# Harvesting a Sea of Data

*Using authentic data to investigate marine migrations*

**Amy Busey, Ruth Krumhansl, Julianne Mueller-Northcott, Josephine Louie, Randy Kochevar, Kira Krumhansl, and Virgil Zetterlind**

**A baby elephant seal on the Valdes Peninsula, Argentina.**

"My students were hot on the trail of a giant elephant seal," says Julianne Mueller-Northcott, a science educator at Souhegan High School in Amherst, New Hampshire. "They saw it leave the shoreline south of San Francisco, dive 700 meters, and then head north toward Alaska." The students weren't on a research ship but thousands of miles away in a marine biology classroom, following elephant seals and other marine animals virtually, via laptop.

With data from the Tagging of Pelagic Predators research program (see "On the web"), the students navigated the terrain of the ocean floor using Google Earth, following a bright red line tracking the elephant seal (Figure 1) as it circled off the coast of the Aleutian Islands. Adding tracking data from other elephant seals, they looked for patterns across multiple animals—noticing, for example, that some seals traveled north while others went directly out to sea. "I prompted them with such questions as: 'Where is the animal going?' 'What would motivate the seal to migrate like this?' 'Why is it circling in the one area—mating? feeding? avoiding a predator?'" Mueller-Northcott says. "My students were hooked! They had questions and access to a wealth of scientifically collected data and were ready to try to find answers."

**FIGURE 1**

**A tagged northern elephant seal.**

Because of their size, elephant seals can wear large electronic instruments with little effect on their behavior. The tags they wear can record location, salinity, temperature, and depth information. With such data, students can develop multiple lines of evidence to inform their ideas and support their claims.

DAN COSTA/TOPP

## Ocean Tracks

Ocean Tracks: Investigating Marine Migrations in a Changing Ocean (see "On the web") is an innovative program that provides students free access to authentic data collected from migrating elephant seals, white sharks, albatross, tuna, drifting buoys, and satellites, as well as customized analysis tools modeled after those used by scientists. Ocean Tracks allows teachers and students to use large, professionally collected data sets to investigate scientific questions of current, real-world importance: What do marine animals' movements tell us about areas of the ocean that are critical in supporting biodiversity? In what ways are human activities affecting these areas?

## Big data in the high school classroom

Scientific research is undergoing a "big data" revolution, as probes deployed in oceans, the atmosphere, and outer space provide near real-time data streams. As more and more data sets such as Ocean Tracks become available online, opportunities to engage students in the *Next Generation Science Standards* (NGSS Lead States 2013) practice of "analyzing and interpreting data" are blossoming (Figure 2). Students and teachers have unprecedented access to weather and climate data, images of stars and galaxies, seismic recordings, and more—data that take them not just outside the classroom but to the edges of our planet and beyond. With such abundant new data, students can ask and answer their own questions, perhaps identifying patterns that have yet to be discovered by scientists.

While large scientific data sets can potentially transform teaching and learning (Barstow and Geary 2002; Borne et al. 2009; Ledley et al. 2008; Marlino, Sumner, and Wright 2004; NSF Cyberinfrastructure Council 2007; Rainey et al. 2013; Slater, Slater, and Olsen 2009), access to data often comes with a catch: Data portals meant for scientists can be unintelligible to students and teachers due to cryptic labeling, unintuitive navigation structures, unfamiliar data visualizations, and complicated analysis tools. There is a need for critical scaffolds, including customized interfaces, guiding curricula, and tools that allow teachers to assess students' progress (Edelson, Gordin, and Pea 1997; Krumhansl et al. 2012; Quintana et al. 2004; Sandoval 2001).

To tackle these challenges, Oceans of Data, a National Science Foundation–funded project, set out to find and summarize what is known about designing data interfaces and

FIGURE 2

## Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013).

