Underwater Music: Tuning Composition to the Sounds of Science

CHAPTER 6

UNDERWATER MUSIC: TUNING COMPOSITION TO THE SOUNDS OF SCIENCE

STEFAN HELMREICH

Introduction

How should we apprehend sounds subaqueous and submarine? As humans, our access to underwater sonic realms is modulated by means fleshy and technological. Bones, endolymph fluid, cilia, hydrophones, and sonar equipment are just a few apparatuses that bring watery sounds into human audio worlds. As this list suggests, the media through which humans hear sound under water can reach from the scale of the singular biological body up through the socially distributed and technologically tuned-in community. For the social scale, which is peopled by submariners, physical oceanographers, marine biologists, and others, the underwater world—and the undersea world in particular—often emerge as a "field" (a wildish, distributed space for investigation) and occasionally as a "lab" (a contained place for controlled experiments).

In this chapter I investigate the ways the underwater realm manifests as such a scientifically, technologically, and epistemologically apprehensible zone. I do so by auditing underwater music, a genre of twentieth- and twenty-first-century

composition performed or recorded under water in settings ranging from swimming pools to the ocean, with playback unfolding above water or beneath. Composers of underwater music are especially curious about scientific accounts of how sound behaves in water and eager to acquire technologies of subaqueous sound production. We can learn much about how the underwater domain has been made sonically perceptible by attending to how composers adapt their practice to scientific language and technique in ways both rigorous and fanciful. We can learn how sound has been abstracted from the water medium to reveal and produce resources imagined as musical. We can track how technologies of underwater audition are often adjusted to deliver aesthetic experiences in line with the way composers imagine submerged sound *should* sound; how, to take one example, the notion of water as sublimely immersive can be reinforced in compositions that make use of hydrophonic listening and playback. We can also sometimes discern a querying of dominant thinking about the symbolism of underwater sound.*[1]

One tradition in the history of sound tells us the ocean was once taken to be a place of silence (thus, in 1953, Jacques Cousteau's book *The Silent World*). Auguste and Jacques Piccard the same year described travel two miles down in their bathyscaphe *Trieste* as surrounded by the "quiet of death" (Long 1953, quoted in Schwartz, forthcoming). That tone had been set in 1896, when Kipling wrote in his poem "The Deep-Sea Cables," "There is no sound, no echo of sound, in the deserts of the deep" (resonating with early nineteenth-century theories of the deep as a lifeless "azoic zone"). However, there has existed a more sonorous imagination of the sea—think of singing mermaids and sea monsters. In Charles Kingsley's 1863 novel, *The Water-Babies*, the boy protagonist, approaching a submarine volcano, comes "to the white lap of the great Sea-mother, ten thousand fathoms deep . . . aware of a hissing and a roaring, and thumping, and a pumping, as of all the steam engines of the world at once" (quoted in Kaharl 1989, xiii). As we will hear, the underwater world was, even in its first scientific manifestations, full of sound—even music—echoed in the poetic descriptions such vibration often called forth. Such soundful seas found expression in Romantic musical efforts to evoke underwater realms, which bequeathed a store of symbolism to later music meant to be realized under water. Notions of the immersive and sublime continue to saturate audio work. However, listening closely to such work, as this chapter does, also reveals how underwater music tracks shifting perceptions of the sea (from a space of cold-war mystery to a commons imperiled by global warming), changing ways of inhabiting swimming pools (primarily implicating gender), and fashions of connecting sound, art,

* I thank Karin Bijsterveld and Trevor Pinch for inviting me to the Sound Studies workshop. Participants in Maastricht provided invaluable comments, particularly Eefje Cleophas. For careful readings, I also thank Etienne Benson, Caitlin Berrigan, Beth Coleman, Kieran Downes, Douglas Kahn, Ernst Karel, Heather Paxson, Tara Rodgers, Sophia Roosth, Michael Rossi, Hillel Schwartz, Nick Seaver, Malcolm Shick, Nicole Starosielski, and Peter Whincop.

and science in contemporary practices such as field recording, sampling, and sound art.

Evoking, Invoking, Soaking

I distinguish three modes through which music meets water. In the first, musical composition or performance *evokes* water symbolically, metaphorically, or timbrally—in the arrangement of notes, the organization of rhythms, or the choice of instrument.[2] In the second, music *invokes* water as a material instrument or sonic element. In the third, music *soaks* in water—that is, music is immersed in actual water as an encompassing medium within which it is performed, recorded, played back, or listened to (see the end of the chapter for a musicography organized according to *evoking*, *invoking*, and *soaking*). This chapter concentrates on the third mode.

Before focusing on soaking, however, here are some notes on evoking and invoking:

Evoking: Romantic composers Berlioz, Debussy, and Ravel, along with modernists Satie and Schoenberg, are known for portraying tranquil and tumultuous seas with an orchestral palette.[3] Acoustic ecologist R. Murray Schafer tested the waters of scientific seas in 1978 with String Quartet no. 2, *Waves*, which offered "dynamic, undulating wave patterns, the rhythm and structure of which [were] based on his analysis of wave patterns off both the Pacific and Atlantic coasts of Canada" (Knight 2006, 58).[4] The undersea world came into palpability in soundtracks to science documentary and science fiction film and television. Cousteau's *The Silent World* (1956)—not at all silent (bubble noises and scuba breathing abound)—features an Yves Baudrier score, towed down by dropping cello lines, suspended with gurgly horns, and buoyed up with tinkling harp notes (indebted to Liszt's 1877 "The Fountains of the Villa d'Este," full of rippling piano[5]).[6] In soundtracks to *20,000 Leagues under the Sea* (Paul J. Smith 1954) and *The Deep* (John Barry 1977), composers evoke the undersea with arpeggiating harps and minor-keyed swelling strings. In line with apprehensions of the ocean as a feminized, mysterious other, Western composers often employ orientalist motifs. In Angela Morley's 1969 "Martineau and Organ," from *Captain Nemo and the Underwater City*, the Mellotron organ and the Theremin evoke mellow swirls and half-forgotten siren songs. A lexicon for music evocative of the underwater world comes into being.[7]

In the mid-twentieth century, composers move from iconic to onomatopoetic, seeking to create sounds that *sound* as though they originate in water. Electronic effects become important.[8] Ussachevsky's 1951 "Underwater Waltz" employs reverberated piano. Synthesizers burble onto the scene: For Jean Painlevé and Genevieve Hamon's 1965 film, *The Love Life of the Octopus*, *musique concrète* composer Pierre Henry offers oozy synthesizer noodlings.[9] The electric guitar is adapted

for surf music. The "sopping-wet 'surf' sound" (Bogdanov 2001, 105), realized by "[l]iquid guitar drenched in deep-tank reverb" (Priore 2007, 72), results from reverberation: "Surf guitarists are noted for extensive use of the 'wet' spring reverb sound and use of the vibrato arm on their guitar to bend the pitch of notes downward."[10] Jamaican dub drips reverb. David Toop suggests that "sonar transmit pulses, reverberations and echoes of underwater echo ranging and bioacoustics" constitute the "nearest approximation to dub" (1995, 116; cf. Henriques 2003). In the late twentieth century, Detroit techno outfit Drexciya conjured an imagined underwater sonic universe—their homage to Kraftwerk's "Autobahn." "Aquabon" guides German electronica into a disturbing fantasy of a black Atlantis founded by Africans thrown overboard during the Middle Passage.[11] Important in these works is how the underwater world is imagined, for this imagination remains influential when composers work under "real" water as they coax out of the medium that which they imagine they should hear. Underwater soundworlds are unearthly, evanescent, all encompassing, dreamlike, alien.[12] Aesthetics saturates technique.

Invoking: Douglas Kahn's *Noise Water Meat* is the essential scholarly work about modernist music that calls upon water. "The first notable use of wet percussion was Erik Satie's use of *boutelliphone* (a series of tuned bottles suspended from a rack, 'a poor man's glockenspiel') in *Parade* (1918)" (Kahn 1999, 247).[13] John Cage's 1952 *Water Music* "included among its forty-one events a duck whistle blown into a bowl of water and two receptacles for receiving and pouring water" (Kahn 1999, 242). The genre of "drip music," starting in the 1950s, dipped into nonsense, babbling.[14] However, "Drops of water were [also] conducive to music because they could comfortably assume musical speeds and were amenable to total organization by the composer" (Kahn 1999, 251), as in Hugh Le Caine's 1955 "Dripsody: An Etude for Variable Speed Recorder." Yoko Ono's 1963 "Water Piece" (followed by her 1971 "Toilet Piece") keys us into the context for drip music, the art movement known as "Fluxus," Latin for "flow."[15] In the late 1960s, flows and drips—artificially created in laboratories of modernist aesthetics—were joined by a new genre of field recordings. In 1966–1967 New Zealand composer Annea Lockwood began a project called "The River Archive," recording sounds of rivers around the world.

