Jennifer Stock: You're listening to Ocean Currents, a podcast brought to you by NOAA's Cordell Bank National Marine Sanctuary. This radio program was originally broadcast on KWMR in Point Reyes Station, California. Thanks for listening!

(Ocean Sounds)

(Music)

Jennifer Stock: Welcome to Ocean Currents. My name is Jennifer Stock. I'm the host for this show, which is part of the West Marin Matters series, the first…are every Monday of the month. There is a topic relating to our local environment or economy here in West Marin and Ocean Currents is always the first Monday of every month. On this show, we dive into all sorts of topics relating to the big, blue ocean on our planet. Everything from research, science, exploration, conservation, expeditions, and adventures as well, anything about that blue planet we will be talking about on this show. So, thank you for joining us on this nice, cold wintery day and today's topic is somewhat difficult in the sense of solutions and I'm hoping to hear a lot more about the topic today with our guest.

If you've been out and what you think is wilderness or a quiet, natural area away from civilization, surrounded by nature and then all of the sudden you start hearing loud airplanes flying overhead, motorcycles zooming by, boats in the distance or even seasonal guns going off, this is the sort of thing we'll be talking about today: ambient noise. However, today we're talking about it in the ocean and if you've ever spent time underwater in relatively shallow depths, you know there's a lot of natural, wonderful sounds to hear from the lapping of the water itself to snapping shrimp, some fish, dolphins, whales, all sorts of wonderful sounds as well as the huge natural sounds of underwater earthquakes that we probably couldn't hear in the shallow waters, but as civilization has advanced on our planet, so has our technology and from recreational boating to shipping and general maritime commerce to oil exploration and drilling and naval sonar, sound in the ocean has increased steadily in the last few decades and my guest today has been studying this quite a bit.

So, we'll be talking about how sound is measured in the ocean, how scientists use it as a tool and what are the trends going on right now. My guest today, joining us by phone, is Dr. John Hildebrand, who is joining us from San Diego. John, welcome. You're live on the air.

John Hildebrand: Thank you, Jennifer.

Jennifer Stock: John is a professor of oceanography with Scripps Institution of Oceanography in San Diego. In addition to overseeing graduate students and teaching classes on bioacoustics, John has contributed to over 100 publications on topics ranging from acoustic wave propagation to passive acoustic monitoring for marine mammals. His recent research has focused on the use of acoustic techniques for marine mammal population census and the impact of anthropogenic noise on marine mammals. So, welcome John. Thank you for joining us today.

John Hildebrand: Thank you for having me and, you know, I was up and I visited with the Cordell Bank sanctuary folks, must've been two years ago. I think they invited me up to give a talk about ambient noise

Jennifer Stock: That's exactly how I got your name because I was at that talk and I thought, "John would be a great guest to really discuss this issue broadly." So, this is a really difficult topic and I think for some of us that may not be that familiar with sound and science in general, I'm wondering if you can just give us a real brief overview about what sound is, sound waves, and how it's different in air versus in water.

John Hildebrand: Well, you know that, you know, we all have ears and , you know, it's not the most important sense for us. People are very visually oriented. It's much easier to get a detailed sense of your surroundings by looking than by listening. Now..and that's just, you know, a matter of our environment, but on the other hand, we do use our ears and you know how annoying noise can be, noise in the sense of sounds that is not wanted, sound that interferes with other sounds that you'd like to hear and, in fact, my real estate agent once told me as I was looking for a house, there's nothing worse than having…buying your house next to the freeway, right, because of the presence of all of this unwanted sound.

So, in the undersea world, it's exactly the opposite where light, anyone who's been a diver or even just kind of stick your head underwater, you'll realize that light is very limited in terms of the distance that it will propagate underwater. It's really hard to see any great distance and it's both the fact that the light is absorbed by the water and that there's a lot of particulate matter, you know, things floating in the water that scatter the light and so, it's just not a great sense to detect things that are very far away and in the worst case situation, in really turbid water, you can stick your hand in front of your face and you can hardly see it. Now, on the other

hand, sound propagates incredibly efficiently underwater and at low frequencies, sound can propagate essentially without any absorption by the ocean and what this means is that animals who are adapted to live in the ocean make a lot of use of the ambient sound and they make use of the sound to know the setting that they're in, you know, are they in shallow water or deep water?

They know their direction. Here's a noisy object off in the direction like the waves of the shore. Obviously, if you can hear that you can orient yourself and certain groups of marine animals, like whales and dolphins, in particular, have adapted fairly sensitive mechanisms to hear sound and also to generate sound. So, dolphins, for instance, their main way of capturing prey, which is mostly fish, is to create a high frequency click, you know, which is just a really short snap like snapping my fingers and then the reflection of that sound off of their prey tells them the presence of it and also they can navigate in at night with no light whatsoever. You can cover the eyes of a dolphin and it still is perfectly efficient at capturing fish.

