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DAP II
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Underwater Sound and Digital Audio Applications

Introduction

When it comes to sound being heard underwater, it is abundantly clear that humans were not made with that in mind. However, that has not stopped us from attempting to be able to hear sounds that come from underneath. Considering the fact that the vast majority of the world is covered in water, it only makes sense that the continuously growing field of sound recording and digital audio become part of it in some way shape or form. This year, 2006, actually marks the one hundred year anniversary for the first SONAR system ever developed and used. (Wikipedia 2006) Since the invention of SONAR, research has been done in developing tools for hearing, recording, and tracking sounds underwater, not only for experimental purposes but for several other reasons as well, some of which are still in development. Through the combination of underwater recording techniques and current technologies in digital audio, marine biologists, scientists in other fields, and even composers have an enormous range of tools available to them that were not there before.

The point of this paper is to inform the reader about all aspects of underwater sound and how digital audio is becoming more and more important to the field. To be able to get to digital audio area we must first go through some of the basics of underwater recording, as well as some of the history and techniques created that eventually evolved into the tools and instruments that we have today. Furthermore, in order to explain how some of the tools are used for recording the underwater vocalizations of marine life, we must look at the biological structure of animals in order to gain a full understanding. Topics that will be discussed in the paper include basic underwater acoustics, SONAR, hydrophones, the work done at the Cornell Lab of Ornithology, and finally current underwater musical and digital applications. While the range of subjects in the paper may seem broad, I feel that it is important to grasp all of the different aspects of work being done in underwater sound to better see how they can all be used together in order to help further their own individual fields.

Basic Underwater Acoustics

While I do not want to spend too much time discussing this, I do think it is important to go over the basics of how sounds travels and acts underwater as I think it will make it much easier to understand the ideas behind some of the applications use to hear and record it.

Sound, as we know, is a disturbance (vibrations in our case) in energy that moves through matter in the form of a wave. The density of the matter affects how fast the sound travels and needless to say, sound travels much faster in water than in air. Like its speed in air, sound's speed in water has several different factors that can drastically change it, such as salinity, pressure, and temperature, thus it can be very difficult to come up with an accurate speed of sound in water. However there are some very complex equations, one "containing 19 terms with coefficients with 12 significant figures", in which to determine the speed of sound. (Medwin 2005) On average, it is found that sound travels at 1435 meters per second, which is about five times faster than the speed of sound in air. One interesting assumption that is usually made when referring to underwater sound is that there tends to be no absorption while a sounds wave is traveling. Because of this sounds are able to travel great distances, something that whales use to their advantage when communicating with one another.

Another important thing to note is that intensities of sound, usually measured in decibels (dB) are much different for sound intensities underwater. Underwater sound intensities were decided by scientists to be measured in microPascals (μPa) with the idea that a sound wave underwater that has the intensity of 1 μPa is just barely audible. The above water equivalent of the same sound wave would come out to be 20 μPa, which turns out to have a difference of around 61.5 dB between sounds heard above water and those heard underneath it. (Island 2005) Needless to say, sounds heard underwater can be very loud and intense to both humans and more importantly, the marine life who actually have the ability to clearly hear sound underwater. This will be an important piece of information to remember later as noise pollution underwater has become a serious problem for its ecosystem.

There are several types of sounds, both natural and man-made, which create the underwater ocean ambience. The general ambient noise is called "Knudsen noise," named after Vern O. Knudsen, which has a frequency range of 500 – 20,000 Hz, and was found to directly correlate with the wind speed above the ocean. (Medwin 2005) Surface bubbles play an important part in that they tend to dampen the sound level at the surface. Rainfall can also add to the overall energy level, depending on the intensity of the rain. Tools are now being developed to measure the intensity of rainfall in the ocean, which would serve as a great warning and weather watching system for boats at sea. Adding to the underwater soundscape are other natural features such as lightning strikes and volcanic eruptions, both of which have levels around the 250 dB range. (Island 2005) Marine life vocalizations, which will be discussed more in depth later in this paper, have a frequency range of around 10 – 200,000 Hz. Amazingly enough, man made sounds have about the same range for SONAR devices and engines of large ships.

