CATCHING WAVES

MAKING WAVE PRINTS TO INTRODUCE WAVE PROPERTIES

by Lauren Kaupp, Joanna Philippoff, Kanesa Duncan Seraphin, and Matthew Lurie

When asked to imagine a wave, many students imagine a physical wave, such as a breaking ocean wave or a ripple in a pond. Physical-science courses, however, usually examine more abstract waves, such as sound and electromagnetic waves. Water waves may be more relatable to students than typical periodic motion models like springs, strings, or pendulums. This activity uses water waves as an engaging hook, provides a kinesthetic experience for students, and incorporates modeling, measurement, and mathematics into understanding wave properties. The activity also aligns with a range of practices and concepts in the *Next Generation Science Standards (NGSS)*, the *Common Core State Standards*, and the Ocean Literacy Principles (Figure 1).

FIGURE 1 *Next Generation Science Standards* **and Ocean Literacy Principles alignment**

Next Generation Science Standards (Achieve Inc. 2013)
- Standard (MS-PS4): Waves and their applications in technologies for information transfer
- Performance expectation (MS-PS4-1): Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

Common Core State Standards, Mathematics (NGAC and CCSSO 2010)
- CCSS.Math.Content.6.RP.A.3d Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.
- CCSS.Math.Content.6.EE.B.6 Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.
- CCSS.Math.Content.7.RP.A.2c Represent proportional relationships by equations. *For example, if total cost* t *is proportional to the number* n *of items purchased at a constant price* p*, the relationship between the total cost and the number of items can be expressed as* t = pn.
- CCSS.Math.Content.7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

Ocean Literacy Principles & Fundamental Concepts (Ocean Literacy Network 2011)
Principle 1: The Earth has one big ocean with many features.
- The ocean is the dominant physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

Principle 7: The ocean is largely unexplored.
- Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

Background

Water waves are similar to other types of waves. Waves are generally caused by a disturbance or vibration, and they transfer energy without causing a net movement of matter. In the ocean, waves are usually generated by wind. When waves move across the ocean, water does not travel great distances, but energy does. Water waves that travel at a constant rate and do not change significantly over time can be described using standard wave terminology (Figure 2). A wave profile diagram (Figure 3) is a side view of a water wave used to show wave features, including crests, troughs, wave height, and wavelength.

This introductory wave activity is adapted for middle school, with permission, from Exploring Our Fluid Earth, a free, online aquatic science curriculum (Duncan Seraphin et al., forthcoming; *www.exploringourfluidearth.org*) based on *The Fluid Earth* (Klemm et al. 1990) and *The Living Ocean* (Klemm et al., 1995). Before this investigation, students observe waves in an ocean, lake, river, or even swimming pool or puddle. Although in-person observations are preferred, students can instead watch videos of waves. Students describe features such as wave shape, wavelength, wave height, wave direction, and how waves break. In class, students share their wave observations, discussing the features they noted. This discussion can serve as formative assessment, revealing students' prior knowledge through their use of wave vocabulary. For example, students may understand that waves have crests and troughs but may refer to these wave features us-

FIGURE 2 **Wave terms (table adapted with permission from Exploring Our Fluid Earth (Duncan Seraphin et al., forthcoming)**

Crest: The highest point of a wave.

Trough: The lowest point of a wave.

Wave height (H): The vertical distance from crest to trough.

Wavelength (L): The horizontal distance from crest to crest.

Wave period (T): The time that it takes for one complete wave, from crest to crest, to pass a fixed point, usually expressed in seconds per wave. Period is the inverse of frequency. Period is usually measured in seconds per wave.

Wave frequency (F): The number of wave crests that pass a fixed point per unit of time, usually expressed in waves per second. Frequency is the inverse of period.

Wave speed (S): The speed of the wave in a certain direction expressed as distance per unit of time. It can be calculated by dividing the wavelength of a wave by the period. Wave speed is reported in units of distance per unit of time, for example meters per second (m/s).

ing alternate descriptions, such as "top" and "bottom." During the class discussion, basic wave terms can be introduced or reviewed, referring both to students' wave observations and a diagram of a transverse wave (Figure 3). If a student refers to the "top" and "bottom" of a wave, you may ask if other students observed similar wave shapes. Then you can create a diagram of a transverse wave (such as in Figure 3) and label the crest and the trough.