So, the sound is just a really important part of their world and when you look at the anatomy of their brain, there is much more circuitry devoted to processing the sound than there is to processing light and, of course, our brains are exactly the opposite. So, this means that the noise environment of the ocean is very important for the health of the ocean in terms of the animals being able to make use of their natural environment. Now, that's where the concept of anthropogenic sound comes in. In other words, noise that we humans have introduced into the ocean and over the last say, 50, 60 years there has just been a really rapid increase in the amount of goods that are transported across the ocean in container ships or oil tankers and so, we're using the ocean as a highway of commerce and one of the byproducts of that is increasing the ambient sound level, the ambient noise level, especially at low frequencies like 100 hertz or 10 hertz at the bottom end of our hearing.

We've really dramatically increased the noise levels in the ocean over the last, say, 40 years and so, it's a level where it's as if you're peacefully living in your house and steadily, year by year, the surroundings of your house get noisier and noisier until it's really decreased the quality of your life.

Jennifer Stock: Yeah. I can relate very, very much so with the office that I work in the days that nobody are there versus the days that everybody are there and just the chatter and the background and it's so hard to get

work done. So, I can imagine the stress that could create in mammals specifically in regards to always being there.

John Hildebrand: Yeah. Well, it's stress, but it's also…you miss things. Let's say, for baleen whales there are songs that males produce to try to attract a mate to try to impress females. Well, if those sounds are intended to propagate a certain distance so that you're actually getting to be heard by your potential mate, as the background then from the shipping goes up, then the range at which you can actually be successful in terms of attracting a mate, it goes down. Now, it's kind of tricky. This is an issue in a lot of ocean problems is that we wish we had a baseline. We wish we knew a lot more about what things were like 100 years ago or more and the problem is we don't have a really good baseline. This goes for the presence of various animals, but also in terms of the ambient noise state of the ocean and so, one thing that we found was that about forty years ago, maybe a little bit more, the Navy was worried about tracking Soviet submarines off the west coast of the US and also in the Atlantic and so, they installed a series of listening posts and these were called the SOSUS Arrays and, in fact, I think there was a SOSUS Array at one point off of Mendocino, which is not too far from where you are and these listening posts, as they put them in, they needed to know what the ambient noise background was as a measure of how well they could detect a submarine.

So, with your Uncle Sam's support, a lot of effort was put into measuring background noise at various sites along the west coast of the US.

Jennifer Stock: So, these are just listening stations. They're not putting sound out. They're just listening.

John Hildebrand: Absolutely just listening and using, at the time, they were tracking submarines and by combining the signals from various other stations you can, sort of, triangulate the location of where the submarine would be. Well, so…but, they produced just fabulous documents in terms of documenting over more than a year what kind of changes you'd see in ambient sound at all of these sites and one of the things that they realized is that there were these sounds made around 20 hertz and 100 hertz that were clearly biological in origin, but at the time, they didn't know what. They would just give them names like, there's the….20 hertz long is the tone at 20 hertz that lasts for a long time and it turns out now, today, we know these are made by blue whales, but it was just a mystery of the deep at the time, but from these records, which were classified in the 60's, they've now been declassified because of the strategic

importance of them has gone away, but the value in terms of documenting the background of ambient noise is really great because now we can go back to 1961, 62 and say, "What were the sound conditions like?" And when we do that, we made a measurement at exactly the same site using a calibrated system.

We found that there was about a factor of 10 increase in the power of the ambient noise at these sites, which is significant. In other words, the perceived sound level had gone up by a factor of ten.

Jennifer Stock: Now, this was a site that you studied off of southern California, San Nicholas Island?

John Hildebrand: Yes. Saint Nicholas Island and it was also done at Point Sur, which is just, you know a bit to the south of you and both of these sites had essentially the same result that the ambient noise increases, there's a doubling of ambient noise about every decade.

Jennifer Stock: Wow. So, then I'm sure the noise is attributed to increased shipping traffic, correct?

John Hildebrand: Yes, yes.

Jennifer Stock: I used to dive at San Nicholas Island. I used to dive at Catalina and we did a dive trip over there and I remember there was a lot of concern of us, as far as getting in the water, would they know that we were there if they were going to do any testing because they do testing and when we were underwater, we heard some huge bomb go off, I remember, and it was like, "Oh my god. We gotta get out of here," just because of the types of things that happen on that island, but I'm sure the noises that you're collecting over the long term there were from multiple sources, not just the testing that's happening on the island.

John Hildebrand: Well, the…we were talking about how efficient sound propagates underwater and it turns out that the noise that you hear in a place like Saint Nicholas Island or Point Sur is really an average of all of the noise sources, all of the ships in the north Pacific. You're literally hearing ships that the sound of the ship is propagated all the way across the ocean basin, thousands of kilometers because the sound propagation is so efficient. So, it's just kind of, I mean, there are sounds of individual events like a ship going by or someone setting off an explosion or something that you can put your finger on it, but generally, that's one of the things about ambient noise is it's just a collection of all the noise sources that, in this case, are across the entire north Pacific Basin.

