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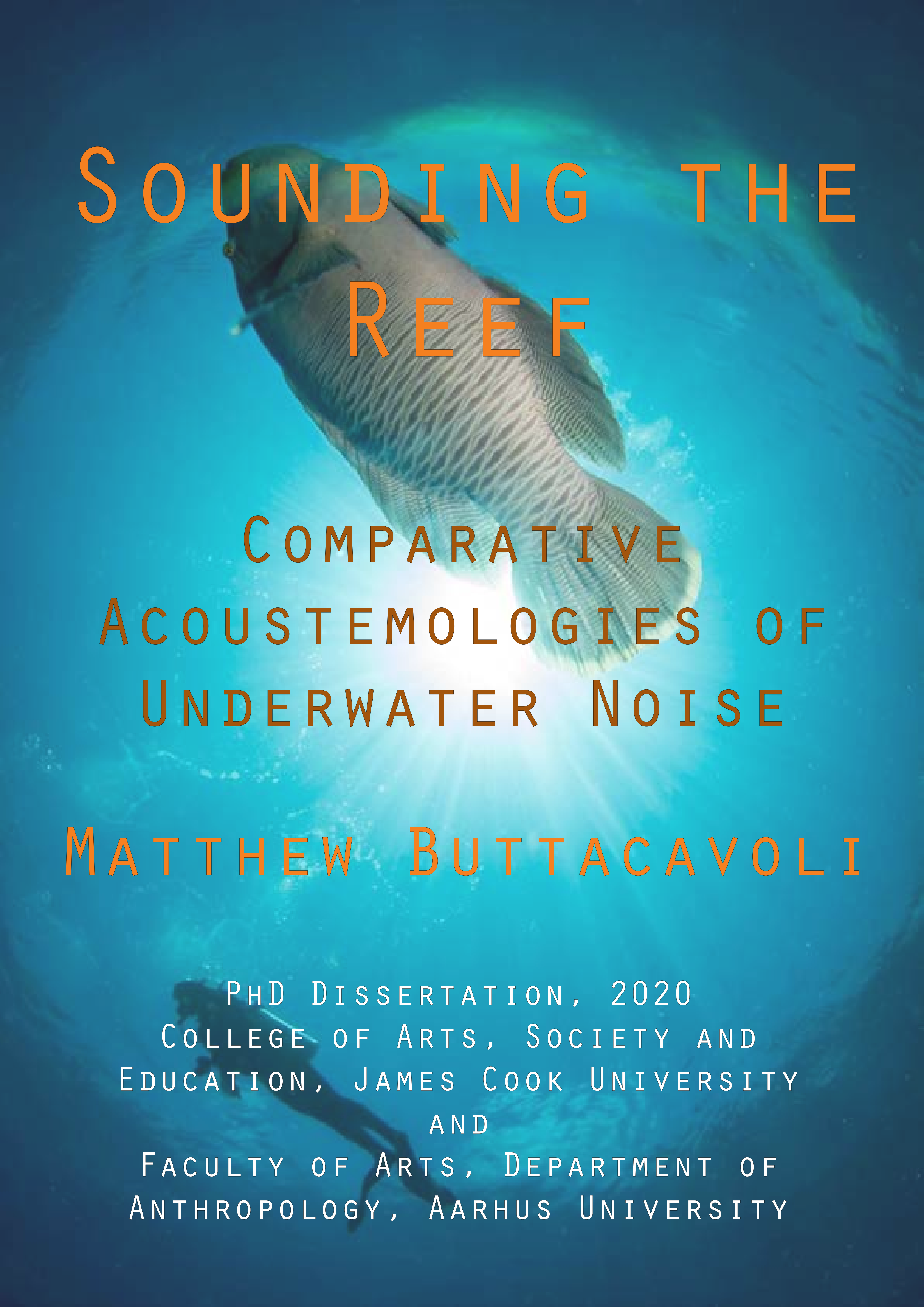

Sounding the Reef

Comparative Acoustemologies of Underwater Noise

Matthew Buttacavoli

PhD Dissertation, 2020

College of Arts, Society and Education, James Cook University
and
Faculty of Arts, Department of Anthropology, Aarhus University

Sounding the Reef

Comparative Acoustemologies of Underwater Noise Pollution

Pejling af revet: Komparativ akustemologi af undersøisk støjforurening

by

Matthew Buttacavoli

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Figure 1	The American Association for the Advancement of Science (with permission)
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Abstract

The continuing crises of the Anthropocene have propelled an intensification in projects attempting to grasp the worlds of non-humans under the aegis of conservation. Heat, acidity, and turbidity have all been documented spectacularly for the Great Barrier Reef, most often visually. The stressors impacting the sonic world of the Reef have been substantially less documented resulting in a poor understanding of the role sound plays in the lifeways of marine organisms. This thesis is an exploration of the relationships between the people, the Great Barrier Reef, and noise with the aim to describe practices of listening that enable humans to perceive phenomena beyond their biological sensory affordances. In doing so, this project pays particular attention to the use of science, technology, and art in order to grasp non-human worlds.

This thesis takes an ethnographic approach towards studying how interested listeners attempt to perceive and reconstruct the sonic marine world. Participant observation and interviews are paired with recording and creative practices to chart the (imperfect) ways listeners (including the author) attempt to grasp the sound worlds of marine beings. At focus are those listening practices developed by scuba divers, marine scientists, acousticians, and community groups.

Sound and the perception of acoustic energy is vital for all marine vertebrates and many marine invertebrates. For many reef species and other marine organisms, sound is the primary pathway in which these creatures interact with each other and their environment. Much of this sound world remains inaccessible to human beings due to a combination of their limited capacity to hear in water and the inaccessibility of the marine environment. These facts have cut-off most humans from hearing the underwater world and lead to the myth of the silent sea. Within this void, anthropogenic noise from shipping, coastal development, resource extraction, and warfare have been allowed to proliferate to the detriment of marine beings. Now, as Western attention turns back towards the environment and the oceans, maritime communities must renew their efforts to listen in.

This thesis melds together theory from anthropology, science and technology studies, sound studies, and the ecological sciences to create a radical approach to listening. Having pushed at the limits of traditional phenomenological techniques, this thesis argues for a multi-sensory listening that includes the aural, visual, tactile, and abstract. This new phenomenological approach to sound and acoustic energy emerges from the listening practices developed by active marine listeners. Key to these listening practices is the concept of transduction in which sound takes new forms as it switches media and the development of skilled listeners.

As a means of characterizing these radical practices, the author introduces a new form of engagement called echo-logics. Echo-logics is a practice of organizing human/non-human sonic relationships that are respectful and responsible through the synthesis of a more-than-human phenomenology, transduction, and political ontology. Echo-logics draws from the listening practices described in this thesis as well as the ethics of conservation biology which calls for public engagement.