The aesthetic aim in pieces that *evoke* and *invoke* water is a sense of immersion (cf. Grimshaw, this volume), and one purpose of this chapter—especially as I turn in the remainder of this text to underwater music that *soaks*—is to think critically about how that immersion is achieved in controlled lablike spaces such as swimming pools and in the wilder field of the ocean. It turns out that immersion is accomplished through composers' appropriation of scientific and technical models of underwater soundworlds, as well as their tweaks of those models to align with ideas about how the underwater domain should sound. If the sounds of science (Mody 2005; Pinch and Bijsterveld 2004) saturate underwater music, these sounds are multiply mediated and manipulated.

Tacking between Field and Lab in Underwater Music: Submarine Noises and Whale Songs

Musical language shapes descriptions of early experiments in underwater sound propagation. In a 1708 issue of the Royal Society's *Philosophical Transactions*, Francis Hauksbee published an "Account of an Experiment Touching upon the Propagation of Sound through Water," in which he pronounced that a bell under water sounded "much more mellow, sweet, and grave at least three notes deeper than it was before" (1708, 372).[16] Imagery of music played under water reverberates through early technoscientific inquiries into submerged sound.

By the early and mid-twentieth century, as oceanographers and antisubmarine warfare researchers listened closely to the underwater realm—realizing that it was not a place of silence—music and its metaphors continued to shape sea sound description. Maritime military research history entwines with musical history:

> In World War I the composer and conductor Sir Hamilton Harty was called in by the British Admiralty's Board for Invention and Research to identify the most likely frequency bands of hull and propeller noises. . . . Ernest Rutherford also took a colleague with perfect pitch out in a small boat as part of the war effort. At a prearranged spot one of the great names in atomic physics took a firm grip of his companion's ankles while this man stuck his head into the Firth of Forth and listened to the engine note of a British submarine. Hauled back into the dinghy and toweling his head he announced it was a submersible in A-flat. (Hamilton-Paterson 1992, 114–15)

Submarine pilots used less fanciful discernment. The U.S. Navy created instructional LPs to train submariners to distinguish enemy sub sounds from ambient noise.[17] "Still," writes Hillel Schwartz:

> Sonarmen went "ping-happy." Straining to identify threats within an underwater environment that behaved "very much like a large empty room with bad acoustic properties," they heard pings bouncing off what turned out to be whales and schools of fish, heard pips refracting off what turned out to be temperature gradients, heard roars from what turned out to be waves rushing at rocks on distant shores, and heard much better in mid-morning than in the late afternoon. (forthcoming)

In order to endow submarine space with immersive sonic depth, to carve a soundscape for humans out of the subaqueous milieu, it takes technical and cultural work and translation. Equipment must be constructed that can capture submarine vibrations in the audio register and ready them for humans to listen to—equipment like hydrophones, which can capture underwater vibrations using microphones fashioned of ceramic or some other material sufficiently denser than water to allow propagating waves to be impeded. The earliest hydrophones were

manufactured in 1901 by the Submarine Signal Company of Boston, which imagined "a network of underwater bells whose sonorous gongs would carry through the water at great distances" (Schlee 1973, 246). The company, seeking an alternative to foghorns, built receivers to capture underwater bell sounds for listeners on surface ships—though plans to use bells for Morse code were scuttled by the turbulence of the submarine medium. Hydrophones came into their own on submarines with sonar (sound navigation and ranging), which was in operation by the 1930s. Sonar works by bouncing signals off the ocean bottom or other boundaries in water, permitting submariners to time echoes to compute distances. It produces a dimensional portrait—not so much a soundscape as a *soundedscape*. Hydrophonic signals were rendered into stereo by the use of devices that transformed signals arriving at separate underwater receivers into "binaurally centered" impressions in headphones, creating spatial relations meaningful to hearing humans (Höhler 2003). If, as Emily Thompson (2002) has argued, the soundscape of modernity is patterned by sounds fed through technological filters, underwater soundscapes do not exist at all for humans without such filtering all the way through.

It was incumbent on early submariners to be attentive auditors of sonar, and it was through such listening that the crackling of crustaceans and the snapping of shrimp were disclosed, providing a portrait of soundscapes already in existence for underwater creatures with means to hear them (see Iselin and Ewing 1941). Such human listening participated in "field" science in its canonical form—the investigation of a space of shifting boundaries, of natural and cultural agents (Kohler 2002; see also Bruyninckx, this volume). The care with which submariners listened emerged in part from cold-war anxieties about the possibility that missing the faintest signal might be disastrous.

It was through such field listening—filtering "noise" from sound, tuning it to the human auditory range—that whale "songs" were discovered. Biologist William Schevill of Woods Hole was the first to call these sounds whale "music," though musical metaphors—and comparisons to birds—circulated earlier. Once whale sounds had been separated, they were aestheticized as lonely, majestic, ecologically tuned-in arias to the wounded sea (see Madsen 1999, 33). They were pressed onto LP, notably by bioacoustician Roger Payne on *Songs of the Humpback Whale*, in 1970. They were fused with classical composition in Alan Hovhaness's 1970 *And God Created Great Whales*, a mix of recorded and represented, indexical and iconic sounds.

One could describe the trajectory this way: The underwater realm starts out as silent, becomes soundful (eerie with cold-war echoes), occasionally noisy, and, once so revealed, turns out to be full of music from creatures imagined close to humans in cognitive power, creatures whose songs can then be separated from their medium—field—for contemplation. This trajectory is accompanied by another, in which humans experiment with their own subaqueous music to see whether they can move from the iconic and symbolic mode of Ravel and Debussy, from the octopoid onomatopoeia of Pierre Henry, to a more indexical evocation of "actual" immersion, or soaking. This other trajectory for underwater music is less natural

historical than "experimental." Having learned lessons from the oceanographic "field," musicians tinker in lablike settings, spaces where they control boundaries and variables. The primary such space is the swimming pool, and one of the first to dive in is John Cage.

The Pool of Experiment: Cage and Neuhaus

Cage—son of an engineer who worked with hydrophones—first brought water sound/noise into his modernist composition

> in his collaboration with Lou Harrison, *Double Music* (1941), in which Cage specified the use of a "water gong (small—12"–16" diameter—Chinese gong raised or lowered into tub of water during production of tone)." . . . Cage . . . traces his use of the water gong to 1937 at UCLA, where, acting as an accompanist, he sought a solution to the problem of providing musical cues to water ballet swimmers when their heads were under water. (Kahn 1999, 249–50; see also Hines 1994, 90)

Cage's approach later became more experimental, mixing subjective and scientific methods. Water was important to Cage because, as he put it, it "prepared me for the renunciation of intention and the use of chance operations" (quoted in Kahn 1999, 249–50). In such renunciations, the authorial self-dissolved—as in Cage's tale of his time in an anechoic chamber, in which he heard his own blood flow as part of the environment. Water stood as a symbol of gentle noise, of a scientific modernist sublime into which an individual might dissipate, a view literalized in the self-experiments of dolphin researcher John Lilly, who reported auditory hallucinations while floating in isolation tanks.

In some measure, this immersive symbolism is read out of how human hearing works under water. Sound waves travel four times faster in water than air—making it nearly impossible for humans to use underwater acoustic vibration to locate themselves in space. This difficulty is compounded by the fact that human eardrums are too similar in density to water to provide the resistance that can interrupt many underwater vibrations so they might be translated into tympanic movement—sound—in the ears; many vibrations pass right through our bodies. For humans, underwater sound is largely registered by bones in the skull, which allow enough resistance—impedance—for vibrational motion to be rendered into resonances in the body. Moreover, conduction of sound by bone directly to the inner ear confounds differences in signals received by both ears, making it impossible to compose a "stereo image." Unaided human ears perceive underwater sound as omniphonic: coming from all directions at once (and because of sound's seemingly instantaneous arrival, often as emanating from within one's own body).