Reverberation is an issue in underwater sound and while similar to that in air, does not produce the same desired effects. Acoustical effects, such as reverberation, make it much more difficult for SONAR systems to locate objects, which is due to the scattering of sound caused by the enormous amount of marine animals that live underwater. (Ulvaeus 2001) Sometimes this backscattering can serve as a useful too, for instance when attempting to create a sonic map of the seabed. Most of the time, however, it is an inconvenience that must be overcome by filtering tools and stronger SONAR signals.

I will now go through some of the basics of marine life sounds, which I believe will then make it easier to see how scientists came up with SONAR and hydrophone technologies.

Marine Life Sounds

Almost everything in life emits some form of sound, some above or below the human hearing frequency range. Life forms underwater are no different. It is important for these animals and mammals to use sound as a visual tool since they do not have a good sense of smell, like the shark, because the visibility level underwater is extremely limited. Most of the work being done today studies the vocalizations of marine mammals, such as whales and dolphins, however there are plenty of other animals that make noises as well. Snapping shrimp, which were once thought to produce sound from the clicking of their big claw, actually make the sound by using that claw to pop tiny air bubbles. In my experience, these sounds can be heard by the human ear by simply sticking your head underwater. However, for the purpose of this paper, dolphin and whale vocalizations are what we will be doing most of our focusing on.

Before we get into the reasons behind the sounds, let us first look at how the sounds are created. For "toothed animals", such as certain types of dolphins and whales, "sounds are generated by passing air from the respiratory system through a series of sacs that divert off of the animal's nares ('sinuses')." (Wikipedia 2006) The sound is then reflected off of the skull is focused with the animal's "melon" (see *Figure 1*). The sounds created by these mammals are often described as clicks and whistles, each discovered to be used for different communication or echolocation purposes. That of course is only half of the process. The sound or reflections of sound are then received back through the lower jaw of the mammal, which then resonate to the ear bone. In addition to that, the fat around the ear bone, similar to the ear lobe on a human, may also receive sound laterally. (Wikipedia 2006) On a side note, humans are able to hear underwater as well but not through their ears, due to bad impedance. It is actually quite similar to underwater mammals in that we use bone conduction, in which our bones stop the sound waves and then the "bones from the neck and skull resonate and carry the vibrations simultaneously to both of the inner ears." (Maurer 1998)

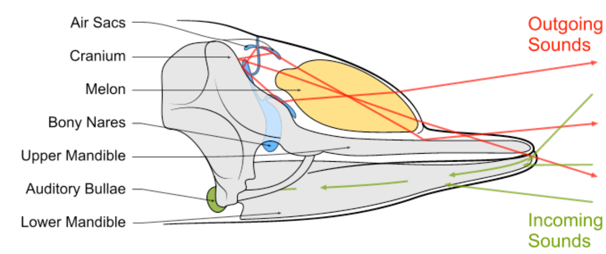

Figure 1 – Whale vocalizing system.

"Non-toothed" mammals, such as the blue whale, produce sound through their larynx but scientists are still unclear how this works, as they have no vocal chords. However it is known that for these mammals to produce sound they must do so through exhaling, much a like a human. Because of they live underwater it is thought they have are able to recycle the air to create a sort of cyclic breathing pattern.

Another interesting sound that is being researched is that of the tail slaps of Norwegian and Icelandic killer whales. The tail slaps are created on the surface and used to debilitate schools of fish, which the orcas then prey upon. These tail slaps have a frequency range up to 150 kHz and are capable of producing levels around 186 dB. (Malene Simon 2005) What I found even more interesting in my field work in California is that depending on the part of the world, orcas prefer different forms of food, meaning that orcas in north America would not use tail slaps against their prey as they eat dolphins and other whales.

One of the main purposes for these vocalizations is not for communication purposes at all, but for echolocation. Echolocation is essentially a biological form of SONAR, a technology that will be discussed later in the paper, that animals and mammals use to determine the location of other animals or to create an auditory map of the underwater environment. What happens is that the mammal sends out a series of loud clicks, ranging anywhere from 100 – 250 dB, and then because of their highly acute sense of hearing, the mammal is able to determine the location of other objects by measuring the delay in time it takes for the sound to come back. (Medwin 2005) Because they can use both their jaw bones as well as the fatty lobe area around their ears, whales and dolphins are able to create nearly perfect images of objects in their surrounding area.