The materials/lessons/activities outlined in this article are just one step toward reaching the standards listed below. Additional supporting materials/lessons/activities will be required.

| Disciplinary Core Ideas | Example |
|---|---|
| ESS2.E: Biogeology<br>• The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. | The Ocean Tracks interface and curriculum engage students in thinking about how Earth and ocean processes influence life in the oceans. For example, students use tracking data to identify areas of the ocean heavily used by marine life and investigate the oceanographic processes that create these biologically productive areas. (Curriculum Module 2) |
| ESS3.C: Human impacts on Earth systems<br>• The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. | The Human Impacts overlay uses data on a variety of activities and processes (e.g., pollution, shipping) to show the intensity of human impacts in different regions of the Pacific Ocean. Students use this overlay to describe human impacts on areas of the ocean that students have determined to be of importance to the Ocean Tracks species. (Curriculum Module 4) |
| LS2.A: Interdependent relationships in ecosystems<br>• Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. | Students use tracking data to identify the coast of California as an area heavily used by the Ocean Tracks species. To understand why, students learn how the process of upwelling creates productive areas for the prey of the Ocean Tracks species. Students must then understand the link between the Ocean Tracks species and the prey. (Curriculum Module 3) |
| LS2.B: Cycles of matter and energy transfer in ecosystems<br>• Photosynthesis and cellular respiration provide most of the energy for life processes. | Students investigate the behavior of elephant seals by taking measurements from their tracks and linking these to a chlorophyll overlay to generate a map of where the elephant seal prey are likely to be found. Students construct a food web to illustrate the levels of energy transfer between these two groups of organisms. (Curriculum Module 2) |
| LS2.C: Ecosystem dynamics, functioning, and resilience<br>• A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. | After generating support for hypotheses about how the Ocean Tracks species are influenced by environmental conditions, students make predictions about how human impacts may affect marine species. (Curriculum Module 4) |
| LS4.C: Adaptations<br>• Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. | As students investigate the tracks of the Ocean Tracks species, they make discoveries about the habits of these animals. They examine how deep elephant seals can dive, the trans-Pacific journeys of the bluefin tuna, and the Laysan albatross's ability to fly incredible distances over short periods of time. Resources in the Ocean Tracks library help students understand how adaptations enable Ocean Tracks animals to accomplish remarkable feats. (Curriculum Modules 1–4) |
| LS4.D: Biodiversity and humans<br>• Humans depend on the living world for the resources and other benefits provided by biodiversity . . . sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. | The Ocean Tracks "Hot Spot" tool measures the density of track points in a particular area of the ocean. Using background information on biodiversity from the Ocean Tracks Library, students consider whether the hot spots they identify are species hot spots or biodiversity hot spots. Using the Human Impact overlay, students see how extensively human activity affects their hot spot. With this information, students construct a plan to mitigate the effects of overexploitation, pollution, and other factors on their hot spot. (Curriculum Modules 3 and 4) |

| Science and Engineering Practices | Example |
|---|---|
| Practice 4: Analyzing and Interpreting Data<br>Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. | Students take measurements from tracks of Elephant Seals (speed, depth, and track curviness), and interpret this data to generate support for hypotheses about where the animals are displaying feeding behavior. (Curriculum Module 2) |
| Practice 6: Constructing Explanations<br>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. | Students use animal tracking data and oceanographic data overlays to identify habitat hotspots in the Pacific Basin. They then construct explanations for these phenomena, which requires them to integrate their measurements and observations with their understanding of the underlying mechanisms that create productive ocean habitat. (Curriculum Module 3) |
| Practice 7: Engaging in Argument from Evidence<br>Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). | Students make a case for the design and location of a marine protected area. Engaging in this debate requires that students provide data supporting why some areas of the ocean are more important than others for marine species, what human activities may affect those areas, and whether the location of these areas changes over time. (Curriculum Module 5) |
| **Crosscutting Concepts** | **Example** |
| Patterns<br>• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. | Students describe and quantify patterns in the tracks of elephant seals, white sharks, bluefin tuna, and Laysan albatross. They then make quantitative comparisons between the migration patterns of these four species to determine the species that travels the fastest and farthest. (Curriculum Module 1) |
| Cause and Effect<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. | Students observe patterns in habitat use by large marine animals and use data and background information to identify the underlying causes of these patterns. (Curriculum Modules 2 and 3) |

**Ocean Literacy Principles (Ocean Literacy Network 2013)**

| Literacy Principle | Example |
|---|---|
| Principle 5: The ocean supports a great diversity of life and ecosystems. | Students observe the ocean in four dimensions as they follow the individual animals across the surface, down to the seafloor, and examine environmental factors that vary across space and time. Through an in-depth investigation of the Ocean Tracks species, students gain an appreciation for the remarkable adaptations of these animals to their ocean environment. (Curriculum Modules 2 and 3) |
| Principle 7: The ocean is largely unexplored. | Ocean Tracks uses data collected by the Tagging of Pelagic Predators research program. Using satellite technology, electronic tags allow us to learn more about ocean inhabitants and their environment than ever before. Students investigate questions of interest to practicing scientists as they examine where these animals live, travel, feed, and breed. (Curriculum Modules 1–4) |

**FIGURE 3**

## Learning science with big data.

Students discuss measurements they've taken from an elephant seal track. Working collaboratively allows students to support each other's thinking and often encourages spontaneous discussion about how to analyze and interpret the data.

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visualizations for high school students. Guidelines emerged (Krumhansl et al. 2012) that are being implemented and tested in the Ocean Tracks project introduced above.

## Piloting the data interface

To develop Ocean Tracks, a team of marine biologists, geoscientists, curriculum developers, web designers, teachers, and education researchers collaborated to generate a web interface and teaching resources and to conduct preliminary research on the program. One of the teachers, Mueller-Northcott, piloted Ocean Tracks in her high school marine biology classrooms in the spring and fall of 2013. Her efforts and experiences, as well as those of the other pilot teachers, have provided insights about the potential of such programs to facilitate learning with big data in high school classrooms.

RANDY WILDER/MONTEREY BAY AQUARIUM

Pacific bluefin tuna migrate thousands of miles.

"After my marine biology students developed ideas about the seal's behavior based on their observations and background research," Mueller-Northcott says, "I challenged them to gather and use quantitative evidence to paint a clearer picture of the factors that might be influencing migration patterns." Working in pairs, the students identified key portions of the track that might support their hypotheses and created plots of the animal's speed and deepest daily dive (Figures 3 and 4), recording their measurements in a data table. Based on these measurements, along with their observations and the research they conducted using the online Ocean Tracks library, they formed hypotheses that they tested by gathering additional evidence. They added sea surface temperature and chlorophyll concentration overlays and took measurements from these data in areas of interest along the track.

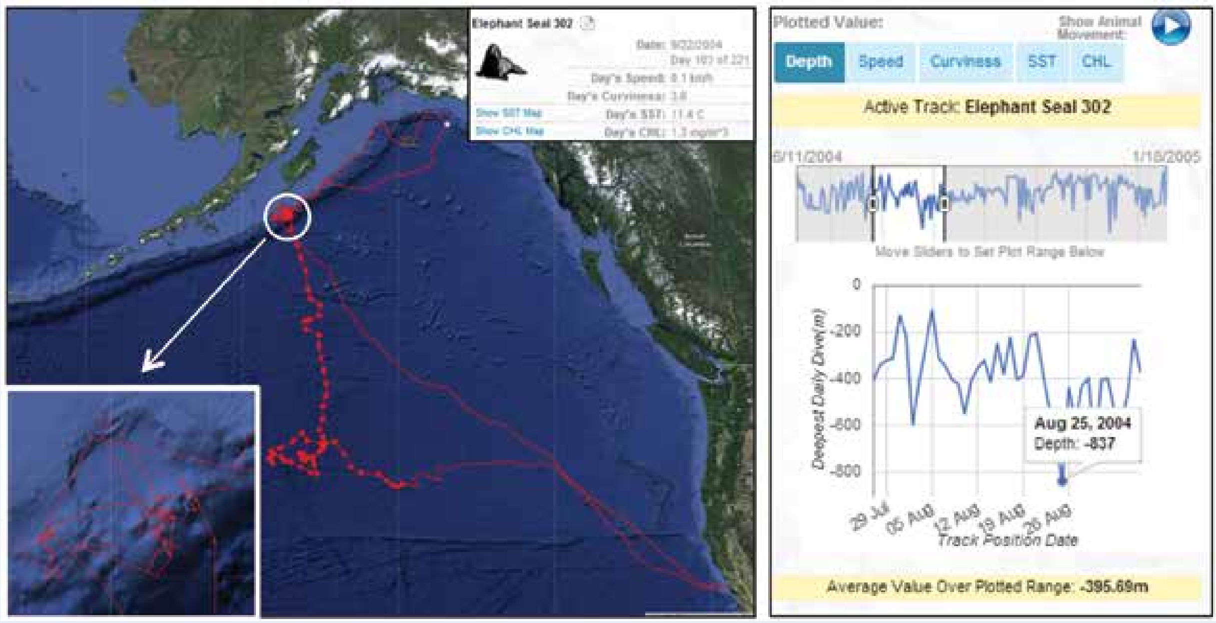
The students looked for patterns consistent with their hypotheses. Feeling confident in their claims, the students moved about the classroom, comparing other groups' seal track measurements displayed on posters with their own data. At first, some students were alarmed: "Our measurements aren't the same!" But then they surmised that the different groups may not have chosen exactly the same track intervals to measure and that, in fact, the patterns were similar in all the groups' data: "The elephant seal's average speed is lower, and the dives are deeper in the portions of the track where we think they're feeding," one student said.

"This was not the kind of discussion that we have very often in my marine biology course," Mueller-Northcott says. "When confronted with variation in their measurements and conflicting claims, my students helped each other grapple with issues such as what constitutes evidence, what the data (and differences in the data) actually represent, the significance of patterns and the meaning of data that don't fit those patterns, and how to assess confidence in your own and others' claims and evidence." As students delved into the data more deeply, the teacher pushed their thinking further by asking: "What do the data tell you?" "What other information can you use to help you?" "Who can gather the most evidence to support their hypothesis?"

**FIGURE 4**

## Investigating elephant seal migrations in Ocean Tracks.

Students focus on sections of the elephant seal's track to measure the animal's speed, depth, and curviness (how much a track deviates from a straight line). Students determine the average, maximum, and minimum values for each variable and examine their data to look for patterns.

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## Lessons learned

Teachers' and students' pilot work with Ocean Tracks yielded valuable lessons about how to engage students with professionally collected data sets accessible online. The following suggestions are based on pilot teachers' experiences and reflections (Sickler and Cherry 2011):

- Finding and preparing authentic data can be labor intensive for the teacher, and student experiences with these data are often limited to analyzing and interpreting a single set or type of data. In contrast, easy access to rich data sets can inspire questions, allow for explorations, and spur classroom discussions that are only possible when students explore multiple lines of evidence.
- Even when using a customized data interface, students still need support interpreting data and reading data visualizations, such as sea surface temperature maps or depth plots. Teachers who piloted Ocean Tracks found that students were particularly engaged when working in pairs or small groups and that it's important to have whole-class discussions and spontaneous debates about data in the classroom.
- Orientation experiences and teacher-support materials (e.g., curriculum guides, suggestions for implementation, content supports) are important, particularly for new teachers, as they help students learn to use scientific data. (Ocean Tracks pilot teachers used a teacher guide and attended a one-day training session on the interface and curriculum materials.) Ocean Tracks plans to offer expanded opportunities for virtual and in-person professional development in future phases of the program.
- To achieve the best results, supplement students' time on the computer with offline activities that let them practice their new skills.

DAN COSTA/TOPP

Male elephant seals can weigh up to 4,500 pounds.

- Encourage students to face the challenges of working with scientific data. Many will find it difficult to work without definitive "right" or "wrong" answers, to assess their work on how well data support their claims, and to make claims based on multiple types of data and repeated measurements. Remind students that the data are authentic and that their investigations are similar to the work of real scientists.
- Connecting students' experiences with data to their own lives can motivate them to explore questions related to that data.

## Conclusion

Students and teachers today are poised alongside scientists at the frontier of the big data phenomenon. The opportunities for providing better access to big data sets are rife, and Ocean Tracks is serving as a model. However, much still needs to be learned about what teaching strategies may help students (and teachers) learn to work with and analyze big data. This article can spur further exploration of using big data in the high school classroom. Armed with the right tools and instructional strategies, the possibilities for learning about the world through data are boundless. ■

*Amy Busey* (abusey@edc.org) *is a research associate, Ruth Krumhansl* (rkrumhansl@edc.org) *is a principal research scientist and director of the Oceans of Data Institute, Josephine Louie* (jlouie@edc.org) *is a research scientist, and Kira Krumhansl* (kkrumhansl@edc.org) *is a research associate at Education Development Center, Inc., in Waltham, Massachusetts; Julianne Mueller-Northcott* (jmueller-northcott@sprise.com) *is a science educator at Souhegan High School in Amherst, New Hampshire; Randy Kochevar* (kochevar@stanford.edu) *is a marine biologist at Stanford University's Hopkins Marine Station, in Pacific Grove, California; and Virgil Zetterlind* (vzett@earthnc.com) *is the chief technology officer at EarthNC in Delray Beach, Florida.*

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### On the web

Ocean Tracks learning modules (a series of investigations); teacher guide, including supplemental activities; and multimedia supports (virtual library and video resources for students and teachers): *http://oceantracks.org*

Programs, products, and research focused on unlocking the potential of big data in education: *http:oceansofdata.org*

Tagging of Pelagic Predators (TOPP): *www.topp.org*

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