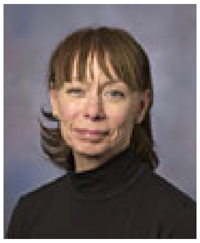

North Atlantic Right Whale Forum - Darlene Ketten

# RIGHT WHALES' EARS

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*A unique collection of right whale ears offers critical understanding of the functional morphology of the whales' primary sense organ.*

» Biography
» PDF version of talk (760 kb)

This presentation is going to be something of a tag-team match. You'll shortly learn more than you ever wanted to know about right whale ears. I'll tell you about the approaches that my lab has been taking for studying whale ears in general, then I'll ask Susan to tell you about what she has done working in my lab specifically on right whale ears as an adjunct to her thesis on whale reactions to sound.

We have a rather unique collection in my laboratory: about 20 right whale ears collected over the years from strandings—not all of them what you would call "splendid" based on looks (or smell) alone. Some are downright foul, but every one of them is in its own way quite beautiful. They are literally invaluable for research.

Collection of right whale ears in the field

None of this work, especially in my lab, can get done without the assistance of many people. Every necropsy, every ear collected, requires a team effort. Frankly, none of this work on ears is exciting. It’s exacting, tedious, and would be absolutely pointless if we couldn’t collaborate with other scientists such as Peter Tyack (Woods Hole) and Chris Clark (Cornell) to get feedback about what these animals actually do in the wild. A critical element you’re seeing in this workshop is how everyone’s work has to interact to get the right answers.

We’ve heard a lot about ship collisions with right whales. According to the literature on ship strikes, they were infrequent from 1870 to 1950. You’ve heard the expression “Speed kills.” It’s true for ship strikes, too. There was a rapid increase in the incidence of ship strikes after 1950, when ship speeds increased. Essentially, about 5 species were most frequently impacted; and in particular, the right whale. Approximately 30 percent of stranding mortalities in the literature resulted from high-impact strikes. In addition to the speed factor, the severity of strikes also increased with the length and tonnage of ships. The bigger the ship, the worse the accident.

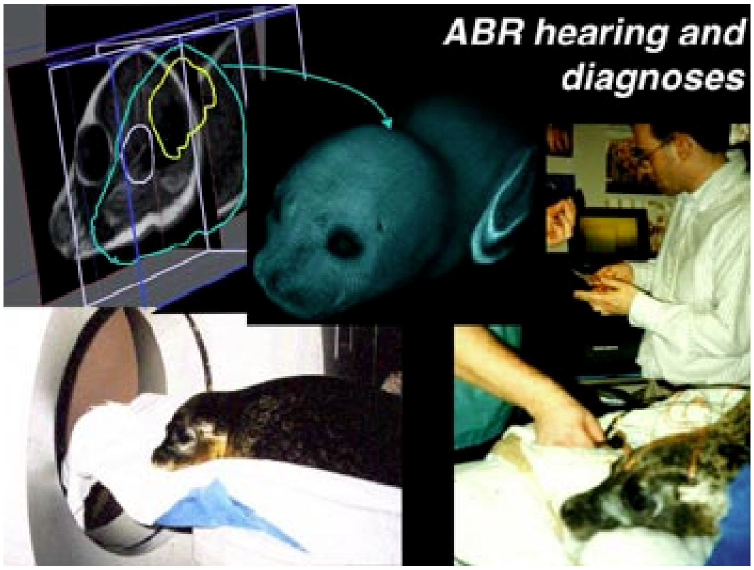
What we’re seeing with ship strikes is a pattern of impact coming from the back or side of a whale, not generally head-on.

This pattern brings up a good question: Do right whales hear vessels coming? That central question, in turn, leads to a whole series of questions that we need to answer about hearing in right whales:

- What manmade sounds can right whales detect?
- What kinds of acoustic alerts might allow right whales to avoid ships?

- What is the frequency range heard by right whales?
- How well do they localize sound sources, that is, discern from where the sound is coming?
- Are there pathologies that affect their perception?

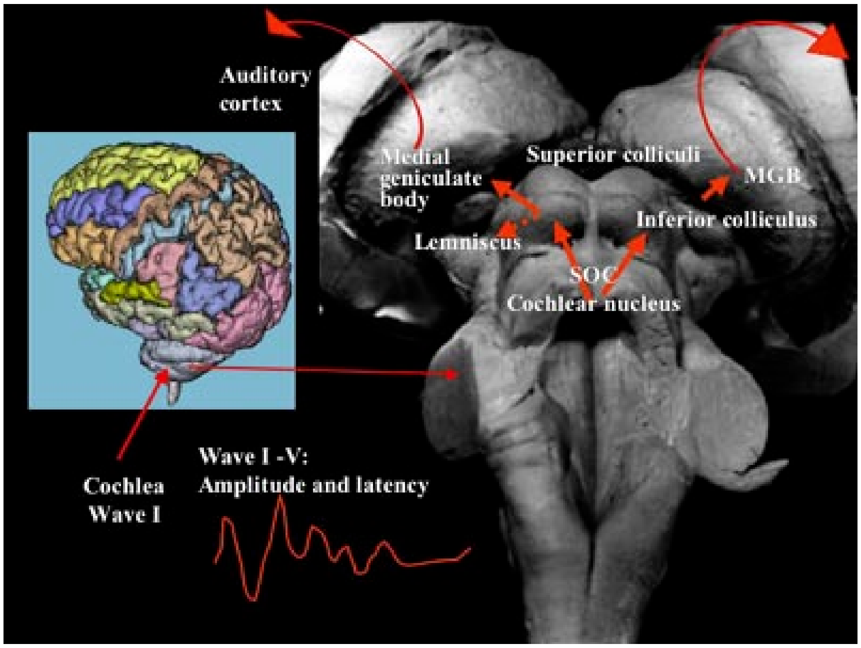
A promising method for getting at these questions is one that we've used on animals that are much smaller than whales. Suction electrodes are placed on the surface of an animal's head, a sound is played, and we record the brainwaves. It's non-invasive, it's fast, and it's an indirect way of asking, "Can you hear me now?"