Jennifer Stock: So, it's just kind of generally raising up all along. It's just like starting from the bottom and coming up. It's magnified everywhere.

John Hildebrand: Yeah. Well, it just…it kind of…there's also a feature of the ocean in the north Pacific, which is that it has a wave guide, it's called the sound channel, that essentially keeps the sound trapped in…it's not…I wouldn't call it a surface layer because it's most of the ocean depth, but it means that the sound doesn't dissipate by bumping into either the surface or the bottom. It's just…it's like a wave guide is the way that people describe it.

Jennifer Stock: It's just like if you were going into a small room that had a lot of flat surfaces…you...

John Hildebrand: …where the sound just reverberates forever.

Jennifer Stock: …and those are typically unique underwater features that may also be associated with productivity and perhaps concentrate marine life as well. So, that might be quite a concern for those who study marine mammals.

John Hildebrand: Yeah and you would guess that the whales know about this and exploit it. Of course, this is why some of the signals are really optimized for transmitting a long way and maybe, I don't know, this is at risk of people having low frequency speakers or whatever, but I sent you a sound that's something like…it's a blue whale.

Jennifer Stock: Okay. So, that's the first track.

John Hildebrand: Yeah. So, that would be an interesting one to play just to give a sense of the kinds of sounds that the whales make.

Jennifer Stock: Sure. Okay. Stand by here. Let's try this track out.

(Whale Sounds)

John Hildebrand: Yeah, there was a sea lion barking there, but...

Jennifer Stock: So, that thumping...

John Hildebrand: Yeah, that thumping noise. That low-frequency thumping. You have to have really good speakers and I have to say that my telephone headset didn't do it justice, but I hope that you could hear, there's a low frequency, kind of, thumping.

Jennifer Stock: So, that's the blue whale?

John Hildebrand: That's the blue whale. It's just at the lower end of our perception of hearing. Now, there's another track I sent that has ship noise, but with the blue whale included and it may be a little bit too long to play the whole track.

Jennifer Stock: Is this the fifth track.

John Hildebrand: Yeah.

Jennifer Stock: Ship-blue it's titled?

John Hildebrand: Yes. Ship blue.

Jennifer Stock: Okay. So, let's try this one as well.

(Ocean Noises)

John Hildebrand: The clacking noise is the sound of the ship and eventually in this track a blue whale comes along, but you can get a sense of how the ship is interfering with the sounds that the whale is making.

Jennifer Stock: I hear it now, okay. Let's listen.

(Ocean Noises)

John Hildebrand: Now that was made in the Santa Barbara Channel where there's just a real coincidence of lots of whales and lots of ships.

Jennifer Stock: I'm not sure how well these are transmitting because on the little control here the needle is not budging much so I'm not sure how well these are coming out, but we'll keep trying.

John Hildebrand: Okay. So, just as an example, I sent a track from a gray whale and we know, of course, the gray whales migrate up and down along the coast, the west coast here, going up into the arctic and the Bering Sea to feed in the summer and then coming down to have their calves in the winter and if you could play the gray whale…that also gives a sense…it's a sound that's made to be transmitted in the shallow waters along the coast.

Jennifer Stock: I see. Okay. Let's play this.

(Ocean Sounds)

Jennifer Stock: Wow. I did not know they made those clicking sounds.

John Hildebrand: Did you ever own a pair of bongo drums.

Jennifer Stock: Yeah.

John Hildebrand: Well, that's what's inside the gray whale, apparently.

Jennifer Stock: So, those are two very distinct sounds.

John Hildebrand: Yes. There's kind of a burly sound and then there's a bongo kind of sound. The…as I said, these animals, the gray whales, like to stay in shallow water and they've come up with sounds that are almost perfectly optimized to propagate in the shallow water so that they can hear each other and keep track of each other. The knocking kind of sound is just, that's very characteristic of what gray whales do and so, in the same sense though, shipping or, in this case, small boats or whatever nearby you can see how it would be disruptive to that, but this is kind of how they keep track of each other.

Jennifer Stock: For those just tuning in, we're talking about ambient sound in the ocean. This is Dr. John Hildebrand from Scripps University in San Diego, Scripps Institution of Oceanography in San Diego and we're talking about different ambient sounds in the ocean and we just were listening to some gray whale sounds. Now, John, I wanted to ask you about the gray whales. As far as…do they also use sound for the calves staying with the mom as far as keeping in touch with each other because I know with elephant seals and sea lions, they do a lot of imprinting when they're on land as communicating to be together, but do whales do something similar.

John Hildebrand: There's certainly suggestions of that, but one of the things that when the mothers and calves are migrating up and down the coast, they tend to be fairly quiet because they don't want to attract attention in terms of predation from killer whales. So, they tend to be more silent and males tend to be making more of the sound, but that's not always the case. Now, I included also a track from a humpback whale.

Jennifer Stock: Yes.

John Hildebrand: Could we hear that. Yeah. Let's bring that on.

(Ocean Sounds)

Jennifer Stock: That's amazing.

