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Moderator: Courtney Chambers
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Courtney Chambers: Okay, before we jump into our presentation today, Mr. Joe Wilson from USACE headquarters asked me to share a message with you regarding the technical guidance related to our topic today issued by NOAA in July of 2016. It was titled, "Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing." He said that this is in fact only technical guidance and therefore should not be used to make regulatory decisions. That was a message he wanted me to share with you all before we begin today and, or just to listen in light of that.

If you have questions regarding that NOAA document or its relevance to our work, I'm sure Mr. Joe Wilson would be happy to discuss with you further. And I've included his email at the end of our presentation today for any follow-up questions you might have.

Okay, at this time, I'd like to introduce our speaker today. Dr. Andrew McQueen is a research biologist at the US army engineering research and development center in Vicksburg, Mississippi. Andrew's expertise is in environmental toxicology, water quality, and risk management and water resources. Among other activities, his work includes technical support for the dredging operations and environmental research program (DOER) and the dredging operations technical support (DOTS) program which is sponsoring our webinar today.

More information about Dr. McQueen can be found in his bio that'll, again, be posted on the DOTS webinar page along with today's presentation. Andrew, we are very happy to have you with us today and learn from you. At this time, you can go ahead and share your screen and we can begin.

Dr. Andrew McQueen: Okay, thank you, Courtney for that introduction. All right, well, thank you everybody for attending this webinar and I'd like to share some research that's been part of an ongoing task in the DOER program. And also like to identify the other researchers that were involved in this task. This included (Burton Suedel) who is the program manager for the dredging operation technical support program as well as (Justin Wilkens) and (Morris Fields) who both provided technical support for this reserach.

And just to provide some context into what we're discussing today, there has been an increase in both national and international focus on adverse impacts associated with anthropogenic underwater sound. And so those impacts usually are focused on both recreationally important as well as commercially important organisms. So marine mammals, fish, turtles, invertebrates.

And (Joe Wilson's) comment was very pertinent because, really, the impetus for some of this research came from those released guidelines from NOAA. Again, those are not a regulation, they are just that, guidelines. And so we'll get into a little bit of the mechanisms of what those guidelines are towards the end of this presentation, but very simply, they're broken down into impulsive sounds as well as non-impulsive sounds. So, really, one of the fundamental questions that we're addressing here is where does dredging fit into this overall scope of things with other anthropogenic sources and is there an inherent problem with dredging underwater sounds in terms of risk to some of our important eco-systems?

So an outline for the presentation today, we'll characterize what underwater dredging sounds look like in terms of what's their intensity, what's their frequency, what special and temporal patterns do they have? We'll also evaluate and look at some of the research surrounding the supported biological effects with dredging sounds and put that in context with some of the other anthropogenic sounds. And then the third piece here is really, what do we do with this information? Where does it fit in the context of these NOAA guidance documents as well as a larger risk framework that needs to be developed for anthropogenic underwater sound.

So the approach that we used in this research was conducting a focused literature review to really look at the available information, not only from USACE, but other parties, for what characteristics of dredge sounds can be. And again, there are a number of field studies that have done extensive efforts to characterize dredging sounds, so I really - we're looking at a holistic approach of what is that information telling us? And also look at the relevant information on what are the reported biological effects from these dredging sounds?

And so fundamentally, what we're looking at is what is that exposure response relationship associated with, with dredge sounds? And that relationships going to be important of really understanding the risk and understanding the potential adverse effects and how do we manage that if needed.

So as a brief background, we're going to discuss some of the exposure metrics that are important. And, you know, in the context of dredging operations with different activities that are occurring, that underwater activity is generating these complex pressure waveforms. And in terms of the metrics that are important to us, we're interested in both the sound pressure level in terms of that pressure wave form and we're also interested in what frequency are these sound waves being produced at.

And so, just to keep everybody on the same page with terminology, in terms of the pressure waves, if you think about the sigmoidal pressure wave form, higher intensity is that higher peak pressure and lower intensity in terms of thinking about this as a receiver, this is a quieter sound would be a lower intensity. And obviously, a louder sound, a higher intensity.