As part of the responsibility towards the sound world and sonic stressors of the Reef, this thesis explores the use of sound art as a conservation intervention. Drawing from public engagement projects documented throughout this study, the author has organized a collaborative sound art project to probe the possible forms of engagement which are appropriate for the Reef.

The findings from this research conclude that affordances of the human body and the inaccessibility of the marine world conspire to make underwater noise pollution difficult to sense. But these limitations can be overcome through the responsible use of sensing technologies and creative practices. The inattention to the marine soundscape of the Great Barrier Reef does not signify a lack of aesthetic appeal. Instead, as indicated by this study, there exists a potential aesthetics which require the implementation of transductive technologies and the skilling of listening practices to access. Accessing this aesthetic and the greater knowledge bound in the Reef soundscape will open pathways to anthropogenic noise mitigation.

Resumé

Antropocænens kontinuerlige kriser har fremdrevet en intensivering af projekter, der forsøger at forstå ikkemenneskelige verdener under naturbeskyttelse. Varme, surhed og grumsethed er blevet veldokumenteret, især i forhold til Great Barrier Reef, dog oftest visuelt. De stressfaktorer, der har indflydelse på revets lydverden, er blevet dokumenteret i væsentlig mindre grad, hvilket fører til en dårlig forståelse af den rolle, lyd har på havorganismers levevis. Denne afhandling er en undersøgelse af forholdet mellem mennesker, Great Barrier Reef og lyd med det formål at beskrive lyttemetoder, der sætter mennesker i stand til at opfatte fænomener ud over deres biologiske sanser (affordance). Dermed sætter dette projekt særlig fokus på anvendelsen af videnskab, teknologi og kunst til at forstå ikkemenneskelige verdener.

Denne afhandling vælger en etnografisk strategi til at undersøge, hvordan interesserede lyttere forsøger at opfatte og rekonstruere det akustiske havmiljø. Observation og interviews af deltagere sættes sammen med optagelse og kreative metoder for at kortlægge de (ufuldkomne) måder, hvorpå lyttere (herunder forfatteren) forsøger at forstå havskabningers lydverdener. I fokus er de lyttemetoder, der blev udviklet af dykkere, havforskere, akustikere og interesseorganisationer.

Lyd og opfattelsen af akustisk energi er afgørende for alle hvirveldyr og mange hvirvelløse dyr. For mange revarter og andre havorganismer er lyd den primære måde, hvorpå disse skabninger interagerer med hinanden og deres omgivelser. Mange af disse lydverdener er stadig utilgængelige for mennesker som følge af en kombination af deres begrænsede evne til at høre i vand og havmiljøets utilgængelighed. Disse kendsgerninger har afskåret de fleste mennesker fra at høre den undersøiske verden og ført til myten om det lydløse hav. I dette tomrum har menneskeskabt støj fra skibsfart, udvikling af kystområder, ressourceudvinding og krig fået mulighed for at blive udbredt på bekostning af havskabninger.

Nu hvor Vestens opmærksomhed igen har fokus på miljøet og verdenshavene, er det bydende nødvendigt, at man i de maritime samfund intensiverer bestræbelserne på at lytte med.

Denne afhandling forener teori fra antropologiske, videnskabelige og teknologiske undersøgelser, lydundersøgelser samt økologiske undersøgelser for at skabe en radikal tilgang til at lytte. Efter at have rykket grænserne for traditionelle, fænomenologiske metoder, argumenterer denne afhandling for en flersanselig lytning, der omfatter det lydlige, visuelle,

taktile og det abstrakte. Denne nye fænomenologiske tilgang til lyd og akustisk energi er resultatet af de lyttemetoder, der er udviklet af aktive maritime lyttere. Centralt for disse lyttemetoder er begrebet transduktion, hvor lyden tager nye former, når den skifter medie, og udviklingen af dygtige lyttere.

Som et middel til at karakterisere disse radikale metoder, introducerer forfatteren en ny form for engagement kaldet "echo-logics". Echo-logics er en metode til at organisere menneskelige/ikkemenneskelige lydforhold, der er respektfulde og ansvarlige via en sammenfatning af en mere-end-menneskelig fænomenologi, transduktion og politisk ontologi. Echo-logics bygger på de lyttemetoder, der er beskrevet i denne afhandling, samt bevaringsøkologiens etik, der opfordrer til offentlig deltagelse.

Som en del af ansvaret over for revets lydverden og akustiske stressfaktorer, undersøger denne afhandling anvendelsen af lydkunst som en naturbeskyttelsesintervention. På grundlag af projekter med offentlig deltagelse, som er dokumenteret i denne undersøgelse, har forfatteren organiseret et samarbejdsprojekt om lydkunst for at undersøge de mulige former for deltagelse, som er hensigtsmæssige for revet.

Resultaterne fra denne forskning konkluderer, at den menneskelige krops handlemuligheder med omgivelserne og utilgængeligheden til havets verden er medvirkende til at gøre undersøisk støjforurening vanskelig at registrere. Men disse begrænsninger kan overvindes gennem ansvarlig brug af sensorteknologi og kreative metoder. Den manglende opmærksomhed på Great Barrier Reefs maritime lydlandskab er ikke et tegn på manglende æstetisk tiltrækningskraft. Ifølge denne undersøgelse findes der i stedet for en potentiel æstetik, der kræver gennemførelsen af transduktive teknologier og opkvalificering af lyttemetoder for tilgængelighed. Tilgængeligheden til denne æstetiske og større viden, der er bundet i revets lydlandskab, vil åbne veje til menneskeskabt støjdæmpning.

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Thesis Audio (Track 0) [52:01]

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Chapter 1: Sounding out a Living Reef

Snapping Shrimp Sizzle (Track 1) [01:00]

There is a unique sizzle to the Great Barrier Reef. It is omnipresent and omnidirectional. It can be heard throughout the shallow coastal waters of the tropic and temperate seas, but it is especially strong around coral reefs. It is undoubtedly the sound of life, but where does is come from? The source of all that crackling and popping remains hidden from the average reef visitor.