In the activity, students create a standing wave in a wave tank and "catch" the wave by making a print of it. Many practices of science described in the *NGSS* are incorporated in this activity, which also highlights some particular processes used in scientific inquiry, including replication and description (Duncan Seraphin et al., forthcoming). *Replication* is validating knowledge through repetition. Scientists replicate their own work using multiple trials in an experiment and also replicate the work of other scientists in order to confirm their methods and findings. In science, *description* means creating an accurate and adequate representation of ideas, things, or events using words or mathematical equations. Multiple processes occur throughout scientific investigations in the laboratory, the field, and the classroom.

Subsequent wave-tank activities in the Exploring Our Fluid Earth curriculum explore wave interference, wave shoaling and breaking, and orbital water motion in waves. These activities can be used as follow-up or extensions to learn more about waves and wave properties.

The activity

Materials

Materials are listed in the Activity Worksheet. Clear wave tanks are best so that waves can be seen from multiple angles, and this unique piece of equipment quickly captures student interest. The procedures are written for an acrylic tank 1.4 m long, 30 cm high, and 12 cm wide (Figure 4), which we had made by an aquarium builder. Other types of tanks also work, with adjustments to the procedure (see Figure 5). A paddle just narrower and higher than the tank is placed in a groove at the bottom of the tank (Figure 4).

We have had success conducting this activity various ways: with multiple tanks in one classroom, as a station in a rotation, and as a demonstration. When using multiple tanks or as a station in a rotation, students should work in groups of three or four. If used as a station in a rotation, groups that have already collected data using the tank can analyze their data while groups that have not yet worked with the tank make predictions or practice wave calculations.

FIGURE 3 **Wave profile diagram**

A wave profile diagram is a transverse wave.
Illustration by Byron Inouye. Figure used with permission from Exploring Our Fluid Earth.

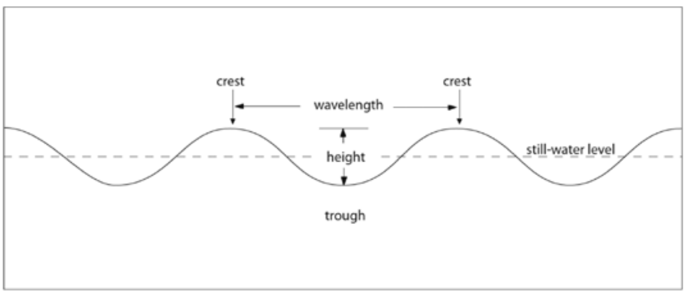
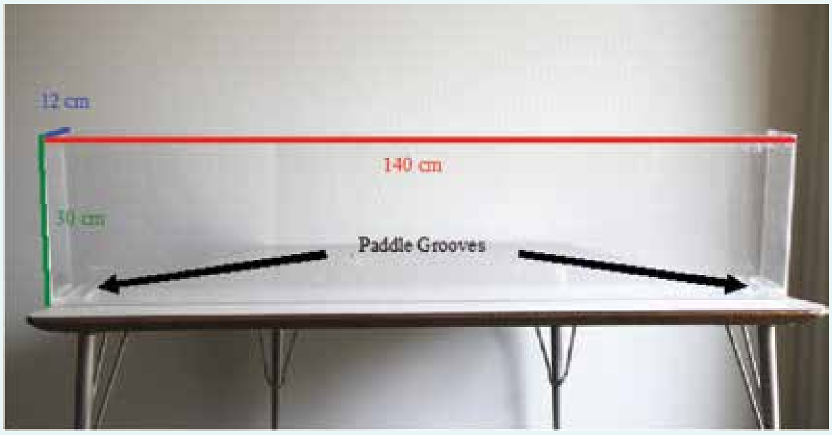


FIGURE 4 Acrylic wave tank

This activity was tested with and written for an acrylic wave tank that is 1.4 m long, 30 cm high, and 12 cm wide. Note the built-in paddle grooves in the bottom corners. In this activity, only one groove is used. Both grooves can be used to explore wave interference.