The other main reason for vocalization by marine life is for communication purposes, and are usually referred to as whistles and moans. The mammal's vocalizations are used by scientists to determine sex, population, families, as well as mating habits. Currently there are attempts being made by Earthtrust and Apple computers to create audio systems in which to communicate with dolphins. Scientists are also looking at dolphin vocalizations with the hopes of drawing some correlation between them and their behavior. One of the most incredible aspects of whale communication has to be the fact that due to the acoustical features of the ocean as well as the frequency range of their vocalizations, whales are capable of sending messages back and forth at distances over 2,600 km.

A controversial topic in whale vocalizations concerns the song of the male humpback whale. For a long time, scientists believed that it was part of the mating process and used to attract females. New studies are showing that this is not true and that it serves more as an echolocation system that the whales use to determine where the females are. (Bently 2005) In their paper, *A Sonar Model for Humpback Whale Song*, Frazer and Mercado argue that during the mating season, humpback whales position themselves in shallow sandy waters, which are ideal for determining the positions of other pods of whales through echolocation. Their songs, which do not fall under the category of clicks commonly used for echolocation, range from 5 – 6 octaves. (Mercado 2000) Countering their hypothesis with an article titled, *Against the Humpback Whale Sonar Hypothesis*, Au and colleagues believe that Frazer and Mercado's theory goes against all evolutionary evidence and that their SONAR model does not fit with the biological model of the mammals. (Whitlow Au 2001)

As you will see in the sections on SONAR and digital audio applications in underwater sound, these vocalization habits of whales, dolphins, and other marine life, plays an important factor on how they were developed.

SONAR and Hydrophones

It is difficult to discuss hydrophones and SONAR on their own, since SONAR is essentially a type of hydrophone. This section will be on the history, design, and use of both technologies.

In 1906, Lewis Nixon created the first-ever passive SONAR device, which was developed to determine the location of icebergs. (Wikipedia 2006) What is ironic about this device was that apparently cruise liners did not use it since six years later marked the sinking of the Titanic. A month after the disaster L.R. Richardson made a patent for "detecting the presence of large objects under water by means of the echo of compressional waves – directed in a beam – by a projector." (Medwin 2005) In 1915, Paul Langevin and Constantin Chilowski "invented the first active sonar-type device for detecting submarines." (Wiggins 2001) From there the Anti-Submarine Detection Investigation Committee (ASDIC) was formed to test such technologies for Naval and scientific uses. From then on, SONAR became the standard for underwater detection devices.

SONAR stands for **SO**und **NA**vigation and **R**anging and is used universally by all forms of watercrafts. (Medwin 2005) There are two types of SONAR, active and passive, and both are used to determine the distance between the user and the objects. Active SONAR, as you will see, is a much more invasive type of technology, especially to the ocean marine life. What it does is create a sound, usually a type of "ping", and then listens for the reflections of the sound. Based on the intensity and direction from which the reflecting sounds are coming, it creates a visual map of objects beneath the ocean (see *Figure 2*). It is easy to see the exact similarities between SONAR and the echolocating systems used by dolphins and whales. To get a more accurate underwater map, several SONAR devices, or hydrophones, are used with the results compiled into one map. The sounds can be constant or delayed depending on the system used. By using SONAR one can determine the geological features of the seabed with the help of understanding the acoustical features of certain materials and how sound is reflected of them.

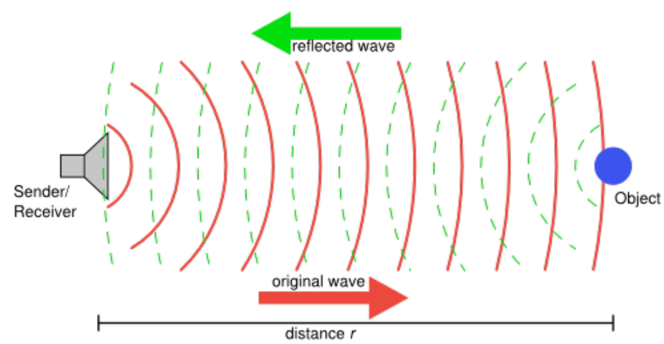

Figure 2 – How SONAR works.

Fish-finder systems tend to use a constant high-frequency pulse because they are not searching over a large area. Long distant SONAR systems use lower frequencies because of their abilities to travel better over long distance, but of course to be able to do so they must be emitted at very loud levels. While these levels would probably go unnoticed by a human listening underwater, marine life, because of their highly acute sense of hearing, are seriously affected by these sounds.

