DOSITS Webinar: Fundamentals of Underwater Sound (June 2, 2020)

Question and Answer Summary
(questions asked/answered in real time during the webinar or in the Q&A box)

Questions asked/answered live by Dr. Tracianne Neilsen during the webinar

Question: If there are a dozen microphones in an ecosystem with lots of species, can we process the signal to know how many of a particular vocalizing species are in that area that the hydrophones cover?

Answer: If I was talking or playing the recorder and another person was also playing the recorder you would expect that you would have a higher level. If we were playing the same note, we would have about the same spectrum but the level would be higher. So, if you know the average sound level for a single animal, or their range (how high or low they can go) then you could get an estimate by just seeing how much higher they can go. It wouldn't be the same as counting on an image but you could get an estimate.

Question: Can we process the signal of anthropogenic sound like boats within that same area to recognize and map?

Answer: It again comes back to those spectrograms because different kinds of sounds will have higher frequencies in different parts of the spectrograms. So, if I go back, you can see if I was looking for bearded seals, then I would want to look in particular in the 1-2 kHz region because that's where they're making the most noise. Now of course if there's a lot of snapping shrimp around, they're making a lot of noise over all the other frequencies. Yet, if I was looking in particular for beluga whales it'll depend on the background noise that is the loudest in this region, for example looking for high chirps is important because, if I met below our region of human hearing which is 20 Hertz in the area, which is called infrasound there's a lot of just wave noise and or geological and seismic related noise. Yet, if I come up to higher frequencies that get above that infrasound then that's where you expect to be able to see some of those signature components above the background noise such as the beluga whale. So, the different frequency regions of the spectrograms and how they are displayed are really useful in that way.

Question: Could you explain the difference between measures in one-octave bands and one-third octave bands?

Answer: An octave is a doubling of frequency. If you think of the piano middle C, it is roughly 250 Hertz. So, if I press middle C at 250 Hertz that means the octave below middle C on the piano is 125 Hertz, and the octave two octaves below middle C then would be like 65 Hertz. If I go up, then it would go roughly from 250 to 500 then to 1000, and then two octaves above. So, in terms of Hertz, there’s more Hertz in octaves as you go up, but our process sounds very well on this octave-type scale. For example, when you go from 125 Hertz to 250 Hertz it sounds like an octave, but if you go from 250 to 500 it also sounds like an octave. So, the idea with one-third octave band processing is different than this narrowband processing which I showed you. In narrowband processing, every 1 Hertz band is treated the same. Yet, if you're doing octave processing or one third octave processing then you take that whole octave that’s doubling your frequency and you sum up all the sound in this octave and then you take the next level in your frequency, and you sum up all the sound in that octave. For one-third octaves then you assign three center frequencies in each octave and then you sum up all the sound that's in that one-third octave band.

Question: When you're positioning hydrophones to record how important is getting a CTD profile of the water column?

Answer: The CTD profile of the water column gives you an estimate of the temperature and the salinity in the water. From that, you can calculate the sound speed in the water. There are some average sound speed profiles, or the dependence of the change in the sound speed as a function of depth for different places, and different times of the year. If you want to figure out how far away something is for locating sound, having a good estimate of that sound speed profile is important. So, because the sound speed of the temperature, say, varies with depth, that sound speed will also vary with depth. That's super important to take into account because of the principle of refraction which is that the sound will bend whenever the sound's speed changes. Sound is a wave principle after all, and it applies to all waves. So that means that if the temperature at the top of the water is hotter or warmer than at lower down, if you have a very deep source then that sound may never reach the surface because as the sound waves travel away from that source then they will bend back down towards the regions of cooler sound speed. So, that effect is called refraction, and it makes a big difference.

Question: What is the difference between amplitude and magnitude?

Answer: When we talk about the amplitude of a soundwave, we usually are referring to the peaks, remember how when I played the sine wave it went up and down. Well, the amplitude of the wave would be the peaks, how high those peaks go.

Question: Can you describe the Doppler effect, a bit more? Why does the frequency increase or decrease as the source approaches or moves away from the hydrophone?

Answer: If you think of the waves that are traveling from the sound source…if I'm just playing a sine wave those regions of the peaks will be traveling outward from the source sound. So, for example, if I take a sound source then as the sound goes outward in time, we have waves that are traveling out. So, pretend there is a circle that is a wave. It gets bigger, but it's still centered on the sound. The sound wave would go out and that first circle is representing the first peak, traveling out and then the next peak would be the second traveling out. So, these two circles would be like a wavelength apart, the wavelength is the distance between those subsequent peaks or the distance for one cycle. So now if I take these and now instead of sitting still if all of a sudden, my sound source is moving, by the time this outer circle reaches me, the sound sources moved. So, the time between when this first wave hits me and the next wave is less than if the sound was still, and so that difference in the time, which is called the period of the wave, is the inverse to the frequency. So, as that period gets shorter, the frequency goes up. I don't know if that was very good. But I can send you a link to a nice demo and animation where that's showing how those waves are getting closer together as the sound source comes towards you, is what causes that increase in the frequency.

Question: Can sound penetrate sand? For example, cetacean echolocation to detect prey items?

Answer: So that's a very interesting question and it depends, again on the frequencies. So, it depends if the sand which the sound is bouncing off is very reflective to high frequencies or low frequencies. So, the low frequencies tend to penetrate deeper into the sand than high frequencies, because they have a longer wavelength. So, you can kind of go back to the idea of your curtains and your couch. If you're singing in that living room, then it's the high frequencies that get absorbed and the sound just doesn't sound as bright as when you're in the bathroom. So, that the absorption and/or reflection, which is the opposite, totally depends on frequency. Overall, sand is more reflective compared to other seabeds, if you're just considering sand it will be more reflective at high frequencies than low frequencies.