MATT LURIE/LAUREN KAUPP

FIGURE 5 Window-box tank

A wave tank can be made using a plastic window-box planter. Window boxes are economical and allow multiple groups to have tanks. Use a 76.2 cm (sold as 30 in.) molded, square-bottom plastic window-box planter, which is usually the longest size at home improvement stores. For the backstop and paddle stop, cut slits or drill holes into the side of the box for wooden skewers. The tank in this figure shows both options, with holes drilled in one end and slits cut in the other end. Make a paddle groove by creating two ridges with hot glue on the bottom at the end of the tank. Modify the procedure by increasing the frequencies to 130 and 150 waves per minute and decreasing the paddle-stop settings to 2.5 and 5 cm. The water level should be kept below the decorative ridge near the top of the window box. Wave heights will be lower in the window box than in longer tanks, because waves are generated at higher frequencies.

MATT LURIE

There are a few safety precautions. Tanks are very heavy when filled and should not be moved when full. Towels should be on hand to clean up possible splashes and keep the floor dry to prevent slip-and-fall accidents. Students must wear chemical splash goggles.

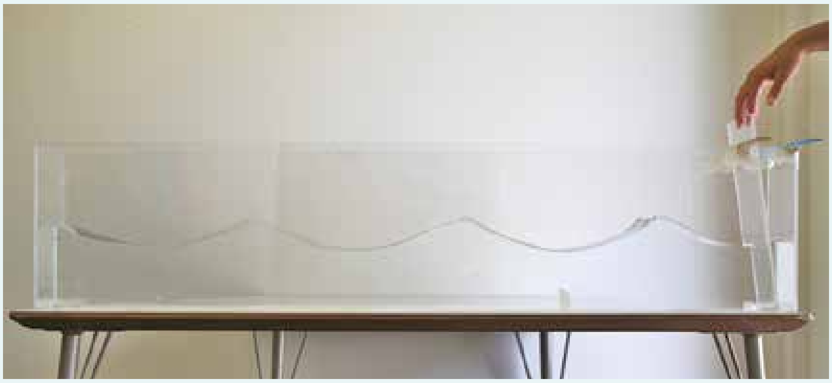
Generating wave profiles

A standing wave is one that only moves up and down, not forward, in the tank. Generating standing waves takes practice. Some people are better "wave makers" than others, so students should take turns trying to generate standing waves. Initially, students have an open-ended opportunity to determine how to generate standing waves. This involves replication—students have to be consistent in timing and technique to create standing waves. Description is also necessary when students explain to each other the shape and motion of the wave and discuss how to create a standing wave. While one student practices, others watch and tell the wave maker when a standing wave is generated. Students are often surprised at how hard it is to create standing waves and usually nominate a skilled wave maker for the next part of the procedure.

Next, students create waves at set frequencies and paddle-stop distances. To create the frequencies, a metronome is played over either speakers or headphones. Digital metronomes can be found online or downloaded as apps onto mobile devices. For each wave, the paddle hits the front paddle stop once per beat (Figure 6).

Once students can generate standing waves at a set frequency, they are ready to "catch"

FIGURE 6 Standing waves being generated



MATT LURIE

some waves, i.e., create watermark wave profiles by dipping paper into a standing wave. Each group needs a few long sheets of paper, which can be created before the activity by taping together smaller pieces of paper. Regular-sized pieces of colored construction paper taped end-to-end to a length of about two-thirds of the tank work well. Students create standing-wave profiles with combinations of two paddle-stop settings and two frequencies, predicting what will happen to the wave when they change the settings.

Teamwork is fundamental to making prints. One person creates waves, another watches the side of the tank for a standing wave, and a third person dips the paper. The "dipper" has to be told when to dip, because it is hard to see the standing wave when looking straight down into the tank. The paper is dipped quickly and carefully into the standing wave, avoiding the sides of the tank. A good print is a watermarked profile with a regular wave pattern (Figure 7). Students can be discouraged by prints that are crooked or lumpy, but this is an opportunity to develop and test strategies to create better standing waves and prints. Again, replication is key here, both in the wave generation and the printmaking. With a few practice prints, and some encouragement, students can make good profiles for making measurements.

Data collection and analysis

The paper will begin to dry and absorb water, changing the wave shape, so students should trace their profile immediately after making a print (Figure 7). Each profile should also be labeled with the paddle-stop setting and frequency. Students then identify the crests and troughs of the wave and measure the wavelength and wave height (Figure 3). Each group makes four prints, one of each combination of paddle stop and frequency. As a modification, different groups can be assigned to one combination each. Replication and calculating group or class averages reduce the error due to timing, measurement, or irregular prints. Representative results for two trials of each combination of frequency and paddle-stop setting are shown in Figure 8. Results will vary based on wave-tank dimensions.

