Military Cetology

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Abstract Throughout the Cold War, the US Navy aggressively explored the sound-making and sound-detecting capacities of cetaceans to help it retain its supremacy in marine battle space. Whales, dolphins, and porpoises were engaged as animals that "see with sound," that produce sophisticated echolocation "clicks," and that harness the ocean's complex acoustic waveguide to detect signals thousands of miles away. Other scholars have touched on the navy's legacy in cetology (whale science), but none have made it their object of study. Our article places this relationship at the center of burgeoning engagements among media studies, sound studies, and marine spatial theory. We focus on the Cold War period, when new interests in submarine warfare facilitated the growth of naval interests in cetology. We understand the dynamic outcomes of these interests in terms of acoustemology—Steven Feld's concept for a theory of what can be known and experienced through situated sonic encounter. At stake in this account is not only the question of cetology's power-laden ways of engaging cetaceans but the role of sound in shifting conceptions of the ocean itself.

Keywords whales, sound, ocean, acoustemology, environmental history

Introduction

Since the early 1990s, the beached bodies of whales and dolphins have generated a trail of controversy around the US Navy's use of high-intensity sonar.[1] Autopsies on the animals revealed hemorrhaging in the brain, inner ears, and "acoustic" fats. Growing evidence of sonar's violent effects would lead environmentalists to call for a shuttering of navy projects. The ensuing lawsuits between the navy and the National Resources Defense Council (NRDC) suggest institutional tensions in increasingly ensonified ocean space.[2] It is easy to suppose that the navy simply sees the ocean as one thing, and conservation-oriented cetology sees it as another. But such a distinction would

1. See Jasny, *Sounding the Depths*.
2. Horwitz, *War of the Whales*.

Environmental Humanities 8:2 (November 2016)
DOI 10.1215/22011919-3664220

obscure the deep entanglement of these fields. The navy, the very producers of deafening cetacean sounds, made possible much of the knowledge cetologists claim about whales today—about their environments, their sensory capacities, even their emotional states. If the navy bears the distinction of inspiring the environmentalist rallying cry "A deaf whale is a dead whale," the navy is also the locus for the postulate that cetaceans are animals worthy of sonic study in the first place.

This article explores cetology's debt to naval bioacoustics. We show how the history of underwater listening reveals a coproduction of military strategy and animal science. Unifying these fields is a sustained interest in the tantalizing acoustic capacities of cetaceans, "acoustic animals" with sensing capacities well adapted for complex ocean environments. The military's now decades-long engagement with cetology is wide ranging but persistently orients around a central contention: "What these animals can do has a definite bearing on our national defense."[3] The rapid growth of cetology in the United States since the Cold War owes much to the navy's financial and logistical support. Today, cetology remains locked in a complex embrace with the navy. It is both committed to the continuance of military approaches to acoustic animals and simultaneously seeking to overcome the blind spots of an agenda that has rarely questioned the biological impacts of its own acoustics programs.

While other scholars have touched upon cetology's naval inheritance, few have explored it in detail.[4] Our effort presents it as an engagement among media studies, sound studies, and marine spatial thought.[5] We consider how naval bioacoustics shaped cetology's acoustic conceptions, including the spaces, soundings, practices, and listenings that define the discipline. Our goal is to identify the fundamental links between naval bioacoustic and cetological ways of hearing and hence knowing these animals.[6] To realize this effort, we employ "acoustemology"—Steven Feld's concept for a theory of what can be known and experienced through sound.[7] Acoustemology helps us understand how cetology emerged from the Cold War as a resolutely "environmental" science, actively engaged with the sounding conditions of its study contexts. It also sheds light on why cetology became an "environmentalist" science, defined by growing popular interest in sophisticated and "musical" cetaceans. Ultimately, this latter development—foregrounded in the third part of our article—would foment cetology's conflicted relationship with the navy today. Listening to the disciplinary history of cetology becomes a means of reflecting on the evolving nature of disciplinarity itself.

3. Kellogg, *Porpoises and Sonar*, 152.

4. But see Bryld and Lykke, *Cosmodolphins*; and Burnett, *Sounding of the Whale*.

5. See Shiga, "Sonar and the Channelization of the Ocean"; Nicole Starosielski, *Undersea Network*; and Peters, *Marvelous Clouds*. For marine spatial thought, see, especially, new work in human geography: Steinberg, "Deepwater Horizon"; and Gluck, "Piracy and the Production of Security Space."

6. Oreskes, "Context of Motivation."

7. Feld, "Waterfalls of Song"; Feld, "Rainforest Acoustemology," 226.

We hope to add to recent scholarship interrogating the dramatic expansion of the earth sciences during the Cold War. There is an abundance of work at the intersection of naval policy and oceanography, and our stories of Cold War cetology reveal new moments within this ambit.[8] Scholars have observed the sense of scale and urgency with which the navy sought to understand currents, seaquakes, and various other features of the ocean environment.[9] Much of what became known about the sonic capacities of cetaceans was, like these efforts, tethered to aspirations to master subsurface space for the purposes of submarine movement. Support for our claims comes from various textual sources and also from anecdotal remarks drawn from twenty-five interviews conducted with cetologists in Canada and the United States. At stake in our account, then, is not only a set of power-laden ways of engaging marine mammals during the Cold War but a contribution to understanding the momentous shift that took place in scientific conceptions of the ocean itself—"from the ocean as deep, dark, vast, and . . . not terribly important . . . to the ocean as a vast abode of life, both familiar and strange, and a place on which all life, both marine and terrestrial, depends."[10]

The Cold War engagement we trace here continues to inform the present claims of cetology. But the military's presence in the history of cetology is not as overdetermining as some theoretical approaches would have us believe—those extended by Friedrich Kittler and Paul Virilio, for instance.[11] As Melody Jue suggests, the ocean medium "changes the conditions of knowledge production."[12] Committed though they might be to military goals, US Navy scientists were often stymied by the challenges of their research environment. What later cetologists celebrated as "whale song," naval listeners noted as "communications as yet indecipherable."[13] Improvements in tools to detect ocean signals often produced new forms of incomprehension. In grateful acknowledgment of Donna Haraway's work on primatology, our findings reveal power and influence but also contingency and possibility in cetology's evolving forms of animal encounter.[14]

Military Cetology in Context

For much of its history, cetology revolved around the possibilities of carcass analysis. Whale research frequently took place on factory ships where whale bodies were dumped and disassembled for industrial purposes.[15] This situation changed during the Second World War, when the military organization and funding of science rose to

8. Edwards, *Vast Machine*; Doel and Harper, "Prometheus Unleashed"; Hamblin, *Oceanographers and the Cold War*.

9. Hamblin, *Arming Mother Nature*, 6.

10. Oreskes, "Scaling Up Our Vision," 384.

11. Kittler, *Gramophone, Film, Typewriter*; Virilio, *War and Cinema*; Virilio, *Speed and Politics*.

12. Jue, "Vampire Squid Media," 85.

13. Schwartz, *Making Noise*.

14. Haraway, *Primate Visions*.

15. Burnett, *Sounding of the Whale*.

unprecedented levels.[16] As would be the case for many life sciences—including primatology and entomology—the Second World War provided a crucial impetus for new funding opportunities.[17] As Harvey M. Sapolsky explains, "It was the conflict in which the world discovered that effective military action was significantly dependent on scientific and technological advances."[18] The US government began to earmark billions of dollars for the development of underwater weapons systems while also spending lavishly on projects with long-term applicability. The navy's Office of Naval Research (ONR), already an "advanced" military sector in the eyes of the US government, became a prized recipient of new funding windfalls. It also became a key support for cetology during a time in which civilian-funding agencies experienced no comparable growth.