John Hildebrand: So, in this case, it's a male humpback that's singing. He's trying to attract a mate and we call this humpback song and we hear it, almost, in a musical way. I mean, we can relate to it as a song. It has a repetition, there are phrases, there are themes that get repeated, there's an overall song cycle, usually somewhere between ten and fifteen minutes and it seems like a conscious performance on the part of the whale, you know, a conscious projection of something about their, probably, fitness for breeding, trying to attract a mate. Now, people think about these humpback songs, the most famous place to hear this is near Hawaii because there is one set of humpbacks that spend the summer in Alaska feeding and the winter in Hawaii. Sounds like a nice life, doesn't it?

Jennifer Stock: Yeah.

John Hildebrand: Breeding, but, you know, the intestine thing is that we also along the coast of California have our own humpbacks and they tend to go back and forth from Central America in the winter and then in the summer and also in some other seasons and somewhat in the spring and fall, they're up along the coast of California and we've recorded them singing up here just as well as down in Costa Rica. That particular song was from Central America, but they sing the same kind of songs when they're up here in the summer months and…but, it's just…there's so much put into it in terms of males, they have a place, they're stationary, they'll do this song, and they'll do it for days on end. So, it must have some real significance in terms of the lives of the animals.

Jennifer Stock: Now, do they only do it on the breeding grounds? I just read somewhere that some recordings were done actually near Cordell Bank of humpback whales making these calls and I was surprised because I had thought it was only the breeding grounds.

John Hildebrand: Yeah, well that's the standard theory goes that they only sing on the breeding grounds, but we've recorded it up here in southern California and I wouldn't be surprised at Cordell Bank as well. So, I think it's something that just goes on all year long and maybe there is a more intense effort put in during the winter months, during the breeding months, but I think it's just part of their culture, part of what they do.

Jennifer Stock: Now, based on the sounds, based on what you were saying earlier, that the sounds can propagate all the way across the ocean…are those specific frequencies because…would we be able to hear

humpback whale calls here in California that are being generated in Hawaii or is it generated based on the frequency of the sound?

John Hildebrand: The songs of the humpback whale are not that high amplitude that you'd hear them all the way from Hawaii, but in…the reason when I talk about the ships, if you have, let's say, 1,000 ships spread across the north Pacific, all of that energy kind of adds together to create this background end and also the ships are a little bit higher amplitude than the whale in terms of the sound production and also, a little lower frequency. So, there are these sort of multiple factors. Low frequency propagates better than high frequency. Obviously, if you produce a louder sound then it will go further.

So, we can hear the humpbacks if you've ever been lucky enough to be close to a singing one, it's quite loud if you stick your head in the water near one or you can actually hear it even in the air close to one, but more on the order of sort of 10 to 20 miles would be about the limit of where you could still be hearing a singing humpback and that may be matched to the range in which they're interested in attracting a mate. In other words, if you can swim over to me within a couple of hours and, you know, then I would be happy, right? Whereas if you're 1,000 miles away and it's going to take days and days to swim over then I may be wasting my breath to be singing.

Jennifer Stock: Interesting. So, the humpback whale sounds are in our listening range as far as what we can hear.

John Hildebrand: They're nicely in our range, yes.

Jennifer Stock: But, the blue whale….was that a track that had been sped up to be able to hear within our listening range?

John Hildebrand: No, that track was raw. That was a real frequency as recorded by the whale and it's just at the lower limit of our hearing and so the humpbacks will easily go up to kilohertz. The best hearing for humans is about a kilohertz high. Humpbacks sing right around that. Blue whales, the highest energy is 15 Hz, which you know, is just right at the bottom of what we can hear.

Jennifer Stock: Now, is it different when you're closer to a blue whale as far as the intensity goes?

John Hildebrand: Well, you actually, if you're in the water or close to a blue whale that's singing, you feel it. I mean, it's more like your whole body feels it as opposed to hearing it. And if you get sort of rockstar kind of subwoofers and play the sound back, you can get that experience.

Jennifer Stock: Wow. So, you were talking a lot about mammals. Do we know much about impact of sound or how sound is used by other animals in the ocean like these snapping shrimp. Is that just their exoskeletons clicking together as they move around or there's a lot of fishes that make a lot of thumping sounds as well. Do we know much about how they used sound?

John Hildebrand: Well, we for all of these, we're just starting to learn. The snapping shrimp actually, it's part of their moving around, pushing the water. They actually do what's called cavitation. They push the water so hard that it actually opens up a little cavity, a little vacuum, and then the collapse of that vacuum is the snap, but I have to think that there's an aspect of staying together, they're in aggregate, these shrimp. They're not one animal all by themselves. They're living in sort of a colony and the sound is part of that, that knowing where you are with respect to your colony or, this may be a good feeling if you're surrounded by other snaps and so, you're not alone for an animal that's working in sort of a school like that, but we really don't know.

