Exploring Acoustic Fish Tagging in Gray's Reef National Marine Sanctuary

Lesson Specifications

Age

8-12

Timeframe

One 45-minute classroom session
One 90-minute pool mission

Materials

Lesson:
- Computer w/ internet
- Projector
- Towel
- Paper

Scuba:
- All required scuba gear
- Slate & pencil
- Measuring tape (2)
- Noisemakers

Key Words

acoustic tagging, simulation, live bottom reef

Standards

PADI, SSI, NAUI, Ocean Literacy Principles 5 & 7

The rocky seafloor is home to a variety of organisms. Photo: Greg McFall/NOAA

The seafloor at Gray's Reef is home to many different sponges and soft corals. Photo: Greg McFall/NOAA

Activity Summary

This lesson introduces students to Gray's Reef National Marine Sanctuary and the important resources it protects. Students simulate tracking fish with acoustic tags both in the classroom and in the pool. Students practice buoyancy control, awareness of their environment and buddy, and air management during the pool portion of the simulation.

Learning Objectives

Students will be able to:

- Explain, by using examples, the importance of Gray's Reef National Marine Sanctuary.
- Compare and contrast Gray's Reef to a coral reef.
- Simulate the use of acoustic tagging to track organism movement.

Essential Questions

1. What are national marine sanctuaries and why are they important?
2. What important resources are protected by Gray's Reef National Marine Sanctuary?
3. How is Gray's Reef similar to, and different from, a coral reef?
4. Why do fish move locations?
5. How does the acoustic fish tagging research at Gray's Reef National Marine Sanctuary work? What information is it providing to scientists?

National Marine Sanctuary Diver Performance Requirements

At the surface, students will:

- Streamline gear prior to entry.
- Perform a comprehensive buddy check.
- Review necessary hand signals.
- Establish an air management plan.
- Perform a weight check and adjust weighting as necessary.

Underwater, students will:

- Demonstrate proper descent techniques and awareness of the environment.
- Demonstrate proper buddy awareness and air management.
- Demonstrate appropriate use of hand signals.
- Demonstrate appropriate buoyancy control.

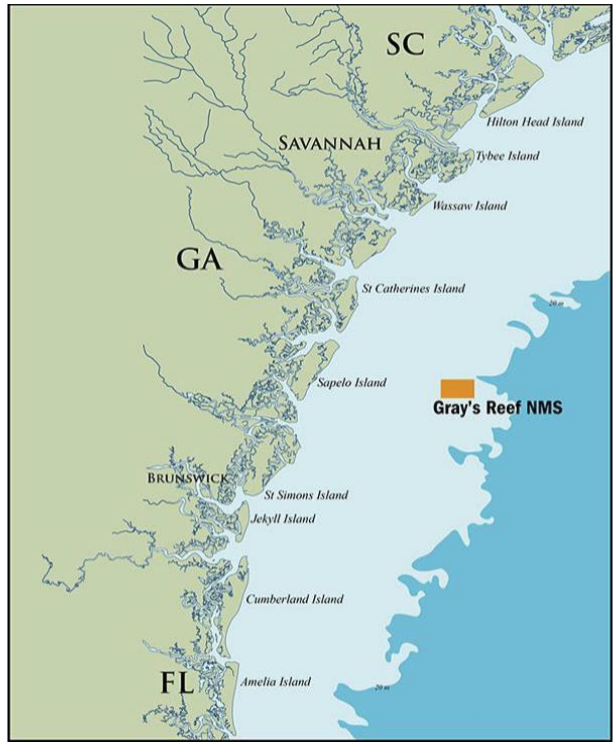
A map of the National Marine Sanctuary System in the U.S. and its territories.

Background Information

<u>Gray's Reef National Marine Sanctuary</u>

NOAA's Office of National Marine Sanctuaries serves as the trustee for a network of underwater areas encompassing more than 620,000 square miles of marine and Great Lakes waters. The network includes a system of national marine sanctuaries as well as Papahānaumokuākea and Rose Atoll marine national monuments. Few places on the planet can compete with the diversity of the National Marine Sanctuary System, which protects America's most iconic natural and cultural marine resources. The system works with diverse partners, treaty holders, and stakeholders to promote responsible, sustainable ocean uses that ensure the health of our most valued ocean places. Healthy aquatic ecosystems, whether fresh, brackish, or marine, are the basis for thriving recreation, tourism, and commercial activities that drive coastal economies.