The sound you are hearing is the cumulative result of thousands of little shrimp living in highly social communities in the coral and surrounding sandflats. Snapping shrimp (family *Alpheidae*) are small, cryptic shrimp living in burrows in the sandy floor. Rarely seen, these animals are the most soniferous beings in shallow tropical waters and one of the loudest animals in the ocean (Versluis, et al. 2000). They create sound by using their abnormally large claw. Their claw is cocked open and then shut around 100 km/hr, shooting out a jet of water. The jet creates a low-pressure area, vaporizing the water in a process known as cavitation, and forms a cavitation bubble. The outside pressure of the water quickly collapses the bubble, creating an intense POP and sending out powerful acoustic waves. These waves can stun, kill, or even dismember prey. In high density areas, the characteristic crackle can disrupt ship sonar (Schwartz 2016). We can even look at that sound. Figure 1 shows a frame-by-frame shot of (1) the shrimp's claw closing to (2) form the bubble followed by (3) the bubble's collapse.

Each snap from the shrimp builds up to a cacophonous chorus that, for this human, has come to serve as an indicator of an ongoing symphony of life accompanied by the shuffle of sea urchins, the croaks and grunts of fish, the squeaks of dolphins, and the songs of whales. Indigenous Australians have also been part of that sonic ecology since the birth of the current reef system at the end of the Last Glacial Maximum (Tobin 2003[1998]).

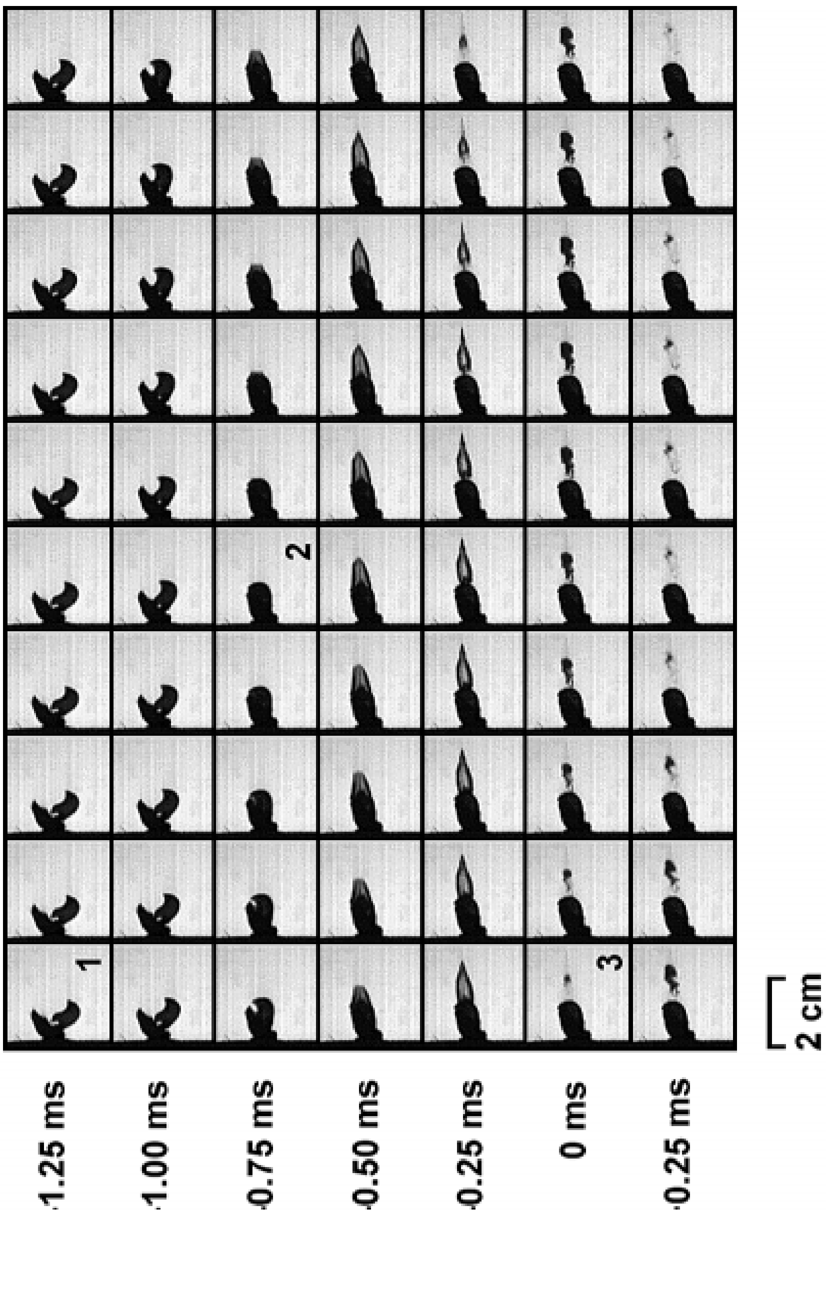

Figure 1. A sequence of high-speed images in top view showing the closure of the snapper claw taken at 25-µs intervals (40,500 fps) (originally appearing as fig. 2(B) in Versluis, et al. 2000, 2115)

More recently, humans (particularly from Western colonial states) have started to take over the marine soundscape. Ever since the Industrial Revolution and the rise in combustion-powered ships, the world's oceans have become noisier (Chapman and Price 2011). The industrialization of today's aquatic environments has poured in noise from hydrocarbon exploration and extraction, military sonar, and coastal development. In the Great Barrier Reef, the main human contribution to the marine soundscape has been the noise from shipping and boating.

When it comes to making noise, ships and shrimp share a common instrument: the cavitation bubble. Low-pressure areas form along the edges of the propeller blades as a ship's propeller turns. With enough speed, those low-pressure areas spawn minuscule cavitation bubbles which implode with ferocious energy (at least on the micro scale). As tiny bubbles continue to form in the millions, micro-implosions quickly add up to a deafening roar.

Marine noise pollution is an anthropogenic force that is having wide ranging effects across the ocean basins of the world. Although it will not leave a direct geological trace,[1] it is creating new, global environmental challenges. Marine creatures are unevenly faced with those challenges depending on their sensitivities to sound and acoustic energy.

Humans walking around on the mainland are mostly unaware of the lively sound space below the waves, much less our own unwelcomed contribution. The sea to most Australians (and most Westerners more generally) is a silent place, out of ear and out of mind. How then do people come to know the sounds of the sea and start hearing anthropogenic underwater noise? This question compels my research. It invites a form of politics and care in learning how other beings sense their world and how we can advocate for more respectful action through hearing other creatures.

Interrogating Marine Soundscapes

Coral reefs, and the Great Barrier Reef particularly, have been a growing focus of environmental humanities scholars over the past decade. In his widely popular book, McCalman (2013) explores the social history of the Great Barrier Reef, starting with the Cook expedition and continuing through the current climate crisis. Following that thread, Braverman (2018) takes a more contemporary approach and documents the ongoing struggles of coral scientists as they attempt to save coral reefs from ocean warming, acidification, and

[1] Acoustic energy is used in hydrocarbon exploration and does result and a geologic impact in that way.

pollution. Taking a different tact, Elias (2019) examines the historical links between early visual media of coral reefs (specifically, the Caribbean reefs and the Great Barrier Reef) and the colonialization towards the end of the Age of Empire. Through this thesis, I continue these scholarly pursuits by investigating how coral ecosystems mediated and socialized in the face of growing environmental threat.