There hasn't been good experiments to see the uses made by snapping shrimp of the sound. Fish, on the other hand, we know a little bit more because there's a definite cycle, mostly the sounds of fish can either be done by males or females, but there is a certain time window and it's quite often, it's called corpuscular, it's right at sunset or right at sunrise, but and you see this where just within a window of ten minutes before or after sunrise and sunset where the fish are going crazy and there are various theories about why they chose that particular time, but, of course, if you're a fish you don't want to do something that would attract attention of a potential predator, right? So, that's a downside of making sound.

The upside, though, is if there's another fish you want to mate with and you need to attract them or tell them where you are, then you know there's a time you need to make that sound. So, these corpuscular times, right around sunrise or sunset, I guess the theory is that there's not…it's in that kind of twilight period where the light isn't so strong that the predators are going to get you, but on the other hand your mate might still be able to find you.

Jennifer Stock: It's happy hour.

John Hildebrand: Yeah, exactly. Happy hour in the fish school. So, but I think there's a lot that we can do and that hopefully we will do with identifying the species that make these various sounds and then using the acoustics as a tool for assessing the fish schools. One of the things we found in the recording that was made near Saint Nicholas Island by the Navy in the 60's was that it was absolutely full of fish sounds, lots of fish sounds and when we went back to the same site in 2007, there were no fish at all, which is kind of a sad statement. Now, I don't know actually what kind of fish were in the Navy recording. We don't have enough information right now to go back and reconstruct what happened, but there were fish present that are no longer present. So, again, it's be nice if we had baselines on these various things. It would help us to see how things have changed and so, when I make an acoustic recording now, I really think about it in that mode of…there is usually some particular species I'm trying to record, a humpback or a blue whale or something, for a particular study, but I'm trying to archive the sounds as a way of preserving them for the future where all of these other things like fish and other sounds that we can't identify yet, where we can go back and say, "Okay, well, this is what was present in this time at this place."

It's like in many ways, it may be one of the best ways that we can record the health of the ocean by getting a sense for what kind of sounds were out there. There's so many natural sounds, biological sounds, that we might be able to associate that with a particular state of the ocean.

Jennifer Stock: John, I'd like to come back to that to that topic in just one minute. We need to take a short break here at the station, but if you'd hold that thought about this research and this long-term plan, I'd like to come back to that topic in just a few moments. So, please stay on the line. Please stay with us.

John Hildebrand: Okay.

Jennifer Stock: For those of you tuning in, this is Ocean Currents and you're listening to KWMR, 90.5 FM, Point Reyes Station and 89.9 in Bolinas. Ocean Currents is the first Monday of every month and today we're talking about noise is the ocean, sound in the ocean with Dr. John Hildebrand. We'll be back in just a minute, returning to our interview with John.

(Ocean Sounds)

Jennifer Stock: John, we're back. Thank you for taking a quick little break.

John Hildebrand: My pleasure.

Jennifer Stock: I wanted to just go back to this idea about this research. In collecting sounds now, we may not know what they are now, but maybe in the future we'll be able to interpret them, but also I wanted to ask you how have you used acoustic listening and sound for studying marine mammal populations? Typically, I've talked with people and we've had people on the show talk about marine mammals from surface observations and I'm curious how you pair the listening aspect underwater, the information you collect with that with surface observations and what types of things are you trying to find out through that, the listening?

John Hildebrand: Yeah, well, the first thing that has happened over the last, say, ten years is that everybody has computer. You have a computer sitting on your desk, right? And your computer that you have now is dramatically different than what you had ten years ago, in every possible way: it's speed, it's ability to store data, everything about it. Well, what this has done is revolutionize the kind of instruments that we can put together to put out, in the ocean, the fact that we could have low-power and very fast and lots of disc storage on it on a computer. So, we've been able to create instruments and my particular brand of them are called acoustic recording packages or ARPs and we've been able to create these ARPs that we can just put out in, sometimes, in very remote spots in the ocean and let them record the sound for months and even up to a year in one session and it's basically a matter of having a lot of discs and a lot of batteries and a low-power computer.

So, with that we've opened up sort of a new window on to the ocean because in days of old, people would go out with a hydrophone, this is a listening device, and dip it over the side of a boat and they're looking and they're listening at the same time, but they can only be there for an order of a few hours and so, now we've created these kind of listening stations, really, almost around the planet to give us a sense for what's there and so, for instance, as we speak we have recorders up under the ice in the arctic. We have recorders out by Hawaii. We have a number of them along the coast of California and Washington. We have a recorder in the Gulf of California and also down in the southern ocean.