The underwater world is not immediately a soundscape for humans because it does not have the spatiality of a landscape; one might, rather, think of it as a zone of sonic immanence and intensity: a *soundstate*.[18]

Sound installation artist Max Neuhaus was next in the pool:

> In *Water Whistle* [1971–1974], water was forced through whistles under water to produce pitched sounds that could be heard by the audience only when they submerged themselves. In *Underwater Music* [1976–1978], he modified this technique by using specially designed underwater loudspeakers and electronically generated sounds, which were composed through a combination of scientific experiment and intuitive, creative decisions. (Miller 2002, 26)

Simon Miller writes, "Such compositions literally immersed Neuhaus in the medium—the sites were swimming pools—as he adjusted pitch perimeters and envelopes, in effect 'coloring' the sound. They dramatized the spaces of sound, its limits, because the medium contained them" (2002, 26). In planning for these works, Neuhaus made drawings to think through "configurations of the sound sources in the three-dimensional space of each body of water" (see figure 6.1). Neuhaus's experiment, like the use of hydrophones and sonar, took place within a soundscape of modernity (Thompson 2002), depending crucially on standardized knowledge of how sound behaves in water.

In this work, the pool is a lab, a site with clear boundaries within which variables can be manipulated and in which the "nature" of water can be brought "indoors" to be controlled and cleaned of agents that populate it in "the wild" (see Knorr-Cetina 1999; Kohler 2002). It becomes a placeless, universalized space, though because of its artistic repurposing, it also becomes a space in which subjective experience—objectively modulated—can be realized as immersive. So, rather than a space in which scientists generate inscriptions on paper (Latour and Woolgar 1986), it becomes a space for generating *impressions*. In addition, as with the "house of experiment" described by historian Steven Shapin (1999)—a site where gentleman scientists could gather to agree on matters of fact—this "pool of experiment" admits a properly trained public of modest auditors, ready to be immersed.

Conducting Transduction: Redolfi's *Musique Subaquatique*

The aim of immersion is elaborated in work of French composer Michel Redolfi, who in 1982 performed in Dartmouth College's indoor pool. As Redolfi put it, "[L]isteners of the *Underwater Concerts* 'immerse themselves not only in the 90-degree heated swimming pool, but in the sound itself'" (quoted in Charles 1993, 60). How does this immersion work?

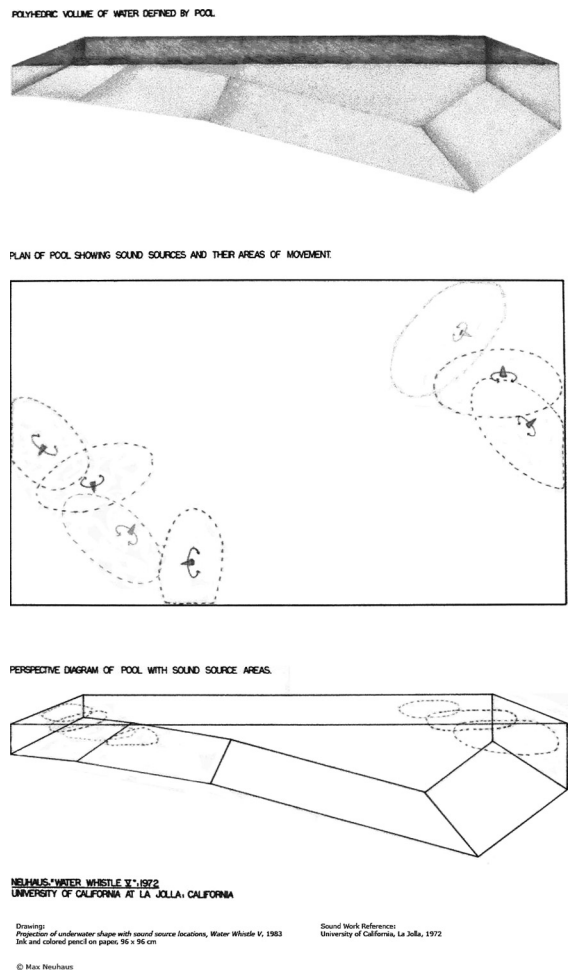

Figure 6.1. Projection of underwater shape with sound source locations, Water Whistle V, 1983, ink and colored pencil on paper, 96 × 96 cm; sound work reference: University of California, La Jolla, 1972 (www.max-neuhaus.info/drawings/waterwhistle/index_drawings.htm).

Redolfi uses modified speakers in his underwater events. Managing the mix of electricity and water is key. Redolfi's sound engineer, Daniel Harris, explains:

> Having people, the audience, and speakers with electrical connections in the water together can be a concern unless proper measures are taken to insure that no harm comes to the audience. The SWSS (Sonic Waters Safety System) was developed in response to our concern about the speaker systems introducing stray electrical currents in the water. The SWSS inserts a 50-kHz pulse wave into all cables entering the water in the same manner as DC power is introduced into microphone cables to power microphones. The return signal is passed through a counter/comparator circuit, which will instantly shut down any line that drops a settable number of pulses, usually 3, indicating a short or other malfunction.[19]

As this list of equipment makes clear, "immersion" is a hard-won pun, a hard-won laboratory effect. It depends on engineering a sequence of *transductions*—translations of signals across various media, acoustic, electronic, watery—so that the transduction itself is inaudible, seamless. The immersive effect would be ruined if Redolfi's listeners were electrocuted.

The symbolism of water as a sublimely immersive medium must be actively realized technologically. Harris writes that "The genius of Michel Redolfi is in how he applies his knowledge of the human acoustics of underwater sound and intimate familiarity with the playback systems to the composing and mixing of his very original and enchanting music." In some cases, however, that knowledge is subordinated to Redolfi's sense of how underwater music *should* sound. Harris writes as follows, of an underwater xylophone:

> Hitting a metal bar under water results in a very unsatisfying "tink," no matter how hard the performer strikes the instrument, nor how heavy the bar. [So] I glued piezo sensors on the bars, which, when struck, triggered samples or other electronic sound sources via MIDI triggers. . . . The resultant audio was mixed with other sources and sent to the SWSS and then to the underwater speakers.[20]

Philosopher of music Daniel Charles hears such modulations as an ideal meeting of water and music: "What is at stake, then, is not the spatial idiosyncrasy of the environment, but the degree of achievement of the blending of a music which can be described as simple, tranquil and transparent, with the physical characteristics of water—its density, temperature, and color" (1993, 63). Redolfi is, of course, alive to how science and symbolism come together, though he doesn't always call attention to the artificiality of that relationship. In connection with a later piece, *Sonic Waters*, he writes as follows:

> [W]ater materializes sound, thickens it, and makes it palpable and penetrable. Water and sound, combined together at the molecular level, create a sonic and fluid substance that can be appreciated not only by looking at its surface reflections, but by sinking oneself into its volume, density, warmth and vibrations (quoted in Charles 1993, 63).

In addition:

> [T]he very concept of underwater sound, Redolfi says, goes all the way back to the songs of sirens, the bells of submerged cathedrals, the voices of lost mariners. "These noisy and eerie myths," he notices, "have been swept away by the XXth Century and replaced by a quiet and sterile belief in the ocean as a silent world and occasionally disturbed by the long song of the Aqua Diva whale. But the fact is that the sea is a cacophony of sound, complete with fish "barking and croaking," shrimp "snapping," dolphins "whistling" and sea urchins "click-click-clicking." (Charles 1993, 63)

Note that Redolfi does not mention sonar surveys, pings, or the like; technological intrusions do not figure in his impression of water. Such intrusions are far from trivial—as the ears of cetaceans damaged by underwater sounds attest (James 2005). Dialing in to deployments of sound deleterious to dolphins and

whales might reveal a genre of underwater music no one has yet considered: cetacean death metal.[21]

So, while Redolfi knows that transductions are necessary to immersion, he ontologizes water as dreamy, alive, penetrable. Charles argues that Redolfi has done something radical here, however. Redolfi not only seeks to:

> *reduce all metaphors of presence, but make of presence the metaphor of itself*. In that sense, Redolfi is no more a minimalist: thanks to technology, he transforms the very status of presence until presence becomes, through the acceptance of its reproducibility, an instance which does not need any more to be interpreted or symbolized or displaced, because it entails its own interpretation or symbolization or displacements. (1993, 67)

However, if we thought not of reproducibility but of *transducibility*, we might hear more clearly the material conditions of Redolfi's "presence," which depends, again, on making sure the underwater audience is not flash-fried by subaqueous electronica (cf. Helmreich [2007, 2009] on how transduction bolsters perceptions of "presence" in submersibles; Henriques [2003] on transduction in reggae; and Roosth [2009] on transduction in sonocytology, listening to cellular life).