In the activity questions (see Activity Worksheet), description is important. Students describe how they created standing waves, as well as trends in wavelength and wave height related to frequency and paddle-stop settings. Students are asked to describe the relationship between frequency and wavelength both in words and mathematically. Finally, students calculate wave speed and period and describe the relationship between the two. Centimeters should be converted to meters if appropriate for the scale of the tank.

Assessment and evidence of learning

Assessment occurs throughout the activity. Students engage in informal self-assessment and metacognitive reflection as they determine how to make a standing wave and "catch" the wave in a print. For both teachers and students, clear wave tanks make formative assessment easier, as the waves are visible from multiple angles. Informal assessment can also happen through inquiry questioning by the teacher. Wave prints, data tables, and written answers to questions provide evidence of learning and can be used for formal, summative assessment.

Discussion

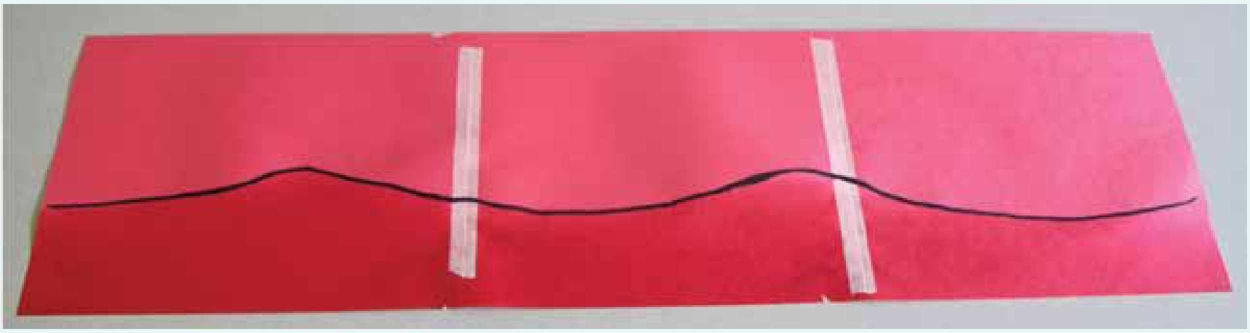
Making and analyzing wave prints is an inquiry-based, hands-on way to introduce waves and wave properties. Expected results will show that

- as frequency increases, wavelength decreases;
- at the same paddle-stop setting, wave height increases as frequency increases; and
- as paddle-stop setting distance increases with constant frequency, wave height increases.

Students create three wave models: one in the tank,

FIGURE 7 Example of a watermarked profile

This wave was generated in the acrylic tank (Figure 4) at a frequency of 120 waves per minute and a 5 cm paddle stop.



JOANNA PHILIPPOFF/LAUREN KAUPP

one in their prints, and one using equations. When using models to teach science, it is important to point out how the model is like and unlike the target concept (Harrison and Coll 2008). Water waves have similarities and differences compared to other wave types. For example, water waves and sound waves are both mechanical waves, but sound waves are longitudinal waves, whereas water waves are transverse. Another difference exists between the energies of classical mechanical waves, such as water waves, and electromagnetic waves—the energy of a classical wave is proportional to its amplitude, but the energy of an electromagnetic wave is proportional to its frequency. It is also worth noting that the wave model in the tank is a standing wave, but ocean waves propagate, or move, across the surface of the ocean. Although these differences are not explicitly addressed in this activity, it is possible that these connections could be made in subsequent activities. This activity was designed as an introduction or review of waves, and it provides a context for using water waves as a model for other waves.

This activity has been adapted for a range of middle school students. Modeling portions of the activity, such as setting up the wave tank and dipping the paper, can reduce student reading anxiety and increase comprehension of the procedure. Another way to adapt the activity is to focus on qualitative relationships rather than quantitative measurements. Doing examples as a class or in small groups can help students with algebraic calculations. More advanced students can manipulate multiple combinations of paddle-stop settings and frequencies and use graphs to analyze data. Working in groups and taking turns in different roles gives all students the opportunity to participate and work together to generate data. The physical, visual, mathematical, and even musical (keeping time with the metronome) processes of this activity provide various ways for students to tap into different strengths. Finally, we believe that relating the activity to the ocean can increase engagement in all learners.