So, it's just this new way of looking at the ocean with these long-term sound records. So, then once you've done that, you realize that in the recordings, there are events where animals have come

within the hearing range of the instrument and so, for instance, if you put a recorder on the southern California continental shelf, for instance, up by Santa Barbara, many, many times a day, perhaps half of the time in the day there will be some kind of marine mammal within range of the hydrophone, either dolphins or pinnipeds or baleen whales and, of course, we're getting the ambient noise at the same time, the ships and that kind of thing. Now, your first challenge in dealing with these kind of data sets is to look at the recording or listen to the recording and say, "I know that this sound was made by," for instance, "a blue whale or a humpback whale." And the way we collect those kind of comparative data is that we actually go out in a small boat or a larger boat, find the animal and then make recordings in the presence of the animal and we have to do that enough to where we're comfortable and I, earlier in the show, we played some kind of typical sounds of a blue whale or a gray whale and so, you get to know what the frequency of the sounds and sort of the character of the sounds and before long, you can listen to it and say, "Oh yes. Of course that's a blue whale."

So, we put a lot of effort into making recordings in the presence of various species and then using those recordings as kind of a comparative catalog to say something about the recordings that we've made that are unattended, where no one was there to see what kind of animal it was and that's been fairly productive and we've discovered in some of the clicks that are made by dolphins that they're very distinctive, almost like a signature or a fingerprint for a particular species of dolphin and we think this has to do with the actual shape of the sounds that dolphin make are actually made in their foreheads. They have a sort of fat body in the top of their forehead. This is called the melon and the sound is actually rattling around inside the melon and that sort of bouncing of the sound produces a very distinctive character to it and so, we've just sort of discovered this by making a bunch of recordings in the presence of it.

Now, the next step once you've done that and we haven't totally solved this problem, but I'd like to see that we would, but it's probably going to be at least more than my lifetime before we can categorize all of the different sounds of all of the different animals, but we've made progress, but on those where we do know what kind of sounds they made, we can scan through the record. Let's say you have…it's kind of a daunting task, really….you have a year or more of acoustic data in front of you and if you just tell the graduate student to sit down and listen to it all, it really doesn't get very far because they like to go home and that sort of thing so, we

really have to train computers to find the sounds. The volume of data is just so great that we have to have computer software and algorhythms to find the sounds and then, once you've done that and you sort of have to test it, then you can get this incredible snapshot of when the animal was present at this site and what you see, first of all, is that there are very distinct patterns during the day. For most species, there's a certain time of day that you'll hear them make the sounds. I mean, we were talking about fish and how fish make sound near sunset. Well, dolphins, many of them, when they're foraging, they like to forage at night and this is probably because they don't need the light. They have their sonar to actually find the fish and so, there's some sort of advantage to them in foraging at night and so, the prevalence of this echolocation clicks from dolphins can be anywhere from, I don't know, 5 to 10 times more prominent at night than during the day, right?

So, and that's a discovery we've made just recently because people who are studying dolphins didn't typically go out in their boat at night because you can't see them. It's dark. So, then the other thing is that we're starting to tease out the cycle of where the animals are along the coast. Some of the animals migrate either up and down the coast or offshore and onshore, different seasons and so, by having a number of those sites, some far offshore and some inshore and some in Northern California and some down in Mexico and…we can start to tease out where the animals are at various times. So, this is called the seasonality and that's helping to create a picture of their migrations that we didn't have before.

Jennifer Stock: Yeah, it's important for the resource managers as well to get a good picture of where animals are concentrated at times of year in case of unfortunate events.

John Hildebrand: Yeah. Well, actually, for a place like Cordell Bank, if I could…and I don't have a sense of there, I would love to have one. If you know someone who would like to facilitate that, but in order to say when marine mammals are coming into your sanctuary or leaving is an important thing.

Jennifer Stock: That would be so interesting to know. It's kind of like entering and exiting. They are entering the sanctuary. They are leaving the sanctuary with these sounds. That would be really interesting.

John Hildebrand: Yeah, and when they're there you need to think about their conservation. So, the other thing we've discovered, which was kind of unexpected is that within a particular species like, let's say, blue whales, for instance, because I've put a lot of effort into this

particular one…blue whales in different parts of the planet will make different songs and there are boundaries and people who study birds are very familiar with this and the phase there in bird singing, they call it dialects. So, there's a kind of bird song and there's a boundary between different dialects. Well, this same phenomena happens with whale songs and so, the west coast of the US is one dialect of blue whale, which I would call the California blue whale, and then there's a different song that's out in the deep water in the Central and North Pacific. Now, and I think globally when we've looked at blue whale songs we find ten different regions, geographic regions, with different songs and I would like to call these acoustic populations, meaning that there must be some greater interaction within a group that's singing the same song as opposed to the adjacent group, probably helping them to know which animals are proper to mate with and which ones aren't, not that there's a hard boundary, but it's some sort of cohesive group or population or if you were in the management business, you would call it the stock, right?

So, by acoustics, we've actually been able to define the stocks of blue whales somewhat better than people have done before because, I mean, despite the fact there was a lot of whaling and people would capture the animals and try to describe them, there wasn't really a good system set up for describing differences between the animals. I mean, some place they're larger than others or their head is shaped slightly differently, but with the acoustics, I think we're getting a snapshot of how the animals are interacting right now and we've discovered in the dolphins, at least in the Pacific white-sided dolphins along the west coast, that there are stocks. There are differences in terms of the kinds of sounds that they make and these may translate into these acoustic stocks.