This thesis explores the phenomenon of underwater noise pollution and how it emerges from the relationships between people, technologies, institutions, and the marine world of the Great Barrier Reef. Through those relationships, Western culture has attempted to shape and contest the narrative of underwater noise pollution through environmental management, tourism, public activation, and artistic interventions. In interrogating these relationships and actions, I am guided by my primary research questions: How does sound become noise, and according to whom? How is noise detection and management on the Great Barrier Reef mediated through listening technologies? How can we learn to hear the sound worlds of non-humans in a respectful and careful manner?

The Great Barrier Reef is a sprawling system of tropical coral reefs skirting the northeast Australian coast between the shore and the edge of the continental shelf. The Reef starts in the Torres Strait to the north and cascades down to Lady Eliot Island and the Queensland town of Bundaberg to the south. Its spread is truly great and encompasses many different ecosystems from mangrove forests and seagrass meadows to sand flats and coral reefs. The marine habitats provide homes for a variety of fish, crustaceans and other invertebrates, reptiles, and mammals while the islands and cays provide safe refuge and nesting grounds for many migratory sea birds.

The Reef also exists in many forms. There is the ecological Reef which vaguely encompasses all those ecosystems and knows no human boundaries. This Reef is bounded by currents, continents, and great submarine drop-offs. The Great Barrier Reef Marine Park (GBRMP) is a well bounded space between 10°41’ S and 24°30’ S managed by the Great Barrier Reef Marine Park Authority (GBRMPA). Then there is the Great Barrier Reef World Heritage Site (GBRWHS) which is generally the same area as the Maine Park (if slightly larger) and is monitored by the United Nations Educational, Scientific and Cultural Organization (UNESCO). The International Maritime Organization (IMO, another UN agency) manages a Great Barrier Reef as a Particularly Sensitive Sea Area (PSSA) which combines the Reef with the Torres Strait and portions of the Coral Sea. The IMO dictates how marine traffic is to interact with the environment in a PSSA. There are also the many and sometimes competing cultural forms: the Reef as Indigenous sea country, the Reef in the Australian imaginary, and the Reef in the international imaginary (Bergin 1993; Deloitte 2017).

In this way, the Reef embodies Annemarie Mol's (2002) multiplicity, "more than one less than many." The multiplicity of Reefs (GBRMP, GBRWHS, PSSA, etc.) make this particular marine ecosystem a highly contested space of competing interests held mostly together by its collapse back into the Reef made up of intensely connected more-than-human relationships.[2] Each manifestation of the Reef is structured around the continuation of a stable tropical coral ecosystem with high biodiversity which humans can interact with (e.g. through fishing, diving, boating, etc.). The multiplicity of Reefs would dissolve if the relationships which sustain the Reef as a living ecosystem were to fall away.[3]

Noise may be a shadow multiplicity to the Reef. It threatens to disrupt and dissolve relationships and unsettle the Reef ecology. Noise is subjective, manifesting itself in relation to the perceiver. In that way, noise to a human, a whale, and a fish is multiple. But these noises can be generated from the same general source (e.g. shipping or geological survey methods) which is why noise is also treated as a categorical whole by marine experts and managers. As the experience of noise increase, it further threatens to damage the more-than-human relationships with hold together ecosystems (at least for the time being). More on how noise does exactly that will be covered in Chapter 2.

The multiplicities of the Reef and noise are enmeshed in a shared relatedness of humans, non-humans, and place. Noise exists in a spatiotemporal relationship between two or more entities. That relationship develops first as a sonic relationship between the sound source and the hearer and then becomes noise as that relationship is strained due to spatial or temporal variables. The quality of the relationship between you and a lawnmower depends on if the lawnmower is running at noon or midnight, in your neighbor's yard or your own. The same is true for more-than-human relationships which become more complicated when variables such as perception and sensitivity are mixed in.

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[2] Throughout this thesis I use more-than-human to denote elements which included human and non-humans and beyond-the-human for elements which include non-humans but exclude humans.

[3] As a result of the 2016 and 2017 major bleaching events, the Great Barrier Reefs status as a World Heritage site has already been put into question.

Methods for Hearing

The method I employ in this thesis so that I might start to understand these multiplicities and complex relationships is one of learning to hear underwater noise pollution. My research was a tandem exercise where I both developed my own listening skills and documented the listening practices of others.

I chose to link my exploration of underwater noise pollution with a variety of people working the marine environment. In Australia, I partnered with a local dive tourism company, acousticians, marine scientists, and environmental managers all active in the Great Barrier Reef. In North America, I had the opportunity to work with managers, educators, researchers, and community activists. Elsewhere, I partnered with sound artists and musicians. Notably, these individuals tended to be Westerners. Thus, this project reflects Western notions of underwater noise and the marine environment which is reflected in techno-scientific and governmental categorizations of noise (among other things). While many non-Western and Indigenous voices have been left out of this current thesis,[4] I do not wish to suggest that they have nothing to contribute to the growing understanding of noise and sound. My narrow focus is a reflection of current institutional realities and my decisions in response to resource constraints.

In order improve my hearing of underwater noise, I combined anthropological methods of participant observation and interviewing with textual methods more common in critical philosophy of science and policy research. I started my fieldwork diving with a local dive operator in Cairns in order to orientate myself with the coral ecosystem and sound as well as to better comprehend the role that dive tourism plays in mediating relationships between humans of the Reef. From there, I have visited labs, research stations, educational institutions, and conferences in Australia, the United States, and Canada. I have also conducted numerous interviews with subject experts and activists.

To complement my fieldwork, I analyzed the conversations on underwater noise pollution occurring in textural media. A notable portion of those texts include government documents covering the historical development and current policies towards underwater noise pollution in the forms of position papers, policy reviews, legislation, and parliamentary debate. These documents ranged in scale form the international to state-level. The other major source of text came from scientific and industrial research in acoustics, oceanography,

[4] The reasons why are discussed in Chapter 7.

and marine biology. Collectively, these documents did more than provide empirical support for observations made during fieldwork; they provided direct evidence for evolving notions of what noise is and how non-humans perceive such disturbances. These documents provide a history of how the field has, itself, learn to hear.