Throughout the activity, students engage in different aspects of scientific inquiry. The process of creating waves is open ended. We encourage teachers to allow students to determine how to make standing waves and create the best wave prints. Analyzing wave prints is more guided inquiry, in which students use mathematical formulas to support their understanding of wave properties. In addition to the standards listed in Figure 1, this activity aligns with *NGSS* practices, disciplinary core ideas, and crosscutting concepts (Figure 9).

The wave standards in the *NGSS* emphasize the use of waves in transmitting information and in technology systems, especially in digital communication technologies. Water waves are also used in technological and information-transmitting applications. In many places, wave buoys and turbines are used to generate electricity. Other types of buoys are deployed across the world ocean to collect and transmit information for weather, tsunami, and surf forecasting. At a more low-tech level, sailors and surfers read ocean waves to determine surf and weather conditions before using waves for transportation and recreation. Finally, wave content can be covered using water waves in classes such as marine or Earth science, providing exposure to physical-science concepts outside of physics-based courses. Multiple entry points to the same content can deepen student understanding over time (NRC 2012).

FIGURE 8 Representative results

These results are from two trials with frequencies of 100 and 120 waves per minute and paddle-stop settings of 5 and 10 cm. The average wavelength, wave height, period, and speed are calculated. Table adapted with permission from Exploring Our Fluid Earth (Duncan Seraphin et. al, forthcoming).

	Number of wave pulses per minute (frequency)			
Length of wave pulse paddlestop setting (cm)	Frequency (F) = 120 waves per minute = 2 waves per second		Frequency (F) = 100 waves per minute = 1.7 waves per second	
5 cm	Wavelength (L)	trial 1 = 37.5 cm trial 2 = 38 cm *average = 37.8 cm*	Wavelength (L)	trial 1 = 53 cm trial 2 = 51.5 cm *average = 52.3 cm*
	Wave height (H)	trial 1 = 5.5 cm trial 2 = 5.7 cm *average = 5.6 cm*	Wave height (H)	trial 1 = 2 cm trial 2 = 2.6 cm *average = 2.3 cm*
	Wave period (T)	0.5 seconds	Wave period (T)	0.59 seconds
	Wave speed (S)	75.5 cm per second	Wave speed (S)	88.8 cm per second
10 cm	Wavelength (L)	trial 1 = 37.5 cm trial 2 = 38.5 cm *average = 38 cm*	Wavelength (L)	trial 1 = 53 cm trial 2 = 50.4 cm *average = 51.7 cm*
	Wave height (H)	trial 1 = 8 cm trial 2 = 7.8 cm *average = 7.9 cm*	Wave height (H)	trial 1 = 7 cm trial 2 = 5.5 cm *average = 6.25 cm*
	Wave period (T)	0.5 seconds	Wave period (T)	0.59 seconds
	Wave speed (S)	76 cm per second	Wave speed (S)	87.9 cm per second

Conclusion

Even without a surfboard, any student can catch a wave. In this inquiry activity, students experience waves kinesthetically and visually, generate standing waves, and "catch" those waves by making wave prints. Students explore and quantify the effects of wave frequency and pulse size on wavelength and wave height by measuring their wave prints. Generating standing waves and making wave prints is a unique introduction to wave properties that goes beyond traditional springs, pendulums, and strings. Through this activity, students learn content and engage in many *NGSS* practices of science and engineering. We encourage you to teach about wavelength, wave period, frequency, wave height, and wave speed by exploring water waves. ■

Acknowledegment

The authors would like to acknowledge Jordan Wang for his assistance in wave-tank setup and picture-taking.

References

Achieve Inc. 2013. *Next generation science standards.* Washington, DC: National Academies Press.