Since the Second World War, acoustics has played a central role in cetology's evolution. Why is this? "It comes down to what you can measure and record," one cetologist interviewed posits. "Acoustics is probably the simplest and most consistent thing that can be done."[19] While this appears to be true, there were institutional reasons for the sound emphasis too. One of the greatest threats to US domination of the oceans during this period was the submarine. One of the few reliable means of identifying and targeting these threats was through sound. Acoustics research proved useful for submarine detection even though much about the ocean's sound propagation characteristics remained a mystery.[20] Seawater's propensity to enhance sound conductivity (five times the speed of airborne emissions) and filter out light suggested that acoustics contained fundamental tactical advantages. "We cannot really foresee all the possible uses of sound at sea which depend on transmission," one 1950 US Navy report offered.[21] Forays into acoustics emerged during an anxious historical moment in which the tremendous unknowns of the enemy apparatus demanded scientific improvements of all kinds. Captivated by insights about cetaceans' sound-producing capacities, the navy elaborated a comprehensive program of military cetology over the ensuing decades.

As the Second World War morphed into the Cold War, underwater acoustics research grew in stature. The US Navy supported new institutes capable of analyzing underwater sound, such as Harvard's Psycho-Acoustic Laboratory (established in 1940 but expanded in the 1960s) and Stanford's Bio-Sonar Lab (established in 1963). Bioacoustics became central to efforts to organize the ocean's sound field as a kind of transmission circuit composed of acoustic pathways, barriers, and noise sources. These developments would tighten associations between cetology and acoustics. Sonar operators, oceanographers, and cetologists collaborated on efforts to isolate and classify cetacean sound sources. The vast majority of these efforts were accountable to their navy

16. For an overview, see Mirowski, *Science Mart*.
17. Haraway, *Primate Visions*.
18. Sapolsky, *Science and the Navy*.
19. Andrew Trites, in discussion with the coauthor, May 6, 2013.
20. Urick and Hoover, "Backscattering of Sound from the Sea Surface."
21. Lindsay, *Survey Report of Basic Problems*.

patrons and little else. The studies were typically peer-reviewed by experts in acoustics and not by marine mammal biologists at universities.[22] In the navy's secretive uptake of cetology, the lines between operational data and basic research are frequently impossible to identify.

We suggest that acoustemology presents a powerful analytic for understanding the filiations between military strategy, instrumentality, and animal study. For Feld, an acoustemology is a lived theory of the cognitive potentials of sound. "By acoustemology," he writes, "I wish to suggest a union of acoustics and epistemology, and to investigate the primacy of sound as a modality of knowing and being in the world."[23] Acoustemologies can entail various practices, from everyday forms of listening as orientation to formalized sensory regimes. In this study, acoustemology becomes a means of attending to the world-making practices of researchers whose engagements with cetaceans have crossed distance, medium, and technology and who have consistently sought to overcome the vast challenges of cetacean study through acts of listening.

A great virtue of acoustemology is its emphasis on the conditions of sound production and reception. Acoustemology directs attention to the transformation of ideas through context—to vibrations propagating through seawater, rebounding through hydrophones to create embodied experiences in laboratory-based listeners, and then serving in turn to inspire new marine spatial practices. In this article, we show how the headphones and hydrophone preamps of underwater acoustics, the ocean's currents, and the dense materiality of seawater all shaped the claims cetologists advanced. At the same time, acoustemology insists that an embodied listening subject is always required for the elaboration of new sonic knowledge. There is always "fleshy emplacement."[24] Naval researchers were not swimmers but rather headphone-wearing subjects striving to make sense of the ocean environment from shore-based (or boat-based) listening stations.

Acoustemology reveals that media technologies depend upon "a range of matter . . . harnessed, manipulated, and exchanged in the service of human communication."[25] As Nicole Starosielski and Janet Walker note, a "media materialism" must be about more than "the mere physicality of media infrastructures, technologies, or objects."[26] It must also be mindful of the interplays between perceptual labors, institutional logics, and a communication system's material substrates (water, air, light, etc.).[27] While suggesting acoustemology as a useful concept for this line of thinking, we also hope to push the idea in another direction. Understood as acoustemology, cetology becomes a richly interspecies engagement. It reveals humans, hydrophones,

22. See Oreskes, "Scaling Up Our Vision."

23. Feld, "Anthropologies of Sound," 226. See also Feld, "Waterfalls of Sound," 91.

24. We thank an anonymous reviewer for this concept.

25. Starosielski and Walker, introduction to *Sustainable Media*, 12.

26. Ibid., 12.

27. Ibid., 13.

cetaceans, and sonic theories as components of contingent media *complexes*. These complexes have resulted in shifting "conditions of possibility" that afford a broad spectrum of cetacean sonic experience.[28] While whale sound was a basis for powerfully divergent ways of perceiving marine space, cetology was in many respects responsible for the "inappropriate contiguities" that emerged across different social narratives in the 1970s—such as between military and environmentalist cultures.[29]

By converting waterborne sound into electrical signals, hydrophones are vital components of the stories we collect here. Their incorporation into cetological practice massively expanded the spatial range of animal study along with the questions cetologists would ask. From hydrophonic listening came the realization that cetaceans "see with sound"[30] and navigate ocean space through species-specific forms of sounding and listening. "Use of the hydrophone array made us aware of a variety of behaviours we had been unable to observe before," ONR-funded scientist William A. Watkins confirmed.[31] By facilitating new listening practices, naval researchers redefined their study subjects—for example, porpoises, bottlenose dolphins, and killer whales. Animal behaviors were refigured in terms of functionality and efficacy. Killer whale species perceive "targeted" objects[32] and send "target signals."[33] Baleen whales labor with "energy budgets"[34] and use "optimal" calling frequencies.[35] Certain species experience forms of communication-induced stress, much as a noise-addled radio operator might.[36] US naval research even advanced claims about interspecies "vocal-acoustic interlock" or communication.[37]

The wealth and range of research defining military cetology's postwar period cannot be reduced to singular directives. And yet underlying consistencies do appear. As with the primatology studied by Haraway, a "loving attention to strategic possibilities and the cost-benefit analysis of everything" characterizes various aspects of naval cetacean research.[38] In the following sections, we analyze this research in terms of three sonic tropes. These tropes, which comprise the fundaments of cetology's acoustemology, can be summarized in the following terms: noise and signals, pings and echoes, and passive acoustic monitoring (PAM). What unites these concepts is a contribution to the idea that the acoustic lives of whales can be abstracted, mechanized, and to some extent automated in the submarine warfare apparatus.