From 1981 to 1984 Redolfi scaled up his enterprise, moving into the field—the ocean—when *Sonic Waters* was performed off the coast of Southern California. This opening up of the dream lab of the pool into the field was accompanied by campy sea creaturey devices, such as the giant colorful "jellyfish" that kept a low-frequency speaker afloat in La Jolla Cove. Such playfulness is a reminder that Redolfi does not imagine crustaceans, fish, or marine mammals as audiences: "Redolfi is concerned with humans: 'Every dolphin, he says, has a person nowadays to take care of him. . . . I prefer to take care of humans' " (Charles 1993, 63). Redolfi's approach looks similar to that of the Florida Keys underwater music festival. Celebrating its twenty-fifth anniversary in 2009, the festival offers to scuba divers music played over Lubell Laboratory speakers attached to boats floating near the reef.[22] Attendees dress up as fish.

Listening to the Sounds of Science: The Wet Sounds Festival

In 2008 announcements of the United Kingdom's first underwater sound festival, "Wet Sounds," asked people to dip into municipal swimming pools to listen to music specially composed by industrial, electronica, and noise performers, as well as sound artists (Blanning 2008). Sound art—a genre of art that creates sound objects to be experienced in galleries, in public spaces, and via headphones—made a good match with this festival, which treated the pool not just as a chill-out room but also as a gallery space/lab (on sound art, see Labelle 2006;

Licht 2007). Listeners' attention was persistently drawn to technoscientific frames of reference.

Wet Sounds pieces are archived online. A few are hydrophonic recordings—so that the fact that they were played back under water raises the question of whether these are compound or redundant underwater pieces (and what happens when we listen in air?). The attempt to superimpose one underwater space (the ocean) on another (the pool) makes particularly explicit the multiple meanings of "medium" in this practice of *schizophonia*—the splitting of sound from its source.[23] Slavek Kwi's "Sonafon," for example, is "a structural and textural exploration of echolocation sounds made by Pink Dolphins recorded in Rio Jaupeperi in Amazonas, Brazil, using ultrasound range hydrophones." Klaus Osterwaldt's "Donatus Subaqua" offers "Recordings made in a quiet lake in the forest using hydrophones placed two meters below the surface. There are sounds of the underwater environment like gas bubbling up from the bottom, plants producing oxygen, insects and even the calls of waterboatman." Amie Slavin's "Wave Play" is "an abstract interweaving of pulse, saw, and triangular waves designed to invoke the playfulness and the latent power of waves, in both sound and water."[24] In addition, Disinformation's "Ghost Shells" plays back sferics and whistlers, sounds produced by storm disturbances in Earth's electromagnetosphere (and captured on very low-frequency radio bands): "These phenomena are referred to as 'hydrodynamic' because the math used for modelling their behaviour has been extrapolated from observations of how equivalent wave phenomena behave in the variety of fluid media" (see Motschmann, Sauer, and Baumgaertel 1984).[25] By 2008, then, scientific representation—as a warrant for underwater realism, as an aestheticized device for delivering other worlds, as a fetish for formatting serious art—was sharply in presence as a passage point for making underwater music and sound art.

Queering the Mermaid: Snapper, Oleson, Leber, Chesworth

In May 2009 singer Juliana Snapper premiered an underwater opera titled "You Who Will Emerge from the Flood" (written with composer Andrew Infanti) at the Victoria Baths, a historic public swimming pool in Manchester, England. Snapper took on the challenge of singing under water, fusing technique and aesthetic: "Maximizing bone conduction and controlling bubble output as part of a new vocal fabric," her website reports, "Snapper merges extended techniques with Baroque tropes that represent human longing and passion as aspects of weather. Pre-recorded sounds from oceanic bubble fields and birdcalls throb above the water as Snapper's voice (amplified by an underwater microphone) presses through the soundscape."[26]

There is a virtuoso, alien effect to be won from doing something under water that requires breathing.

As with the work of Neuhaus, Redolfi, and Wet Sounds participants, this is music that requires *research*. About the field. About the body. Snapper writes as follows:

> I have researched underwater acoustics by reading, consulting at the Scripps Institute of Oceanography, and spending hours submerged in my bathtub and borrowed pools. My experimentation up to now has allowed me to control my voice for long stretches under water, negotiate changes in depth and pressure, and to invent a new expressive vocal language that I call mouth-to-water singing. . . . Vocalizing in water involves working with air pressure shifts that compress the air in the lungs and effect the sound of the phonation at varying depths. Mouth-to-water singing relies heavily on bone conduction to transmit voice, and that vibration is also the basis for sensing/hearing sounds in the water. The interference of bubble sounds in the breath-born phonation begets lightly percussive rhythmic textures, and it may be possible to control the pitch material and rate of bubble noise through breath pressure and buccal aperture so that as I sing I am also releasing a secondary melody in duet with my vocal cords.

Snapper imagines herself a modern day mermaid—though one schooled in critical feminism. Snapper, who performed at the "Queer Up North" festival in the UK, does not stage herself as a deliquescent delicacy for a heterosexual masculine imagination, a woman merging with a uterine medium, a möbius mother/lover in the way that, as Douglas Kahn has argued, "submerged women" have persistently been posed, particularly in surrealist representation (see Redolfi's website, full of pictures of bikini-clad women floating in pools).[27] Snapper modulates water as feminized other into a critical substance, one that can detour the way water and waves have been symbolized as feminized flux (see Rodgers forthcoming). She is an active rather than a passive part of the medium—the aim of her work is thus distinct from Cage's, which sought to eliminate intentionality. She is interested, too, in the pool as a simultaneously public and intimate space in which sex and sexuality have historically been subject to disturbance—and also strictly ordered, policed, and ranked (she reports that, historically, the water used on "women's days" in the Victoria Baths was recycled from "men's days"!); what better place to play with gender and sexuality?

Snapper's critique of canonical mermaid models becomes crisp in work in private spaces. In "Aquaoperas," Snapper joins Jeanine Oleson to visit home bathrooms and perform minioperas, with Snapper in the tub and Oleson singing into the toilet (see figure 6.2), their voices fusing through a "snorkelabra." Snapper and Oleson's performance of what they call the "hot lez flower duet" from the opera *Lakmé* by Léo Delibes combines a lesbian sublime with a heterodox dabbling with the abject space of the toilet. In this "pool of experiment," this soak opera, the relation of water to public/private, feminine/feminist/queer is up for grabs.

Figure 6.2. Photo of Juliana Snapper and Jeanine Oleson performing Aquaopera #2 (SF/Lakme Redux at Shotwell Shack, San Francisco).

Snapper and Oleson's work is kin to the sinister work of Australian sound artists Sonia Leber and David Chesworth, who in *The Gordon Assumption* (2004) offer a recording installed in the subterranean toilets of Gordon Reserve at Parliament Station, Melbourne:

> An incessant outpouring of female voices lures passers-by down the stairwell to the cave-like subterranean toilets. At the lower gates, they are confronted with an asynchronous chorus of female voices in infinitely rising pitch. The voices gather and thicken without respite, in upwards glissandi, constantly trailing upwards. . . . The voices recall the mythologies and mysteries of voices heard in caves, where the voices of spirits, sibyls and oracles are believed to announce predictions and warnings from the mouth of a cave. (Leber and Chesworth 2004, quoted in Kouvaras 2009, 101)

Linda Kouvaras reads *The Gordon Assumption* as a feminist critique of mythological siren songs; the songs float indeterminately above signification, yes, but are sited in an abject locale. The piece recalls Duchamp's urinal. Pools, baths, and toilets become laboratories for rethinking water, gender, and sexuality.

But this laboratory research longs to go into the field. Snapper writes, "I am now fully prepared to realize opera in the ocean depths." Why? Snapper writes, "I am interested in the rub of cultural metaphors in which water represents a dangerous zone of 'pure' emotion and now-urgent specters of drought and drowned cities." Though she doesn't mention it, Snapper's words summon memories of Hurricane Katrina (recalled in the image of an "underwater jazz funeral" used in a

review of a 2008 play staged by Tulane Environmental Law Society students in New Orleans). Snapper suggests that "the material tension between water and air (breath, foam, thirst) . . . speaks to an unknown ecological future." Ecology is of signal interest in new underwater music. This is another arena in which science and sentiment, substance and symbol join.

