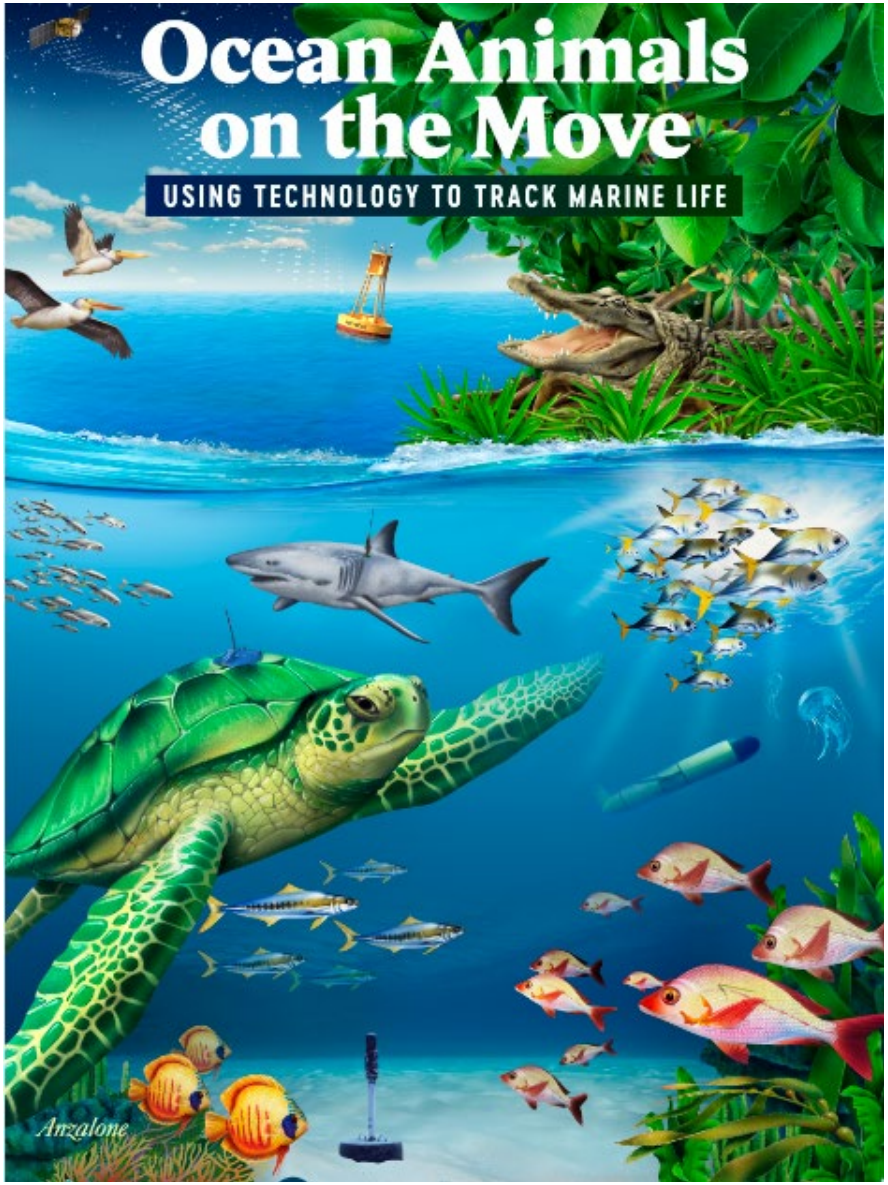

Ocean Animals on the Move

Using Technology to Track Marine Life and Understand Environmental Change

An ESIP FUNding Friday Collaboration

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Objective

To understand the purpose and process of animal tracking, and the data stewardship practices needed to apply the information to real-world challenges.

Three lessons targeting Grades 8-12 support this objective:

Lesson 1 Introduction to Animal Tracking

Lesson 2 Animal Tracking Tools and Technology

Lesson 3 Using Passive Acoustic Telemetry to Study the Movement Ecology of Bull Sharks

Content in this slide deck constitutes Lesson 2 of 3

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National Education Standards

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS-LS2-2.Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS2-7.Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-LS2-8.Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce.

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

LS2.D: Social Interactions and Group Behavior

LS2.D: Biodiversity and Humans

ETS1.B: Developing Possible Solutions

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National Education Standards

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics (Cont.)