28. Ibid., 4–5.
29. Bryld and Lykke, *Cosmodolphins*, 14.
30. Kellogg, *Porpoises and Sonar*, viii.
31. Watkins, "Acoustic Behavior of Sperm Whales," 57.
32. Schevill, "Underwater Sounds of Cetaceans," 307.
33. Tavolga, *Review of Marine Bio-Acoustics*, 9.
34. Lockyer, "Growth and Energy Budgets of Large Baleen Whales," 379.
35. Payne, Tyack, and Payne, "Progressive Changes in the Song of Humpback Whales," 191.
36. See Dalheim, "Bioacoustics of the Gray Whale."
37. Lilly, Miller, and Truby, "Reprogramming of the Sonic Output of the Dolphin," 1412.
38. Haraway, *Primate Visions*, 127.

From Noise: Interference and Cetology

As Naomi Oreskes observes, "the stuff of science itself—the materials of the natural world that natural science aims to understand—in many ways continues to elude us."[39] In this section, we suggest that early naval encounters with underwater noise encouraged the navy's interests in cetology. Bringing noise into an acoustemological register also offers a means of responding to Oreskes's concern. It draws our attention to the US Navy's recursive responding to a constant feature of the marine environment. The most common refrain in the early accounts of naval acousticians was the pronouncement of "noise" as the experiential result of ocean listening. What noise meant to US Navy researchers during the Second World War tells us a lot about why future cetological worlds emerged as they did. We can start by noting the persistent concern with "degraded" or "impure" signals that characterized the early listening accounts.

For the US Navy, listening to the precise features of a submarine—gears and blowers, shaft and blade speeds, engine explosion rates, and cavitation speeds—could reveal "signature" information about particular enemy activities. Nonsubmarine sounds interfered by creating what was repeatedly observed as "clutter."[40] This clutter was noise insofar as it interfered with the sonar operator's ability to analyze a sound's properties and localize its source. The ensuing danger of arriving at false positives (e.g., inaccurate identifications) was enormous, because false positives compromised the advanced detection of enemy attacks.[41] The high value listeners placed on sound fidelity, articulated consistently in discussions of noise, thus expressed a desire to "capture the world" for tactical intervention.[42] New techniques of visualizing noise greatly aided these efforts. Future cetologists would follow naval scientists in relying on such "sonograms" or "spectrograms"—graphic displays of sonic information—to reveal details about the frequency and intensity structure of whale sounds.[43]

Noise became an important spur for new naval research, but the problems it posed persisted. According to underwater acoustics theory, the speed and range of underwater sound transmissions could be harnessed to spatially extend human auditory perception. But in practice, the many sources of sound in the ocean environment, combined with mediating effects of the ocean floor and surface and the temperature, turbulence, and other variables of the water itself, meant that seemingly random sounds (noise) tended to predominate over patterned ones (signals). Thus, in addition to inventorying the sounds of the sea, naval bioacousticians endeavored to manage noise by rendering noise itself as something predictable and calculable. By parsing different noises in terms of "wave equations," noise became signal. As signal, it conveyed the

39. Oreskes, "Scaling Up Our Vision," 380.

40. See Urick and Hoover, "Backscattering of Sound"; Wenz, "Acoustic Ambient Noise in the Ocean."

41. Tavolga, *Review of Marine Bio-Acoustics*.

42. Sterne, *Audible Past*, 218.

43. Donald Borror, "Analysis of Animal Sounds."

fact that high-frequency sounds rapidly attenuated (decayed) in seawater, whereas low-frequency sounds (less than 500 Hz) experienced little attenuation and could be detected thousands of kilometers away.[44] The constantly shifting designation of noise thus describes shifts in acoustemology. Across different Cold War accounts, noise is variously apprehended as a "distraction," a "disturbance," and many other things as well.[45]

These efforts outlined a key acoustemological theme in naval sensing—the signal/noise dualism. As a 1953 US Navy sonar manual describes, "The sound-listening problem for the operator consists primarily of learning to distinguish *between sounds emitted by another ship's machinery through the hull and from the propeller, and the multitude of other sounds* that exist in the ocean."[46] Such manuals used binary logics to distinguish what should be heard (signals) and, equally important, what should be ignored (noise)—aka the "false acoustic targets in the sea."[47] Particularly relevant for our purposes is the fact that cetacean sounds were initially subsumed amid the range of phenomena in the ocean's cluttered totality.[48] While not all noise was "biological," all biological sounds were noise insofar as they impeded the detection and identification of mechanically generated sounds. Biological noises persistently challenged US Navy classification schemes. "It is often difficult to know which animal is responsible for which sound," William Schevill and Barbara Lawrence noted, "especially in the case of the larger and more active ones."[49] For instance, research on the white porpoise, whose "loquaciousness" was comparable to "such chatterboxes as monkeys and men," was frequently interrupted by the noise of fish "biting and pulling at the hydrophone."[50]

In the early period of the Cold War, "biologics" were curiosities at best, fatal diversions at worst. The US Navy was concerned that fatigue and other human factors hampered the continuous monitoring of sonar transmissions. Techniques for improving auditory detection were repeatedly explored and included binaural over monaural listening, "coincident visual stimulation," and the cultivation of sustained listening practices.[51] Eventually, new listening practices emerged alongside the development of more sensitive hydrophones as well as visual bearing and range finders to better plot incoming signals. These new affordances help to turn "biological noise" into another thing entirely. It was only after repeated exposure to cetacean sounds that naval scientists

44. Carey and Evans, *Ocean Ambient Noise*, 58. See also Sontag and Drew, *Blind Man's Bluff*. According to Sontag and Drew, visual records of signals picked up by US Navy hydrophone arrays were key to the search for nuclear submarines that vanished during the Cold War.

45. See Urick, *Principles of Underwater Sound for Engineers*; and Payne and McVay, "Songs of Humpback Whales."

46. Bureau of Naval Personnel, *Naval Sonar*, 58 (emphasis added).

47. *Ocean Science Program of the US Navy*, 40.