FIGURE 9 Alignment of activity with *NGSS* practices, disciplinary core ideas, and crosscutting concepts

Practices	Disciplinary core ideas	Crosscutting concepts
Asking questions and defining problems Students evaluate their data and qualitative relationships as compared to known wave equation.	*Wave Properties* Students determine the relationship between wavelength, frequency, and wave speed.	*Patterns* Students use wave prints and recorded and calculated data to identify patterns.
Developing and using models Students use transverse wave models to describe waves and create wave prints.	*Defining and delimiting engineering problems* Students are tasked with creating a standing wave under specific frequency and paddle-stop conditions.	*Cause and effect* Empirical evidence is used to make claims about the effect of changing paddle-stop settings and frequency on other wave properties.
Using mathematics and computational thinking Students use mathematical expressions to describe the relationships among wave properties.	*Developing possible solutions* Students take turns making waves, and developing strategies to create standing waves.	*Systems and system models* A wave model is used to simulate waves and the interactions between paddle-stop settings, frequency, and wave properties.
Obtaining, evaluating, and communicating information Students collect, analyze, and share data through written and oral communication.	*Optimizing the design solution* Students observe the effects of their various wave-making strategies and optimize their standing waves.	

Duncan Seraphin, K., J. Philippoff, F.M. Pottenger, L. Kaupp, M.H. Lurie, D. Lin, and E. Baumgartner. Forthcoming. Exploring our fluid Earth. *www.exploringourfluidearth.org*.

Harrison, A.G., and R.K. Coll, eds. 2008. *Using analogies in middle and secondary science classrooms: The FAR guide—An interesting way to teach with analogies*. Thousand, Oaks, CA: Corwin.

Klemm, E.B., F.M. Pottenger III, T.W. Speitel, S.A. Reed, and A.E. Coopersmith. 1990. *The fluid Earth: Physical science and technology of the marine environment.* 3rd ed. Honolulu: University of Hawai‘i.

Klemm, E.B., S.A. Reed, F.M. Pottenger III, C. Porter, and T.W. Speitel. 1995. *The living ocean: Biology and technology of the marine environment*. 3rd ed. Honolulu: University of Hawai‘i.

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common core state standards.* Washington, DC: NGAC and CCSSO.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Ocean Literacy Network. 2011. Ocean literacy. *http://oceanliteracy.wp2.coexploration.org.*

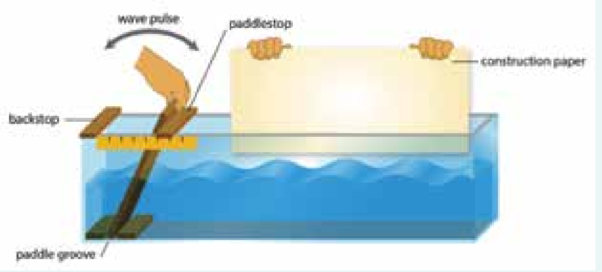
Lauren Kaupp *(kaupp@hawaii.edu)* is a science specialist at the Curriculum Research & Development Group (CRDG) in the College of Education at the University of Hawai‘i at Manoa in Honolulu, Hawaii. ***Joanna Philippoff*** is the program manager for Teaching Science as Inquiry: Aquatic Science, also with CRDG. ***Kanesa Duncan Seraphin*** is an associate professor at CRDG and the director of the Center for Marine Science Education with the University of Hawai‘i Sea Grant Program. ***Matthew Lurie*** is a graduate assistant with CRDG and a doctoral candidate in the Department of Botany at the University of Hawai‘i at Manoa.

ACTIVITY WORKSHEET: Catching a Wave

In this activity, you will create standing waves in a wave tank and examine the effect of frequency and length of wave pulse on wavelength (L), wave height (H), wave speed (S), and wave period (T). Standing waves appear to move up and down in place and do not move forward in the tank.

Materials (per tank)

- Paddle
- Water
- 3 rulers
- Masking tape
- Metronome
- Construction paper
- Pencil or pen
- Chemical splash goggles for all group members



(Making a watermarked wave profile picture in a long wave tank. Illustration by Byron Inouye. Figure used with permission from *Exploring Our Fluid Earth* [Duncan Seraphin et al., forthcoming].)

Procedure

1. Set up the wave tank as shown in the diagram above.
   - Fill the wave tank halfway with water.
   - Tape one ruler to the end of the wave tank as a backstop to stop the paddle from going past vertical.
   - Tape a second ruler along the top edge of the wave tank (the yellow ruler in the diagram).
   - Tape a third ruler 5 cm in front of the backstop as the paddle stop.

