CATCHING THE WRONG SPECIES

Engineering a solution to the problem of bycatch in the tuna fishery

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Most of our students enjoy seafood, and studies show that overall seafood consumption in the United States is rising (Agriculture and Agri-Food Canada 2012). Other research estimates that as much as 40% of the seafood caught worldwide is discarded, while countless sharks, whales, dolphins, birds, sea turtles, and other animals are unintentionally killed or injured by fishing gear (Kledjian et al. 2014). This capture of non-targeted species—known as bycatch—is a worldwide challenge to maintaining sustainable fisheries and protecting endangered species.

In this activity, students use a simple classroom model to design and test solutions to bycatch in the tuna fishery. They collect and use data to optimize their design and consider how their model might look in real life. We tested the lessons in a high school marine science course, but it could be adapted to an environmental science or biology course from eighth grade up. After this lesson, students should be able to:

- discuss the need for sustainable fishing in the world's oceans
- design, evaluate, and refine a solution for reducing bycatch
- relate their model design to real life

The activity takes 90–100 minutes as written—less if background reading is done as homework or more if discussion of the reading or data analysis is extended or if students do deeper research of real-life bycatch reduction strategies. Based on your classroom location, consider focusing on a nearby body of water (and its particular species) rather than the ocean.

Students should work in groups of four. We've had good results blending students who have diverse talents and skill levels.

Engage

Begin by asking students if they ever eat seafood, reminding them of popular foods such as canned tuna and shrimp. Explain that students will be simulating with household materials (Figure 1, p. 26) one of the ecological effects of fishing. First, show students the contents of the mop bucket (representing the ocean) and refer to what each item represents as you record it on the board or chart paper (e.g., red beans = squid). Have one student come up to represent a fisher wanting to catch tuna (marbles). Have the fisher dip the paper cup into the ocean (bucket) without looking and scoop up a cupful of "catch." The fisher can then gently pour out the catch onto a paper plate. Discuss the catch, using questions such as:

FIGURE 1

Materials and preparation.

Materials (for eight groups of students): Feel free to vary the materials and/or allow students to use other materials available in your lab room.

- 20 8 oz paper cups
- 20 3 oz paper cups (bathroom size)
- 30 coffee filters (basket style)
- 50 frozen treat sticks
- 20 small (cake size) paper plates
- 1 roll aluminum foil
- 4 rolls masking tape
- 4 rolls transparent tape
- 12 pairs scissors
- 60 pipe cleaners
- 2 bags dried garbanzo beans
- 2 bags dried red beans
- 2 bags dried white beans
- 120 marbles
- 40 table tennis balls
- 8 pint-size deli containers, with lids
- 1 two-gallon mop bucket

Preparation of "species":
In each small container, place:

- ¼ cup dried garbanzo beans (represents shrimp)
- ¼ cup red beans (squid)
- ¼ cup white beans (herring)
- 12 marbles (tuna)
- 4 table tennis balls (dolphins)

In the mop bucket, place at least double the amount of "species" materials placed in the small containers. Lay out the rest of the materials on a table.

How many tuna did the fisher catch? What else did the fisher catch? If this were real life, why would this be a problem?

Introduce the following terms, using examples

- Target species: The species that the fisher seeks to catch, in this case, a species of tuna.
- Non-target species: Unwanted species found in the same waters.
- Bycatch: Non-target species caught in the fishing gear.

Explain that bycatch is common (up to two billion pounds annually in the United States [Kledjian et al. 2014]) and typically discarded. Ask students to identify examples of non-target species caught in this simulation. Discuss other non-target species that can be caught in fishing gear, e.g., sharks, marine mammals, and sea turtles. Ask students to reflect on the unnecessary loss of individuals of these populations, some of which are threatened or endangered.

Distribute the Bycatch Engineering Design Data Table (Figure 2). In the row for "original net," direct students to record the number of individuals of non-target species caught and the number of individuals of target species caught. They can then calculate the percentage of total catch represented by non-target and target individuals.

Next, have students read the article on sustainable fishing (see "On the web") or a similar article and briefly summarize its central ideas in their own words. We had students use a jigsaw strategy. Each member of a team focused on one section of the article and then discussed that part with other students on their team. They used a graphic organizer to record their understandings (see "On the web" for a link to a graphic organizer and photos of the completed graphic organizer). To save time, students can read the article as homework before the day of the activity.

Discuss the article, using questions such as: How would you explain sustainable fishing in your own words? What is bycatch? Why is it a problem? What is overfishing? Why is it a problem? Using online visual aids (see "On the web"), compare types of fishing gear, the ways fish are caught, and their potential for bycatch. Ask: Which types of gear result in a lot of bycatch? *(purse seine, gill nets, longlines)* Which types of gear result in less bycatch? *(troll/pole, spearfishing)* Why? What are the advantages/disadvantages of each type—for the fisher? For the environment?