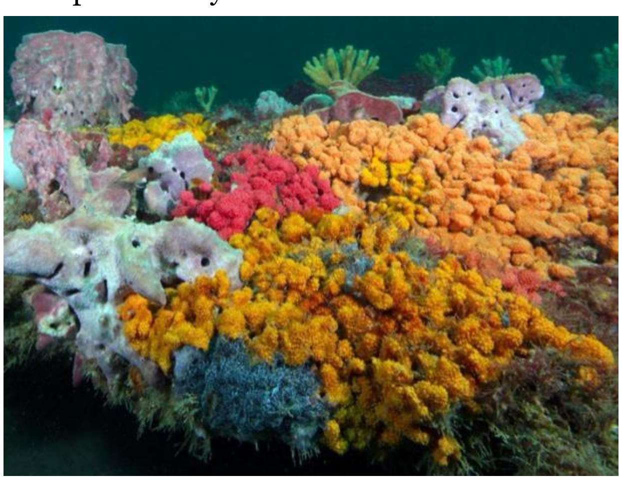
Gray's Reef National Marine Sanctuary is located 19 miles offshore of Sapelo Island, a barrier island on Georgia's southeast coast. The sanctuary was established in 1981 and currently protects 22 mi^2 of rocky ledge and seafloor habitat that supports more than 200 species of fish and 900 species of invertebrates. It is named for Milton "Sam" Gray, a biologist at the University of Georgia Marine Institute, who studied the area in the 1960s. Gray's Reef National Marine Sanctuary is currently the only marine protected area in a region called the South Atlantic Bight, a long, gradual bend in the coastline that forms a large bay between Cape Hatteras, North Carolina, and Cape Canaveral, Florida. As a result of the Gulf Stream, temperate and tropical waters mix in this region, leading to high species diversity.



The location of Gray's Reef National Marine Sanctuary. Photo: NOAA

Up to 20% of the seafloor of the South Atlantic Bight is made up of "live-bottom" reef. "Live bottom" is a term used to refer to hard or rocky seafloor that provides habitat for high invertebrate abundance and diversity, including many species of sea squirts, sponges, and soft corals. Live-bottom reefs support more than 70% of the region's offshore fisheries. Gray's Reef National Marine Sanctuary provides protection to one of the largest near-shore, live-bottom reefs in the southeastern United States.

Gray's Reef is not a coral reef. Instead, it is made of carbonate-cemented sandstone, formed by the consolidation and cementing of pieces of shells, sand, and mud that were originally deposited as loose grains between six and two million years ago. Some of these sediments were brought to the coast by rivers and others were probably transported to the region by ocean currents. Seawater, rich in dissolved calcium carbonate, formed the "cement" that glued the grains together. After the formation of Gray's Reef, during the Pleistocene (approximately 2 million to 10,000 years ago), sea level fluctuated dramatically as glacial ice expanded and melted. As a result, the area that is now the sanctuary was periodically above sea level. The fossils of large Pleistocene terrestrial animals such as mammoths have been found at the reef. Today, the rocky ledges can be as tall as six feet, but lie under 60 to 70 feet of water. The ledges are interspersed with sandy-bottom areas.



A live-bottom reef in Gray's Reef National Marine Sanctuary. Photo: Greg McFall/NOAA

The structural complexity of the rocky ledges provide habitat for many invertebrates, which, in turn, support a diverse and abundant food web, including commercially important fish species like snapper, grouper, mackerel, and sea bass. Loggerhead sea turtles, a threatened species, use Gray's Reef year-round for foraging and resting and the reef is near the only known winter calving ground for the highly endangered North Atlantic right whale. The rocky ledges and sand expanses of the sanctuary are subject to challenging environmental conditions. Survival is largely dependent on a species' tolerance of water temperatures, which range from 40°F to 80°F and violent undersea "sandstorms" associated with winter storms. These constantly changing conditions contribute to an incredible diversity of marine life.