Passive SONAR does the same thing as active, only without emitting any sounds at all. It simply listens to the acoustic activity occurring underwater and then makes its measurements based on how spread out they are. Passive SONAR is very useful for submarines that wish to keep their position hidden. Passive systems in the military are generally configured to determine and classify certain frequencies as well, for instance they can be programmed to know that most US ship engines emit a 60 Hz sound whereas European ships emit sounds at 50 Hz. (Wikipedia 2006) Problems tend to arise in these sort of systems when submarines are below or above thermoclines, which are the places in the oceans where there is a drastic change in temperature. As we know from how sound travels underwater, temperature plays an important role in its speed, as does salinity. Since both of the factors change constantly and drastically throughout the ocean, techniques must be used to combat them. One way to fix this is by towing a series of SONAR devices, or hydrophones, behind the submarine or boat that are both above and below the thermocline.

Aside from creating topographic maps and determining the locations of icebergs and marine life, one of the main purposes of SONAR is for warfare. Since SONAR is able to accurately able to pinpoint objects both above and below water, military units can use it to not only locate enemies, but if they have enough information regarding the types of sounds that they are emitting, they can actually determine the size, type, and even possibly the number of people aboard.

SONAR, in its barest form, is a type of hydrophone and a hydrophone is essentially an underwater microphone. The first one was built in 1914 by Reginald Fessenden and worked both as a projector of sound as well as a receiver. (Medwin 2005) Hydrophones are built in two different styles, electro-mechanical and piezoelectric. Electro-mechanical use a "permanent magnet-moving coil…which forms a mechanical motion into an electrical impulse." (O'Neill 1961) These types have very low impedance but lack the frequency range needed for proper recording of underwater sounds. Piezoelectric hydrophones are most commonly used because they tend to work better. The way that piezoelectricity works is that "when impressed with a force, they generate an electrical charge and conversely, if when electrically excited, they manifest a geometric deformation." (O'Neill 1961) The piezoelectric crystals are then put into the ceramic casing of the hydrophone and when sound or a change in pressure hits them, they are "distorted and the domains are reoriented in the general direction of the field." (O'Neill 1961) Because piezoelectric materials can be molded into any desired shape, have a high-energy conversion ratio as well as have stability over varieties of temperatures, and are uniform over a wide frequency range, they are preferable to any other type of hydrophone system.

Certain hydrophones, including the one I made at home, are contained within oil, which helps when they are dropped several hundred feet below surface because of oil's compressibility level. It makes them capable of withstanding thousands of pounds of pressure. Directionality is also an important aspect of hydrophones, especially when only one is in use. If a single cylindrical hydrophone is used, the "ceramic transducer can achieve near perfect omnidirectional reception." (Wikipedia 2005) This is a great advantage to trained hydrophone users because then they are able to use their own ears as a form of SONAR to be able to locate the direction from which a sound might be coming. I was able to witness this first hand in my fieldwork in the Monterey Bay. According to AES, this style of hydrophone is preferred because of "the open-circuit pressure response is inherently flat below resonance." (Geil 1992)

To create a more directional hydrophone, other techniques must be considered, such as damping and reflecting. Similar to the technique used in shotgun microphones, a cone or conically shaped object can be used to put around the microphone to help direct the sound. Another way would be to set up an array of hydrophones, just like you would with a standard microphone, so that you could "add the signals from the desired direction while subtracting signals from other directions." (Wikipedia 2005) These types of systems are most commonly used in secret governmental SONAR systems that not only monitor for submarines but seismic activity on the ocean floor as well.

Currently there is a lot of controversy regarding these types of SONAR systems since it has been found that low-frequency sounds emitting from them have serious effects on marine life. These systems are capable of emitting pulses at 235 dB that then cause audiogenic seizures in whales, which is essentially death from sound. (Whipple 2005) It also causes whales to beach themselves as well as lose their sense of direction during their migrations. As the effects are not entirely understood as of yet, environmental activist groups are working hand in hand with the Navy to help fix this problem.