Return to the Sounded Sea: Winderen

Tracking back from lab to field, we find Norwegian field recordist Jana Winderen. Winderen uses hydrophonic recordings "sourced from beneath the oceans surrounding Norway, Greenland, and Iceland" (White Line [UK]): "The music here is assembled from various auditory documents gathered from research trips, all treated as improvisational material, and morphed into elaborate sound collages" (Boomkat [UK]). *Heated* (2008) is a recording of warming water. Like other underwater composers, Winderen is interested in technologies of underwater audition. *Heated*'s liner notes report the use of the following: "2 × 8011 DPA hydrophones, 2 × DolphinEAR/PRO hydrophones and 2 × 4060 DPA microphones." Winderen is artist and empirical researcher both.

What is all this water music in search of? Again: immersion, though now in the sea—though a sea accessed by treating it as a lab, a recording studio. One reviewer writes as follows of Winderen: "With my headphones on and my eyes closed it sounds as if you are really in the middle of this water" (Earlabs [Netherlands]). However, the possibility of imagining oneself immersed depends, press rewind, on *transduction*. It depends on a cyborg sensibility—one indexed in David Toop's *Ocean of Sound*, which he concludes with this cybernetically inflected contention: "Music—fluid, quick, ethereal, outreaching, time-based, erotic and mathematical, immersive and intangible, rational and unconscious, ambient and solid—has anticipated the aether talk of the information ocean" (1995, 280).

However, if immersion is a submersion of self in water, water is controllable only in swimming pools. The "field" is different, full of other critters. Winderen, in "The Noisiest Guys on the Planet," uses snapping shrimp to shift us to a multispecies soundscape.[28] Unlike Redolfi, who ignores underwater nonhumans, Winderen calls us back to these creatures, sentries now in climate change. The field, Winderen's work suggests, is becoming more like a lab not only for artists like herself but also for humanity, experimenting on its ecosystem.

What Winderen is creating, then, is not just music but—in the idiom of sound art—*documents* as well, one reason she and others find technological access to and scientific models of the sea compelling. If earlier generations of composers sought simply to replicate a submarine sublime, today's sound artists hope not just to soak in sound but also to broker ear-opening accounts of human relations with the water around us.

Dunn's *Chaos and the Emergent Mind of the Pond*

Skip back to David Dunn's 1992 *Chaos and the Emergent Mind of the Pond*, a collage of recordings of aquatic insects in ponds in North America and Africa. This collage—fusing recordings from different ecologies—stages a different construal of underwater worlds, one that hears a percolating intelligence in water. In *The Illustrated Insectopedia*, Hugh Raffles writes of Dunn's practice:

> Listening to the pond with two omnidirectional ceramic hydrophones and a portable DAT recorder, he hears a rhythmic complexity altogether greater than that in most human music . . . The sounds can't be arbitrary, he decides. These animals are not simply following their instincts. "The musician in me cannot help but hear more." . . . He begins to hear the pond as a kind of superorganism, a transcendent social "mind" created from the autonomous interaction of all the life within it, terms not dissimilar to those used by complexity theorists to describe the nest colonies of the eusocial insects . . . [His] soundscape is more than a recording, more even than a composition. It is also a research method, one that flows easily from a principle of wholeness. (2010, 323–24)

The piece is inspired by anthropologist Gregory Bateson's model of mind as a phenomenon present in worldly relations, not locked in people's heads. Dunn's insect recordings posit water not simply as a medium but also as organically enlivened, cogitating: "[W]hen I see a pond, I think of the water's surface as a membrane enclosing something deep in thought" (quoted in Ingram 2006, 129). Unlike Cage, who would have advocated listening to these sounds "in themselves," Dunn wants to preserve sounds' referentiality, their link to empirical ecological processes (Ingram 2006)—as on his recordings of bugs in piñon trees, in which he tracks how their sounds flag global warming. While there exists a risk of romanticizing balanced nature, Dunn's Batesonian approach tunes into how water may not only contain life but also be constituted through living things. There can be no purely lablike pool of water; water is made of vitality—which gets us to field recordings of the vital signs of ocean Earth.

From the Cold War to Global Warming: Under Arctic Seas

Andrea Polli's *Sonic Antarctica* CD consists of "recordings of the Antarctic soundscape made during the author's seven-week National Science Foundation residency in Antarctica during the 2007/2008 season." Polli mixes field recordings of melting glaciers with audio translations of scientific data ("sonifications" [Supper, this volume]) on climate and peppers these documents with snippets from interviews with

climate scientists. The sound of ice melting and of data about ice melting are signs of global warming. This aesthetic production has a scientific-political point.[29]

Charles Stankievech's "DEW project" has a scientific-political point as well. As Stankievech explains, "As much ideological deterrent as defense infrastructure, the Distant Early Warning (DEW) Line constructed between 1954–56 [near the Arctic Circle] was a joint venture between the US Air Force and the Royal Canadian Air Force. A long-distance radar and communication system, the DEW Line created an electromagnetic boundary able to detect airborne invasion."[30] Stankievech revisits questions of territorial sovereignty, listening not *up* for enemy others but *down* for global humanity's ecological depredations: "The radio station [at Stankievech's Yukon river site] monitors the sounds of the river's ice and underwater flow on a continual basis, transmitting the signals to Dawson City, where the field-recordings are processed and broadcast via the internet."[31] April 6, 2009, saw Stankievech deliver "a sound performance using live samples from the river installation, electromagnetic microphones, radios and computer." Submarine sounds such as these melt the distinction between music and data collection.

However, even data collection is available for aesthetic contemplation. The PerenniAL Acoustic Observatory in the Antarctic Ocean (PALAOA) transmits sound from the Antarctic Ocean. In addition, PALAOA (Hawaiian for "whale") detects marine mammals and provides a research baseline for relatively quiet underwater environments.[32] The PALAOA MP3 audio stream at the Alfred-Wegener-Institut für Polar- und Meeresforschung website anticipates listeners, warning that its sound is "not optimized for easy listening, but for scientific research. . . . [B]eware of sudden extremely loud events."[33] The sound travels from hydrophones to a research station and then to Germany, where it is put online. In addition, PALAOA's hydrophones, hanging just below the hundred-meter-thick Ekström ice shelf (near Neumayer Station, a German research center), are placed well above the SOFAR (Sonar Fixing and Ranging) channel, a layer of seawater in which the speed of sound reaches its underwater minimum. Low-frequency vibrations can travel long distances through this conduit (about 800 to 1,000 meters deep at midlatitudes and higher toward the surface in temperate zones) before they dissipate.[34] Sounds from this region are essential for ocean acoustic tomography, the study of ocean temperature using sound (Munk, Worcester, and Wunsch 1995). Submarine sounds in art and science now echo concerns not about the Cold War but about global warming. Rather than evoking, invoking, or soaking, they broker connections between the ocean understood as natural field and considered, for better or worse, as a lab for global ecopolitical futures.

Conclusions

Summing up the arc of underwater music over the last half-century: There have been two primary venues for underwater music: field settings of the ocean

(with rivers, ponds, and lakes less frequently used) and lab settings of swimming pools. For the field tradition, underwater music emerges from the noise of the Cold War, which reveals the songs of whales. Those songs then become submerged within the worked-over subaqueous soundscapes of modern human enterprise—soundscapes that harbor evidence of global warming, of sea creatures under stress, evidence that becomes source material for composers who mine scientific idioms for artistic and political statements. For the lab tradition, the pool begins as a stage to realize the ascetic aesthetic of Cagean modernism. It then becomes a space to play with meanings of water—either, as with Redolfi, to reinforce canonical symbolisms of dreamy, meditative, womblike space or, as with Snapper, to queer such imagery, to experiment with gender, sexuality, and public and private. However, while the field setting is "wild" and entangled with nonhuman sounds and the lab setting is more social, cultural, or anthropocentric, artists working in both settings seek to *evoke* an "immersive" experience. Moreover, in both settings the transductive properties of water must be managed in order to *invoke* water as a material accomplice in this enterprise, this aim of *soaking* listeners in the sublime surround of sound submerged.

NOTES

1 This is not a history of underwater sound, which historians of oceanography and acoustics have already delivered. Höhler (2002) describes a shift from sounding the sea with metal ropes to sounding with reflected sound, a practice that turned the ocean into a three-dimensional volume (*sound* as fathoming has moorings in the Old English *sund*, "sea," whereas *sound* as vibration reaches back to Old English *swinn*, "melody.").