We're also interested in these wave lengths, so and the distance between pressure waves and the frequency is defined as that wavelength per second. So these are important aspects of the exposure that we'll discuss in terms of characterizing dredging sounds.

And we're also interested in the context of a biological receiver. So how do we summarize this total sound energy, and have it make sense and be predictive to the receptor that we can about, whether that's fish or mammals. For impulsive sounds, in the past, this has been done using peak intensity which makes sense, right? Because you have this very rapid increase in pressure and then it quickly dissipates. So sort of be analogous to a blasting event, underwater blasting or pile driving.

For non-impulsive sounds, which are analogous to shipping or dredging sounds, we can slice this a number of different ways. We can estimate these intensity of sound pressure levels at the source and we can also average these sound metrics out in terms of root means square. Because we're talking about positive and negative pressures, we want a way of averaging that. And we can also break this down into different octave bands or frequency bands. So these are some of the common metrics that are reported for underwater sounds.

And another way of thinking about this, is how do we integrate this information to this receiver? So one method for this is the sound exposure level. And this incorporates both the intensity as well as the duration of that sound event. So the ultimate goal here with all of this is how do we accurately predict that exposure, response relationship? So what metric can we calculate that gives us the best indication of what that problematic response will be?

Some of the end point of interest include, of course, mortality and tissue injury. Again, these are more indicative of impulsive sounds. An example of this for tissue injury would be a fish swim bladder which is very sensitive to pressure changes. So, again, if you think about a blasting event, that rapid pressure change can rupture that swim bladder causing mortality.

Auditory system damage is another end point of interest. So these can be both permanent, meaning that injury is sufficient to where that threshold shift will not recover. And also temporary and that temporary threshold shift, for many organisms, can actually recover from auditory injury. Fish are an example of this where they'll actually regrow cilia hairs in their inner-ear. And within hours to days, recover over the acoustic injury.

We're also interested in masking effect. So this will be changes in communication among species based on overlap of frequency or intensity of sounds. And also behavioral changes. So is there avoidance? Is there changes in schooling or feeding patterns among these organisms? And if you think about this in the context of the real world, where you have a sound source under the water, really, with that propagation of sound without loss of sound intensity through space and time, you can really have any one of these end points potentially occurring around a sound source.

So now that we have some of the basics covered with metrics as well as how we think about these pressure waves underwater, we can take a look at what's relevant for dredging sounds and what information is available. So we'll break this down as hydraulic dredge as well as mechanical dredging. So I'm sure many of you on the phone are familiar with the dredge types, but just briefly, cutter section dredges as well as section hopper dredges are both hydraulic dredge types that are common in the United States.

And as you think about these operations, there's really multiple sources for producing underwater sound based on the operation and based on the site. These can be broken down into propulsion and actual digging or the cutting head in contact with the sea floor as well as pumping that aggregate material.

Again, for mechanical dredging, same story here where you really can have multiple sources of sound. And, again, this can be cyclical or discontinuous based on the operation of the dredge at the time. And, again, some predominate sources here are propulsion and machinery associated with these operations.

So what information do we have at hand to really start evaluating holistically what are the characteristics of dredging sounds? Fortunately, over the past couple decades, USAS has done some extensive field efforts to understand and monitor the underwater sounds with various dredging operations at various locations. Analogous to that in the UK, there have been a number of studies produced in the Netherlands from the Port of Rotterdam expansion where there was some extensive work done monitoring the long-term sound exposures from hydraulic dredging and also estimating sound exposure levels to biota, populations of fish and marine mammals that we in that port as well as the information from the United Kingdom.

So going over an example of the type of sound exposure data that you would get from one of these studies, this example is from (Kevin Ren) and (Dickerson) in 2014. It is for hydraulic dredge and the figure to the right shows the sound pressure level from this dredge and on the x-axis, you have distance from the dredge. And so some of the take home points here are, one, that these filed monitoring efforts are very data intensive. So I usually end up with a very dense number of data points for sound pressure levels.

This particular case was a monitoring event in a shipping channel in California, some which - some may be familiar with. And there was five different monitoring stations which you see these clusters of data points for those five monitoring stations. So some take home points from this, that again, are analogous for a lot of these reports and observations are that you do have a precipitous decline in many of these sites of underwater sounds as you move away from the dredge, as you would expect.

