
Searching
for hidden
sounds
under water

Following Between Music's artistic work creating the Aquasonic project under water, the artists and the sound creator, Romans Komars, decided to delve into an unknown world of underwater acoustics, or more specificly, underwater reverberation.

This booklet reveals the detailed search itself, out there in the unknown depths of lakes and seas in Sweden, Finland , the Faroe Islands and Greenland.

It is told by sound engineer, Romans Komars, who has been crucial to the artistic ambitions of Between Music for years behind the scene- a who lead the way into the unknown in Sound's hidden Journey, bringing back recordings that have never been heard before ashore.

Produced and published 2024 by Between Music, Copenhagen 2024
Words: Romans Komars
Photos: Got Fat Production
Editor: Eva Ørum

"Underwater sounds have a nature, we humans are not built to hear."

Romans Komars, Denmark 2024

Content

6 **FROM IDEA TO RELEASE.** Intro

8 **SOUND AND WAVE REFLECTIONS**

9 **DIFFERENCE BETWEEN AIR AND WATER**

10 **CONVOLUTION REVERB.** Impulse Response

11 **RESEARCH.** Collaboration with researchers from different areas related to sound and water.

13 **SWEDEN 2020.** First try. Invention of recording technique.

15 **FAROE ISLANDS 2020.** Identifying weaknesses in the process.

17 **SWEDEN 2021.** First clear results.

18 **FINLAND 2021.** Great reverb inside a small rocky lake.

20 **GREENLAND 2022.** 3 lucky hours of complete silence for best underwater reverberation.

23 **AFTERTHOUGHTS. The big why**

24 **CREDITS**

From idea to release

INTRO

In my opinion, Between Music's most spectacular project is AquaSonic. It is a concert, performed on special instruments by 5 musicians submerged under the water inside five separate tanks. AquaSonic has been developed over the past 15 years, and since 2016, it has been presented in different parts of the world.

The music is indescribable and not comparable to any known music. It is a genre by itself. Figuring out how to produce the sound has been mind blowing...

After a series of concerts, the need for recording a full-fledged album arose. In this process, an important challenge has come to the surface: Reverberation. Due to the small size of the water tanks, there are very poor reflections going on. It leaves the sound dry, and some instruments sound thin.

As humans, we are subconsciously used to sound reflections in every single moment - to sound bouncing from all the surfaces around us.

In music, reverberation plays a significant role. Reverberation allows us to change the perspective and the mood and to amplify the sound message.

Considering all those factors, we have been using effect machines to reproduce reverberations during live concerts.

But a legitimate question pops up. Is it real? Do we actually hear the real underwater sound? Can we fully trust it?
.
Based on those questions, we started investigating underwater reverberation. Does it exist? Is it possible to use? Has anyone tried it before? Has anyone been able to use it as a music element?

After digging into it, the new project emerged. The biggest inspiration came from the whales. We know that at a certain time of the year, whales start to sing. They use massive rocks under the water to amplify their singing with reverberations and echoes.

Based on this knowledge, our journey, searching for hidden sounds began.

About sound wave reflections

Reverberation is a persistent sound in psychoacoustics and acoustics. A reverberation, or reverb, is created when a sound or signal is reflected, causing numerous reflections to build up and then decay as the sound is absorbed by the surfaces of objects in the space. This is particularly noticeable when the sound source stops, but the reflections continue, the amplitude decreasing until zero is reached.
Reverberation is frequency-dependent: the length of the decay - or reverberation time - receives special consideration in the architectural design of spaces, which need to have specific reverberation times to achieve optimum performance for their intended activity. As time passes, the amplitude of the reflections gradually reduces to non-noticeable levels

The shape of reverberations basically consists of 3 main factors:

1. Early reflections. Early reflections are the echoes of a signal that arrives back. Early reflections are direct copies of the direct sound source, rather than diffuse mixtures as are present in the late reflections, or reverberation, or a sound source.
2. Reverberation decay. Reverberation time is usually stated as a decay time and is measured in seconds. There may or may not be any statement of the frequency band used in the measurement. Decay time is the time it takes the signal to diminish 60 dB (T60 air) below the original sound.
3. Frequency response. The total absorbtion in sabins (and hence reverberation time) generally changes depending on frequency (which is defined by the acoustic properties of the space).

Difference between air and water

The approximate speed of sound in air is 340m/s; In water it is 1500m/s or nearly 4 times faster.

The greater speed of sound in water makes early reflections appear faster and reverberation time shorter than in air.
The speed changes depending on chemical composition, pressure (molecule density) and temperature.