Science and Engineering Practices

Using Mathematics and Computational Thinking

- Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1)
- Use mathematical representations of phenomena or design solutions to support and revise explanations. (HS-LS2-2)

Constructing Explanations and Designing Solutions

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS2-7)

Engaging in Argument from Evidence

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)

Scientific Knowledge is Open to Revision in Light of New Evidence

- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. (HS-LS2-2),(HS-LS2-3)
- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. (HS-LS2-6),(HS-LS2-8)

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8)

Scale Proportion and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1)

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6),(HS-LS2-7)

Lesson 2

Animal Tracking Tools and Technology

Tagging animals requires a skilled team that can work cooperatively and efficiently to keep people and animals safe.

Animal ethics training is often required to participate in field and lab work.

Permits are usually required to conduct field work.

Image credit: sharktagging.com

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Choosing the Right Tag for the Job

ID Tag (e.g., Dart tag)

Satellite Positioning Tag

Archival Tag

Pop-up Satellite Archival Tag

Acoustic Tags—size matters!

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Animal Tracking Tools and Technology

There are different types of tracking techniques, each with different benefits, challenges and costs. Finding the right tool for the job is important.

The **mark recapture method** involves capturing a number of animals, marking them, releasing them back into the population, and then determining the ratio (proportion of marked to unmarked animals) of the population when marked and unmarked animals are captured at a later date. Originally developed to estimate population size, mark recapture is also used for the estimation of birth, death and emigration rates within populations.

Two adult Hunder trout. The fish on top was marked by clipping the adipose fin.
Image credit: Atle Rustadbakken

Juvenile spinner shark, *Carcharhinus brevipinna*, tagged with a dart tag.
Image: NOAA

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Animal Tracking Tools and Technology

ID Tags

The mark/recapture method using an ID tag like this NOAA Dart Tag is one of the most basic forms of tracking animals. Each dart has a unique number so that an individual animal with a tag can be identified.

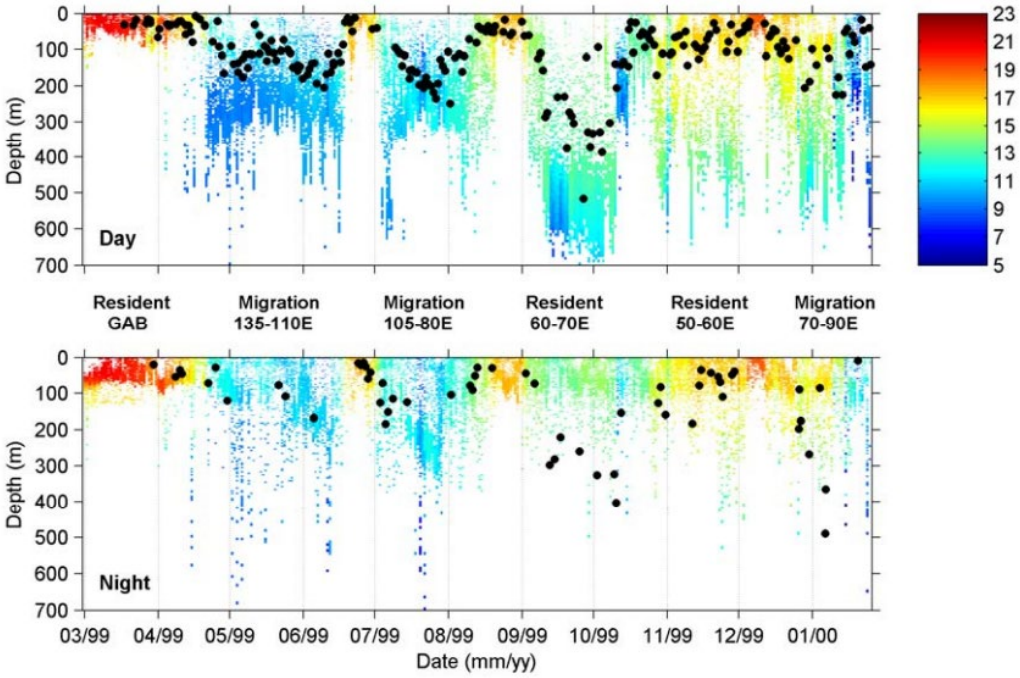
If an animal is recaptured and the tag is reported to the proper agency (i.e., NOAA in this case), then we can see where it moved since it was first caught and tagged. We can also measure how much it has grown and matured (physiologically speaking).