So the propagation of that sound is going to be a critical component of this and overall evaluation of risk of these sounds. And you also see that in comparison to ambient conditions, that within essentially a football field away from the dredge source, you are falling below that ambient 95% percentile. So those ambient conditions and really putting dredging in context to other activities that are happening in these channels with shipping and other things that may be producing underwater sound.

So the next example is for mechanical dredging. So grab dredge. This was a USAS report and, again, the take home here is just that with differing activities of a dredge, you have different sound pressure levels that are analogous to that as well as different frequencies. So again, thinking about these exposure metrics, again, your intensity, your frequency, and the space and time around your dredge activity are all important for evaluating biological effects.

So for dredging-induced sounds, generally speaking, these are intermittent sounds and they are highly dependent on that operational mode. The predominant sound sources that were reported among these studies, some of highest or greatest intensity SPLs were often associated with actual movement of the vessels. So this was tied to the propulsion and specifically, cavitation around the propeller of the vessel. Also machinery pumping as well as the type of aggregate that was being dredged. And again, these are not impulsive sounds.

So in context of the temporal and spatial skills associated with this for hydro dredge, again, we see that decline of sound pressure levels as we move away from a dredge. And also that time or operation of the dredge are important. So with this robust set of data, to compare across studies, what we can do is look at kind of the worst-case scenario. So if we use our maximum concentrations from a given time or operation from a field effort and look at it in the context of the source level, so that predicted sound pressure level, the maximum SPL that would be near the operation of the dredge, we can use that information to compare across different dredge types as well as across different anthropogenic sources of sound.

So that's what this figure indicates. So this is sound pressure levels across different type of sound. On the left-hand side, you have impulsive sounds. On the right-hand side, you have non-impulsive sounds and your y-axis is your sound pressure level in decibels. So for the impulsive sounds, again, for (unintelligible) or sonar or pile driving, as you'd expect, these are higher intensity sounds, typically above 200 decibels.

Some of these, again, have been directly linked with injury associated with marine mammals and fish. So lower intensity sounds for the non-impulsive side of the graph for commercial shipping, typically ranges between 160, 190 decibels. Interestingly, as we started looking across these dredging studies - and, again, this is the higher intensity that was reported for any given field efforts, we see that we are having general trends among the different type of dredges. Hydraulic dredging, again, falling within that commercial shipping intensity.

Which again, makes sense, right? Based on many of these reports, tie that highest intensity sound pressure level back to the propulsion of the dredge. So it's making sense that this is within the same range as commercial shipping and grab dredge typically had lower intensities.

So in summary of what the characteristics of these exposures are for dredging, they typically occur less than 190 decibels. They are non-impulsive and intermittent sounds. The intensity and frequencies are both analogous to commercial shipping. Many of those - the main energy associated with those waveforms are typically less than 1000 hertz which we'll get into a little bit later of why that's important.

Mechanical dredging generally had lower sound pressure levels reported as compared to hydraulic dredging. And connotation from propeller and thrusters was often cited as the predominate intensity of the sound recorded over a given effort.

So now we have some context of where dredging fits in the mix with other types of sounds. We'll also look at what are the reported behavioral responses of both fish and marine mammals to dredging specific sounds.

So this first table shows the biological responses that have been reported in the context of fish. And so, interesting note here is that these are not direct observations. So for a given field effort from each one of these studies, it was an estimation of the exposure level, that intensity of sound was compared to some threshold effect for these given fish receptors.

So the effects that were investigated were temporary threshold shifts on auditory response for fish and also behavioral effects for fish. So the first stuffy here at the top for shipping and dredging, this was, again, part of that port of Rotterdam expansion in the Netherlands. And again, this was a very data intensive field effort and they estimated the sound exposure level to populations of fish that were in the area. Again, so that's both the intensity and incorporating duration of the sound.

