery by around the third turn. This is disappointing for the members of these teams, but the concept of conservative, sustained fishing being a better long-term strategy certainly sets in by the time turn 10 comes around and the slower-starting teams have many more points. Most students who adopt less successful strategies are eager to play the game again, determined not to make the same mistake twice.

If all of your groups choose similar strategies, you may want to mandate the number of fish certain groups remove to demonstrate the key points of the lesson. It is also important to make sure your students are sampling carefully with their tablespoon. During past lessons, some students would clearly take more than one tablespoon for their samples (i.e., a heaping tablespoon). These groups often had highly inaccurate estimations of their fish populations, which occasionally led to overfishing and collapse. However, this mistake may provide a helpful lesson about the importance of being careful in science and reveal how difficult it is to estimate and manage living resources.

Extensions and Cross-Curricular Applications

This lesson can be extended to include a discussion on *bycatch* (the accidental removal of unwanted species). Remind the students about all the other items that came up with the candyfish when they were fishing. In real life, animals and plants are often accidentally caught when people are fishing for something else. Commercial marine fisheries around the world discard 27 million tons of bycatch animals annually, a quantity nearly one-third as large as total landings (Alverson et al. 1994). Often these bycatch animals and plants do not survive the trauma of being caught. Some examples of bycatch include dolphins, sea turtles, sharks, seals, sea stars, algae, coral, crabs, and fish. Extend the lesson by asking students questions such as these: How could we reduce or eliminate bycatch? How could removing bycatch animals from our food web affect the candyfish themselves?

This lesson can also be extended with a discussion of possible fishing regulations. Possible questions for this discussion include the following: What kind of rules could we make to help keep the number of candyfish we remove at sustainable levels (e.g., regulate the number of scoops permitted, limit the number of fish that can be removed, change the fishing gear to chopsticks or smaller spoons)? What would you do if your fishery collapsed? How could you recover a collapsed fishery?

The tragedy of the commons is another theme that could easily be incorporated into this lesson. What happens when each person acts only in his or her self-interest? What happens when we think so much about winning big in the short term that we do not consider the long-term effects of our actions? Would the game have turned out differently if we had stopped after only two or three turns?

Additional extensions might focus on some of these questions and issues: Besides overfishing, what are some other things that could cause populations of fish to change (e.g., natural disasters, predators, food shortage, man-made disasters like oil spills)? Inaccurate sampling can cause big problems for fishery managers. What if you had randomly pulled out most of your candyfish in one sample scoop? What would be the consequence of overestimating your candyfish population size? How could we try to make our sampling more accurate? What are some historical examples of plants or animals that have gone extinct because they were overexploited? Are there any animals that are endangered or threatened with extinction today due to overexploitation? Are there any examples of animals making a comeback from the brink of extinction?

Conclusion

The game presented in this article is a fun and engaging activity that teaches students the importance of sustainability, as well as how scientists estimate and manage renewable natural resources. Through this turn-based activity, students (1) develop their interpersonal communication and teamwork skills, (2) learn how to use mathematics and graphing in science, and (3) understand how the environment and the economy are linked together. These concepts are highly relevant in the world today, where there is often a perceived conflict between environment and economy. It is important for students to understand that, although there is rarely a quick fix to these difficult and controversial problems, if people listen to the needs of others and work together, they can find solutions that work and are fair for everyone.

National Science Standards Addressed

This article addresses the following life science standards: characteristics of organisms, life cycles of organisms, and organisms and environments (levels K–4); structure and function in living systems, reproduction, and populations and ecosystems (levels 5–8); and interdependence of organisms (levels 9–12; National Research Council 1996).

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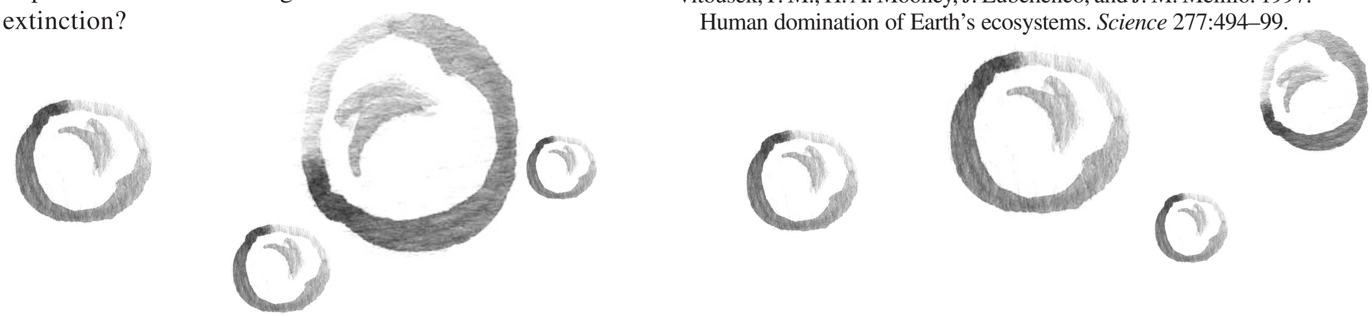

Appendix
Fishery Managers Worksheet

Round	Sample total	Population total	Fish removed	Population after fishing	New fish	New population size
Example	6 candyfish	6 × 4 = 24	10	24 – 10 = 14	14	14 + 14 = 28
1		___ × 4 =				
2		___ × 4 =				
3		___ × 4 =				
4		___ × 4 =				
5		___ × 4 =				
6		___ × 4 =				
7		___ × 4 =				
8		___ × 4 =				
9		___ × 4 =				
10		___ × 4 =