On a consumer level, there are several hydrophone systems available, most of which are not designed for scientific use so much as being able to hear different marine life vocalizations. There are also several sources available online in which one can find instructions on making your hydrophone from parts from electronic stores, which in my experience end up working much better than ones purchased from a company. (Hardy 2000)

I would like to now spend a little time talking about the Cornell Lab of Ornithology, the work they are doing with whales and dolphins in regards to their vocalizations, and the software and tools they have developed for use in analyzing marine life sounds.

The Cornell Lab of Ornithology Bioacoustics Research Program (BRP)

The Bioacoustics Research Program at the Cornell Lab of Ornithology, headed by Dr. Christopher W. Clark, is one of, if not *the*, best labs in the country doing research on whale and dolphin vocalizations. According to their website, "whale research add(s) to the broader understanding of sound communication mechanisms and the evolutionary basis of animal communication systems. Whale research also provides a special opportunity to develop new research tools and analysis techniques." (Ornithology 2006)

One of the main aspects of underwater sound that they are looking for is the impact of man-made sounds on marine life, something that we now can tragically affect the animals. In their attempt to see how these man-made sounds affect the low-frequency vocalizations of whales, they setup a hydrophone array system in the Sea of Cortez to monitor and track fin whales. Similar to humpback and blue whales, fin whales emit low frequencies to help them navigate, mate, and find food. The software that the lab developed helped immensely in their interpretations of different vocalizations to determine the sex of the whales. For this project they use a 16-hydrophone array that was towed behind their boat that was then hooked up to a computer for real-time detection of the mammals. (Ornithology 2000)

In another project they worked directly with the Navy to use their secret undersea hydrophone array that is known as the **SO**und **SU**rveillance **S**ystem (SOSUS), which is part of the Integrated Undersea Surveillance System (IUSS). Originally used to detect submarines and surface ships in the Atlantic and Pacific oceans during the Cold War, Cornell is using it to listen to the low frequency sounds from whales that move between coasts. This was a major breakthrough as not only were they able to detect the sounds, but they were able to more accurately come up with a population count of the in that area. In 1993, with the help of the

IUSS, they were able to create the "first ocean-scale view ever compiled on the distribution of whale vocal activity." (Ornithology 1993) This was a major improvement from the original way of comprising population counts of whales, which consisted of helicopter fly-bys and spotting from the decks of boats. The hydrophone array systems also proved to be very helpful when monitoring the migrations of bowhead whales in Alaska, where almost of all of their traveling is done underneath the ice.

In 1997, Adam Frankel joined the BRP to lead what the lab called, the "Sea Monsters" expeditions. (Ornithology 1997) In cooperation with the Smithsonian, National Geographic, and the US office of Naval Research, Frankel and his colleagues set out to find the giant squid, and do so by recording the sounds made by whales as they dove to deeper depths in order to feed. Since one of the dietary staples of the sperm whale is the giant squid, Frankel figured that this system would work very well. For this system they setup a vertical array of 4 hydrophones that would start recording "when the whale dives and continues until the whale resurfaces or its sound is lost among the clicks of more distant whales." (Ornithology 1997) Because of the way that the array is setup, it is possible to determine the exact location of the sperm whale as it dives by comparing the delay in vocalizations on all of the hydrophones. The sounds were all recorded onto a multi-track recorder, which was then brought into the laboratory for analysis with special software developed at BRP. While no giant squids were actually documented on this expedition, Frankel was able to give the camera crews a better idea as to where they should be sending their robotic submarines with the hopes of finding one.

One of the most interesting technologies developed at BRP has to be their Autonomous Recording Units (ARUs), which consists of a microprocessor, a hard disk, acoustic communications circuitry, and a power supply, all in one small glass ball. A hydrophone, connected to the inside via a waterproof connector, is attached to the outside. They are capable of recording sound at depths up to 6,000 meters. When it is done with making the desired recording, it simply releases itself from its weight and "pops up" to the surface of the ocean. (Ornithology 2005) The information recorded goes through D/A conversion and is saved onto the hard drive depending on its programmed schedule. What is even more interesting is that the system is setup so that when the ARU receives a certain audio signal, coming from the boat above, it releases itself from the weight. There is a special GPS locator in the system as well to help locate the ARU on the surface of the ocean. Once it is picked up, the hard drive can be removed and the data can be analyzed. Currently the ARUs have a recording life span of 10 to 21 days and a hard drive of up to 80 GB. (Ornithology 2005)