NOAA maintains a database of tagged fishes. You don't have to be a scientist to participate--recreational fishers have tagged and released fish and also reported captured tagged fish.

Animal Tracking Technology (credit for this section: CSIRO Australia)

There are also a variety of electronic tags such as archival, pop-up archival and satellite positioning tags, and acoustic tags.
http://www.coml.org/comlfiles/scor/SCOR-tagging.pdf

Archival tags are small data loggers that record dates, times, swim depths, water temperatures, body temperatures and light levels. They can record data every few seconds for up to 10 years, depending on the tags' sampling frequency and battery life. Archival tags can be attached externally or internally, and must be retrieved for their data to be downloaded. They are used most commonly on species that have a high likelihood of recapture – either through fishing, or upon return visits to breeding and feeding grounds – such as fish, seabirds, sea turtles and marine mammals.



These graphs shows the daily diving and feeding behavior (top image-daytime pattern; bottom image, nighttime pattern) of a southern bluefin tuna during 11 months at sea recorded by an archival tag. The colors indicate water temperature and the black circles indicate a feeding event. Credit: CSIRO Australia

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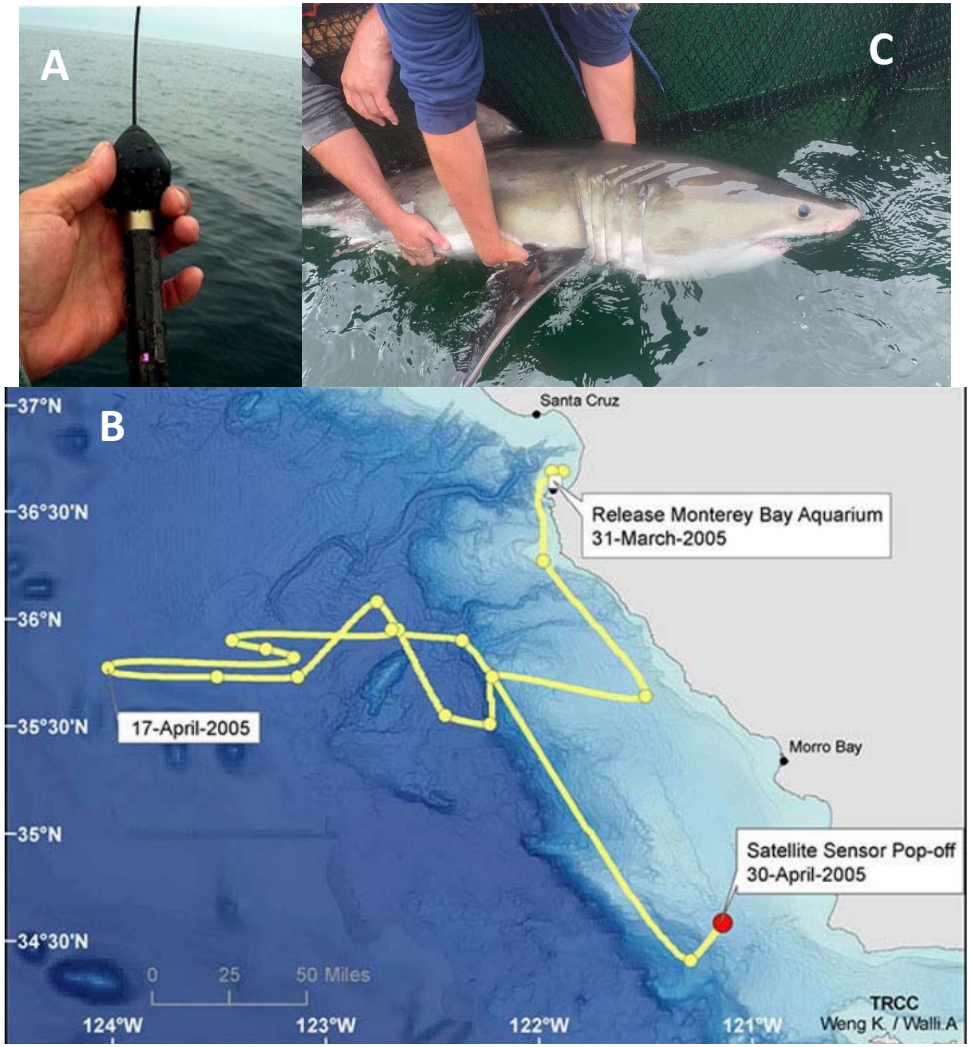
Animal Tracking Technology