Explore

Explain to students that they will engineer a new fishing net to reduce bycatch in our model ocean (bucket) and also to exclude dolphins. Show them the available materials and note that their net must be able to scoop "tuna" (marbles) from the bucket. Direct students to their data table. Say that each group must sketch two possible designs, then build one as a prototype (Figure 3). Provide students with the design rubric (see

FIGURE 2

Bycatch engineering design data table.

Students use this table to record testing results from each prototype. Their goal: Design the best net to reduce the % of non-target species caught and exclude dolphins.

	# individuals of target species caught	# individuals of non-target species caught	Total # individuals caught	% target species (# target/ total #)	% non-target species (# non-target/ total #)	Types of non-target species caught
Original Net						
Prototype 1						
Prototype 2						
Prototype 3						

"On the web"). Students can test their prototype in their own small container or in the shared bucket. Then they should record the number of individuals caught in their "net" and discuss with their group how best to optimize the design.

Groups should go through this test-then-optimize process at least three times before demonstrating their final prototype in front of the class. Remind them to record their data each time in their data tables and calculate the percentages of target and non-target species caught. Give students a clear time limit, e.g., 16 or 18 minutes, to ready their final prototype. This demonstrates that time is often a constraint in real-world engineering design. Use an online stopwatch or another visible time-management tool to help keep groups on task. As the teams work, walk around and ask probing questions such as: What change did you make after your last test? Why? How do you know, based on the data, that your last prototype was better than the previous one?

While students are working, create a bycatch data table on the board or on chart paper (or prepare it before class). Once time has expired, direct all groups to stop working and place their prototypes on a visible front table.

Explain

Designate a recorder to document data in the table you put on the board and two students to calculate the percentages (to double-check one another). Have each group come up to the bucket and demonstrate their device, then quickly count their "catch" and return the "seafood" to the bucket. The teams should also briefly explain their engineering process that led to their final prototype prior to performing their demonstration, noting how they optimized their models based on the data they collected.

Once all groups have presented, discuss the success of the designs. Encourage students to use data from the class data

FIGURE 3

Design in action: Students building their fishing net prototypes.

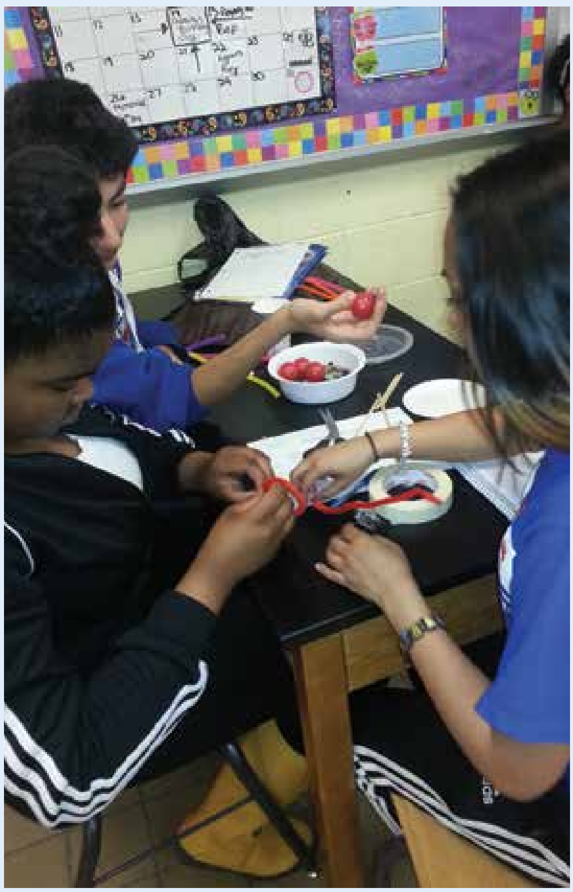

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table to support their answers. Use questions like: Which design was most successful? How do you know? How did your prototype change from the first to the final design? Why? Remind students about the engineering process (Figure 4).

Elaborate

Ask students to discuss in their groups how the most successful designs could be created in real life, i.e., out of nets and lines rather than pipe cleaners and coffee filters. Then discuss their ideas as a class. Also talk about how engineers would work with scientists to first create a model and then a real-life prototype to be tested and optimized. Ask students to describe limitations and considerations that real engineers would consider, e.g., cost, safety, ease of deployment of the device, reliability. When considering these factors, which designs would likely be most successful in real life? Why?