The other technological advancement currently being made BRP is their sound analysis software they call Raven. Raven is used for the "acquisition, visualization, measurement, and analysis of acoustic signals" as well as "to provide a powerful, user-friendly research and teaching tool tailored to the needs of biologists working with acoustic signals." (Ornithology 2006) The program itself is basically just like any other sound analysis software only BRP custom designed it with features that prove to be helpful when analyzing biological acoustic sound (see *Figure 3*). One nice feature of the software is that it is capable of creating three different views of the same waveform, which are the waveform itself, a spectrogram, and slice of the spectrogram. It is

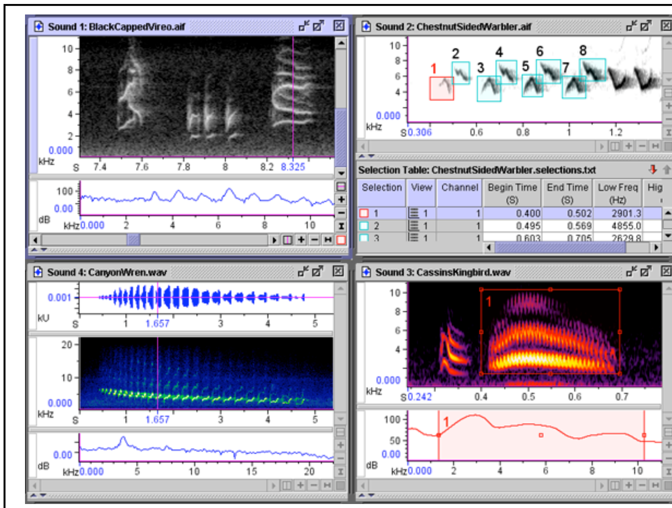

Figure 3 – Raven software screenshot.

also capable of processing the sound in real-time, which is helpful for biologists attempting to classify mammals while on a boat. Another feature that helps biologists is the program's ability to make notes on the spectrograms, which would help the biologist to classify the different vocalizations like a composer might do with a score. Because of the high level of noises occurring underwater, Raven allows its users to setup filters so that they able to see only the frequency ranges that they want. Other than it works just like any other sound analysis software. It costs $400 for a single-user license or $100 for a one-year student subscription.

With all of the work being done at BRP in regards to underwater sound and digital audio technology, I would like to move on to other applications being developed in this area.

Underwater Digital Audio/Music Applications

There are numerous applications in which digital audio can be combined with underwater sound, recording, and activities. This section will give an overview of the technologies being developed in all of the different areas.

With the success of the iPod and other portable music devices, one of the first applications for digital audio that comes to mind is the ability to listen to music underwater. One of the major companies developing hardware for this is H20 Audio. Not only have they created plastic waterproof casings for the entire iPod family, all of which are capable of being submersed 10ft underwater, but they also created underwater headphones in which to listen to your music. While 10ft is not ideal for scuba diving, it would be perfect for someone who wants to listen to their music while swimming laps in a pool or even while surfing. As for the scuba diving option, they did develop a system that works at a maximum of 200ft called the DV-i300. It attaches directly to your scuba mask. Some scuba companies are considering purchasing these for then they could start taking customers on interactive scuba tours. The company itself does not actually create any special digital audio products so much as they make special casings that allow a listener to control their device underwater. (Audio 2005)

One company, Finis, developed a product they call the SwiMP3 player, which is more than just a waterproof housing. It is an MP3 player that is part of a goggles system that allows the swimmer to listen to music while swimming in a pool (see *Figure 4*). The biggest difference between them and the H20 Audio products is that "it relies on bone conduction of sound. When the device is placed on any bones of the skull (i.e. the cheek bones or the mastoid tip) it leads to vibration of the fluid in the inner ear." (Inc. 2005) I really enjoy the idea of this type of product since it actually replicates the way that dolphins and whales hear underwater and allows the user to have the same experience.