Pop-up satellite archival tags: Pop-up archival transmitting (PAT) tags are externally placed tags that are pre-set to detach, rise to the surface and transmit data by radio to the Argos satellite network. This network collects, processes and disseminates environmental data, and has a special channel dedicated to wildlife telemetry. PAT tags provide a means of collecting fishery-independent data, and have been deployed on animals such as tuna, marlin, sharks, swordfish, mola mola, halibut, eels and sea turtles. White sharks tagged in South Africa exhibit return breeding migrations to Australia and some individuals tagged off California migrate as far as the Hawaiian Islands. Building a picture of regularly used white shark migration routes may help to reduce the incidental capture of this threatened species by commercial fisheries and minimize undesirable interactions with humans.



A. PAT tag; B. Movements of an Atlantic shark following her release from the Monterey Bay Aquarium. Image credits: TOPP—Tagging of Pacific Pelagics; C. Juvenile white shark (Credit: Atlantic Shark Institute).

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Animal Tracking Technology

Satellite positioning tags are attached externally on animals and transmit a signal either to the Argos satellite system or the GPS satellite system which determines the position of the tag, providing near-real-time tracking of the animal's movements. Because the tag antenna must be above the water to transmit a signal, these tags are deployed on animals that spend sufficient time at the ocean surface. They are most commonly used on animals such as marine mammals, sea turtles, seabirds and some species of sharks.

Some versions of these tags transmit data on swimming depth, water temperature and salinity, helping to build profiles of oceanographic features in remote parts of the world's oceans that are difficult to access. They've also been deployed on marine mammals such as elephant seals to track diving behavior and foraging activity.

University of Miami diver checks the satellite tag and camera attached to the dorsal fin of a tiger shark. Image: Brian Skerry

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Animal Tracking Technology

Image: Christine Shepard, SharkTagging.com

SPOT (Smart Position and Temperature) transmitting tag on the dorsal fin of a shark.

These are a type of satellite transmitting tag that send out signals to the Argos satellite system in near-real-time. They can pinpoint location close to 250 meters. They are used to track the horizontal movements of animals that routinely spend time at the surface (e.g., dolphins, seals, whales, sharks, sea turtles and sea birds like albatross and penguins).

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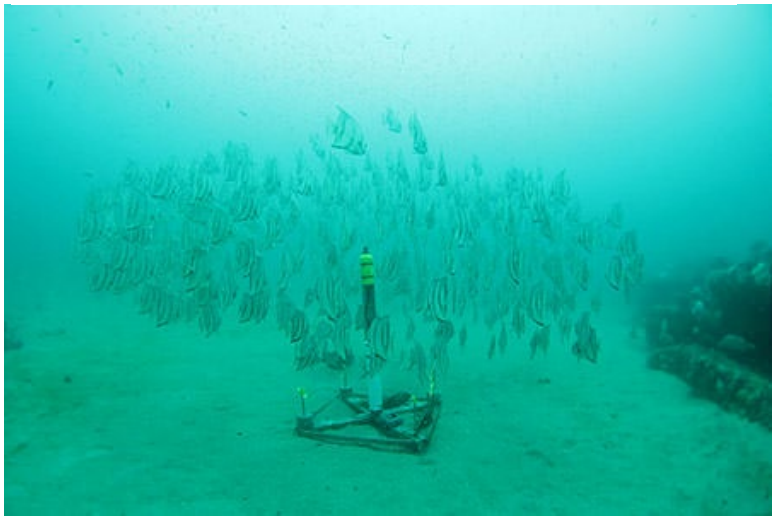
Animal Tracking Technology

Acoustic tags can be attached externally or internally. They transmit a unique sound signal that identifies the tagged individual when it is within range of a fixed receiving instrument (passive acoustics), usually on the seabed, or a hydrophone operated from a mobile platform (active acoustics) like a vessel or autonomous underwater vehicle. They also can transmit data on swim speed (with an accelerometer) and environmental characteristics such as water temperature and depth.

Acoustic tags commonly are used to record the extent to which an animal uses a particular area, and how this behavior may change over time. They are suited to research on any species to which a transmitter can be attached or implanted without modifying its behavior, such as fish, sharks, crustaceans and squid.