Students should also consider what other factors besides size can be used to separate target species from bycatch. Engage students in a "Think, Pair, Share," in which they first think about this question individually, then discuss it with a partner, and then share the partners' ideas with the class. Possible answers include separating species by target habitat, by avoiding areas through which non-target species migrate, or by changing the time of day that fishing takes place.

Share examples of successful bycatch reduction efforts by showing NOAA videos (see "On the web"). Discuss how scientists used data to determine whether the solutions were effective. Emphasize that scientists and engineers work together, using scientific data to assess design effectiveness, much as the students did when testing their prototypes.

As consumers of the ocean, it is up to us to consider how we use its resources and, for example, the types of fishing practices we support. When we purchase seafood in a store or restaurant, we should be cognizant of its origins. Many grocery stores now label fish by country of origin and method caught. Introduce students to resources that can give us information about sustainable seafood choices. Some of the recommended websites also support apps to aid in consumer decision-making.

As an extension, have students survey local supermarkets and/or restaurants and assess the availability of sustainable choices.

Evaluate

Return the discussion to the initial article that the students read. Remind students that the issue of bycatch is just one part of the larger issue of sustainable fishing. As a class, brainstorm a few ideas to address the issue of overfishing. Ask students to consider why managing fishing in a global ocean is such a challenge.

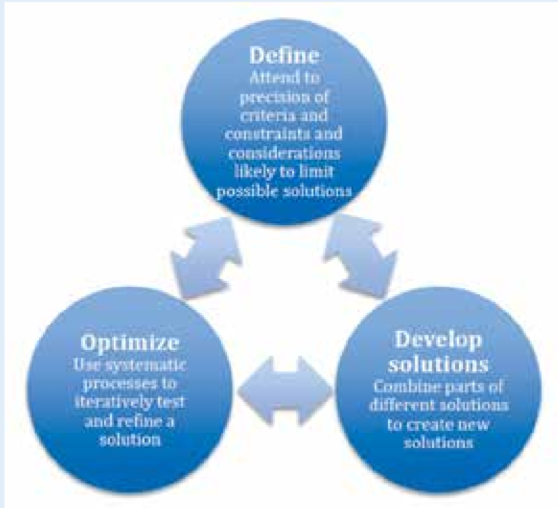
Assign the following task for homework, providing students with links to the online resources from this article. Also provide them with the Evaluate Rubric to guide their work.

Homework assignment: Write two or three paragraphs that answer the questions below. Use examples (ideas, quotes, and data) from the "Sustainable Fishing" article, your in-class activity and worksheet, and the online resources, to support your ideas.

- What is bycatch? Why is reducing bycatch important?
- Why is sustainable fishing important?
- How can engineering design help to address the problem of bycatch?
- How can scientists and engineers work together to ensure that fishing is more sustainable?

FIGURE 4

Engineering design in the *NGSS*.



Conclusion

The ocean is Earth's most dominant feature, and humans are harvesting its resources at an unsustainable rate (FAO 2011). Being ocean literate means that we can make informed decisions about the ocean (Carley et al. 2013). For students, completing this activity will raise their awareness of the global issue of bycatch and get them thinking about the seafood they eat and its cost to the ocean. They will also deepen their knowledge of how science and engineering work together, which addresses a central goal of the *Next Generation Science Standards* (NGSS Lead States 2013) (Figure 5). ■

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FIGURE 5

Connections to the standards.

Next Generation Science Standards (NGSS Lead States 2013)

Performance Expectations

- HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
- HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Science and Engineering Practices

- Developing and Using Models
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations (for science) and Designing Solutions (for engineering)

Disciplinary Core Ideas

- LS4.D: Biodiversity and Humans: Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.
- ETS1.B Developing Possible Solutions: When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.

Crosscutting Concepts

- Systems and System Models
- Structure and Function

On the web

Article on sustainable fishing: *http://bit.ly/X5SAxv*

Graphic organizer, design rubric, evaluate rubric: *www.nsta.org/highschool/connections.aspx*

Ocean literacy: *http://bit.ly/1v4eLkl*

Seafood choice resources: NOAA Fishwatch: *http://1.usa.gov/ZFTUcr;* Blue Ocean Institute: *http://blueocean.org/seafoods;* Monterey Bay Aquarium: *http://bit.ly/1ms3wOc*.

Fishing and Farming Methods: *www.seafoodwatch.org/ocean-issues/fishing-and-farming-methods*

Videos on reducing bycatch: *http://oceantoday.noaa.gov/reducingbycatch/; http://oceantoday.noaa.gov/savingseaturtles/*

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