Finally, I participated in some direct listening practices of my own throughout my research. Using a Zoom audio recorder paired with a hydrophone, I regularly made my own recordings of reef sounds as I tried to become more sensitive to the soundscape.[5] I worked with acousticians and sound artists to develop my practice including the use of Adobe Audition editing software. I have presented some of those recordings throughout this thesis. Towards the end of my project, I collaborated with a group of musicians in a more creative exploration of the subject matter.[6]

Through the process of learning to hear, I have developed a sensitivity to the environmental stakes presented by underwater noise pollution. I will more fully explore the threat of underwater noise in the next chapter. For the rest of this introduction, I will turn my attention to how learning to hear the marine environment through anthropological research has positioned me within field.

Anthropocene Listening and Underwater Noise

There are many potential ways to listen into these noisy more-than-human relationships. This thesis seeks to listen to underwater noise in order to offer a different kind of anthropocentric perspective. I have chosen to study noise in the Great Barrier Reef because it presents unique anthropological and ecological challenges in an era of constant environmental emergencies. Much attention has been given to marine stressors, but the focus has been primarily on stressors related to the carbon cycle (acidification, climate change, ocean warming), land use (agricultural run-off, coastal development, industrial waste), or resource extraction (hydrocarbon extraction, overfishing) (Solan and Whiteley 2016). Much less attention has been put towards energetic pollutants like sound or light. The former group of stressors often have highly observable, dramatic impacts on marine life. The link between those stressors and mass mortality are easily understood. The latter energetic pollutants are more complicated. They may not cause direct mortality in low doses, but instead work to amplify the impact of other stressors.

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[5] A more in-depth description of that process can be found in Chapter 3.
[6] See Chapter 6.

While underwater noise goes mostly unnoticed, those who do listen in have a high level of concern. Listeners in the North Atlantic and Pacific fear that anthropogenic noise may cause mass whale beachings or prevent large marine mammals from finding food. In the tropical coastal seas, listeners worry about fish and other marine animals becoming stressed and being unable to detect predators in noisy environments. What factors drive those who perceive underwater noise contrasted with those who do not? It is a question of general ecological interest as it can help the greater ecological research and action communities understand how noise and other stressors are unevenly understood throughout society. Underwater noise pollution is still an emerging concern for the Great Barrier Reef and other ecosystems, meaning attitudes towards the pollutant and its management are still emerging. Because the study and management of underwater noise is still developing, this field is particularly well suited for investigating the more-than-human relationships which shape the understanding of environmental stressors.

This project also pushes against the limits of current anthropological thought. As I will elaborate on later, underwater noise challenges the ways anthropology studied sensing to date. It is removed from most human activities and requires an intersubjectivity with non-humans to fully comprehend. Most anthropological studies on sound have lacked a multispecies component (Novak and Sakakeeny 2015). Those that do include non-human others feature mostly sounds that are widely accessible to human communities. My research has instead focused on listening with a sense of urgency to sounds which have a potential to damage multispecies relationships. In doing so, I test the boundaries of using anthropological theory and methodology in environmental concerns manifesting at the edges of the field. Such knowledge has the potential to expand anthropological inquiry as well as to better understand the limits and responsibilities of our science in multidisciplinary projects.

Submerging Theory

In this thesis, I engage the phenomenon of marine noise pollution at the convergence of several different theoretical traditions. My understanding of marine noise draws from the traditions of sound studies, science and technology studies, and the new Anthropocene studies, as well as all those places where they overlap. I submerge these areas of study, testing and extending them in underwater contexts, in order to explore their cultural manifestations in the following chapters. For the most part, anthropological (and social science) thought around sound, science, and the environment has developed on land.[7] Terra firma has been an adequate place to build theory from given our own land-bound morphology. But, by submerging terra-centric theory—as in Helmreich's (2016) "theory underwater"(186)—water is given the ability to both dissolve and reshape. The distance and isolation provide by the wet oceanspace[8] helps to clarify the connections between sound, technology, and living beings (human and non-human) much like how vacuous outer space provides clarity on light.

While the implications of submersion will be demonstrated throughout this thesis, I would like to take time to identify the theoretical platform[9] from which this work dives. A complete review of each genealogy of theory would be well beyond the constraints of this thesis, so I am choosing here to reflect on the most important concepts for this research. Reviews of more specific concepts can be found in the appropriate chapters.

Sound

The corpus of theory on sound is very broad but can be approached by breaking it down into some smaller, cohesive units. The majority of theory about sound comes from physical and natural science disciplines and will not be addressed at length here.[10] The much smaller body of work in the humanities, arts, and social sciences (collectively making up the interdisciplinary field of sound studies) can be broken down further. I here focus on the philosophical, historical, and social traditions.

The philosophy of sound attends to the perception, politics, ethics, and aesthetics of sound among other things. Overall, this group is concerned with experience and use of sound as well as its extremes of noise and silence. Within this body of literature can be found fundamental texts (Attali 1985; Schafer 1977), new critical writers (Goddard, et al. 2012; LaBelle 2018), and art criticism (Voegelin 2010, 2014). Notably, this scholarship also contains several practicing musicians (many of the above and Cox and Warner 2004;

[7] Exceptions to this include naval navigation, resource extraction, and fisheries studies.
[8] I use oceanspace here to denote wet phenomenon-as-it-is in contrast to other drier spaces such as the abstract math space, the modelled space, or the digital space. In this way, I am attempting to bypass notions of "real" or "physical" that would privilege one space over others while also indicating the important differences between aquatic and aerial mediums.
[9] I find it inappropriate to call it groundwork here.
[10] Some scientific theory is reviewed in other chapters, specifically biological hearing (chapters 2 and 3) and acoustics (chapters 2 and 4).

Oliveros 2015; Westerkamp 1974), particularly in regards to listening practices and aesthetics.

Historians of sound make up a smaller body of literature, but their contribution is invaluable to field. They tend to investigate either the changing experience of sound through time and place (Corbin 1998; Ochoa Gautier 2014; Schwartz 2016) or on its materiality (Feaster 2012; Sterne 2003, 2012). These texts demonstrate how social relationships have changed around the perception of sound and noise in relation to religious, colonial, and technological forces.

Sound and the social is a wonderfully diverse and growing collection of anthropologists and sociologists studying the perception and use of sound through the cultural context. These writings include ethnographies (Bull 2007; Feld 1990[1982], 1996; Fisher 2016; Novak 2013) as well as social theory (Feld and Brenneis 2004; Helmreich 2016; Novak and Sakakeeny 2015; Schulze 2018). Together, these authors demonstrate how vital and variable sound is to cultural life. This includes the mediation of noise and silence as well.