A loggerhead sea turtle in Gray's Reef National Marine Sanctuary. Photo: Greg McFall/NOAA

Diving in Gray's Reef National Marine Sanctuary

Gray's Reef is a popular destination for recreational anglers, boaters, and experienced divers. Diving in these waters is challenging due to rapidly changing visibility, currents, and weather. Advanced divers who dive in the sanctuary must be familiar with regulations. For example, anchoring is prohibited throughout the sanctuary to help protect the live-bottom reef. Additionally, there are regulations in place to protect critically endangered North Atlantic right whales. Vessel speed restrictions are in place between November 15 and April 15, and both vessels and individuals must stay at least 500 yards away from all whales.

Advanced divers trained for the conditions are a valuable part of the sanctuary's Team Ocean Dive Program, which enlists citizen divers to volunteer with ocean research projects. Team Ocean Divers aid in marine debris monitoring and removal, reef fish surveys, and habitat assessments.

Acoustic Fish Tagging Research in Gray's Reef National Marine Sanctuary

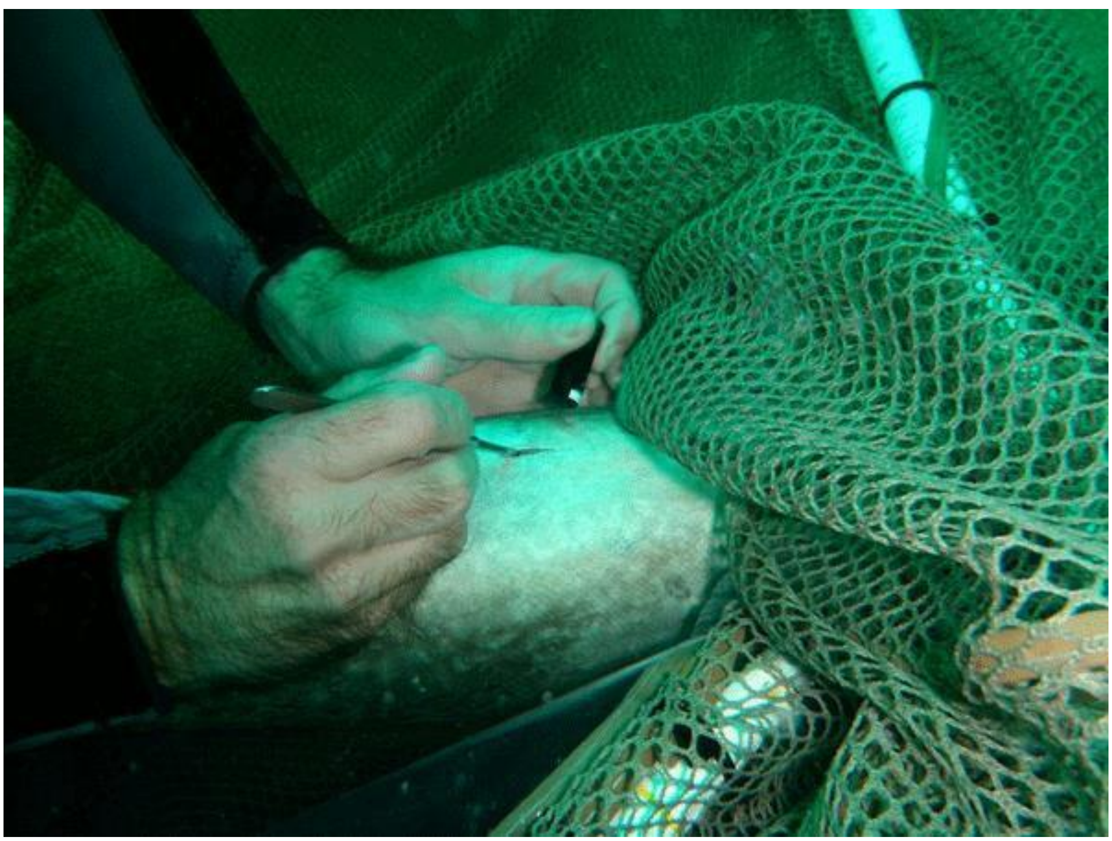
The southern third of the sanctuary is set aside for research only. Activities in the research area are limited in order to study the impact of human activities on sanctuary marine resources and to inform future management and conservation strategies. One such research project is an acoustic telemetry program that tracks the underwater movements of economically and, ecologically important marine species such as snapper and grouper species. Stock assessments suggest that many snapper and grouper species are declining regionally. Tagging studies in Gray's Reef National Marine Sanctuary focus on detecting and recording the movement patterns of red snapper, two grouper species (gag and scamp), and black sea bass. These species are considered more resident species since they spend the majority of their day's at Gray's Reef, but they may go offshore for spawning. The tags last up to five years depending on their size. The acoustic receivers within the sanctuary have also detected species not tagged by sanctuary staff. From May 2008 to September 2017, 11,354,341 detections were recorded on the acoustic receiver array at Gray's Reef. Eighteen different transient/non-resident species, totaling 164 individuals were detected, including 11 species of sharks, six species of bony fishes and sturgeon, and one species of turtle. The majority of these individuals (57.9%) were sharks.