For example: If we imagine a flat wall 170 meters away from where we are placed with our sound source, it will take half a second for sound to travel to the wall. In all we will hear the first reflection coming back in 1 second (1000ms) after it was produced.

If we imagine the same situation in water, sound only needs around 226ms to return to the sound source point.
It means: for a greater reverberation in water we need greater spaces.

The good news is that sound under the water is not only faster, but it can manage to travel longer distances before wave energy reduces to zero level.

It means the spaces surrounded by rocks, which will lock the sound wave, make it bounce back and forward for a long time before energy gets absorbed.

However, i it can be difficult to find such a perfect place. Often, or almost always, there are different substances that can be found in water.

We know for sure that sand and plants are great absorbers of the sound wave, which makes sound reflections weak or not present at all.

From here the critical moment for finding a good underwater reverberation is big spaces surrounded by solid objects like rocks free from sand and plants.

Convolution Reverb. Impulse Response.

We are basically looking for sound reflections underwater.
To be able to get sound reflections there must be massive solid objects like rocks. These might be in different forms and that affect shapes of reverberation directly.

We use a process called convolution reverb.
In audio signal processing, convolution reverb is a process used for digitally simulating the reverberation of a physical or virtual space through the use of software profiles; a piece of software (or algorithm) that creates a simulation of an audio environment.
This means that we need to create an impulse (sound) and record it back by use of hydrophones (underwater microphones).

This recording will become an Impulse Response (IR). With help of a piece of software this IR can be transformed into a digital reproduction of the acoustical environment.

There are different types of IR. In our research we have chosen two most common. Sine Sweep - a glide sweep (or chirp) is a continuous signal in which the frequency increases or decreases logarithmically with time. This provides the complete range of testing frequencies between the start and stop frequency. In our case we use 20hz to 20khz (the range of human hearing). Short impact - very short impulse with all frequency spectrum at once, like a hand clap hand for instance.

To be able to use Sine Sweep, we have to play it through the underwater speakers. Think about sweep as a short impulse like clap stretched in time and divided in frequencies. However, it can cause some difficulties to recognize reflections in order to find a good spot, because it takes a certain time for sweep to be played, and some reflections can appear while sweep is still playing. (Note: this is not a problem for software, but a problem for us as listeners).

In this case we have to make a shorter impulse before playing sweep through the speakers. There are many ways to do so, but we have to be careful not to make too loud sounds that harm water creatures. We have found an easy solution by hitting two hammers under the water. It makes a short impulse, loud enough to recognize reflections.

Research

COLLABORATION WITH RESEARCHERS FROM DIFFERENT AREAS RELATED TO WATER

We know of no one who tried something similar, so we had to try everything by ourselves and invent a technique considering our possibilities.

After the first two recording attempts in Sweden and Faroe Islands, we bumped into several issues in attempts to record under the water. We also had questions about how to create the full experience of the underwater world by integrating underwater reverberation in our music - digitally in the AquaSonic album, where we will use the underwater reverberation to perfect the sounds and to enhance the compositions. And live in the AquaSonic concert, where we want to assimilate the acoustic disorientation the human body experiences underwater through the use of 3D sound and immersive and sensory soundscapes that will enclose the audience from all directions.

Based on those questions, Between Music and AIAS Aarhus Institute of Advanced Studies organized an online workshop where specialists from different areas related to the field of sound and water were invited. .The entire workshop was recorded and the videos are now public via this link to Youtube.

PARTICIPANTS

Laila Skovmand, Artistic Director, Between Music
Romans Komars, Sound Engineer, Between Music
Christina Lidegaard, Producer, Between Music
Søren Rud Keiding, Professor specialized in Water, Laser, Optics, Molecules, AIAS
Preston Wilson, Professor specialized in Underwater and Physical Acoustics, UT Austin
Magnus Walhberg, Associate Professor specialized in Bioacoustics, SDU
Mark Johnson, AIAS fellow specialized in Electrical Engineering and Bioacoustics, AIAS
Niels Chr. Hansen, AIAS fellow specialized in Neuroscience and Music, AIAS
Sylvie Tesson, AIAS fellow specialized in Microorganism and Water, AIAS
Angelo Farina, Professor specialized in Applied Acoustics, Università di Parma
Gorm Wendelboe, Lead Acoustician for Underwater Acoustic Equipment, Teledyne Reson
Bjorn Munster, 3D Sound Specialist and Managing Director, Astro Spatial Audio
Ralph Kessler, Audio Engineer specialized Auralization and Impulse Responses, Master Pinguin


n Music
THE JOURNEY
2020 - 2022

Sweden 2020

FIRST TRY. INVENTION OF RECORDING TECHNIQUE.