2 Kahn calls such evocation "programmatic, depicted, or discursive water" (1999, 245).

3 Wagner linked water and music: "If rhythm and melody are the shores on which music touches and fertilizes the two continents of the arts that share its origin, then sound is its liquid, innate element; but the immeasurable extent of this liquid is the sea of harmony" (quoted in Kahn 1999, 246). This chapter leaves aside evocations of sea creatures, such as Camille Saint-Saëns's Aquarium movement in his 1886 *Le Carnaval des Animaux*, or Edward MacDowell's 1898 Nautilus in *Sea Pieces* (see Shick2007).

4 Toru Takemitsu's *I Hear the Water Dreaming* (1987) evokes water in its Debussy-styled sound and also formally, through an E-flat - E - A motif that—spelled in German as Es-E-A—transliterates the word *sea*.

5 See Chen (2008, 6) on "tremolos to describe the shimmering effects of light on a still water surface; ascending and descending arpeggiated figures and glissandi to depict the undulating of waves."

6 Cousteau's show "The Undersea World of Jacques Cousteau" was soundtracked by Walter Scharf, who sought evocative music for animal subjects. For a special on sea elephants, "The music had a wonderful reedy quality, the same as the sea elephants, but with added feeling" (quoted in Shaheen 1987, 96). Cousteau's editors made modifications: "The sounds of the manatees in *The Forgotten Mermaids* were too abrasive so the music editor rearranged several notes to help soften the manatee munches" (Shaheen 1987, 99).

7 See www.filmscoremonthly.com/board/posts.cfm?threadID=59157&forumID=1&archive=0. Sound recordist Darren Blondin (2007) writes: "Films have taught us that

underwater sounds [are] muffled, echoing, and bubbly. In actuality water is alive with high frequencies, but a bright sounding recording tends to come off as less realistic."

8 Though an earlier—mechanical—precedent is Italian futurist Luigi Russolo's "gurgler" ("gorgogliatore"), an *intonarumori* (noisemaker) described in his 1913 *Art of Noises* manifesto, which called for nonrepresentational sounds—splashing, sirens—in composition. More satirically, Spike Jones's 1948 "William Tell Overture" features gargling. In experimental composition, Francisco Lopez's 1993 *Azoic Zone*, with pieces such as "A Vibrational Trip From Bathyal to Hadal Zones," sounds sourced from hydrophonic recordings but is merely timbrally evocative of them.

9 The indie band *Yo La Tengo*, resoundtracking Painlevé, retains burbly emphases.

10 Http://en.wikipedia.org/wiki/Surf_music. "Wetness" is now taken as such an obvious term that even a sober book on architectural acoustics contains index entries such as "reverberation, excess creates aural soup" and "reverberation, soup and mud" (Blesser and Salter 2007, 428). See Doyle 2005.

11 Listen to Parliament's 1978 "Aquaboogie" for more drowning sounds from the black Atlantic. Compare Sun Ra's vision of a black utopia in outer space (Williams 2001).

12 On FreeSound, a database for sound effects, an MP3 titled "under_alien_ocean" is described as "beneath alien waves, its [*sic*] liquid, but it ain't water . . . oh and its [*sic*] from 1950." www.freesound.org/samplesViewSingle.php?id=14260.

13 Henry Cowell "used '8 Rice Bowls' tuned to no definite pitch using water for *Ostinato Pianissimo (For Percussion Band)* (1934)" (Kahn 1999, 248). South India's Jalatarangam ("water waves") is a carnatic instrument that uses bowls filled with water. Steven Feld (1991) describes flowing water in songs about the Kaluli of Papua New Guinea. Satie wrote satirically on the move from evocative to invocative: "The hydrographic engineers tell us that all the waterfalls of the earth, whatever their social standing might be, yield a low F, clearly audible, upon which it so happens is built a perfect chord in C Major. . . . The Water Company is elated: it is going to install carefully calibrated conduits in all the concert halls to offer musicians an entire chromatic scale of little cascades" (quoted in Kahn 1999, 247). Satie would not have been surprised when "Cage composed . . . *Water Walk: For Solo Television Performer* (1959). . . . The water-related instructions and properties . . . include a bathtub of water, an operating pressure cooker, a supply of ice cubes, a garden sprinkling can, a soda siphon" (Kahn 1999, 250).

14 "Aldous Huxley . . . in 'Water Music' (1920), anticipated the importance of dripping water in Fluxus and, later, in chaos theory: 'Drip drop, drip drap drep drop. So it goes on, this water melody forever without an end. Inconclusive, inconsequent, formless, it is always on the point of deviating into sense and form' " (Kahn 1999, 252).

15 See Dunn and Young 2008), an anthology of drip music. Christian Marclay's 1990 *Bottled Water* is an installation consisting of bottles filled with tape containing the sound of dripping water. The "hydraulophone" uses streams of water in a flutelike apparatus: http://hackedgadgets.com/2007/02/17/ontario-science-centre-hydraulophone-musical-keyboard-water-fountain/.

16 See also Colladon (1893) on 1826 experiments at Lake Geneva.

17 Consult www.hnsa.org/sound/, an archive of navy training sounds.

18 Differences between fresh water and seawater are consequential, too.

19 Http://danielharrismusic.com/Underwater_Music_I.html.

20 Compare Alan Silvestri's soundtrack for *The Abyss* (1989), which uses "electronic pinging and underwater clanging effects" (www.filmtracks.com/titles/abyss.html).

21 Compare the use of whale songs to frighten seals away from Lincolnshire river fish stocks: "To drive the seal family back into the North Sea, the National Rivers Authority

[*sic*] have been playing recordings of killer-whale songs under the surface of the Glen." *The Times*, Oct. 31, 1994, quoted in Toop 1995, 3.

22 Listen also to Erik DeLuca's "The Deep Seascape: The Sonic Sea," which "explores the underwater soundscape of South Florida" (www.erikdeluca.com/).

23 So dimensional has the underwater world become that artist Bill Fontana imagines the transplant of a watery soundscape—as in his 1994 *Ile Sonore*, transposing sound from the beaches of Normandy to the Arc de Triomphe in Paris, making the "white noise of the sea" (Madsen 1999, 29) surround a traffic island.

24 "There has been a long-standing association of water and sound in observational acoustics from antiquity through Chaucer to Helmholtz and beyond, with the sound of a stone hitting water producing a visual counterpart, which was then mapped back onto the invisible movements of sound waves" (Kahn 1999, 246; Rodgers, 2009). The correspondence between water and sound waves is at the heart of "cymatics" (Jenny 1967, 1974; Lauterwasser 2006), which employs sound vibration to generate patterns in watery substrates.

25 The 2009 Wet Sounds festival promised "deep listening" (a term coined by Pauline Oliveros in 1991, which referred less to water than to a mode of attention) (see Allan 2009). Sound artists continue to organize festivals of underwater audio. "Hydrophonia," a festival of hydrophone sound art dedicated to raising public awareness of ocean noise" has been held in 2009 and 2010 in Italy and Spain. Refer to http://hydrophonia.com/

26

27 And in tourist sites such as Florida's Weeki Wachee mermaid attraction, though women there only pretend to sing in the giant fishtank in which they perform. One wonders whether in future they will use Stachowski's (1999) apparatus for talking under water.

28 See Stocker (2002/2003). Sheila Patek studies lobster and shrimp sound and hearing in Biology @ Berkeley: http://www.bio.umass.edu/biology/pateklab/home.

29 Compare DJ Spooky/Paul D. Miller's *Sinfonia Antarctica*, which uses field recordings to "capture the acoustic qualities of Antarctic ice forms, [which] reflect a changing and even vanishing environment under duress" (http://djspooky.com/art/terra_nova.php). Miller's piece is an homage to Ralph Vaughn Williams's 1952 *Sinfonia Antarctica*, which evoked the austral landscape with orchestral arrangements. Miller suggests that his *Sinfonia* will bypass "metaphor" and "go to Antarctica and record the sound of the continent." Compare Peter Cusack's *Baikal Ice (Spring 2003)*, which contains hydrophonic recordings of the springtime sound of ice thawing at Siberia's Lake Baikal.

30 Www.stankievech.net/projects/DEW (accessed 9 September 2009)

31 "A remote transmission station housed in a geodesic dome on the Yukon and Klondike rivers continually records and transmits the sounds of the rivers flowing and the ice shifting using hydrophones embedded in and under the ice."