And so using, as they say, kind of a worst-case scenario, they estimated total exposure durations to the fish over a 24-hour time period -- so assuming that these fish were exposed continuously over 24 hours -- and exposed to the highest source level that was recorded over the total duration of any sound event that they recorded with normal propagation loss. With this kind of screening level assessment, they indicated that there was not a temporary threshold shift risk for fish greater than two grams, but there was a slight exceedance for that risk threshold in terms of that temporary threshold shift for fish less than two grams.

So other studies also looked at different type of fish. So Atlantic Salmon was evaluated in the (Nedwell) study. And based on those dredging operations, they did not observe any behavioral effects associated with changes in spawning behavior or movement of salmon. Again, not a direct measure, but a comparison of those behavioral responses to some laboratory-based end point. And then for the final study here, the (Defra), did not indicate any auditory risk associated with the dredging operation to a number of different species of herring and flat fish.

So moving on to the next piece here, what are those reported biological effects associated with marine mammals. So we're dealing with whales and seals and porpoises for this slide. So again, this first study here was the Port of Rotterdam expansion, and again, they estimated what that sound exposure level would be to populations of marine mammals in the harbor. And, again, that's intensity and duration of that sound exposure. And based on those modeled exposures, they did not exceed any permeant threshold shifts or temporary threshold shifts for those marine mammals.

The next study, (Richardson), evaluated behavioral responses in bowhead whales in the Artic sea based on dredging operations. So they did both field observations. They also recorded dredging sounds during those operations and when they were near whales that were breaching, they would play those back and there were really inconclusive behavioral responses based on that study.

And there's also some anecdotal data that are available from other peer-reviewed literature. So these are observations where there was not a direct exposure level that can be tied back to that response. So some of those examples are an impact assessment of field observations from a dredging activity where Beluga whale were present where they really didn't see any adverse effects reported or observed during that activity. And other studies have indicated some short-term avoidance behavior for dolphins as well as harbor porpoises.

So there's not strong evidence to support that there's direct injury or auditory risk across the board for fish and mammals. So if we think about this in another context of what is the potential exposure of these organisms to anthropogenic sounds as well as dredging-specific sounds, this graphic depicts the biological hearing range among different organisms. And so the top five here are how NOAA breaks down the marine mammals which are of interest in the 2016 technical guidance.

So for a variety of whales and porpoises and seals, also including turtles and a couple of different fish. We see the frequency ranges of which these biode are hearing and communicating with one another. And so, as we overlay anthropogenic activity, we see that there is, obviously, overlap, specifically in that frequency range less than 1000 hertz.

And where does dredging fall in this? Again, it's very similar to the reported ranges for commercial shipping and also natural ambient conditions. So again, this isn't a context of the sound pressures level intensity, but really, the frequency overlap that could occur among biota and the types of sounds being generated by these sound sources. So it may indicate that there are reasons to look into behavioral-based effects or masking effects associated with these organisms and these type of sounds.

So as a summary, for biological responses, there is no direct evidence of mortality or tissue injury due to dredge-induced underwater sounds. However, there are some indications that non-lethal effects may be important. So potential risks for altered hearing thresholds. Again, one study reported that this may be the case for small fingerling fish based on some fairly conservative assumptions as well as some observed behavioral effects in terms of avoidance associated with these activities.

Again, much of this data is anecdotal at this point. And really, as we look across it, what comes - what is important is that there are limited exposure response data associated with dredging-specific sounds and responses of organisms.

So really, let's wrap this up with context of what does this all mean? So not only from the context of the NOAA guidance, but also from a risk framework. So I'll go in briefly into the kind of backbone of the NOAA 2016 technical guidance and put it in context of dredging-induced sounds.

So in 2016, NOAA released their guidance and that was really focused on five groups of marine mammals. So whales and dolphins as well as sea lions and seals. And based on the intent of that document, it was identified at received levels of which individual marine mammals are predicted to experience changes in their hearing sensitivity for acute, incidental exposures to underwater sound.

So they're focused on a number of individual animals. So again, those overlaps with the Endangered Species Act and Marine Mammal Protection Act. So we're not talking about populations, we're talking about individuals. And again, they're interested in hearing changes, so auditory end points.