No one had any experience with underwater impulse response recording for the purpose of music.
Not us, nor anyone else.
So, possessing only theory about overwater reverberation, we packed our equipment and went on a journey.
Our goal was to find a most efficient way to record and test all the equipment.

SWEDEN 2020

We brought 3 types of hydrophones with us.

• Reson TC4032 - the best quality we tried.
• Aquarian Audio H2a - decent.
• Sound Trap (ST) - good, but doesn't give the opportunity to monitor sound in action. And no possibility to gain the signal while recording. But it could go very deep. It gave us an example of how reflections spread at the same place at different depths.

Speakers: 2 pieces Diluvio AQ339 from Clark Synthesis. Maximum depth at 3 meters.
Impulses: hammers, sweep 3 to 3 seconds and straight sweep.

In theory, we knew we would need two types of IR's. Sweep tone for more precise catching of reverberation. And short, something like a clap, for recognising reflection presence. At first, we splashed on the water, hit the boat and did other strange stuff.

It didn't work.

The hardest part was to figure out if *we* did something wrong - or if there simply were no reflections.

After the first try at Friskjön Lake, all we got was the idea of how to hit the hammers under water, and our second attempt brought the first clear result. We found a place between two sheer cliffs, put the hydrophones under water, hit the hammers. And for the first time, it became clear that this project would lead to results.

The next day, we went to Fälgaren Lake. It is a small lake surrounded by granite rock and with a granite field of water. The maximum depth is 98m. Two locals had been kind to lend us their boats, and the hammer had given us flexibility and speeded up the process. So, on Fälgaren Lake, we made numerous great recordings for post-analysis.

We spent the last day at Lindödjupet Bay with sea water, rock shores and little rocky islands. There were minor results, but we got an opportunity to compare relatively silent lake water and restless sea water.

This played a critical role in later research.

Listen

Equipment:
Hydrophones: Reson TC4032; Aquarian Audio H2a; Sound Trap
Field Recorder: Sound Devices MixPre-6
Amplifire: MA AUDIO C-236
Speakers: Clark Synthesis Diluvio AQ339
Battery: 7ah 12v
Player: iPod

Team:
Laila Skovmand, Morten Poulsen, Romans Komars

Locations:

• **Lake Frisksjön**
Loftahammar
57°56'22"N 16°41'41"E
Maximum depth: 12 meters.
Granite rock, sand, vegetation.
Minor results.

• **Lake Fälgaren**
Municipality of Västervik
57°45'29"N 16°22'24"E
Maximum depth: 98 meters.
Granite rock, sand, vegetation.
Good results

• **Lindodjupet Bay**
Västervik
57°41'40"N 16°43'04"E
Maximum depth: -
Granite rock, sand, vegetation. With plenty of small islands.
Minor results

Faroe Islands 2020

IDENTIFYING WEAKNESSES IN THE PROCESS.

From this point, we knew that greater weather conditions, like silent water and no rain, are important parts of the process. But the presence of those factors are far beyond our control.

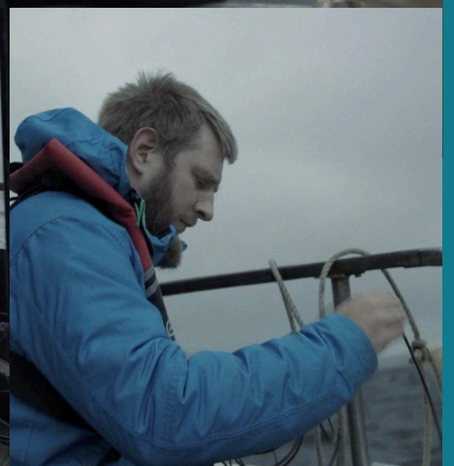
FAROE ISLANDS 2020

The Faroe Islands were exciting due to their geological structure.
The islands appeared millions of years ago as a result of volcanic activity - fully composed of basalt rock. Same time covered with vegetations as plants, even under the water. It makes it difficult to find a great spot.
Another major difficulty is weather conditions. Sea water is always open from at least one side, causing wind and waves. Waves make it difficult staying still, so it a struggle to record. And waves make a constant noise.