Acoustic receivers, or 'listening stations', can record the presence of hundreds of animals tagged with acoustic transmitters with a location accuracy of about a meter. Their detection range can be extended to hundreds of kilometers by placing multiple receivers in grids or lines called arrays.



A hydrophone on the seafloor picks up signals from acoustically tagged fish. Image credit: Peter Auster/University of Connecticut

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Animal Tracking Technology

Size of Acoustic Tags

Image credit: Innovasea https://www.innovasea.com/fish-tracking/

How do you decide what size acoustic tag to use?

As a general rule of thumb, a tag should weigh no more than 2.5% of the animal's body mass.

Calculate: For a 10 lb (4.5 kg) grouper, what is the heaviest tag you should use? (0.25 lb = 4 ounces = 113 grams)

Smaller tags generally cost less so why not just use those all the time, especially if they are under 2.5% of the animal's body mass?

The smaller the tag, the smaller the battery, so the shorter the lifespan of the tag.

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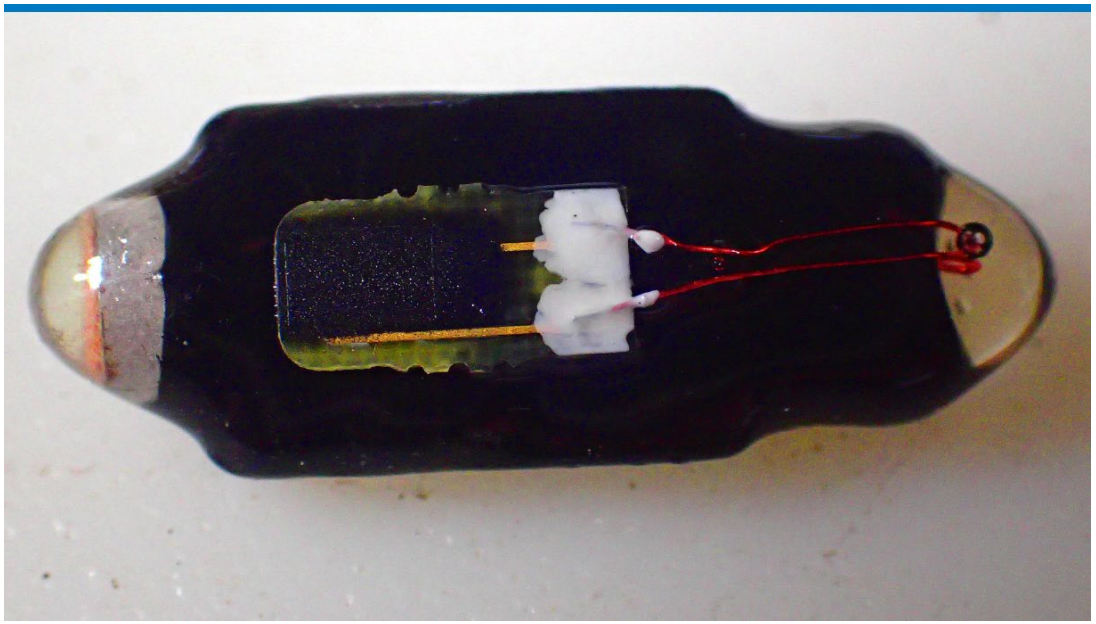
Predation Detection Acoustic Tags



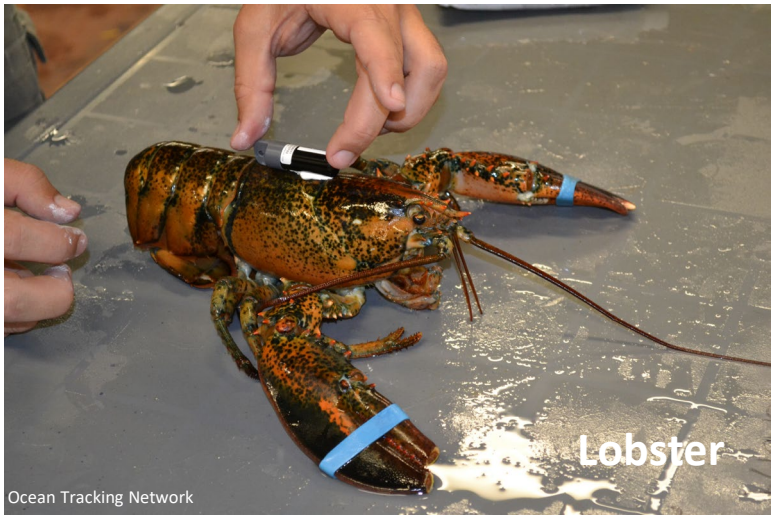
Fuse design on a predation detection acoustic tag. Image credit: Innovasea https://www.innovasea.com/fish-tracking/