48. Wenz, "Acoustical Ambient Noise."

49. Schevill and Lawrence, "Phonograph Record of Underwater Calls," para. 2.

50. Schevill and Lawrence, "Underwater Listening," 144.

51. Shaw, Newman, and Hirsh, "Difference between Monaural and Binaural Thresholds," 734; Wyatt, "Improvability of Pitch Discrimination."

began to realize their potential value. The directive to ignore biological noise was gradually displaced by the directive to describe the variety of sounds listeners detected—from "clicks or clacks, croaks, grunts, rattles, or thumps" (deciphered as fish and crustacea)[52] to "whistles, squeals, chirps, clicks, rasps" (deciphered as whales and other marine mammals).[53] Expanding interest in biological noise required new organizational schemes. The long-range detection of cetacean signals was a promising advance, but "long-range detection is not worth a damn unless you have classification," as one navy captain noted.[54] Accordingly, researchers began to measure cetacean sounds in terms of amplitude, frequency, and phase fluctuations—importing processing techniques from airborne acoustics to do so. All of this shifted the priorities of US naval researchers. To properly attend to cetacean sounds, US naval researchers were given instructional LPs—such as Remington Kellogg's *Sounds of Sea Animals* (1955) and Schevill and Watkins's *Whale and Porpoise Voices* (1962).[55] Early researchers became especially expert at partitioning killer whale sounds into distinct subsets ("clicks," "shrieks," and "screams").[56]

Through its acoustemological efforts, the US Navy slowly generated a new understanding of ocean space. By combining Newtonian wave equations with new understandings of underwater space, the ocean could be attended to in terms of horizontal "stacks" defined by the distinct sound-propagation pathways they inscribed. John Shiga has called this process the "channelization of the ocean" and notes how naval uptakes of channel metaphors (e.g., canals, transmission lines) revealed abiding interests in information processing in complex local environmental conditions.[57] Channels were spatial-acoustic achievements that presented different experiences of noise and signal (e.g., biological noise into killer whale signal). As their summation, the ocean was thus a composite acoustic experience "rich in frequency diversity, temporal variability, and directionality."[58]

The US Navy's engagements with biological noise were a key site for cetology's production of measurable cetacean signals. The navy understood noise as an informational problem, not a biophysical threat. But cetology came to understand noise in both senses. Cetaceans, first studied by navy listeners *through* sound, became reflexively engaged as animals susceptible to *too much* sound (e.g., in terms of received intensity). Now w*hales*—not submarine operators—could lose the ability to decode "information" in a "noisy" environment.[59] Cetology performs an inversion of naval acoustemology,

52. Kellogg, *Porpoises and Sonar*, 34.
53. Sebeok, "Review of Communication," 461.
54. Quoted in Hamblin, "The Navy's 'Sophisticated' Pursuit of Science," 10.
55. Burnett, *Sounding of the Whale*, 539.
56. Schevill and Watkins, *Whale and Porpoise Voices*.
57. Shiga, "Sonar and the Channelization of the Ocean."
58. Farmer, "Acoustical Studies of the Upper Boundary Ocean Layer," 315.
59. Clark et al., "Acoustic Masking in Marine Ecosystems," 201.

seizing the military interest in converting noise into signal to assert the centrality of whale sound. Yet when cetologists began to speculate about "interference"—something the military was also calling "spectrum crowding"—they likewise invoked the navy's "channelized" ocean.[60] Senders and receivers of whale sound (i.e., whales) were likewise identified in terms of channels and frequencies. Thus, when cetology came to treat the shrieks and screams of whales (noise) as valuable information, it shifted the definition of what noise was but not the underlying logic noise adhered to. Like navy researchers, cetology regards whale sounds and ship sounds as shifting components of a signal-to-noise relationship encountered in efforts to track desired targets.

Locative "Pinging" and Naval Weaponry

In W. N. Kellogg's studies on sonar, splashing water sounds are observed to trigger a porpoise's search mechanisms.[61] In Kenneth Norris's work with blindfolded dolphins, cetaceans "seek out" underwater items in a marine pen.[62] Burgeoning associations between cetacean sounds and target acquisition capacity probably encouraged more navy interest in cetology than any other aspect. Much of this work was inspired by the detectable presence of cetacean clicks in the ocean. For navy researchers, the proposition that animal clicks indexed the operation of powerful biological sensing equipment led to a range of communication-centered experiments.[63] From John Lilly's "dolphin telephone" to Dwight Batteau and Peter Markey's "Man to Dolphin Translator" to William Evans's "sonar projector" (implanted in the body of a dead baby dolphin and used to substantiate evidence that dolphins could direct or "beam" their echolocation transmissions), the range of efforts to rationalize cetacean clicks is considerable.[64]

To understand these clicks as acoustemology, we must connect the experience of short, percussive, refracting sounds (clicks) to the objectives of naval researchers. Listening to cetacean clicks, researchers were enticed by an apparent "directional character," by the manner in which clicks could propagate as "beams" that revealed "focus" and "aim."[65] One study found that "short pulse length and high (ultrasonic) frequency" produced "the finest resolution and identification of targets."[66] Another pointed to the value of "long range" clicks, wherein lower-frequency clicks afforded the longer-distance travel of signals through seawater. Naval cetacean research came to grasp clicks in terms of species-specific "detection thresholds"—for example, hearing sensitivities or ability to discriminate between sounds varying in frequency.[67] Examples

60. Committee on Underwater Telecommunication, *Present and Future Civil Uses of Underwater Sound*, 4.

61. Kellogg, *Porpoises and Sonar*, 154.

62. Norris et al., "Experimental Demonstration."

63. Burnett, *Sounding of the Whale*, 548; Dreher and Evans, "Cetacean Communication"; Evans, "Vocalization among Marine Mammals."

64. Burnett, *Sounding of the Whale*, 549–50.

65. Tavolga, *Review of Marine Bio-Acoustics*.

66. Tavolga, "Listening Backward," 12.

67. Hall and Johnson, "Auditory Thresholds of a Killer Whale," 515.

of echolocation in action, percussive click patterns were not only recorded but reconceptualized as events that could be modeled or reproduced in engineering systems.

By listening to clicks, Kellogg learned that "porpoises are able to differentiate between food-fish of different sizes by listening to the echoes reflected from the fishes' bodies."[68] By being able to recognize that "as the animal entrains itself upon objects, the intensity of its signals is sequentially reduced," Norris and William Evans could postulate new techniques for underwater stealth.[69] Here and elsewhere, echolocation research reflected rich enthusiasms for "bionics"—the scientific fusion of biology and engineering to optimize or enhance bodies with sensory prostheses. The echolocation potentials of bottlenose dolphins in particular were imagined as a field of potentials that could be mined across closed information circuits and transoceanic hydrophone networks. Haraway's pithy diagnosis of the US military's Cold War obsession—"the translation of the world into a problem of coding"—finds a rich example here.[70] Through its echolocation research, the navy coded questions of how cetaceans listen into exercises in functionality: for example, "What is that sound *for*?" "What does the whale *do* with it?" Cetaceans' ability to sonically determine "prey" appeared stunningly comparable to navy efforts to identify Soviet submarines.