Within this wide field of research, I have positioned this thesis within a smaller constellation of scholars, most notable Stefan Helmreich (2007, 2016), Johnathan Sterne (2003, 2012), and Patrick Feaster (2012). This group focuses mainly on the technological mediation of sound instead of social interpretation (Feld 1990[1982], 1996; Feld and Brenneis 2004; Novak 2013), moralization of noise (Attali 1985; Schafer 1977), or sound aesthetics (Oliveros 1998, 2015; Voegelin 2010, 2014; Westerkamp 1974, 2002). While the latter traditions have their place in this thesis, for reasons that will become clear, sound's intersection with technology has facilitated the most socially important relationships with marine noise.

These authors, especially Feaster (2012), have enabled me to attend to a more multimodal formulation of sound. Most sound scholarship within the humanities and social sciences are narrowly focused on sound that is heard by the human ear. This formulation of sound as the audible is at odds with the physical and natural sciences which describes sound as acoustic energy. Quite clearly, sound is capable of being sensed in many forms. What Feaster (2012) has shown is that sound is even more versatile and is capable of existing in non-aural formats. His work has examined how sound has historically been recorded in visual forms and he has worked to develop techniques in which he can educe audio from those forms. Helmreich (2007, 2016) and Sterne (2003, 2012) further support such a position through their work on the technological and social process of transduction, or the transformation of energy and information from one form to another.[11] I refer to these processes as synesthetic due to the fact that they allow for the perception of sound by other senses. I have already given examples of the multimodality of sound at the beginning of this chapter. The audio file, the image of the shrimp claw, and textual phonography have stored and presented sound and acoustic energy in some manner. This shift away from pure aurality is in part a necessity for presenting a sound phenomenon that exists beyond our human senses.

Multispecies Ethnography

To explore the sound worlds of non-humans, I also draw upon multispecies ethnography.

Many scholars working in environmental anthropology have chosen to engage in multispecies ethnography (Haraway 2003, 2008; Helmreich 2009, 2016; Kohn 2013; Morton 2017; Tsing 2015). This approach places non-human living beings at the center of ethnography while the anthropologist explores how they engage with human worlds. The multispecies ethnographer reads the impact of human society in the being's body and behavior following Haraway's (2008) suggestion to take other species in their own terms (see also van Dooren 2014).

As a method, multispecies ethnography is still exploring its limits. Some authors limit their investigation to human/non-human interactions (Helmreich 2009; Law and Lien 2018) while others are willing to push further and make the non-humans the primary subject of writing (Kohn 2013; Tsing 2015). How far one is willing to stray from the human depends on phenomenological distance between humans and non-humans as argued by Nagel (1974) and von Uexküll (2010[1934]).[12] All authors do come to some final agreement that some divide exists. For my purposes, finding that boundary in multispecies ethnography is part of the project of unwater noise research. Unfortunately, there are few sound studies researchers who truly participate in multispecies writing (Helmreich and Krause are notable exceptions) and they do not focus on these specific questions of perception and knowledge. In my own delving into multispecies relationships, I have worried about how far away I can get from the human before I leave anthropology. I am not a marine biologist or an acoustician, so I have

[11] See Interlude I for an expanded discussion on transduction.
[12] See Interlude II for an expanded discussion on phenomenology of non-humans.

decided to only go so far as a human tether will allow (a point to which I will return in Interlude II).

This once again frames the thesis in an anthropocentric perspective. As I will elaborate on later, anthropocentrism in this case refers to a thematic positioning rather than a theoretical failing. Because of the difficulties in sensing beyond the species divide and my training as an anthropologist, I find that presenting my research from the human perspective is my most ethical position. The anthropocentrism I choose to employ is also critical in that I remain aware the limitations of my abilities to sense and understand non-human experience as well as being cautious of any biases that might arise.

Anthropocene Studies

Some scholars in environmental anthropology have started to turn to Anthropocene studies (Crate 2008; de la Cadena and Blaser 2018; Gibson-Graham 2009, 2011; Haraway 2017; Howard 2017; Latour 2017; Moore 2015; Puig de la Bellacasa 2017; Stengers 2005, 2013; Tsing, et al. 2017). This scholarship has been motivated by an urgent need to focus on the impact of humans onto the environment. While several scholars overlap with multispecies ethnography, they also include science and technology scholars (Stengers 2013), feminists (Gibson-Graham 2011), post-colonialists (Corsín Jiménez 2018), and Indigenous writers (Whyte 2017).

The concept of the Anthropocene started its life in the realm of geology as an acknowledgement that human beings may have become the most dominant geological force of our time (Crutzen and Stoermer 2000). While the proposal of a new geological epoch is still being debated within the geology community, theorists in the social sciences have picked up the concept and run with it. Anthropocene studies in anthropology explore how human societies (typically, but not limited to, industrial and capitalistic societies) have transformed the environments around them and led to unexpected knock-on effects in the wider world. Anthropocene anthropology has also examined how the effects of anthropogenic environmental changes have unevenly impacted Indigenous and southern peoples. While some have critiqued the concept by offering up other names and other configurations of agency (cf. Haraway 2017; Latour 2017) there is general agreement that modern human action has forced us to reflect on human/animal/plant/environment relationships.

Anthropocene anthropology sets itself apart from other environmental movements by refusing the nature-culture dichotomy (see Latour 1987; Latour 1993). Humans are always already a part of the greater environment around them. Because of this, these areas of study are critical of practices which try to reinforce such divisions. Instead, they support actions which focus on mending the relationships between humans and non-humans.

A growing number of scholars are finding that constructive ground in practicing ontological politics (de la Cadena and Blaser 2018; Escobar 2018; Gibson-Graham 2009, 2011; Gibson-Graham and Roelvink 2011; Haraway 2008; Kohn 2013; Stengers 2005, 2013).[13] Through my own research, I have aligned myself with these politics. Ontological politics states that we inhabit a world of many worlds which push against and overlap each other. Westerners, Indigenous peoples, and non-humans must negotiate ways of living with and working with each other through respect for these worlds. This is not a philosophy of harmony as the politics of it allow the worlds to challenge each other as equals. It is a process which slows down deliberation in favor of practices of belonging which allow a careful connection to be drawn between worlds and prevents negative impacts from careless actions from multiplying.

A large part of my research falls within the Anthropocene movement. Marine noise pollution is an anthropogenic force that is having wide ranging effects across the ocean basins of the world. Although it will not leave direct geological traces,[14] it is creating new, pervasive environmental challenges.