The two groups of exposures that they were focused on, broadly speaking, we impulsive sounds and the metrics that they chose for that is peak sound pressure level, which, again, makes sense for those high-intensity impulsive sounds like blasting or pile driving, as well as cumulative sound exposure level, which again, is that summation of that total sound energy with some unit of time. For non-impulsive sounds, again, the intent here was to include a metric to estimate an auditory risk and they chose, again, the sound exposure level. And the two-response metrics that were chosen for the marine mammals were both temporary threshold shifts as well as permanent threshold shifts.

So where does dredging fit into this bigger picture of what they proposed? Well, for one, the sound metrics of the SEL are challenging to be broadly applicable to the reported dredge exposures. So why is that? Well, there's a couple pieces there. The sound exposure level is intended to be a received level for a biota and so that does have a spatial and temporal component to it if you think about where it is in relation to an underwater sound source.

So this is typically going to be site specific. It's going to be highly dependent on the sound propagation of that activity in a given site. And so there's some really critical pieces in there that need to be considered and really, an important piece is not to pull the sound pressure levels that are reported and start comparing them to sound exposure levels, because you do have fundamentally two different metrics. So that's one point to get across.

And also the guidance doesn't really give any direction for what to do with intermittent sounds. So they're assuming that exposure level is consistent over 24 hours of exposure and, again, there's some challenges with really how to summarize and how to average out that total sound exposure and make it predicative for an end point.

So NOAA recognizes some of this and they state explicitly in their document that the current available data really make it challenging to estimate this for a single source and it may not be appropriate for situations where multiple exposures are occurring. They also say that it's not intended for accumulating sound exposures from multiple activities occurring within the same area or over the same time to estimate impacts for animals occurring over various spatial and temporal scales.

They go on to state that, really, if there's a better way to do this, then certainly, that needs to be evaluated for a given site specific situations. So really, what this is indicating is that there's certainly a need for a larger risk framework, not only for marine mammals, but other biota, that can be applied not only for dredging sounds, but other anthropogenic sources so. So certainly, that framework would need to be flexible. So I would consider the information in the NOAA guidance, but also could include, for dredging perspective for example, you know, how do we incorporate blasting activities when that's the case or other types of sounds that are occurring in the harbor?

So, again, the goal here is to be comprehensive. So this is part of our task for 2018. So we're currently developing this framework in coordination with the dredging industry as well as NOAA and some of the researchers in the Netherlands. And so part of the basis for this framework is borrowed from EPA's 1992 risk framework which is really walking through, let's identify the risk in terms of receptors that we care about and put that in the context of what the overall exposure is between a given sound and the receiver. And then understand what the exposure response relationship is among that exposure and the biota that we care about and use this information in an overall risk characterization in management context.

So to summarize this, again, for dredging-induced sounds, mortality or injury have not been documented. The adverse effects that are likely of interest are non-lethal effects and that would typically include auditory risk or behavioral changes. And the 2016 NOAA guidance is not directly applicable for dredging sounds for a variety of reasons. And, again, what is needed is a broader risk framework for assessing and managing underwater sounds associated with dredging. And so, with that, I'd like to open the floor for any questions or comments from the group and, again, thank everybody for joining this call.

Courtney Chambers: Great, thank you very much, (Andrew). Okay, at this time, feel free, if you'd like to ask your question over the phone, you need to select Star 6 and then you can speak, or you can continue to utilize the chat feature.

(Andrew), to kick us off, I received one private message. They made reference to the 150 decibel RMS that is typically used for harassment of all fish in literature. And the question was, do you know where that figure comes from or why?

(Dr. Andrew McQueen): Yes, sure. There is a number of threshold effect levels for fish and mammals for both harassment or behavioral changes. Those are predominantly based on exposures from laboratory-based studies that were either impulsive or playback sounds. And so that could be a variety of things, either white noise -- so having this broadband sound -- or a tonal frequency. So if you think about it, again, for pile driving, for example -- which is really the impetus of how a lot of these were developed -- of striking a pile and then observing an effect for an organism.

So really, there's a fundamental question woven into that of how analogous are those responses for other types of sounds, low frequency sounds, for example, for light commercial shipping or dredging.