Listening to echolocation marked an evolution in the acoustemology of naval cetacean research. It elevated the significance of cetacean sound production and enriched the analogy between cetacean bodies and submarines. Consider, for illustration, the experience of "ping"—an acoustic artefact produced by sonar operators in their hunt for enemy ships. Sounds were "pings" when reflected back to their search vessels after hitting the desired object. Sonar operators were often called "ping men" in reference to these acoustic encounters. But echolocative cetacean clicks, researchers discovered, could sound like pings too. When researchers came to expound upon echolocation, pings and clicks both became understood as isolable sound events able to penetrate water with projectile-like accuracy. Naval listeners had to condition themselves to various forms of pinging and clicking activity, as various underwater objects now appeared capable of echolocative activity. It was common naval practice to attach acoustic sensors, or "pingers," to waterborne objects. But because of the limited sensory abilities of human divers, cetaceans themselves became preferred for retrieval missions.[71] Through the confusion of clicks and pings, a kind of pinging cetacean emerged, a biotechnology capable of tracking discreet objects through target acquisition.

Whereas the research around noise and signals aimed for classificatory and sorting schemes that encompassed every sound in the ocean, echolocation positioned

68. Kellogg, *Porpoises and Sonar*, 155.
69. Quoted in Norris, *Final Report*, 22.
70. Haraway, *Simians, Cyborgs, and Women*, 164.
71. Johnson, "Sound Detection Thresholds in Marine Mammals."

cetaceans as “special” study cases. It directly inspired the notion that cetaceans were complex animals capable of hearing the texture and composition of objects. As elements of composite sounding machines, cetacean body parts offered various insights for submarine designers. Dolphin torsos were models for torpedoes; dolphin brains were “biocomputers” that exceeded even the capacity of human brains.[72] Some naval researchers became fascinated with the linguistic capacities of cetaceans, with certain forms of “dolphinese” potentially measurable and exportable into human language.[73] Here, acoustemology as “fleshy emplacement” acquires a new (and gruesome) meaning. Cetacean body parts were routinely resourced as a means of navigating problems in undersea communicative practice. The integration of cetaceans into technological research produced a veritable bioeconomy of audio components—with jawbones, inner ears, and cortexes emerging as ideal types in design strategies. In the 1950s and 1960s, a time when legal protections for marine mammals in the United States had yet to be established (this would not happen until 1972), a veritable resourcing of cetaceans proceeded unabated.

What ultimately emerged from the echolocative scheme was a renovated concept of the cetacean itself, one that did much to galvanize the environmental movement of the 1970s. Cold War valorizations in communication and extraterrestrial space became the weight-bearing ideological pillars of new eco-ideologies.[74] Having first been models for undersea media and weapons, cetaceans became models for enlightened environmental experience.[75] Again, echolocative clicks provided materials for these new inferences. “I dropped my posture of remoteness, opened my mind, and personally engaged myself in [the killer whale’s] learning,” exclaimed cetologist Paul Spong of his time at the Vancouver Aquarium.[76] Such experiences inspired Spong’s commitment to “research without interference”—an idea we explore in the article’s final section.[77] Throughout the 1970s, the legacies of naval echolocation research found audiences across a range of environmentalisms. John Sutphen’s inference that echolocation’s sound waves conveyed to their receiver the interior emotional state of their sender—an idea that followed from naval speculation about dolphin “telekinesis”—is exemplary of how naval discourses could be translated to support new valorizations of cetacean sound.[78] Environmentalist engagements with echolocation thus mark a further shift in the acoustemological formation in question. They suggest how new social desires could affix themselves to the rich engagement of cetaceans and naval research.

72. Lilly, *Man and Dolphin*.

73. Lilly, *Communication*, 159; Lilly, *Mind of the Dolphin*.

74. Bryld and Lykke, *Cosmodolphins*, 159.

75. Susan Davis and Gregg Mitman demonstrate that the new forms of environmental spectacle that caught middle-class ears and eyes in 1960s aquariums and television shows were also essential to this reenchantment of the cetacean. See Davis, *Spectacular Nature*; and Mitman, *Reel Nature*.

76. Quoted in McIntyre, *Mind in the Waters*, 9.

77. Horwitz, *War of the Whales*, 227.

78. Quoted in McIntyre, *Mind in the Waters*, 142.

Passive Acoustic Monitoring

The third acoustemological trope we consider here is not a sound object but a modality of listening. PAM follows in the long line of naval techniques aimed at making the ocean record itself.[79] For naval researchers, the virtue of "passive" surveillance was its ability to acoustically identify objects while preventing identifying sound from moving in the opposite direction—that is, from listener to "object." New international discussion about extension of state control over continental shelves in the 1970s, including at the United Nations Convention on the Law of the Sea (1973–82), empowered states to assert control over marine spaces hundreds of nautical miles from shore. A technological means of facilitating marine spatial mastery, Navy PAM research heralded these political developments by mooring dozens of hydrophones off the US Pacific and Atlantic coasts.[80] PAM allowed the navy to erect barriers against submarine infiltration across vast undersea spaces. As Weir argues, the US Navy's PAM-related surveillance infrastructure, SOSUS, effectively "made it impossible for the Soviets to sortie a submarine anywhere in the world without detection."[81]

PAM also represents a distinct inflection in the acoustemological formation we are concerned with. For naval listeners, PAM promoted a new awareness of the contingent technological apparatus through which they were listening to whales. It made them newly concerned with the efficient circulation (and not simply detection) of cetacean signals—analogues of military "goods." As such, we can understand this moment as connoting an intensified awareness of the logistics of underwater listening. Recall that modern logistics emerged as fundamentally military exercises concerned with the efficient circulation and coordination of material flows.[82] PAM-related projects such as Project Jezebel consisted of extensive fixed listening arrays (LOFAR) spanning thousands of kilometers of ocean space. Major contractors such as Bell Labs were commissioned to develop finely calibrated hydrophones that remain the envy of cetologists today. As naval reliance on this infrastructure grew, listeners became more aware of what allowed them to listen and what did not. Listening was understood to be not only the result but also the experience of detailed coordinations of complex operations.

PAM was itself a highly logistical process. Hydrophones had to be attached to speakers, preamps, and radio transmitters and then moved around in difficult environmental conditions. Cables had to be carefully repositioned to properly relay sounds to listeners who were often in remote locations. Multiple hydrophone arrays were used to "triangulate" (localize) incoming signals via differences in intensity or sound-arrival time. As an identifiable acoustemological trope, PAM encouraged new attention to the overall legibility of the sound environment under varying conditions. This demanded

79. Burnett, "Self-Recording Seas."

80. For discussion along these lines, see Office of Naval Research, *Navy Research Task Summary*, 135.

81. Weir, "American Sound Surveillance System," 1.

82. Cowen, *Deadly Life of Logistics*.

several forms of listening attention. "You were expected to maintain your position on the watch, which was . . . learning plotting techniques, learning how to track contacts . . . to detect, localize, track, and report threat contacts," noted one official of his PAM training.[83] At the same time, PAM also inspired a new concern with "self-noise," or attention to what we identify as PAM's logistical apparatus. Malfunctioning hydrophones, broken transmitters, but also the hum of a proper operating system became relevant as indexes of quality control.[84]

Cetaceans enter this picture as agents whose "detectability" serves to augment navy PAM efforts. Cetology's uptake of PAM followed in turn by using it to track and pursue cetaceans—fin whales moving through the western northwest Atlantic[85] or grey-whale sounds in the mid-Pacific.[86] Cetologists also followed the US Navy in using triangulation to locate these animals.[87] Across both examples, an acoustemological experience of geocoded space—space made for the logistics of information flow—thus depended on the emplacement of ocean sensors such as networks of hydrophones suspended in the ocean. In terms of listening, it would be more accurate to say this geocoding expressed a sort of geo-channeling experience, with spatial knowledge shaped by the understanding of how quickly topographies "sounded" in relation to sensor depth. PAM thus suggested ebbs and flows in the composition of ocean space, with particular channels emerging as key tactical sites owing to their ability to propagate signals across long distances.