Cool fact
Tag technology is advancing all the time. A Predation Detection Acoustic Tag has a unique digestible fuse. Stomach enzymes in the predatory fish break down the fuse. This alters the tag signal so the researcher knows the transmission signal is now from the predator, not the original animal tagged!

HTI-VEMCO developed this tag and scientists at FISHBIO partnered with them to test it.

Acoustic tags can be attached to almost any marine animal!

However, attachment methods can differ among animal species and ages



Examples of different acoustic tag attachments on sea turtles.

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Assessment: Choosing the right tracking tool

The right tool for the job considers multiple factors! For each scenario below, select the most appropriate method to track. If you are not familiar with the animals listed, do some fact-finding first. Don't forget to balance matters of cost—for tags themselves and operational costs, life style of species, the resolution of information needed, and the frequency and duration of data needed.

1. The Marine Mammal Commission is working with foreign nations to determine the seasonal migratory routes of gray whales so they can determine shipping routes that will avoid collisions.
2. Before a coral reef restoration project can proceed, scientists need to know the percent of time that nurse sharks, a near-bottom species, spend in a particular area of the reef.
3. A fish hatchery wants to distinguish between wild and hatchery-released sea trout that are caught by commercial fishermen.
4. Florida Fish and Wildlife needs to know the specific location that bonefish, a near-bottom species, aggregate to mate in Biscayne Bay.
5. NOAA Fisheries is trying to determine how much time leatherback sea turtles spend at different depths in a foraging area off Nantucket so they can determine possible interactions with lobster pots.
6. Researchers in Louisiana want to understand how Mako shark feeding behavior is associated with offshore oil rigs.

Assessment: Choosing the right tracking tool

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1. The Marine Mammal Commission is working with foreign nations to determine the seasonal migratory routes of gray whales so they can determine shipping routes that will avoid collisions. (Satellite tags)
2. Before a coral reef restoration project can proceed, scientists need to know the percent of time that nurse sharks, a near-bottom species, spend in a particular area of the reef. (Acoustic tags—defined area, benthic species)
3. A fish hatchery wants to distinguish between wild and hatchery-released sea trout that are caught by commercial fishermen. (Mark recapture methods)
4. Florida Fish and Wildlife needs to know the specific location that bonefish, a near-bottom species, aggregate to mate in Biscayne Bay. (Acoustic tracking)
5. NOAA Fisheries is trying to determine how much time leatherback sea turtles spend at different depths in a foraging area off Nantucket so they can determine possible interactions with lobster pots. (Pop-up satellite archival tag)
6. Researchers in Louisiana want to understand how Mako shark feeding behavior is associated with offshore oil rigs. (Archival tag)

Resources

https://www.teachengineering.org/lessons/view/duk_marine_musc_less2

https://nationalzoo.si.edu/migratory-birds/what-satellite-telemetry

https://www.researchgate.net/publication/334044228_Animal-Borne_Telemetry_An_Integral_Component_of_the_Ocean_Observing_Toolkit

https://www.sciencedirect.com/science/article/abs/pii/S0169534719300242

https://link.springer.com/article/10.1007/s10452-021-09845-6

https://www.frontiersin.org/articles/10.3389/fmars.2020.608848/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaign=Email_publication&field=&journalName=Frontiers_in_Marine_Science&id=608848

https://necoopunit.unl.edu/downloads/Publications/Joseph%20TJ%20Fontaine%20publ/Laskowski%20et%20al%202016-1.pdf

https://masweb.vims.edu/bridge/index.cfm

https://sharks.panda.org/images/RAT/pdf/WWF_RAT_Tool5_TaggingTracking.pdf

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

https://www.fisheries.noaa.gov/new-england-mid-atlantic/atlantic-highly-migratory-species/tagging-instructions-and-resources-volunteers

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