Courtney Chambers: Okay, good. Thank you. All right, I received another question. Then I'll pause for a minute for anyone that wants to speak. This question, they would like to get a list of the referenced published papers that you cite for sound impact and, if possible, copies of the slides. And so to answer the later part of that, we will certainly have slides posted and I will email all who have joined the meeting today in a few days with the link to all of these files, including the slides.

And then, (Andrew), regarding the list of cited papers, is that something that you could share with us?

(Dr. Andrew McQueen): Sure, and I forgot to mention that all of this information that was presented is part of a broader technical report that was done last year. And that is currently under management review and should be hitting the streets very soon. But I can include, again, all the references that are associated with that. And there's more comprehensive references from the technical report. So I'll pull some of those and make that available and maybe even attach it to the back end of this presentation before it goes out.

Courtney Chambers: Yes, either as a final slide or if it's a separate document, we could post that as a resource with the rest of the meeting stuff. So watch for our follow-up link on the DOTS website to get those resources. All right, at this time, if anyone wants to ask a question over the phone.

(James Lagrone): I have one question.

Courtney Chambers: Okay, go right ahead.

(James Lagrone): My name's (James Lagrone) and I work over at the Jacksonville district and I have a question associated. You mentioned that the sound source level was done in a lab. And was there any reflection of sound or sound - did you occur any reflection of sound associated with those events? Because sometimes source level is like ambient noise. It keeps increasing if the sound is not abatement. Over.

(Dr. Andrew McQueen): Yes, that's a good point, (James). And, again, so a lot of the basis for these reported and peer reviewed literature are these laboratory-based exposures if you will. And many of them do have efforts to minimize any kind of reflections or rebound of those sound waves in their exposure chambers. So they'll spend great efforts - and really, that's a component of the dimension of the chamber, correct, as well as any kind of dampening material in those exposure chambers. So again, talking with some of the folks at TNO that does this - that have been part of some of these studies that are the basis for some of these thresholds, they do spend a good bit of effort to minimize any type of compounding factors associated with that.

Courtney Chambers: All right, anyone else have a question.

(Steve Conger): Yes, hi, this is (Steve Conger) in Jacksonville. I had a question about the sound - the field measurements for sound that were taken. Was any consideration given to documenting the material types being dredged and was there any distinction - if so, has any distinction been made between the various types - different types of materials that are being dredged and the sounds being produced? Over.

(Dr. Andrew McQueen): Yes, that's a great question. There are several reported studies that - well, I should say report that there are different sound intensities and frequencies that are measured associated with that dredge material. So as they're moving from maybe silty to sandy, they are seeing certainly a frequency change. In terms of the sound pressure level, it's not as prominent of a change, but that is a part of - especially some of the USAS studies. They were able to distinguish some of the trends, if you will, associated with the dredge material type and the type of sound that was being generated. So that is a factor to consider.

(Steve Conger): Okay, thank you. And then just a quick other couple questions. I saw one graphic where it was providing the measurements based on dredging and shipping and then one of the graphics mentioned shipping and dredging combined, I presume. So was that combined? Was that actual measurements combined or were you combining measurements that were taken at different times or different places and then just combining them?

(Dr. Andrew McQueen): So the shipping and dredging was a reflection of, they were unable to really decouple those in terms of their overall sound metric. And the reason why is during their, you know, operations, there was continuous shipping activity that was occurring in the same shipping lanes where they were dredging. And so that, you know, really lends to the challenges of monitoring this, of really separating out the dredging specific sounds to other sounds that are occurring localized within the same area.

(Steve Conger): Okay, well the reason I mentioned that was that most often times during our projects, the dredger has to actually cease dredging and move out of the way for the shipping. So I was wondering whether you were taking measurements with both activities going on at the same time or not. Because as often is the case, the dredger has to cease while the ship passed by. So you really don't have a compounded effect. You only have one or the other.

(Dr. Andrew McQueen): Yes, in this particular case, again, this was a project in the Netherlands and in that particular case, there was still shipping activity co-inciting with the dredging activity.

(Steve Conger): Okay, and then the last thing I wanted to point out was that in the early - some of the early slides, you were showing the different sound producers so to speak from the overall operation. I was curious as to why you indicated sounds from spudding on a cutter suction dredge but didn't identify spudding on either the backhoe or the clamshell dredge when in fact, those probably spud up and down more often than cutter suction dredges do.