From this point, we knew that better weather conditions, like silent water and no rain, were important for the process. Unfortunately, there was never a moment of silence, so all recordings have noise. However, we found some wonderful spots, like Vestmannasund and Vestmanna Hydroelectric Station. The latter is surrounded by rocks and protected from direct wind, making it a great place for exploration.

Equipment:
Hydrophones: Reson TC4032; Aquarian Audio H2a
Field Recorder: Zoom H6
Amplifire: MA AUDIO C-236
Speakers: Clark Synthesis Diluvio AQ339
Battery: 7ah 12v
Player: iPod
Hummers

Team:
Laila Skovmand, Romans Komars, Jens L. Thomsen



Locations:

• Skálafjørður Bay
Eysturoy
62°09'27"N 6°45'41"W

Maximum depth: 70 meters.
Basalt rock, sand, vegetation.
Minor results.

• Vestmannasund Bay
Vestmanna
62°07'58"N 7°10'41"W

Maximum depth:
Basalt rock, sand, vegetation.
Good results.

• Vestmanna Hydroelectric Station Water reservoir
Vestmanna
62°09'13"N 7°07'22"W

Maximum depth:
Basalt rock, sand, vegetation.
Some results.

• Sundini Bay
Hósvik
62°09'19"N 6°54'36"W

Maximum depth:
Basalt rock, sand, vegetation.

Listen

SWEDEN 2021

After the two previous attempts. We found out that recording underwater echoes is possible...!

It has a unique nature, very different from the character of sound in air. Also, it has a different length, a different shape and different echoes.

All the weak points in the recording process became apparent, so we reached out for scientists and researchers that helped us troubleshoot all issues at a long, concentrated and engaged online conference.

We adjusted our equipment and brought new and important knowledge back to Fälgaren Lake in Sweden.

At this point, we knew exactly how to do it, and the results were amazing.

So, we explored the entire lake, and was amazed by the amount of great and clear results.

From here, the gateway opened for us to move forward.

Equipment:
Hydrophones: Reson TC4032;
Aquarian Audio H2a
Field Recorder: Zoom F6
Amplifire: MA AUDIO C-236
Speakers: Clark Synthesis Diluvio AQ339
Battery: 7ah 12v
Player: iPod

Team:
Ralf Rendigs, Romans Komars

Location:

• **Lake Fälgaren**
Municipality of Västervik
57°45'29"N 16°22'24"E

Maximum depth: 98 meters.
Granite rock.
Good results

Listen

Finland 2021

GREAT REVERB INSIDE A SMALL ROCKY LAKE.

At this point, we had solved all issues with one exception. So, we set off to figure that one out, too. .

.

FINLAND 2021

After successful recordings in Sweden, Finland became our next exciting point.
We have solved all the issues with only one exception. It's hard to know what the shores and bottom of the water look like. So it is a lottery in a way. But we knew it and prepared as much as we could.

Our main destination in Finland has been Lake Kilpisjärvi, where the Biological Station lies and scientists from different countries meet and do their research. So we came with our. Kilpisjärvi is quite a big lake with vegetation. We got more or less through the whole lake and got minor results. Plan B appears to be more successful.

Not far from Biological Station lies two smaller lakes.
One with the name Tshahkajävri. Beautiful green lake with vegetation. It has minor echoes.
And the lake called Saanajävri. A very small lake lies higher compared to sea level, at the foot of the Saana hill. Very beautiful and rocky landscape. A lake lies in a bowl of granulate rock. With no sand or vegetation. It gave us great and clear results.

Listen

Equipment:
Hydrophones: Reson TC4032; Aquarian Audio H2a
Field Recorder: Zoom F6
Amplifire: MA AUDIO C-236
Speakers: Clark Synthesis Diluvio AQ339
Batterie: 7ah 12v
Player: iPod

Team:
Laila Skovmand, Petri Kuljuntausta, Romans Komars
Location:
• Lake Kilpisjärvi
Enontekiö, Lapland
69°02'18"N 20°47'20"E

Maximum depth: 57 meters.
Granulite rock, sand, vegetation.
Minor results

• Lake Saanajävri
Enontekiö, Lapland
69°02'56"N 20°52'44"E

Maximum depth: 13 meters.
Granulite rock.
Great results.

• Lake Tshahkajävri
Enontekiö, Lapland
69°01'34"N 20°54'47"E

Maximum depth: 13 meters.
Granulite rock, sand, vegetation.
Minor results.

Greenland 2022

3 LUCKY HOURS OF COMPLETE SILENCE FOR BEST UNDERWATER REVERBERATION

We learned that what we hoped for is, in fact, possible.....