Jennifer Stock: Do you think they ever adapt their sound to change, to fit into another group? I'm thinking of socially, if somehow one whale, with one acoustic pattern met up with another whale with a different acoustic pattern, would they be like, "Who are you?" And, I mean, I'm thinking of the social relations there. It must be so interesting to study.

John Hildebrand: Yeah, well, there's a lot we don't know about that, but there's a really interesting case in Australia where, well-documented, there's a western Australia and an eastern Australia stock of humpback, different songs, and the case a few years ago, someone noticed in and among the western stock of humpbacks there was one whale apparently singing the eastern song and bizarrely, by the end of the season all of the western animals had switched to the eastern song.

So, the humpbacks are interesting because they have a flexibility and an attention to novelty in their songs that most of the baleen whales don't. Blue whales, I don't think would do that.

We've seen a stability of the song of blue whales over more than 40 years along the coast of California. So...

Jennifer Stock: We have just about eight or so minutes left. I want to talk a little bit more about some of the impacts from the sounds. How does the raising ambient level of noise in the ocean impact this research that you're trying to do as far as being able to detect these changes?

John Hildebrand: Well, we're trying to tease out…one of the focuses of our research is how are the animals reacting to the fact that ambient noise has increased and how do they react to individual events like a ship going by or someone using air guns or sonar near the animals? And so, that's just part of what we're trying to tease out because, you know, our understanding of the actual impact is rather limited because most of the time where we've had these kind of high quality recordings, the ambient noise has been quite high. So, I mean, going back to the issue of having a baseline, we don't have a good baseline and so, what we have to do is tease out…so, for instance, one thing that we think that we can document is that there is an effect of the animal producing a higher source level, in other words, yelling louder in the presence of higher ambient noise and in the human world this is called the Lombard effect after a French guy named Lombard who noticed that when you go to a cocktail party, everybody is shouting at each other in this noisy room and it's a natural response to just being heard is you shout louder.

Well, there's a limit and what we've seen, more or less, is that for every decibel, for one dB increase in background noise, the animals can compensate for about half of it by shouting a little louder, not that this is,,,it's probably stressful for them as it is stressful for us if you've ever been at a cocktail party too long...

Jennifer Stock: What just concerns me too is if the sound levels keep rising in the ocean are they going to have to continue doing that as well or can they?

John Hildebrand: There is a limit. There definitely is a limit and so, we're trying to document this in the place where we've been trying to work this out, mostly is in the Santa Brbara Channel because there's just a constant flow of ships heading towards the ports of LA and Long Beach and also, it's a really important habitat for humpbacks and blue whales and fin whales.

Jennifer Stock: Well, was it last summer, a couple blue whales had been killed by ship strikes?

John Hildebrand: Yes.

Jennifer Stock: Which, we wonder, I mean, can whales hear these ships? Can they hear them? Can they see them?

John Hildebrand: Yeah. Well, they probably get kind of used to it being loud and that may be part of the problem is that they're getting habituated to these loud sounds and then, you know, you surface right in front of a car carrier and even if they wanted to stop, they couldn't stop. So, it is a concern and that particular incident there was a request for the ships to slow down after there had been, I think, three of these ship strikes. There was a request, a voluntary, "Would you please slow down while you're in Santa Barbara Channel?" And, we looked at the compliance and saw absolutely zero, no slowing at all and the common wisdom in terms of ship strike is that if ships are going less than 10 knots, then the animals can get out of the way, but ships going substantially more than 10 knots and kind of 20 plus knots is a standard speed in the Santa Barbara Channel and it's more difficult for the whales to get out of the way.

Jennifer Stock: Now, John, I just want to ask, we only have a few minutes left, but how about the use of sonar and how do we know about this right now as far as impacting marine mammals? There's been a lot of stuff in the news, the Navy in and out of court, and marine mammals apparently showing effects from that. Can you talk about that a little bit?

John Hildebrand: Yeah. It's a controversial topic, but it comes down to there's certain incidents where it's fairly clear that a particular kind of marine mammal, these are called the beaked whales, and they're deep-diving animals that they stranded, which is that they put themselves on the beach coincident with a naval exercise and this has happened not just once, but on several occasions and so, the mystery is why the animals beach themselves and was it some sort of direct physical impact from the sonar or was it that the animals were reacting behaviorally and then the injury occurred because of their behavior or reaction and one of the theories has to do with what is essentially a decompression sickness. These are deep diving animals. They're accumulating high levels of saturation of gas in their system and if they...it's like a diver, you know, surfacing too rapidly where you don't allow the gas to come out

that the animals might have been induced to do some kind of behavior like that that then gave them injuries.

So, it's controversial. It's gone back and forth. There are a lot of studies going on right now to try to tease that out, but they're very difficult animals to study because they spend so much time submerged. I mean, in terms of sighting, when you see one of them, you see its back at the surface, maybe it gets a couple of breaths, it's at the surface no more than a minute or so and then its gone for 20 minutes, maybe 40 minutes, maybe an hour.