(Dr. Andrew McQueen): Yes, for the purpose of this, it was to be more representative than comprehensive. And we go into some more detail of those total operations and how that influences the overall sound exposures from those reports. So again, that would be digging into the technical report a little bit more to see how things like spudding would influence that overall sound measurements.

(Steve Conger): Okay, thank you. Very interesting.

Courtney Chambers: Hey, (Andrew), I received another chat question. The question was, are you doing Fourier transforms on data to get the natural frequency of a dredge?

(Dr. Andrew McQueen): So, it's really a combination of what's reported of how that total sound energy propagates. So, again, most of it is non-linear. So there's a number of different ways that folks have estimated that sound propagation with distance. So I can't speak to any one particular method, because it's really going to be a combination across these studies.

Courtney Chambers: Okay, and as a follow-up comment to his question, he stated that could be a way maybe to isolate the sounds generated from ships as those from the dredge.

(Dr. Andrew McQueen): Yes, agreed. Thank you.

Courtney Chambers: All right, any other questions?
Okay, I have one more question. Sound abatement techniques?

(Dr. Andrew McQueen): Sure, so another piece of this overall project and tech report is looking into what mitigation options do we have for dredging activities? And so we kind of outlined what those possibilities are. It's everything from avoidance, again, if you think about if we have sensitive areas. Again, this may already be covered in existing environmental windows due to other stressors associated with dredging operations like turbidity. So there's avoidance.

There's also some mechanical and operational things that can be done. So that's everything from how the dredge is operated to some, you know, mechanical changes that can be done on a dredge vessel. And there's a fair amount of information that's available, especially in the shipping industry, has come a long way with the reports of what can be done to minimize underwater sound and especially - there's been great success with even just the cavitation of propellers and, really, decreasing those higher-intensity sounds. So there are some simple things that can be done, but, again, the point is really evaluating these effects to see if those mitigation strategies are even necessary and really trying to understand what that overall risk is.

Courtney Chambers: Thank you. Any other questions?

(Matt Miller): Yes, one more. This is (Matt Miller) with Jacksonville district. You know, I've spoken with (Christa Woodley) and (Allan Catsenmeyer) a bit on these topics. I'm currently working with them a little bit, because we're looking at - their called deflagration cartridges. So they're kind of comparable to a black powder as compared to high explosives. So the way to kid of describe this, a lazier way than the one that's produced by high explosives. So they don't produce a shockwave.

What I was going to say is, I'd like to send you a paper that was done back in 1952, because I don't think much research has been done on low explosives. But a lot of the ideas are really counter-intuitive. So for instance, the black powder produced pressure wave - extremely high-pressure waves that you would expect to, I guess, kill the fish, but they were, like, oblivious to it. And they speculated it was just because of the shape of the curve was so much slower than the shockwave that's produced that that may have been a factor.

But I'd like to send that paper to you just to get your thoughts. It's very interesting to me. Thanks.

(Dr. Andrew McQueen): Sure thing, thanks for that. Yes, we've been aware of the deflagration cartridges and how the potential changes in that sound pressure wave can occur with those. So, yes, I'd be interested to see that paper, because often, that's a function of both that initial pressure wave and then the negative pressure wave that that organism is experiencing. So, yes, it'd be interesting to see that.

(Matt Miller): But, yes, they also speculate on the negative side of the wave, that's it much lower. So I guess that's the side where you'd expect to expect that expansion to occur where things would rupture. But, you know, it's an interesting paper. I'll send it to you. Thanks.

Courtney Chambers: All right, other questions or thoughts? Okay then, hearing none, (Andrew), thank you very much for sharing with us today. Do you have any parting thoughts for us before we finish?

(Dr. Andrew McQueen): Well, I'd just like to thank everybody for joining and appreciate the time.

Courtney Chambers: Yes, well thank you for sharing your work with us and participants, thank you for taking the time to tune in. Please watch for upcoming Outlook invitations for our next DOTS webinar and I hope you all have a great afternoon. That'll conclude our meeting.

(Dr. Andrew McQueen): Thank you.

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