Several cetologists interviewed suggest PAM entered disciplinary conversations in the early 1970s.[88] But for many in the field, PAM was useful not only for cetacean tracking but for inscribing the additional benefit of being "passive" and hence noninvasive. Here, then, is another reflexive engagement with listening infrastructure. For environmentally minded cetologists of the 1970s, PAM stages an acoustic "join" between embodied but spatially distanced encounters with technology, thus affirming the sovereignty of cetacean research subjects. It was through PAM that Roger Payne first identified humpback whale "songs."[89] As environmentalists began to celebrate these songs, new listeners took to PAM. Hydrophones and other military tracking tools were reappropriated by artists and musicians.[90] For many, it was a "kind of eavesdropping" that was "safe for the animals" and could very likely result in resplendent musical experiences too.[91]

83. Quoted in Weir, "American Sound Surveillance System," 6.

84. Ross Chapman, in discussion with the lead author, May 21, 2014.

85. Walker, "Some Intense, Low Frequency, Underwater Sounds," 11.

86. Bostian, *Single Hydrophone Technique*.

87. Urick, *Principles of Underwater Sound for Engineers*.

88. Ken Balcomb, in discussion with the lead author, March 3, 2013; Paul Spong, in discussion with the lead author, June 21, 2013; Harald Yurk, in discussion with the lead author, June 27, 2013.

89. Payne and McVay, "Songs of Humpback Whales."

90. See Benson, *Wired Wilderness*.

91. Paul Spong, in discussion with the lead author, August 23, 2013.

These ethically minded appraisals of PAM are highly suggestive of Jonathan Sterne's "audio-visual litany."[92] Sterne's concept describes a dualistic framework, consistently propagated throughout the Western tradition, that installs a dichotomous logic of listening as passive and seeing as active. Rendering animals locatable and identifiable through technological means is not a passive act, however. It empowers humans to opportunistically extract locational information from bodies proximate to hydrophone networks. In proclaiming passive acoustic monitoring, cetology repeats the military disavowal of logistics as a political act, naturalizing the construction of dense underwater infrastructures for tracking and geocoding. Cold War PAM efforts proceeded against the backdrop of a geopolitical scramble to gain territorial control over the mid-Pacific.[93] In the hands of the US Navy, PAM infrastructure made the monitoring of key supply routes used by US and Russian forces possible in new ways.

Conclusion

Given the affordances of underwater acoustics for the study of marine space (noted at this article's outset), it is not surprising that US naval research would leave a deep impression in cetological research. Contemporary cetology features many research tools at its disposal besides acoustic ones—such as genetic sampling and radio tagging. Inquiries into the military origins of these tools—as have been commenced by the likes of Naomi Oreskes and Etienne Benson—are both necessary and beyond the ambit of this project. Here, we simply wish to assert that to the extent that cetacean research (and cetacean bioacoustics in particular) came to inspire the US Navy, acoustics was part of a system of "total war" that included other modalities of sense perception and the resourcing of other geo-environmental processes.[94]

The history of cetology is a history of relays among military expenditure, electronics and communications industries, academic bioacoustics, and situated listening subjects. It suggests a veritable military-industrial-animal complex in the political economy of scientific research during the Cold War, thus amending standard approaches to the Cold War by stressing the role of animals in new ways. Cetology's acoustic forays may have originated in US naval research, but they rapidly entered other institutional domains, as the entwined history of 1970s environmentalism suggests. In the United tates, more diverse funding structures have given cetology greater autonomy from the US Navy, but the navy remains one of cetology's primary benefactors and supports some of the very cetologists who research its sonar programs today.[95] While legitimate concerns have been raised about the objectivity of navy-funded policy recommendations, it is

92. Sterne, *Audible Past*, 15.

93. Hamblin, *Arming Mother Nature*.

94. Ibid., 7. As Hamblin points out, the US Navy was also interested in generating artificial tsunamis, inducing sudden rises in sea levels (to destroy coastal cities), and in contaminating water supplies with radioactive material.

95. Whitehead and Weilgart, "Scientific Correspondence."

important to note that outspoken critics of navy sonar—such as Roger Payne and Christopher Clark—have long been recipients of ONR grants. The sensory activities defining naval research into cetaceans and underwater spaces are much more than sites of theoretical elaboration. They are also portals into the complex machinations of powerful institutions. With the recent rise in submarine construction activity and the heating up of geopolitical tensions between the United States and Russia, we are well advised to embark upon additional studies of naval engagements with cetaceans—past and present.[96]

In this article, we have considered cetology as a troubling of human and nonhuman categories of experience, interpretation, and purpose. Many of the issues cetology's practitioners first posed in the 1950s remain vital. As one practicing cetologist remarked, "I've been listening to whales for a long time, and there is still so much I can't imagine in how whales listen to us."[97] Added to the host of philosophical challenges to understanding whale communication are fundamental incommensurabilities between species and environmental media. As Peters explains, "If dolphins can 'see' [hear] into their surroundings with three dimensional sonar, this would not even mean seeing for us, since our vision distantly touches the opaque surface of things."[98] Put into our terms, Peters is saying that the embodied realties of seeing and listening cannot be translated across species, as they describe different acoustemological projects. We nevertheless have more reason than ever to take seriously these species sensory differences. "The post–World War II threat is not decay," Haraway notes, "but the failure of communication, the malfunction of stressed systems."[99] In a world of rising marine risks—ocean noise, piracy, acidification, and melting icecaps—the promises of connection that attend the history of cetology are more necessary and more perplexing than ever before.

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Acknowledgments
We wish to thank Kelsey Johnson, Rafico Ruiz, Chris Russill, and Nicole Starosielski for their helpful suggestions on earlier drafts of this article. We would also like to thank the journal editors and the three anonymous reviewers of this paper for thorough and helpful feedback.

96. See Schmitt, "Russia Bolsters Its Submarine Fleet."
97. Janie Wray, in discussion with the lead author, March 18, 2014.
98. Peters, *Marvelous Clouds*, 68.
99. Haraway, *Primate Visions*, 135.