Divers assess fish in a trap.
Photo: Greg McFall/NOAA

Target species are either caught from a boat using rod and reel from or with a trap by a diver. The fish are then tagged with a small internal transmitter that is surgically implanted into their abdominal cavity and an external tag attached near the dorsal fin. Snapper and grouper are tagged underwater to prevent barotrauma. Black sea bass are not as susceptible to pressure injuries. As a result, their surgeries are conducted topside. Once brought up on hook and line, their swim bladder is deflated with a needle. After the transmitter is inserted, the fish is either taken back underwater by a diver or returned to depth using a descending device. Each internal transmitter emits a unique acoustic "ping" that allows scientists to track each individual fish. The transmitters ping at 69kHz, which is above the threshold for human hearing. The transmitters are tracked by acoustic receivers.

Each transmitter pings at a different rate to ensure that no tags ping at the same time which would possibly prevent the receiver from detecting the ping. When the receivers detect a transmitter's ping, the ping's unique signal, time, and date are recorded. Detections can be made from as far as 200 meters away from the receiver. The detection range of the receiver varies with water density. Water density changes throughout the day as a result of tides, as well as with the seasons and weather conditions. The receivers are located in sandy-bottom areas, but are within a few meters of live-bottom reef area which fish use as habitat. Scientists retrieve the receivers and download the data onto a computer.

Fish move for a variety of reasons, including to find mates, food, and/or shelter, as well as in response to environmental conditions, like water temperature. The data helps scientists understand when the fish are present or absent from a study area, the habitats fish prefer, and whether those preferences change over time. Over the course of the telemetry project, over 40 fish have been tagged. Currently, 16 receivers are collecting data throughout Gray's Reef National Marine Sanctuary.



A diver performs surgery to insert the transmitter underwater, which is much less harmful than catching the fish with a hook and bringing the fish to the surface. Photo: Jamie Park

Vocabulary	
acoustic tagging	the use of small sound-emitting devices that allow the detection and/or remote tracking of organisms in aquatic ecosystems
bight	a long, gradual bend in the coastline that forms a large bay
live-bottom reef	a term used to refer to hard or rocky seafloor that provides habitat for high invertebrate abundance and diversity
ping	a transmitter's unique acoustic signal
receiver	the device that senses the signal from the transmitter and records the information relayed by the signal
South Atlantic Bight	a large bay between Cape Hatteras, NC and Cape Canaveral, FL; technically this is a misnomer as the South Atlantic lies below the equator; this name refers to the southern part of the Atlantic coast of the U.S.
transmitter	the device implanted in the organism that emits a unique acoustic signal

Preparation - *Classroom*

Review slide deck. Be aware of important information, as well as suggestions for instruction, located in slide notes.