Science and Technology Studies

My focus on sound technologies and noise as a scientific phenomenon has predictably brought me to the field of science and technology studies (STS). STS is a much bigger and more diverse field than sound studies, but Helmreich helps me to orientate myself in the transition. Like me, Helmreich is interested in the relationship between science, sound, and the ocean (see Helmreich 2009; Helmreich 2016). His work has provided a structure for thinking about tricky scientific phenomena. Helmreich (2014) has identified scientific things (Helmreich uses ocean waves as an example) as phenomena that exist both as a material substance and as a scientific, measured concept. These scientific things are material (the phenomenon-in-the-world) and non-material (the scientific theory which explains and predicts the phenomenon). Helmreich (2009, 2016) further clarifies how anthropologists should engage with scientific things by suggesting we work "athwart theory." Like a crab scuttling back and forth, anthropologists should feel free to move between theory which

[13] See Interlude III for an expanded discussion on ontological politics.
[14] Acoustic energy is used in hydrocarbon exploration and does result and a geologic impact in that way.

explains the thing and theory which emerges from it. This frees up the researcher from any specific materialist or social constructivist approach and instead recognizes the thing as being formed by both contexts. An anthropologist working athwart theory is able to examine how a given phenomenon emerges from concepts, schemas, formulas, and hypotheses as well as examine its material make up. A boat, for instance, is not only all those scientific principles which allow it to float or the rituals enacted in building the vessel. The boat is also all the pieces of timber, iron, and rope which hold it together, the bodies who propel it, and the economies which support and motivate its voyage.

To help me map my movements as I work athwart theory, I have turned to actor-network theory (just like Helmreich and Sterne have). Callon, Latour, Law and Woolgar (Callon and Latour 1981; Callon and Law 1982, 1997; Latour 1987, 1993, 1996, 1999, 2005, 2010, 2013; Latour and Woolgar 1986; Law 1987, 2002) have provided a broad structure for understanding the development and change of scientific and technological objects. The materiality of any actor in ANT is irrelevant. What is relevant is that each actor can effect action in another networked actor. An ANT researcher's role is then to map those exchanges. ANT is thus agnostic of the materiality of the objects which produce a scientific field or piece of technology. While ANT does have its shortcoming—mostly notably in its ability to explain what networks are but not why they exist (Hakken 1999)—I have found ANT useful in making decisions about what was and was not contributing to the construction of underwater noise pollution and how those things interacted.

The technologies I discuss throughout this thesis are technologies of sensing, and as such they are intimately related to bodies. Many of these technologies allow me to enter the watery world and hear sounds beyond my individual capability. To understand these intimate relations, I enroll the figure of the cyborg. Haraway (1991) writes, "the cyborg is our ontology; it gives us our politics. The cyborg is a condensed image of both imagination and material reality, the two jointed centres structuring any possibility of historic transformation" (150). The cybernetic organism, or cyborg (Clynes and Kline [1960] 1995), is the organism augmented by technology (in the original, material sense) although current cyborg theory suggests that technology need not be material. It can also be a psychic technology that shapes our scientific sensing (in the Harawayian sense). A psychic technology is most often referred to as a skill or knowledge set that we must learn to manipulate the world. Language and arithmetic are examples of psychic technologies which allow for extensive manipulation. The cyborg is a body+. For me, it is the body+scuba or the body+hydrophone, although it can also be body+audiogram (see Chapters 2 and 4) or body+skill (see Chapters 5 and 6) which allow me to augment my hearing without plugging into technology. Haraway's words ring truest underwater since it is only through bodily augmentation that underwater noise pollution can be fully heard and made political. The entire modern history of marine sound has been structured through technological augmentation of the senses (Schwartz 2016).

Cyborg anthropology (Downey and Dumit 1997; Downey, et al. 1995; Gray 1995; Hakken 1999) developed from Haraway's writing around the end of the last millennium, during the rise of consumer access to digital technologies and biomedical interventions. Since then, it has become an intellectual touchstone for its application of feminist and critical theories. Most notably, cyborg anthropology seeks to frame the human-technology relationships as more than material, similarly to Helmreich's (2014) later contribution of scientific things. It attempts to shake up anthropology by decentering the human from the ethnographic narrative. As part of the greater posthuman movement (see Hayles 1999), these scholars made the technology or the science the focus of analysis. While I have my own doubts about how far anthropology can move away from the anthropos, it does set up a sort of intellectual freedom to wander beyond our human bounds to see how we extend out into the world.

Drifting Theories

By submerging theory, it becomes difficult to hold together all those promising theoretical positionings. While sharing many similarities, these theories do not naturally all fit together. They compete and contrast with one another. These tensions become all the more straining when placed in aqueous environments which makes everything stranger.

As methodological theories go, sound studies and multispecies ethnography are surprisingly difficult to pair. Most writings on sound (especially those in anthropology) have covered human sound worlds. Those writings which attune to non-humans have not payed attention to relational aspects and challenges. Those relationships are further strained underwater as sound studies in marine spaces become rare and writings on non-humans are further removed from human observations.

One might think that multispecies ethnography, Anthropocene studies, and STS should get along together easily, but the relationship becomes disturbed by the presence of sound. There already exists some contention within those fields as they attempt to negotiate their boundaries. Not all Anthropocene writing is multispecies or falls within the field of STS. Sound complicates because it has not been generally taken up as an anthropocentric problem. Sound and perception further push at the limits of what scholars are willing to claim in these fields.

This thesis sits within these diverging theories and tries to find some connection. Findings those places where theories overlap and clash is just as important as finding unity of thought. The tensions indicate the limits of these fields or new places to explore.

Sensing

Diving in the Great Barrier Reef is a very different experience than visiting a local aquarium. The aquarium keeps the watery world behind glass. You cannot smell the saltwater, feel its coldness, nor hear the crackling, snapping, grunting, munching sea life. The aquarium space is designed to limit the amount of noise from pumps and filters which could bleed into the exhibition space and to absorb as much of the racket as possible coming from visitors and bouncing off the smooth glass surfaces. Being in the ocean with marine life is a sensorial thing, and this is a thesis about sensing.

Traditional theory on sensing traces back to the phenomenology of Merleau-Ponty (1962) on perception. It is a type of phenomenology situated in bodily sensations. Generally, this strand of phenomenological investigations has served sound studies (Voegelin 2010, 2014) and marine studies (Picken and Ferguson 2014) well. But, that service is incumbent on the phenomenon in question to be sensible to the human body. For most of sound studies, the sensibility of sound is taken for granted. If it could not be heard, it was not within their realm.

Within anthropology, such phenomenological sensing of sound was further refined, mainly through Feld's acoustemology (Feld 1990[1982], 1996, 2015; Feld and Brenneis 2004). Feld proposed that sound was not neutrally sensed. All sound sensing was culturally mediated and included a sensual knowledge that encompassed more than just the physical world. Feld had provided an epistemological filter to phenomenology but acoustemology still generally fell back on physically sensing.