References

Axtell, Matthew A. “Bioacoustical Warfare.” *minnesota review* 10 (2009): 73–74.

Benson, Etienne. *Wired Wilderness: Technologies of Tracking and the Making of Modern Wildlife*. Baltimore: Johns Hopkins University Press, 2010.

Borror, Donald. “The Analysis of Animal Sounds.” In *Animal Sounds and Communication*, edited by W. E. Lanyon and W. Tavolga, 137–320. Washington, DC: Institute of Biological Sciences, 1961.

Bostian, Medwin. “Single Hydrophone Technique for Obtaining Spectral Source Levels of Marine Mammals in Coastal Waters.” PhD diss., Naval Postgraduate School, Monterey, 1977.

Bryld, Mette, and Nina Lykke. *Cosmodolphins: Feminist Cultural Studies of Technology, Animals, and the Sacred*. London: Zed, 2000.

Bureau of Naval Personnel. *Naval Sonar*. Washington, DC: US Navy Training Publications Center, 1953. archive.hnsa.org/doc/sonar/index.htm.

Burnett, D. Graham. “Self-Recording Seas.” In *Oceanomania: Souvenirs of Mysterious Seas from the Expedition to the Aquarium*, edited by Mark Dion, 134–45. London: Mack, 2011.

———. *The Sounding of the Whale: Science and Cetaceans in the Twentieth Century*. Chicago: University of Chicago Press, 2012.

Carey, W. M., and R. B. Evans. *Ocean Ambient Noise: Measurement and Theory*. New York: Springer, 2011.

Clark, Christopher, William Ellison, Brandon Southall, Leila Hatch, Sofie Van Parijs, Adam Frankel, and Dimitri Ponirakis. “Acoustic Masking in Marine Ecosystems: Intuitions, Analysis, and Implication.” *Marine Ecology Progress Series* 395 (2009): 201–22.

Committee on Underwater Telecommunication. *Present and Future Civil Uses of Underwater Sound*. Washington, DC: National Research Council, National Academy of Sciences, 1970.

Cowen, Deborah. *The Deadly Life of Logistics*. Minneapolis: University of Minnesota Press, 2014.

Dalheim, M. E. “Bioacoustics of the Gray Whale (*Eschrichtius robustus*).” PhD diss., University of British Columbia, 1987.

Davis, Susan. *Spectacular Nature: Corporate Culture and the Sea World Experience*. Berkeley: University of California Press, 1997.

Doel, Ronald E., and Kristine C. Harper. “Prometheus Unleashed: Science as a Diplomatic Weapon in the Lyndon B. Johnson Administration.” *Osiris* 21 (2006): 66–85.

Dreher, J. L., and E. Evans. “Cetacean Communication.” In *Marine Bioacoustics*, edited by W. N. Tavolga, 373–93. Oxford: Pergamon, 1967.

Edwards, Paul. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. Cambridge, MA: MIT Press, 2010.

Evans, W. E. “Vocalization among Marine Animals.” In *Marine Bioacoustics*, vol. 2, edited by W. N. Tavolga, 159–86. New York: Pergamon, 1967.

Farmer, David. “Acoustical Studies of the Upper Boundary Ocean Layer.” In *Sounds of the Sea: From Ocean Acoustics to Acoustical Oceanography*, edited by Herman Mediwin, 315–40. Cambridge: Cambridge University Press, 2005.

Feld, Steven. “A Rainforest Acoustemology.” In *The Auditory Culture Reader*, edited by Michael Bull and Les Back, 223–41. Oxford: Berg, 2003.

———. “Waterfalls of Song: An Acoustemology of Place Resounding in Bosavi, Papua New Guinea.” In *Senses of Place*, edited by Steven Feld and Keith Basso, 91–135. Santa Fe, NM: School of American Research Press, 1996.

Gluck, Zoltan. “Piracy and the Production of Security Space.” *Environment and Planning D: Society and Space* 33 (2015): 642–59.

Hall, J. D., and C. S. Johnson. “Auditory Thresholds of a Killer Whale.” *Journal of the Acoustical Society of America* 51 (1971): 515–17.

Hamblin, Jacob Darwin. *Arming Mother Nature: The Birth of Catastrophic Environmentalism*. New York: Oxford University Press, 2013.

———. “The Navy’s ‘Sophisticated’ Pursuit of Science: Undersea Warfare, the Limits of Internationalism, and the Utility of Basic Research, 1945–1956.” *Isis* 93, no. 1 (2002): 1–27.

———. *Oceanographers and the Cold War: Disciples of Marine Science*. Seattle: University of Washington Press, 2005.

Haraway, Donna. *Primate Visions: Gender, Race, and Nature in the World of Modern Science*. New York: Routledge, 1989.

———. *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York: Routledge, 1991.

Horwitz, Joshua. *War of the Whales: A True Story*. New York: Simon and Schuster, 2014.

Jasny, Michael. *Sounding the Depths: Supertankers, Sonar, and the Rise of Undersea Noise*. New York: Natural Resources Defense Council, 1999.

Johnson, C. S. "Sound Detection Thresholds in Marine Mammals." In *Marine Bioacoustics*, vol. 2, edited by W. N. Tavolga, 247–60. New York: Pergamon, 1967.

Jue, Melody. "Vampire Squid Media." *Grey Room* 57 (2014): 82–105.

Kellogg, Winthrop N. *Porpoises and Sonar*. Chicago: University of Chicago Press, 1961.

Kittler, Friedrich. *Gramophone, Film, Typewriter*. Stanford, CA: Stanford University Press, 1999.

Lilly, John Cunningham. *Communication between Man and Dolphin: The Possibilities of Talking with Other Species*. New York: Crown, 1978.

———. *Man and Dolphin*. Garden City, NY: Doubleday, 1961.

———. *The Mind of the Dolphin: A Nonhuman Intelligence*. Garden City, NY: Doubleday, 1967.

Lilly, John, Alice Miller, and Henry Truby. "Reprogramming of the Sonic Output of the Dolphin—Sonic Burst-Count Matching." *Journal of the Acoustical Society of America* 16, no. 6/7: 1412–24.

Lindsay, R. *A Survey Report of Basic Problems of Underwater Acoustics Research*. Washington, DC: Committee on Undersea Warfare, National Research Council, 1950.

Lockyer, C. "Growth and Energy Budgets of Large Baleen Whales from the Southern Hemisphere." In *Mammals of the Sea*, FAO Fisheries Series no. 5, 3:379–487. Rome: Food and Agriculture Association of the United Nations, 1981.

McIntyre, Joan. *Mind in the Waters: A Book to Celebrate the Consciousness of Whales and Dolphins*. Toronto: McClelland and Stewart, 1974.

Mirowski, Philip. *Science Mart: Privatizing American Science*. Cambridge, MA: Harvard University Press, 2011.