Procedure

Introduction

Follow the prompts in the slide deck notes to introduce the following concepts:

- What are national marine sanctuaries and why are they important?
- Where is Gray's Reef National Marine Sanctuary and what resources does it protect?
- How is Gray's Reef similar to, and different from, a coral reef?
- Why do fish move locations?
- How does the acoustic fish tagging research at Gray's Reef National Marine Sanctuary work? What information is it giving scientists?

Activity

1. Explain the simulation to the group as described below:
    a. One student will simulate the acoustic receiver. This person must listen for the unique transmitter signals and record data.
    b. Other students will simulate tagged fish. Each student has been "tagged" and will be assigned a unique sound. Some possible sounds include: tongue clicks, snaps, claps, and whistles. Enlist student help with brainstorming other unique and easily-produced sounds as necessary.

    c. Tagged fish will “swim” around the classroom and emit their “ping” every 15 seconds, but only when within the range of the receiver. Make it clear that this is different from how acoustic tags work in real life. Real-world acoustic tags ping regardless of proximity to the receiver.

2. On a piece of paper, have each student copy the data table below. This table is included in the slide deck. You may wish to share the types of sounds that will be used as pings in advance to aid the receiver's data collection.

Ping (Examples below)	**# Detections**
Tongue click	
Snap	
Clap	

3. Assign one student to be the receiver. Place this student in a chair in the center of the space. Drape a towel over the student’s head so that she/he/they can see their data table, but not the rest of the room.
4. Assign a fish type (snapper, grouper, sea bass) and a unique ping to each student who is simulating a tagged fish. Ensure each fish type is represented. The instructor should record the student name, fish type, and unique sound for each “fish.” This information will be needed for the analysis. Give students time to decide on, and practice, their ping. Direct students to move about the room randomly. Stagger their start. Make it clear that they should ping every 20 steps, but only if they are within the range of the receiver. Determine the range of the receiver as makes sense for the space.
5. The receiver should listen for the pings and record data. It is suggested that the simulation run for between two to three minutes.
6. At the conclusion of the simulation, all students should copy the receiver data into their table and complete the analysis explained in the slide deck. The instructor will need to share the student name, fish type, and unique sound for each “fish.”

Notes:

Consider walking through the simulation prior to implementation. At your discretion, add additional receivers and/or run the simulation multiple times to allow students to experience different roles.

Differentiating pings will be challenging. The objective of the simulation is not necessarily to accurately differentiate pings but to simulate the general concept of acoustic tagging.

Debrief

Discuss the activity using the questions below. These questions are also included in the slide deck. Accept all reasoned responses. Some possible responses are in italics.

- Rank the fish types in order of most to least detections. How does the number of detections relate to abundance? *Rankings will vary. Generally, more detections of a fish type (not of an individual) convey greater abundance.*
- Which fish type was actually the most abundant? Is this what the data showed? If not, propose a possible explanation for your results. *The most abundant fish type in the simulation will vary. Results will vary. If a different fish type other than the most abundance had more detections, it may be because those fish were not in range of the receiver.*
- How many individual fish were detected? *Answers will vary. Make it clear that a fish could be present but not detected by the receiver.*
- Were any fish detected multiple times? *Answers will vary.*
- Why do you think it is important that each transmitter have a unique ping? *This is important so that individual organisms can be recognized. This way if the same individual is detected multiple times it does not impact conclusions about abundance.*
- How does this simulation successfully model acoustic tagging? *Accept all reasoned responses.*
- How could this simulation be improved? *Accept all reasoned responses.*

Preparation - *Pool Mission*

1. Gather an underwater noisemaker for each student who is simulating a tagged fish and an underwater slate and pencil for the student simulating the acoustic receiver.
2. Use the underwater measuring tapes to divide the pool bottom into quadrants.
3. Reproduce the data table (below) on the slate prior to entering the pool.

Procedure

1. Remind students of the acoustic tagging simulation conducted in the classroom. They will transfer their learning to the pool where again one student will simulate the acoustic receiver and the others tagged fish.
2. The student simulating the acoustic receiver will station her/him/themself in one corner of the pool. This student should face in the corner with her/his/their back to the pool. This way, they will detect tagged fish without using vision. This student requires an underwater slate on which the data table below has been drawn. Again, you may wish to share the types of sounds that will be used as pings in advance to aid the receiver's data collection.