This method works beautifully on dolphins, porpoises, and seals, but is it going to work on whales? I'm very excited about that possibility. I'm also rather disappointed that it won't happen soon. Here's why. When you compare the percentage of brain weight to body weight in dolphins, humans, and baleen whales, you find a huge difference among the three groups.

Relative to body weight, the brain of a baleen whale is more than a magnitude smaller than for humans or dolphins. Nothing personal about right whales, but they have, in proportion to their bodies, rather little brains, which are also surrounded by a huge mass of bone, muscle, and fat. These are very, very big heads. That means you're going to get large amounts of interference when you try to measure brainstem activity. It might be a terrific technique if we get a small baleen whale like a newborn, but not larger whales. Because of the size alone, we're going to have substantial problems with this approach.

What we're doing instead at this time is modeling anatomical components of the ears and heads in order to understand exactly what right whales hear.

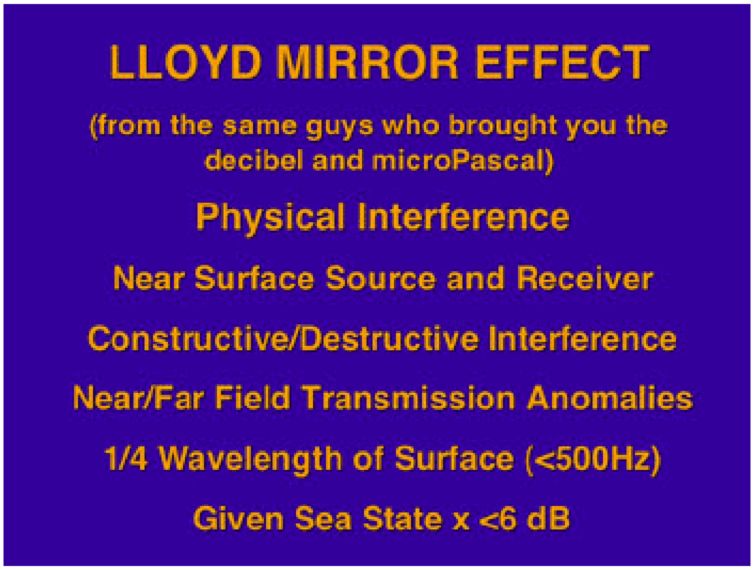


Our plan is to look at the auditory system of right whales and develop maps of their cochlea (the spiral-shaped part of the internal ear containing the membranes and auditory receptor cells) that tell us the frequency range of what an animal hears.
The ear of a right whale, like that of any mammal, has an outer-ear (sound collector), a middle-ear (amplifier), and an inner-ear (cochlea). The anatomy of the cochlea of any mammal dictates the frequency range it perceives.

With ears, size isn't important. Hearing is dependent on the stiffness and mass along the inner-ear membrane and how the membrane is organized mechanically. Some animals are clearly specialists in hearing low freuquencies (infrasonic); others very high frequencies (ultrasonic). We, with our human ears and focus on human hearing, are arbitrarily the standard for mid-range or "sonic" hearing capabilities. Basically, what we do to find a whale's range of hearing is to measure various parts of the cochlea and then use that information to calculate what frequencies the animals hear.

The technique works, and now Susan will explain to you in much more detail how our lab determines an animal's hearing ranges.

**Conclusion:**



LLOYD MIRROR EFFECT

(from the same guys who brought you the decibel and microPascal)

Physical Interference

Near Surface Source and Receiver

Constructive/Destructive Interference

Near/Far Field Transmission Anomalies

1/4 Wavelength of Surface (<500Hz)

Given Sea State x <6 dB

I'd like to bring up two final points. One is a phenomenon called "masking." That is, a noise within your hearing range can cause interference in a variety of ways. It can raise the threshold at which you will be able to hear a noise you're producing. It can also make other sounds in a similar domain, making it difficult to detect, for instance, the sounds of ships.

The second thing is a physical principle in the ocean called the Lloyd Mirror Effect. It is to some extent theoretical, because it hasn't been measured in the actual ocean. One theory is that the Lloyd Mirror Effect creates a zone in which sound is reflected and attenuated such that an animal at the surface will hear very little. In other words, the propagation of sound at the surface may create acoustic nulls, or dead spots, making it difficult for whales to hear the noise of ships.

Consequently, it is not enough to know simply what a whale ideally can hear. Instead, it is important that we consider the real-world interference and impacts, such as the potential for masking or nullifying hearing, in order to really understand what is "heard" rather than what they "ought to hear."

One final word. For our research on the frequency range and sensitivity of whale hearing to be worthwhile and helpful for conservation, we need continuously to interact with scientists working in the field who can test the model predictions. For the right whale, one of the most productive outcomes of the models would be to inform the design of acoustic alarm systems that will:

- decrease the number of ship strikes
- induce avoidance (with minimal stress) by whales
- avoid the problem of habituation, so that the alarm remains effective.

Thank you very much for your attention.

## Biography

Darlene Ketten has pioneered the use of the computerized tomographic (CT) scanner to study marine life anatomy. She has focused on understanding how the ears of marine animals, particularly whales and dolphins, are able to hear and use underwater sounds.