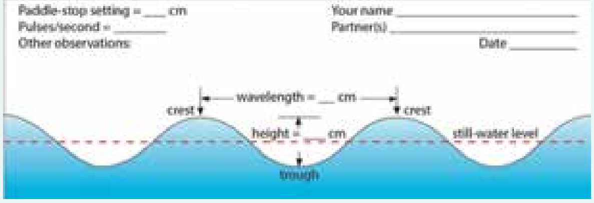
2. Set the paddle in the paddle groove and practice generating standing waves.
   - Predict what will happen when you use the paddle to create wave pulses. Draw or describe your predictions.
   - Wear chemical splash goggles. Take turns creating waves. Observe as others create waves and let the wave maker know when a standing wave is created.
   - Determine the best method for creating a standing wave.
   - Record your method for creating a standing wave.

3. Make profiles of a standing wave at a frequency of 120 beats (waves) per minute and a paddle-stop setting of 5 cm.
   - Set the metronome to 120 beats per minute.
   - Make a standing wave using your method from step 2. The paddle should hit the front paddle stop once per beat.
   - How do you know when you have created a standing wave?

4. Print a watermark profile of the standing waves.
   - Tape construction paper together to make a long sheet two-thirds the length of the wave tank.
   - Hold the paper near the top corners just above the water level (see diagram above).
   - Quickly but carefully dip the paper in and out of the water.
   - Trace the profile of the waves with a pencil.

5. Label the crests and troughs on your wave profile.
   - Devise a method for measuring wavelength on your wave profile (see diagram below).
   - Devise a method for measuring wave height on your wave profile (see diagram below).
   - How did you identify the crests and troughs on your wave profile?

6. Use your method from step 5 to measure the wavelength and wave height of your wave profile (see diagram below). Record these measurements on your wave profile and in the data table provided.



(Analysis of a watermarked wave profile. Illustration by Byron Inouye. Figure used with permission from *Exploring Our Fluid Earth* [Duncan Seraphin, forthcoming].)

ACTIVITY WORKSHEET: Catching a Wave (continued)

7. Predict and give reasoning for what will happen when you change the frequency or paddle-stop settings as follows:
   a. Frequency = 100 waves per minute; paddle stop = 5 cm
   b. Frequency = 120 waves per minute; paddle stop = 10 cm
   c. Frequency = 100 waves per minute; paddle stop = 10 cm

8. Test your prediction from step 5. Repeat steps 3–5 for the following conditions:
   a. Frequency = 100 waves per minute; paddle stop = 5 cm
   b. Frequency = 120 waves per minute; paddle stop = 10 cm
   c. Frequency = 100 waves per minute; paddle stop = 10 cm
   - Did your results match your predictions? Explain.
   - What patterns or relationships do you see in your data?

Data table Effects of frequency and length of wave pulse on wavelength (L), wave height (H), wave speed (S), and wave period (T).

	Number of wave pulses per minute (frequency)	
Length of wave-pulse paddle-stop setting	Frequency (F) = 120 waves per minute = 2 waves per second	Frequency (F) = 100 waves per minute = 1.7 waves per second
5 cm	Wavelength (L) =	Wavelength (L) =
	Wave height (H) =	Wave height (H) =
	Wave period (T) =	Wave period (T) =
	Wave speed (S) =	Wave speed (S) =
10 cm	Wavelength (L) =	Wavelength (L) =
	Wave height (H) =	Wave height (H) =
	Wave period (T) =	Wave period (T) =
	Wave speed (S) =	Wave speed (S) =

Questions

1. Describe how you created standing waves in the wave tank. In your description, include information about the paddle and your timing.
2. If the paddle stop is constant, what happens to the wavelength as the frequency decreases?
3. Describe the relationship between frequency and wavelength that you observed. How could you express this relationship mathematically?
4. How did frequency and paddle-stop setting affect the wave height? Explain your answer.
5. One equation for wave speed is speed = frequency × wavelength (S = FL).
   a. Using the information in the data table, calculate wave speed (cm/s) for each of the four standing waves you measured. Record your results in the data table.
   b. Describe how frequency and wave speed are related.
6. The period of a wave is the inverse of its frequency (T = 1/F). Use this relationship to calculate wave period in seconds per wave.
7. What is the relationship between wave period and wave speed?
8. How are the waves you created in the tank similar to and different from waves in the ocean?