Sensing marine noise pollution demands modes of perception that stretch beyond humans' innate sensorial capacity. Due to some biological properties of the human ear, marine sound for most of its range is inaudible to the physical body (see Chapter 3 for more detail). Noise pollution exists at scales beyond the human sensorium and also requires a multispecies sympathy to comprehend how noise effects other beings. These realities of underwater sound and noise take the sonic experience well beyond corporeal hearing.

I must recruit transducers into a multispecies/cyborgic sensing in order to include these beyond-the-human phenomenologies. Transducers are special devices that, as

Johnathan Sterne (2003) puts it, "turn sound into something else and that something else back into sound"(22). They do the transformative magic trick that makes all modern audio equipment work. Take for instance a microphone which converts acoustic waves into an electric signal through the movements of a diaphragm and an electromagnet. Or, take a loud speaker that does all that in reverse. Transducers do not do their work with complete accuracy, nor is that always a desirable goal. The devices mediate the signal as they transform it by cutting off certain frequencies or adding in extra information (such as metadata) with the intent of making the signal useful to the system.[15] Biological organisms, too, have transducers. For mammals, it is the ear structure,[16] while fish use otoliths and swim bladders. All marine vertebrates and most invertebrates have a brain or a decentralized, sensing nervous system with a whole complex of innate and learned behaviors – knowledges – that further transduce acoustic signals.

Transduction entered the field of phenomenology through Gilbert Simondon (1992[1964], 2017[1958]) who was a student of Merleau-Ponty. Simondon opposed Heidegger's (1977) essentialist and instrumentalist approach to the phenomenology of technology (a sentiment shared by Ihde (2010)). In Simondon's terms, technology does not have one end use and instead, its use and development are shaped through a process of discovery. He uses transduction to define a process in which technical relationships are shaped and changed within human-technic systems rather than through outside inspiration. In this way Simondon's transduction mirrors the transductive work done by technical transducers.

This thesis is about the transducers around us who focus on underwater noise. It is about the beings and technologies that convert acoustic waves into useful and organized objects. Stefan Helmreich (2007) recommends the use of a transductive ethnography as "a mode of attention that asks how definitions of *subjects*, *objects*, and *field* emerge in material relations that cannot be modeled in advance" (632, emphasis added). A transductive ethnography explores how the agency to transduce manifested the work needed to link elements together through signals, the infrastructure that supports transmission, and the

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[15] By "useful," I mean that the system, such as a computer system can actively manage or manipulate the data. Useful can also mean that the signal has been paired down to be within the system's capacity such as the reduction in signal quality for telephone systems to be efficient. All this ignores the other reality that transducers can add unwanted information to the signal. That is, noise.

[16] Most human-made transducers mimic the function of the mammalian ear and some have gone so far as to incorporate actual body parts into the mechanism (Stern 2003)!

resistance within those networks. I am taking up Helmreich's call to think transductively and to attend to the larger networks and contexts that the transducers work in to define the field of noise pollution. I must also think transductively about myself as an ethnographer and the work I have done to place myself with in these networks. For I have done my fair share of transducing noise.

Importantly, transductive anthropology does not supplant phenomenology or acoustemology. Instead, it augments it by allowing sonic experience to be mediated by cultural frames and technological agencies.

> To think transductively is to attend to the earache, to imbalance, to all the embodied capacitances of the ethnographer—and to the work necessary to place oneself in particular networks, machinic and social. . . To think transductively is thereby also to consider ethnography itself as transductive—and the ethnographer as a kind of transducer. (Helmreich 2007, 633)

Through the process of transduction, the medium in which sound is consumed is no longer limited to the aural. Since transduction allows sound signals to freely change formats, a transductive anthropology is enabled to apply the same phenomenological and acoustemological techniques to tactile and visuals forms of sound without losing theoretical validity. Because transducers provide access to sound beyond the sensorium, transductive anthropology allows for a sound study beyond-the-human.

Echo-logics

The people I have worked with throughout this thesis engage with sound and marine beings in a wide variety of ways. They come from many different backgrounds and disciplines, making it difficult to identify one general theme to their interactions. What I did identify was a recurring practice to marine sounds that directed how they engaged with it. While the uptake and application of this practice varied, I have done my best to identify its qualities. I call these practices echo-logics[17] and offer them up as my contribution to the fields in which I am working. A variety of echo-logics appear throughout this thesis, so I will take time now to explain what unites them.

Echo-logics are practices of engaging with the ecology of sound. They are engagements that reflexively consider the relationship between the listener and the sounding being as well as the listener's responsibility in listening. They are engagements rooted in

[17] Not to be confused with Glazebrook's (2005) eco-logics.

practices of listening and sounding as developed by skilled listeners.[18] They are alternative engagements with non-human sound: a mode of deliberate, yet uninvited, listening in that challenges standard notions of eavesdropping on the environment.

I consider echo-logics to be practices because they require a continuous, active tracing of relationships between the listener and the sounding being and then between the listener and the wider community of interested subjects. One listens through assisting technologies (e.g., hydrophones, microphones, recording devices) or unassisted to the environmental sounds. The practitioner then communicates those sounds to a wider public through creative interventions, political action, or other dissemination tools (e.g., live steams, public lectures). This practice contrasts with other sound practices such as measuring and recording for machine learning and monitoring, use of sound as a tool (e.g., sonar, seismic surveying), or through purely inventive sound art. Echo-logics are practices which are consciously structured to produce and maintain engagement with the environmental soundscape. They connect potential listeners to sound subjects. They are practices enlivened by politics and a sense of environmental urgency.

The echo-logical practices I describe in this thesis are designed to directly engage with non-human animals firstly, but some principles can be extended to non-humans more generally. Non-human animals are the focus because they intentionally produce sound to communicate or for other vital functions as well as listen to sound through their own being. While trees, rivers, and storms produce sound, those sounds do not inhabit the same sort of information cycles and, thus, the listener's responsibility towards them is different. Anthropocentric sound, in this case, is an extension of biological (human) sound making rather than sound from objects. Finally, echo-logics is an inappropriate form for engaging with human sound worlds as humans are capable of direct dialogue and should be direct participants in further sounding practices.

Echoes

Echo-logics, in other words, involves a kind of participatory listening, though always at some kind of remove.[19] There is a relational and ethical dimension to this listening across

[18] Skilled listening is based on Grasseni's (2004; 2007) skilled vision which is discussed later in this chapter and fully developed in Chapter 5.
[19] See Metcalf (2008) for more on mediated intimacy with non-human beings.

separations and sensory divergence, as echo-logics assumes that this listening results in processes of onward sounding. