Community Ecology
Measuring the Distribution of Animals in the Sea

Kelly Benoit-Bird is Assistant Professor of Biological Oceanography at the College of Oceanic and Atmospheric Sciences at Oregon State University. Her research focus is in pelagic ecology, with an emphasis on applying acoustical techniques to zooplankton and nekton.

What kinds of biological activity can be measured acoustically?
Researchers can look at the distribution of organisms: how things are patterned in space. By looking at patterns over time, we can start to understand how things interact with each other. We can look at size classes, for example, to look at what the big animals are doing in relation to the small animals. Sometimes we can make categorical descriptions about the animals being measured. For example, dolphins are easy to tell apart from fish, using acoustics. A major focus of what I look at with acoustics is predator-prey interactions.

We use both passive and active acoustics to study animals in the ocean. With passive acoustics, researchers stick a hydrophone (microphone) into the water and listen to the sounds the animals make. With active acoustics, equipment sends out sounds and listens to the sounds bouncing back; one type of active acoustics is sonar.

What are the benefits and drawbacks of using acoustics?
The benefits are that researchers can use acoustics in shallow water, rapidly survey a large volume of water at high resolution, and survey the entire water column in depth.

The difficulty is in telling what is making the sound—that's particularly true with active acoustics. With passive acoustics, we sometimes know enough about the sounds animals can make to know what kind of animal made it. With active acoustics, researchers can use other techniques—optics, imaging, and sometimes trawling and direct sampling—to figure out the species-specific information.

I'm interested in acoustics because it's a helpful tool in combination with other techniques.

Can acoustic backscatter from zooplankton get confused with anything else?
Microstructure in the ocean (e.g., turbulence) can cause scattering that can look like zooplankton. But most of the time, the zooplankton is such a strong echo, even in those environments, that it swamps the physics. It's much harder to measure the physics instead of the biology. Most of the time, physicists use plankton as an indicator of what they're trying to measure. That's how an acoustic Doppler current profiler works—it assumes the zooplankton are passive and measures the movement of the zooplankton. The particles in the water column, the biology, is the marker for the current.

It can also sometimes be difficult to distinguish a densely aggregated group of zooplankton from a larger organism. Van Holliday, at BAE Systems Ocean Sciences Group in San Diego, has been working on distinguishing
the difference with multifrequency acoustics. Holliday has done a lot of work with Tim Cowles of COAS and is a collaborator of mine, as well.

**How did you begin using acoustics as one tool with which to study biology?**

As an undergraduate, I worked with two investigators doing acoustics in different environments: studying tadpoles in aquatic environments and bats in aerial environments. I became interested in how bats deal with their world, which is more three dimensional than is typical in a terrestrial environment. An aerial environment is similar in many ways to the pelagic environment.

The two PIs were married and they ran the lab as a whole, even though their research was different. I had two mentors with very different perspectives, so I didn't get the one-track view of the world that is easy to get as an undergraduate. I learned very quickly that science is not black and white.

**Is your current focus on zooplankton a switch from your past research of predator-prey interactions, e.g., dolphins and micronekton?**

I consider myself a community ecologist. What I was working on in Hawaii, and will continue to be working on, is the micronekton. Micronekton are small animals that can swim; some people call them macrozooplankton—it's all a matter of custom. Micronekton are an important part of the community in Hawaii. My research looks at how those animals serve as a forage base for larger animals like spinner dolphins, deep-water snappers, and tunas. Those micronekton are also the most important consumers of zooplankton in Hawaii.

I just put in a research-grant proposal to look at how the consumption of zooplankton might drive the migration pattern of micronekton and the consequences for the larger community structure.

I don't see myself focusing on a specific taxa. I'm interested in how all the puzzle pieces fit together to give an understanding of the whole system.

**You've recently arrived at COAS. What attracted you? Who are you interested in working with?**

I hope to follow on with some of Emeritus Professor Bill Pearcy's work with micronekton in the Oregon coastal region with scattering—some of the intuitive feelings he had for data that haven't been published. When you collect data, you get a lot of ideas that never come to fruition, but you get all these great questions in your head. Hopefully I'll be able to talk with him and see where he was headed with some of those ideas.

What attracted me to COAS was the breadth of people here. When you do ecology, especially in the ocean, it's extremely interdisciplinary. You have to take into account so many things—physics, biology at many levels, chemistry, and all the techniques to be able to get at all those different sized animals and their environment. Having the full group of people here that all work together under one umbrella, instead of split into different places, was really attractive.

**Do other oceanographic institutions have more divisions?**

Often, divisions are clearer and researchers are not pulled together as much as at COAS. Chemical oceanography and biological oceanography are usually very separate groups, even if they're in the same department. The science is moving to less division among disciplines, especially in the kinds of things in which I'm interested—how the system works
and what are the consequences. My research area is very broad and one researcher can’t do everything. So it’s great to have such breadth in one place, to have people around you who are enthusiastic about what they do and interested in getting involved.

**What relevance does your research have to day-to-day life? Why do you do what you do?**

The applied end of my research, looking at predator-prey interactions with a lot of commercially exploited species, has some significant fisheries management implications.

However, why I do what I do is because my work is really fun. We researchers get to do everything, from coming up with an idea, to getting funding, to building and designing equipment, to collecting the information out in the field, to figuring out what it means, and then telling the story about it at the end. I enjoy that diversity.

The greatest part of the job is that moment at 3 o’clock in the morning when you figure out an answer to a question you’ve been thinking about for months or years. Suddenly you have the answer and you’re the only one who can see it at that point. It’s sort of like being an explorer, except you’re not discovering new continents.

**How have changes in technology changed your research?**

In acoustics, the advances in computing technology have made a significant impact in how much data we can collect and in the resolution of that data, because the computer is fast enough to collect more points. Almost everything we do now is digital rather than recorded on tape.

For example, more computing power means that now we can cover a wider range of frequencies in the acoustics. In animal bio-acoustics, researchers have found that a much greater proportion of dolphin signaling occurs in frequencies beyond human hearing than we ever knew. That’s changing the way we look at how animals communicate with each other and the significance of sounds to them.

As another example, we can now use multi-beam sonars instead of single beams. Multi-beam sonar adds a spatial dimension to the data we collect. Computers are now fast enough to handle 120 beams instead of 1. This change has been significant to my own research on predator-prey interactions. Having that extra dimension has changed how we see what’s happening in a volume of water—think of an overhead light versus a single flashlight beam.

**Do you design any of your own equipment?**

I spend a lot of time developing equipment. It always seems as if there are never existing techniques that work with what I want to accomplish.

For example, one item I just developed is a low-light stereo camera system for micronekton. Micronekton are incredibly fast and manage to avoid nearly every instrument you put in the water, especially those with lights. Camera systems with strobes are not effective for micronekton.

In the last couple of months, I got the camera system into the water. With it, we can identify the fish (something we can’t do with the acoustics) and measure density (which we can’t do with a single camera). The stereo camera has two cameras imaging, which helps get at the size of the fish and how far from the camera they are. We can know there are ten fish per cubic meter rather than just have a picture of ten fish with no idea how much space they take up.

Most of the parts were off-the-shelf. Development meant having the idea of what I wanted to do, researching off-the-shelf components, and doing the assembly. I will write up the equipment, so that other people who are interested in the same kind of questions can build the same kind of equipment. However, by the time you build something it’s usually
In the ocean, plants are microscopic and they move, constantly. You don’t have a stable two-dimensional surface to measure everything against because often that two-dimensional surface of the seafloor is unimportant when it’s 1,000 m or more away from animals living in the water column. But what’s exciting about working in the pelagic environment is how different everything is than what we experience, walking on two legs on land. In the ocean, you can’t see beneath the surface. Everything happens over a vast three-dimensional space and changes quickly. It’s not like on land, where plants are generally large and don’t move much. On land, the time-scale is also slow; trees live a long time.

Outdated and there is better technology to replace what you’ve done. Then, it’s just the concepts that are still useful, not the actual equipment.

**What do you see as the biggest unanswered research questions?**

My field is broadly defined. But my research questions are more narrow:

- How are animals distributed in three-dimensional space over time? In the ocean, the distribution of animals changes quickly and it is very difficult to measure that over any large spatial scale.

- How did they get that way? Once we figure out how to measure the distribution in space and time, we have to figure out what the physical and biological processes are that created those kinds of patterns.

- What are the consequences? For example, what are the implications for how animals find their prey, how their predators find them, or the the chemistry of the system?

Right now, we can’t even pose some of those questions well enough, because we don’t have the measurements to help us understand even a static view of what’s there. Until we can describe a pattern, we can’t begin to understand its importance or how it was generated. To find those general patterns will take a long time, to see what rules apply, in what situations.

**What are the challenges to researchers seeing these patterns?**

Scientific illustrations. Benoit-Bird has illustrated her own papers with maps, animal drawings, and images of equipment. Her work has been published in a variety of scientific journals, as well as all the illustrations in Mark Bertness’ book, the “Ecology of Atlantic Shorelines” (Sinauer Associates, 1998).