Question: What kind of distances can sound travel on the water?

Answer: It depends on the ocean environment. So, if you're in a shallow ocean that sound is interacting a lot with the seabed, and every time if you think of the sound traveling and hitting that seabed, and some of it bounces off and some of it gets absorbed, that dictates how far away you can be to hear it. But if you get into the deep ocean there's a fascinating thing called the SOFAR channel and I know on DOSITS they have a wonderful description of this, and even where you can listen. The sound speed in the deep ocean has an interesting curve where it has a minimum and gets low about a kilometer down, and then it starts getting bigger because the pressure is increasing so much in the deep ocean. But if you have a sound that's initiated in that SOFAR channel, then it can travel very far, I can't remember exactly, but hundreds of kilometers probably is not an overstatement, because of refraction, that sound just kind of goes up and down in that channel and never interacts with the bottom of the top with no loss. So, if you wanted to listen to something from very, very far away, or send messages in the deep ocean, the SOFAR channel would be the place to go.

***SOFAR channel on DOSITS**: https://dosits.org/science/movement/sofar-channel/*

Question: If you have a hydrophone on a moving platform, for example, a Sea Glider, do you have to account for the Doppler effect when you're analyzing those sounds?

Answer: Yes, you do. So again, it depends on speed as one of the key features; that frequency shift is related to how fast the relative motion between the objects is. Say if something was moving parallel to you, then you wouldn't perceive that Doppler effect. Where, as opposed to if something is, you know, moving away, then that would be a faster relative speed, or things are coming together, it would be different. So, it's the relative speed between your objects. So, for example, if you had your hydrophone moving and the source was moving then you would need to take that into account. I was only talking about a stationary listener and a moving source when I talked earlier, but you do have to take into account the motion of both of those.

Question: Can you tell how far away a sound source is from a single hydrophone?

Answer: Yes, as long as you know something about your environment and/or trying to find that out at the same time. So, if you have a really good idea of what the sound speed profile is, and what the seabed is, what the depth of the water is, those kinds of things, then yes. From a single hydrophone, you can get an estimate of the range. In the work I'm currently doing we are trying to apply machine learning, or we have been able to apply machine learning to a single hydrophone to get both the range estimate and an estimate of what seabed type is down there from an impulsive or an explosive charge, and that was for experiments that were done in the ocean. So, I can provide that link as well.

Question: If you have hours of recordings are their algorithms and computer processing that can identify different kinds of animal calls from within that recording based on the spectrum?

Answer: I think the people who have been working in the field a long time, get an idea and they can see it just by looking at it, but the idea of developing algorithms that can robustly detect those I think is a very open active area of research that we're working on right now. You know, Google Photos and all of that do amazing things with image processing. So, you would think that they would be able to discern a bearded seal from a snapping shrimp, but of course, instead of a picture where things are spatially separated and sound, they're all combined. So sound and picture would be added together and that is what makes it a more difficult problem, and people are actively working on it.

Question: Do you know why the reference pressure in water was set differently than the reference pressure and air for decibels?

Answer: So, I don't know the complete history. I do know that it was probably colleagues at the Bell Lab that developed the unit of the bell for sound and the decibel. The deci- is the normal metric prefix that we don't use in many other cases. The one microPascal's makes a lot more sense in terms of other engineering applications that use a logarithmic scale because everything that uses a logarithmic scale has to have a reference. So, you know, if you are using voltage from an electrical signal, you would use a one-volt reference. So, having one of something is a very common reference. I think it was probably the speech folks who said, we want to reference this to our threshold of the hearing who chose the 20 microPascals instead. So, I think it's mostly to make the airborne sounds relate better to our hearing that, that was chosen.

Question: For the SOFAR channel, is it in the same place everywhere, and does it occur in all the oceans and throughout the ocean?

Answer: I will just defer to the DOSITS page I just pulled up because they have a lot of good information there. To answer the question, yes, the SOFAR channel is around the world. So, as a function of depth in kilometers the channel operates based on the physical effect that occurs when the further you get from the surface, the temperature decreases because you're further away from the sun. Then also, as I talked about at the beginning about the ambient or background pressure increasing with depth that eventually overpowers the impact of the temperature as you continue down. So, eventually, that increase in the pressure will take over the impact of that temperature decrease and cause the sounds waves to increase in size. So, that means that any sounds that are generated in this will be refracted to stay in that channel and travel a very, very long way.

***SOFAR channel on DOSITS**: https://dosits.org/science/movement/sofar-channel/*

Question: What's the advantage of using the one-third octave bands in the marine environment when people express things in terms of one-third octave bands, why are they used, and why are they significant?

Answer: One of the reasons, again, has to do with that idea of the background noise. So, if I'm playing the recorder and things like that, then the spectrograms I showed you were narrowband, they had those very, very sharp peaks and then they went down. So, if there's a lot of background noise, then it's likely that overall, the frequencies in the one-third octave band will cancel each other out when I add them all together. So, the way to think of a one-third octave band is that it sums up all the energy at all of the frequencies in the band. This can get confusing if it's not a well-defined band of frequencies over which the energy and how wide your frequency bands are. So, another way to do it is to report what is called spectral densities where you take the energy in the band and you divide it by the width of the band. So, spectral densities will give you a good consistent answer and one-third of octave band levels will give you a good consistent answer, but in between, you would have to know how big the frequency bands are for the transform you did to get that spectrum.