32 Www.awi.de/en/research/new_technologies/marine_observing_systems/ocean_acoustics/palaoa/. Christine James's 2005 "Sonar Technology and Shifts in Environmental Ethics" charts the rise of noninvasive sonar in concert with environmental movements.

33 w.awi.de/en/research/new_technologies/marine_observing_systems/ocean_acoustics/palaoa/palaoa_livestream/.

34 Garry Kilworth's science fiction story "White Noise" tells of a haunted undersea cable station. Characters find that the deep retains noises from ages past because (in a fabulous piece of SF logic), " 'Cold, dense water is less likely to disperse or be infiltrated by warm currents. The circular currents weave their way intact around the ocean floor like blind worms.' 'And they retain sound patterns . . .' 'Like magnetic tape' "(1990, 513). The main characters, listening in on a microphone attached to a deep-sea cable beneath the Red Sea, hear Moses leading his people out of Egypt.

MUSICOGRAPHY

Evoking

Barry, John. 1977. *The Deep*. Motion picture soundtrack.
Berlioz, Hector. 1844. *Le Corsaire*, op. 21.
Bridge, Frank. 1911. *The Sea*, H. 100.
Carpenter, John Alden. 1914. "The Lake" (*Adventures in a Perambulator*, no. 4).
Crackle. 2008. *Heavy Water*. Slowfoot.
Debussy, Claude. 1903–1905. "Jeux de vagues" (*La Mer*, L. 109, no. 2).
———. 1910. "La cathédrale engloutie" (*Préludes* [Book 1], L. 117, no. 10).
Drexciya. 1997. "Aquabon." On *The Quest*. Submerge.
Dunn, Alan, and Jess Young, eds. 2008. *Music for the Williamson Tunnels: A Collection of the Sound of Dripping Water*. Arts Council, England, edition of 1000.
Elgar, Edward. 1899. *Sea Pictures*, op. 37.
Giant Squid. 2006. *Metridium Fields*. The End Records.
Golijov, Osvaldo. 2004. *Oceana*. Deutsche Grammophon.
Hovhaness, Alan. 1970. *And God Created Great Whales*, op. 229.
Ligeti, György. 1961. *Atmosphères*.
Liszt, Franz. 1877. "Les jeux d'eau à la Villa d'Este" (*Années de Pèlerinage: Troisième Année*, S. 163, no. 4).
Lopez, Francisco. 1993. *Azoic Zone*. Geometrik.
MacDowell, Edward. 1898. *Sea Pieces*, op. 55.
Montgomery, Will. 2008. "Submarine." www.touchradio.org.uk/touch_radio_36.html.
Morley, Angela. 1969. *Captain Nemo and the Underwater City*. Motion picture soundtrack
Parliament. 1978. "Aqua Boogie (A Psychoalphadiscobetabioaquadoloop)," single. Casablanca.
Ravel, Maurice. 1901. "Jeux d'eau," M. 30.
———. 1908. "Ondine" (*Gaspard de la Nuit*, M. 55, no.1).
Ritchie, Anthony. 1993. *Underwater Music*.
Russolo, Luigi. 1913. "Gorgogliatore." On *Musica Futurista: The Art of Noises 1909-1935*. LTM, 2004.
Saint-Saëns, Camille. 1886. "Aquarium" (*Le Carnaval des Animaux*, no. 7).
Satie, Erik. 1913. *Embryons desséchés*.
Schafer, R. Murray. 1971. *Miniwanka—Moments of Water*.
———. 1978. String Quartet no. 2, *Waves*.
Schoenburg, Arnold. 1909. "Farben" (Five Pieces for Orchestra, op. 16, no. 3).
Sibelius, Jean. 1914. *The Oceanides*, op. 73.
Slotek. 1999. *Hydrophonic*. WordSound.
Smith, Paul J. 1954. *20,000 Leagues under the Sea*. Motion picture soundtrack.
Takemitsu, Toru. 1987. *I Hear the Water Dreaming*.
Ussachevsky, Vladimir. 1951. "Underwater Waltz."
Vaughan Williams, Ralph. 1903–1908. "A Sea Symphony" (Symphony no.1).
Waterjuice. 2001. *Hydrophonic*. Vaporvent.
Xela. 2009. *The Dead Sea*. Type Records.
Yo La Tengo. 2002. *The Sounds of the Sounds of Science*. Egon Records.
Ziporyn, Evan, with I Wayan Wija. 2003. "Ocean." On *Shadowbang*. Cantaloupe Records.

Invoking

Brecht, George. 1959. "Drip Music."
Cage, John. 1952. *Water Music.*
———, and Lou Harrison. 1941. "Double Music."
Cowell, Henry. 1934. *Ostinato Pianissimo*.
DJ Spooky. 2009. *Sinfonia Antarctica.* www.djspooky.com/art/terra_nova.php.
Feld, Steven. 2006. *Suikinkutsu: A Japanese Underground Water Zither*. VoxLox, Earth Ear.
Feld, Steven, ed. 1991. "Relaxing by the Creek." On *Voices of the Rainforest: A Day in the Life of the Kaluli People*. Rykodisc.
Le Caine, Hugh. 1955. "Dripsody: An Etude for Variable Speed Recorder."
Lockwood, Annea. 1989. *A Sound Map of the Hudson River*. Lovely Music, Ltd.
Ono, Yoko. 1963. "Water Piece."
———. 1971. "Toilet Piece."
Satie, Erik. 1917. "Prestidigitateur Chinois" (*Parade* [*Ballet Réaliste sur un Thème de Jean Cocteau*], no. 2).
Spandau Ballet. 1982. "Innocence and Science." On *Diamond*. Chrysalis.

Soaking

Blackburn, Philip. 2007. Symphony in Sea. http://www.philipblackburn.com/Compositions.html.
Dunn, David. 1992. "Chaos and the Emergent Mind of the Pond." On *Angels and Insects*. Nonsequitur/What Next Recordings.
Harris, Yolande. 2009. *Now Stripe Time.* DNK Amsterdam: A Concert Series for New Live Electronic and Acoustic Music, September 14. http://www.yolandeharris.net/.
Humid, Bob. 2006. "It's Warm Besides [sic] the Submarine Cables." On Second Wind Phenomenon. Suburban Trash.
Polli, Andrea. 2009. *Sonic Antarctica*. Gruenrekorder.
Redolfi, Michel. 1989. *Sonic Waters #2 (Underwater Music) 1983–1989*. Hat Hut Records.
Sauvage, Tomoko. 2009. *Ombrophilia*. Either/OAR.
Snapper, Juliana. 2008–2010. *Five Fathoms Opera Project*. www.julianasnapper.org.
Stankievech, Charles. 2009. *The DEW Project,* Dawson City, Yukon Territory: www.stankievech.net/projects/DEW/stream/index.html.
Winderen, Jana. 2009a. *Heated: Live in Japan*. Touch Music.
———. 2009b. *The Noisiest Guys on the Planet*. Ash International. Cassette only.
———. 2009c. *Submerged*. Touch Music.

REFERENCES

Allan, Jennifer. "Wet Sounds." *Wire* 307 (2009): 77.
Blanning, Lisa. "Wet Sounds." *Wire* 296 (2008): 81.
Blesser, Barry, and Linda-Ruth Salter. *Spaces Speak, Are You Listening?: Experiencing Aural Architecture.* Cambridge, Mass.: MIT Press, 2007.
Blondin, Darren. "Recording Underwater Ambiences." www.dblondin.com/101507.html, 2007.
Bogdanov, Vladimir. *All Music Guide: The Definitive Guide to Popular Music*, 4th ed. Ann Arbor, Mich.: Backbeat, 2001.

Charles, Daniel. "Singing Waves: Notes on Michel Redolfi's Underwater Music." *Contemporary Music Review* 8(1) (1993): 57–69.

Chen, Karen. Water Reflection upon Four Piano Works—Liszt, Debussy, Ravel, and Griffes. Diss. in Musical Arts, Claremont Graduate University, 2008.

Colladon, Jean-Daniel. "Experiments on the Velocity of Sound in Water." In *Acoustics: Historical and Philosophical Development*, ed. and trans. R. Bruce Lindsay, 194–201. Stroudsburg, Penn.: Dowden, Hutchinson, and Ross, 1973. Orig. pub. in *Souvenirs et Mémoires: Autobiographie de Jean-Daniel Colladon* (Geneva: Aubert-Schuchardt, 1893).