Mitman, Gregg. *Reel Nature: America's Romance with Wildlife on Film*. Seattle: University of Washington Press, 1999.

Norris, Kenneth. *A Final Report to the Office of Naval Research on the Scientific Activities Performed under Grant between the Biological Branch of the Office of Naval Research and the Oceanic Institute, Makapuu Point, Waimanalo, Oahu, Hawaii*. Arlington, VA: Office of Naval Research, 1966.

Norris, K. S., J. H. Prescott, P. V. Asa-Dorian, and P. Perkins. "An Experimental Demonstration of Echo-Location Behaviour in the Porpoise *Tursiops truncates* (Montagu)." *Biological Bulletin* 120 (1961): 123–68.

The Ocean Science Program of the US Navy. Alexandria, VA: Office of the Oceanographer of the Navy, 1967. archive.org/stream/oceanscienceprogoounit/oceanscienceprogoounit_djvu.txt.

Office of Naval Research. *Navy Research Task Summary*. Washington, DC: Office of Technical Services, US Department of Commerce, 1961.

———. "A Context of Motivation: US Navy Oceanographic Research and the Discovery of Sea-Floor Hydrothermal Vents." *Social Studies of Science* 33, no. 5 (2003): 697–742.

———. "Scaling Up Our Vision." *Isis* 105, no. 2 (2014): 379–91.

Payne, Roger S., and Scott McVay. "Songs of Humpback Whales." *Science* 173, no. 3997 (1971): 585–97.

Payne, Katy, Peter Tyack, and Roger Payne. "Progressive Changes in the Songs of Humpback Whales (*Megaptera novaeangliae*)." In *Communication and Behavior of Whales*, edited by Roger Payne, 9–57. Boulder, CO: Westview, 1983.

Peters, John Durham. *The Marvelous Clouds: Toward a Philosophy of Elemental Media*. Chicago: University of Chicago Press, 2015.

Sapolsky, Harvey M. *Science and the Navy: The History of the Office of Naval Research*. Princeton, NJ: Princeton University Press, 1990.

Schevill, William E. "Underwater Sounds of Cetaceans." In *Marine Bio-Acoustics*, edited by W. N. Tavolga, 307–16. New York: Pergamon, 1964.

Schevill, William E., and Barbara Lawrence. "Underwater Listening to the White Porpoise (*Delphinapterus leucas*)." *Science* 109 (1949): 143–44.

———. "A Phonograph Record of Underwater Calls of *Delphinapterus leucas*." Woods Hole, MA: Woods Hole Oceanographic Institute, 1950. darchive.mblwhoilibrary.org/bitstream/handle/1912/6302/WHOI-50-1.pdf?sequence =1.

Schevill, William E., and W. A. Watkins. *Whale and Porpoise Voices: A Phonograph Record*. Woods Hole, MA: Woods Hole Oceanographic Institution, 1962.

Schmitt, E. "Russia Bolsters Its Submarine Fleet, and Tensions with U.S. Rise." *New York Times*, April 20, 2016. www.nytimes.com/2016/04/21/world/europe/russia-bolsters-submarine-fleet-and-tensions-with-us-rise.html?_r =0.

Schwartz, Hillel. *Making Noise: From Babel to the Big Bang and Beyond*. New York: Zone, 2011.

Sebeok, Thomas A. *Perspectives in Zoosemiotics*. London: Mouton, 1972.

———. "Review of Communication among Social Bees; Porpoises and Sonar; Man and Dolphin." *Language* 39, no. 3 (1963): 448–66.

Shaw, W. A., E. B. Newman, and I. J. Hirsh. "The Difference between Monaural and Binaural Thresholds." *Journal of the Acoustical Society of America* 19, no. 4 (1947): 734–73.

Shiga, John. "Sonar and the Channelization of the Ocean." In *Living Stereo: Histories and Cultures of Multichannel Sound*, edited by Paul Théberge, Kyle Devine, and Tom Everrett, 85–104. New York: Bloomsbury, 2015.

Sontag, Sherry, and Chris Drew. *Blind Man's Bluff: The Untold Story of American Submarine Espionage*. New York: HarperCollins, 1998.

Starosielski, Nicole. *The Undersea Network*. Durham, NC: Duke University Press, 2014.

Starosielski, Nicole, and Janet Walker. Introduction to *Sustainable Media: Critical Approaches to Media and Environment*, edited by Nicole Starosielski and Janet Walker, 1–20, New York: Routledge, 2016.

Steinberg, Philp. "The Deepwater Horizon, the *Mavi Marmara*, and the Dynamic Zonation of Ocean Space." *Geographical Journal* 177, no. 1 (2011): 12–16

Sterne, Jonathan. *The Audible Past: Cultural Origins of Sound Production*. Durham, NC: Duke University Press, 2003.

Tavolga, W. N. "Listening Backward: Early Days of Marine Bioacoustics." In *The Effects of Noise on Aquatic Life*, edited by A. N. Popper and A. Hawkins, 11–14. New York: Springer, 2012.

———. *Review of Marine Bio-Acoustics*. Technical Report: NAVTRA- DEVCEN 1212–1, Port Washington, NY: US Naval Training Device Center, 1965.

Urick, Robert J. *Principles of Underwater Sound for Engineers*. New York: McGraw-Hill, 1967.

Urick, Robert J., and Robert M. Hoover. "Backscattering of Sound from the Sea Surface: Its Measurement, Causes, and Application to the Prediction of Reverberation Levels." *Journal of the Acoustical Society of America* 28, no. 4 (1956): 1038–42.

Virilio, Paul. *Speed and Politics*. Translated by Mark Polizzotti. New York: Semiotext(e), 1986.

———. *War and Cinema: The Logistics of Perception*. Translated by Patrick Camiller. London: Verso, 1989.

Walker, R. A. "Some Intense, Low Frequency, Underwater Sounds of Wide Geographical Distribution, Apparently of Biological Origin." *Journal of the Acoustical Society of America* 25, no. 11 (1963): 1816–24.

Watkins, William A. "Acoustic Behavior of Sperm Whales." *Oceanus* 20, no. 2 (1977): 50–58.

Weir, Gary E. "The American Sound Surveillance System: Using the Ocean to Hunt Soviet Submarines, 1950–1961." *International Journal of Naval History* 5, no. 2 (2006). www.ijnhonline.org/wp-content/uploads/2012/01/article_weir_aug06.pdf.

Wenz, Gordon M. "Acoustic Ambient Noise in the Ocean: Spectra and Sources." *Journal of the Acoustical Society of America* 34, no. 12 (1962): 1936–56.

Whitehead, Hal, and Linda Weilgart. "Scientific Correspondence: Marine Mammal Science, the U.S. Navy, and Academic Freedom." *Marine Mammal Science* 11, no. 2 (1995): 260–63.

Wyatt, R. F. "Improvability of Pitch Discrimination." *Psychology Monographs* 58, no. 2 (1945): 1–58.