Ping (Examples below)	# Detections
Two quick bangs	
Three quick rattles	
One long (> 5 sec) rattle	

3. Students simulating tagged fish each need to be assigned a fish type and a unique ping, as was done in the classroom simulation. The instructor should record this information. Give students time to decide on, and practice, their pings. Direct these students to swim in a circular pattern around the perimeter of the pool, maintaining a position a few feet off the bottom. Every 15 fin kicks (this number may change depending on the size of the pool) direct tagged fish to ping if they are located within the quadrant of the receiver.
4. The receiver should listen for the pings and record data. It is suggested that the simulation run for between two to three minutes. Establish a signal that indicates the conclusion of the simulation.

Dive Briefing

- Explain the simulation procedure and objectives. Model the simulation above water prior to student participation. Emphasize the importance of safety (air and buddy checks) and good buoyancy control. These objectives are more important than the objective of the simulation.
- Differentiating pings will be challenging. The objective of the simulation is not necessarily to accurately differentiate pings, but to simulate the general concept of acoustic tagging.
- Prior to entry, perform all standard safety and weight checks.

Note: At your discretion, add additional receivers and/or run the simulation multiple times to allow students to experience different roles.

Dive

Participate in the dive mission as described above.

Debrief

Upon completion of the pool mission, assess student understanding by asking the following questions. Accept all reasoned answers:

- How well did you pay attention to your buddy and air? How was your buoyancy control? Why do you feel this way?
- How successful were you in your role as either the acoustic receiver or tagged fish? Why do you feel this way?

Education Standards	
Dive Industry Standards	PADI Seal Team SSI Scuba Ranger NAUI Junior Scuba Diver or Passport Diver
Ocean Literacy Principles	#5: The ocean supports a great diversity of life and ecosystems. (a,c,d) #7: The ocean is largely unexplored. (a,b,d,f)

Additional Resources

Linked Resources:

- 50 Years of National Marine Sanctuaries video
- Live-Bottom Reef Habitat of Gray's Reef National Marine Sanctuary video
- Gray's Reef National Marine Sanctuary video
- Low-relief community virtual dive
- Ledges of biodiversity virtual dive
- Diving at Gray's Reef National Marine Sanctuary video
- Gray's Reef National Marine Sanctuary Fish Tagging Study video
- Acoustic receiver virtual dive
- Release of tagged fish video

NOAA's Office of National Marine Sanctuaries

https://sanctuaries.noaa.gov/

Gray's Reef National Marine Sanctuary

https://graysreef.noaa.gov/

Virtual Dives in Gray's Reef National Marine Sanctuary

https://sanctuaries.noaa.gov/vr/grays-reef/

Ocean Literacy Principles

http://oceanliteracy.wp2.coexploration.org/

Ocean Guardians Dive Club Lessons

Additional lessons available.

https://sanctuaries.noaa.gov/education/ocean_guardian/dive-club/

Gray's Reef National Marine Sanctuary Educational Materials

https://graysreef.noaa.gov/education/activities/welcome.html

Gray's Reef National Marine Sanctuary Acoustic Tagging Project - Background Information

https://graysreef.noaa.gov/science/research/fish_tagging/welcome.html

Gray's Reef National Marine Sanctuary Acoustic Tagging Project - Classroom Activities

https://graysreef.noaa.gov/science/research/fish_tagging/education.html

Georgia Public Broadcasting Educational Materials

https://www.gpb.org/education/liveexplorations/grays-reef

Relevant Primary Sources

https://nmsgraysreef.blob.core.windows.net/graysreef-prod/media/archive/science/publications/pdfs/mathies_et_al_2014.pdf

https://coastalscience.noaa.gov/data_reports/using-acoustic-telemetry-to-understand-connectivity-of-grays-reef-national-sanctuary-to-the-u-s-atlantic-coastal-ocean/

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