Cousteau, Jacques, with Frédéric Dumas. *The Silent World.* New York: Harper and Brothers, 1953.

Crone, Timothy J., William S. D. Wilcock, Andrew H. Barclay, and Jeffrey D. Parsons. The Sound Generated by Mid-Ocean Ridge Black Smoker Hydrothermal Vents. *PLoS* ONE 1(1) (2006). www.plosone.org/article/fetchArticle.action?articleURI=info:doi/10.1371/journal.pone.0000133 (accessed May 20, 2007).

Doyle, Peter. Echo and Reverb: Fabricating Space in Popular Music Recording, 1900–1960. Middletown, Conn.: Wesleyan University Press, 2005.

Hamilton-Paterson, James. *The Great Deep: The Sea and Its Thresholds.* New York: Random, 1992.

Harris, Daniel. "Underwater Music Engineering." www.danielharrismusic.com/Underwater_Music_I.html.

Hauksbee, Francis. "An Account of an Experiment Touching the Propagation of Sound through Water." *Philosophical Transactions* 26 (1708): 371–72.

Helmreich, Stefan. "An Anthropologist under Water: Immersive Soundscapes, Submarine Cyborgs, and Transductive Ethnography." *American Ethnologist* 34(4) (2007): 621–41.

"Submarine Sound." *Wire* 302 (2009): 30–31.

Henriques, Julian. "Sonic Dominance and the Reggae Sound System Session." In *The Auditory Culture Reader*, ed. Michael Bull and Les Back, 451–80. Oxford: Berg, 2003.

Hines, Thomas S. "Then Not Yet 'Cage': The Los Angeles Years, 1912–1938." In *John Cage: Composed in America*, ed. Marjorie Perloff and Charles Junkerman, 65–99. University of Chicago Press, 1994.

Höhler, Sabine. "Depth Records and Ocean Volumes: Ocean Profiling by Sounding Technology, 1850–1930." *History and Technology* 18(2) (2002):119–54.

Ingram, David. " 'A Balance That You Can Hear': Deep Ecology, 'Serious Listening,' and the Soundscape Recordings of David Dunn." *European Journal of American Culture* 25(2) (2006): 123–38.

Iselin, Columbus O'D., and Maurice Ewing. *Sound Transmission in Sea Water: A Preliminary Report.* Woods Hole, Mass.: Woods Hole Oceanographic Institution for the National Defense Research Committee, 1941.

James, Christine. "Sonar Technology and Shifts in Environmental Ethics." *Essays in Philosophy: A Biannual Journal* 6(1) (2005). commons.pacificu.edu/cgi/viewcontent.cgi?article=1172&context=eip.

Jenny, Hans. *Cymatics: A Study of Wave Phenomena and Vibration.* Newmarket, N.H.: MACROmedia, 2001. Orig. pub. 1967 and 1974.

Kaharl, Victoria A. *Water Baby: The Story of Alvin.* New York: Oxford University Press, 1989.

Kahn, Douglas. *Noise Water Meat: A History of Sound in the Arts.* Cambridge, Mass.: MIT Press, 1999.

Kilworth, Garry. "White Noise." *Year's Best Fantasy and Horror,* vol. 3, ed. Ellen Datlow, 508–16. New York: St Martin's, 1990.

Kindermann, Lars, Olaf Boebel, Horst Bornemann, Elke Burkhardt, Holger Klinck, Ilse van Opzeeland, Joachim Plötz, and Anna-Maria Seibert. A Perennial Acoustic Observatory in the Antarctic Ocean. Paper presented at the International Expert Meeting on IT-Based Detection of Bioacoustical Patterns. December 7–10, 2007, International Academy for Nature Conservation (INA), Isle off Vilm, Germany, 2007, http://hdl.handle.net/10013/epic.28799.

Knight, David B. *Landscapes in Music: Space, Place, and Time in the World's Great Music.* Lanham, Md.: Rowman and Littlefield, 2006.

Knorr-Cetina, Karin. *Epistemic Cultures: How the Sciences Make Knowledge.* Harvard: Harvard University Press, 1999.

Kohler, Robert E. *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology.* Chicago: University of Chicago Press, 2002.

Kouvaras, Linda. "Toilets, Tears, and Transcendence: The Postmodern (Dis-)Placement of, and in,Two Water-Based Examples of Australian Sound Art." *Transforming Cultures eJournal* 4(1) (2009): 94–107. epress.lib.uts.edu.au/ojs/index.php/TfC/article/download/1062/1201

Labelle, Brandon. *Background Noise: Perspectives on Sound Art.* New York: Continuum, 2006.

Latour, Bruno, and Steve Woolgar. *Laboratory Life: The Construction of Scientific Facts,* 2nd ed. Princeton, N.J.: Princeton University Press, 1986.

Lauterwasser, Alexander. *Water Sound Images.* Newmarket, N.H.: MACROmedia, 2006.

Licht, Alan. *Sound Art: Beyond Music, between Categories.* New York: Rizzoli, 2007.

Long, James M. " 'Absolute' Calm Two Miles Down." *San Diego Evening Tribune* (October 1, 1953).

Madsen, Virginia. "The Call of the Wild." In *Uncertain Ground: Essays between Art and Nature*, ed. Martin Thomas, 29–43. Art Gallery of NSW, Sydney, 1999.

Miller, Simon. *Visible Deeds of Music: Art and Music from Wagner to Cage.* New Haven, Conn.: Yale University Press, 2002.

Mody, Cyrus C. M. "The Sounds of Science: Listening to Laboratory Practice." *Science, Technology, and Human Values* 30 (2005): 175–98.

Motschmann, U., K. Sauer, and K. Baumgaertel. "Whistler Wave Amplitude Oscillation and Frequency Modulation in the Magnetospheric Cavity." *Astrophysics and Space Science* 105(2) (1984): 373–77.

Munk, Walter, Peter Worcester, and Carl Wunsch. *Ocean Acoustic Tomography.* New York: Cambridge University Press, 1995.

Pinch, Trevor, and Karin Bijsterveld. "Sound Studies: New Technologies and Music." *Social Studies of Science* 34(5) (2004): 635–48.

Priore, Dominic. *Smile: The Story of Brian Wilson's Lost Masterpiece.* Bobcat Books, 2007.

Raffles, Hugh. *The Illustrated Insectopedia.* New York: Pantheon, 2010.

Rodgers, Tara. "Toward a Feminist Epistemology of Sound: Refiguring Waves in Audio-Technological Discourses." Invited plenary lecture. Luce Irigaray Circle, State University of New York at Stony Brook, Manhattan, September 12, 2009.

Roosth, Sophia. "Screaming Yeast: Sonocytology, Cytoplasmic Milieus, and Cellular Subjectivities." *Critical Inquiry* 35(2) (2009): 332–50.

Schlee, Susan. 1973. *The Edge of an Unfamiliar World: A History of Oceanography.* New York: Dutton.

Schwartz, Hillel. *Making Noise: From Babel to the Big Bang & Beyond.* Zone, forthcoming.

Shaheen, Jack G. "The Documentary of Art: 'The Undersea World of Jacques Cousteau.' " *Journal of Popular Culture* 21(1) (1987): 93–101.

Shapin, Steven. "The House of Experiment in Seventeenth-Century England." In *The Science Studies Reader*, ed. Mario Biagioli, 479–504. New York: Routledge, 1999.

Shick, Malcolm. "Siren Song." *Chamber Musings: Newsletter of the Chamber Music Society of the Maine Center for the Arts* 4(2) (2007): 1, 3–4.

Stachowski, Richie. "Device for Talking Under Water." U.S. Patent #5877460, March 2, 1999.

Stocker, Michael. "Ocean Bio-Acoustics and Noise Pollution: Fish, Mollusks, and Other Sea Animals' Use of Sound, and the Impact of Anthropogenic Noise on the Marine Acoustic Environment." *Soundscape: Journal of Acoustic Ecology* 3(2)/4(1) (2002/2003): 16–29.

Toop, David. *Ocean of Sound: Aether Talk, Ambient Sound, and Imaginary Worlds.* London: Serpent's Tail, 1995.

Urick, Robert J. *Principles of Underwater Sound,* 3rd ed. New York: McGraw-Hill, 1983.

Williams, Ben. "Black Secret Technology: Detroit Techno and the Information Age." In *Technicolor: Race, Technology, and Everyday Life*, ed. Alondra Nelson and Thuy Linh N. Tu with Alicia Headlam Hines, 154–76. New York: NYU Press, 2001.