GREENLAND 2022

While Saanajävri was a small lake, covered by hills, with quiet and silent water, Nuuk bay in Greenland is a sea water surrounded by high rocks, but with long sleeves.

It is a place where the weather changes every hour. Our plan was to get through the entire Nuuk Bay regardless of weather conditions to find the best sounding spots. So, that is what we did.

After that, we monitored weather changes and looked for the best time to record. We were pretty unlucky in the beginning. A lot of wind caused waves. It rained, and boat traffic got in the way from time to time.

And then, out of nowhere, came three completely silent hours. Three lucky hours in ten whole days.

The results were astonishing.

It is perhaps the best underwater reverberation we managed to record.




Equipment:
Hydrophones: Reson TC4032; Aquarian Audio H2a
Field Recorder: Zoom F6
Hummers:

Team:
Laila Skovmand, Inuk Silis Høegh, Romans Komars

Locations:

• Kangerluarsunnguaq Bay / Kobbefjord
Nuuk
64°09'11"N 51°35'48"W

Maximum depth: -
Crystalline rock and sand.
Good results.

• Nuup Kangerlua
Godthåbsfjord
64°29'00"N 51°25'44"W

Maximum depth: -
Crystalline rock.
Good results.

Listen

• Kangersunek/isfjord
Godthåbsfjord
64°22'44"N 49°44'02"W

Maximum depth: -
Crystalline rock and Ice.
Minor results.

• Uummannap Sullua
Godthåbsfjord
64°30'45"N 51°06'06"W

Maximum depth: -
Crystalline rock.
Good results.

• Qooqqut
Godthåbsfjord
64°14'19"N 50°58'00"W

Maximum depth: -
Crystalline rock.
Great results.

• Qallussuaq / Cirkus Lake
Nuuk
64°10'45"N 51°38'50"W

Maximum depth: -
Crystalline, sand, ice.
Minor results.

"Water gives life. Water brings death. And it brings everything else in the wide spectrum in between"

Romans Komars, Denmark 2024

Afterthought

It took us 3 years to accomplish this task, challenged not only by the things we needed to figure out but also by external factors such as the Covid pandemic.

Along the way, we have learned about sound behavior under the water. We have Invented great and usable technique for recording, collected great reverbs for future use in sound art exhibitions, during live events and for leveraging the results in the first ever underwater recorded music album that is released in 2025. And we have met a lot of passionate people around Scandinavia, but not only that.

The journey has also evoked some deep philosophical reflections.

The main question we asked ourselves and people we met down the road was about personal relations with water. There is never a definite or final answer. Water gives life. Water brings death. And it brings everything else in the wide spectrum in between.

Water is the most usable element in our everyday lives. At the same time, water and its depth is one of most unknown substances in human life.

As humans, we are not built to see far and to hear clearly under the surface of the water. But there is life in different forms from the surface and all the way to the bottom of the ocean, engulfed by the water as their natural environment. These forms of life can navigate even in darkest places, where the light loses its power. One of the main reasons is sound, which can travel far in no time and bring all the necessary information.

So, this project also triggered the imagination: how does feel to be an underwater creature like a whale, who is searching for echoes to amplify its own voice and sing a song? And the project allowed us to explore not only technique but also the sense of the water as if it was our natural environment, too, with life made possible through sounds underwater.

The experience has been truly amazing, touching something so wellknown, yet foreign, so close to us, yet hidden on not just a technical perspective but also from the one of the soul.

We want to thank everyone who has been with us on this journey.

Sounds hidden journey under Nordic waters

Romans Komars
Sound engineer and explorer of the language of art through sounds.
Ringsted, Denmark 2024

THANK YOU!

Sound's hidden journey was made possible because of help, support
and assistance from many important partners.

Thank you to all!

Nordisk Kulturfond
Nordic Culture Point
Residency and exhibition in Finland
Danish Arts Foundation
Nordic Institute in Greenland
City of Aarhus
KODA kultur
William Demant Foundation
Dansk Komponist Forening
MiklagardArts

Teledyne RESON - Hydrophones
SDU, University of Southern Denmark, Fjord & Bælt - Supervision
AIAS, Aarhus Institue of Advanced Science, Aarhus University -
International online seminar about underwater reverb.

Last but not least, thank you to the artists:
Laila Skovmand, Per L. Thomsen, Petra Kuljuntausta and Inuk Silis Høegh for the journey


www.betweenmusic.dk