Figure 4 – SwiMP3 underwater portable

Along the same lines as listening to portable music players underwater is underwater loudspeaker technology, Lubell Labs being the leading company in this area. Alan Lubell founded the company in 1970, only 2 years after he created the first underwater speaker. With the speaker he was able to play "crystal clear" music into a 20-acre lake. (Labs 2006) Some of the fields currently using his speakers are synchronized swimmers, commercial and military diver recall, NASA, underwater movie production, and the Olympics. They also have a bone conducting piece of hardware is placed against the users head and can be used as a microphone or portable recording device for someone who might need to make notes underwater. These speakers are also being used for research in whale and dolphin communication purposes in

Disney World. The company claims that "one Lubell speaker and 35 watt amplifier is used to fill their 5.3 million gallon tank with powerful sound clearly audible by SCUBA divers and dolphins." (Labs 2006) Unfortunately the technology is proprietary, however the company does state that the speakers are made of the same piezoelectric material as the hydrophones mentioned earlier in this paper.

Another use of Lubell's underwater speakers is the Underwater Music Festival that has happened for the 22 years in Key West, Florida. It takes place in the Looe Key National Marine Sanctuary where literally hundreds of scuba divers and snorkelers congregate to listen to water themed music with the hopes to spread awareness of coral reef conservation. Music is synchronized and played by boats above the water while the divers swim around the reef. (Tripsmarter.com 2006)

Yet another use of underwater loudspeakers is to return broken down or deteriorating reefs back to their natural state. Dr. Stephen D. Simpson of the University of Edinburgh took students and researchers to the Great Barrier Reef with the hopes of attracting marine life through the use of underwater speakers. According to work done by marine biologists, younger fish are more attracted to noisy reefs. Through the use of underwater speakers, Dr. Simpson and his colleagues have had success in reproducing natural reef ambiences underwater and in doing so bringing new fish to make homes in the reefs. (Fountain 2005)

In regards to other technologies being developed for scuba divers, the Raytheon Corporation has developed a new technology to deter divers from certain areas underwater. They developed a form of acoustic weaponry that detects swimmers if they are in an unauthorized zone it triggers a powerful low frequency sound wave that causes the divers to become nauseous. The frequency resonates the organs in such way that makes the diver/swimmer either vomit or causes their organs to rupture. The system is used to combat spies and terrorists. (Fox 2006) The same technology has been used to detonate incoming torpedoes.

Project Delphis, mentioned earlier in the paper, is currently doing work with Apple Computers in regards to dolphin cognition research. The idea behind this project is to help prevent and ultimately stop the death of dolphins that are killed accidentally from harpoons, fishing nets and pollution. One idea that the project is attempting to work on breaking the language barrier between humans and dolphins with the hopes of being able to develop a warning system for the dolphins for areas where these sort of traps might be. Through experiments on self-awareness by use of mirrors and video playbacks, it was found that the dolphins were able to recognize themselves as well as familiar images on screen such as rings and other fish. (Earthtrust 2006) Upon discovering the high level of intelligence in the dolphins, they created computer systems for them to work on featuring what they call an “acoustic” joystick for control. Unfortunately, coming up with a code in which to determine what the dolphins were trying to communicate became frustrating to both the scientists and the dolphins. Eventually they changed the control surface to a touch screen. They did however create a telephone like system where dolphins could go up to screens and see other dolphins and were then able to communicate via hydrophones and underwater speakers and were successfully able to have a mother communicate with its child through this system. They even got a dolphin to do what looked like dancing by playing music for it. Project Delphis and Earthtrust, along with Apple Computers, are currently working on a synthesis program in which they hope to one day use to actually communicate with dolphins. (Earthtrust 2006)

Conclusion

On my spring break this last March, I was lucky enough to go out on the Monterey Bay and do some actual fieldwork in the area of underwater recording. I purchased a hydrophone online for around $150 (one that turned out to be much less responsive than the $30 one I made myself I might add) and borrowed a portable digital hard drive recorder from the Music Technology Department at NYU. Aside from the part where I was almost seasick on the side of the boat, I must say that it was truly one of the most incredible experiences I have ever had. To be able to hear marine life with such clarity and accuracy really makes you feel that much closer to the Earth and its creatures.

Digital audio technology and the field of marine biology have a lot to teach one another, and not only that but they also have several places where they can benefit one another. For instance, hydrophones are now being implemented as a form of tsunami warning system with the help of sound analysis and detection software. (Timbath 2005) We also learned through the use of digital audio technology, coral reefs are being restored to their natural state. The convergence of digital audio and underwater sound will continue to discover new fields of research as well as new jobs for music technologists.

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