Jennifer Stock: And we probably know nothing about the physical, biological, makeup of a whale's brain that's alive because they're alive and they're swimming...we've probably only seen animals that have died and been able to study through necropsies that way.

John Hildebrand: Well, one progress that's been over the last, say, five years is that we've created tags, these are essentially recording devices that we can attach with the animal with suction cups, in this case, like, you know, the cups that hold your roof rack on your car and then that allows us to see...get some sort of window into the submerged behavior of the animal, how deep do they dive, how long do they dive, what's the orientation of the animal as they're foraging, what kind of sounds do they make? So, and even, you know, starting to get some information about how many times they beak their flukes and hopefully we'll be able to measure their heart rate and all these kind of things to try to tease out what is their natural behavior and then what is the behavior when they're exposed to some sort of intense sound?

Jennifer Stock: Now, there have been some strandings that have happened after a use of the sonar and does that not stand alone as evidence of impact?

John Hildebrand: Yeah. Yeah, sure, but it's trying to understand in greater detail, what was the impact? Did the impact occur because the sound created a physical injury, which actually doesn't seem likely based on all the work that people have done or is it some combination of the behavior of the animal and how it reacts to the sound. So, it's a complicated issue and, I mean, yes, there are clear cut associations of these events and so, you know, there's plenty of level of concern, but we haven't really figured out yet how broadly to apply that, for instance to other species besides beaked whales or, you know, is it just when the animal somehow was in a certain bathometric setting where it can't go back down. If you drive it on to shallow water, then it has trouble with submerging again to clear

the gasses out of it's system. In other words, there's this complicated suite of effects that we haven't really sorted out yet.

Jennifer Stock: Now, just with a few more minutes left, as a scientist who...you've been seeing these changes, you've documented this raise of decibels in the ocean, what are recommendations you have for those interested in conservation and trying to preserve out marine mammals and the broader marine ecosystem as far as trying to address this large, global issue? Is there anything that we can do and other folks that may be listening can do to get involved to stay up on the topic and to get involved in the conservation aspect?

John Hildebrand: I personally would really like to see the shipping industry pay more attention to the noise that's being emitted by individual ships and I think this is starting to happen. There was a nice meeting in Germany last year and a paper has now gone forward to the International Maritime Organization, which is kind of the umbrella international organization for shipping and so, I think the first level is to make the shipping industry or to help them to be aware that this is a problem. They just haven't worried about it in the past and that's partly because they don't live with their head in the ocean where marine mammals do. So, I think that's one thing is just, A: raise the level of awareness and b: work for some kind of standard for quieting of ships.
I mean, in the same way that we don't allow ships to go around the ocean discharging oil, you know? It's just socially unacceptable and so...

Jennifer Stock: Just as we're trying to reduce carbon we should be trying to reduce sound as well.

John Hildebrand: Exactly. It's one of a suite of pollutants, in a sense, that we should be looking for the industry to be having less impact than it does right now and in the same sense, we should look for alternatives wherever there are intense sound sources like air guns or SONARs, we should be looking for ways of doing the same job, but without the same sound level and so, for instance, in the seismic exploration business where people are looking for oil, there's a lot of oil underneath Los Angeles, right? And one way to look for oil on land is to dig a hole, put a stick of dynamite in the hole, and blow it up to get sound waves to propagate in the Earth. Well, if you proposed to do a seismic survey along Hollywood Boulevard with sticks of dynamite, that would be socially unacceptable and so, what they've done is they've developed alternative means.

There are these big trucks that kind of bounce up and down and it's a lower level sound that you emit over a longer time period.

Well, it could be that the seismic industry in the ocean creates a similar technology instead of having one big bang, then they have a means of making sound that's more...that gets the job done, but is more environmental benign.

Jennifer Stock: So, it's time to advance our technology. I'm sorry to have to cut you off at this point, but we need to wrap up the show and I just wanted to thank you very much for giving us such a broad overview, a really nice overview of how animals are using sound and some of the issues that we're facing and I really appreciate hearing the recommendation about the shipping industry and that there is work being done in that area. I think that's something to keep an eye on for the future and it's interesting, I hadn't thought a lot about how we're mitigating sound and trying to change...there's been so much work on carbon and reducing carbon and it's nice to hear that there's efforts as well for reducing this type of sound.

John Hildebrand: Great. Well, I appreciate you having me.

Jennifer Stock: Thank you so much for your hard work and I appreciate you coming on the show today. Have a good afternoon.

John Hildebrand: Okay. Bye bye.

Jennifer Stock: Take care. We've been talking with Dr. John Hildebrand from Scripps Institute of Oceanography in San Diego and we've been talking about ambient noise and sound in the ocean and barely scratched the surface...had a whole bunch more questions here, but I definitely learned a lot. I hope you did too. Thank you so much for tuning in to Ocean Currents today. I'm going to leave you with some soothing coral reef sounds. Thanks for tuning in.

(Ocean Sounds)

(Music)

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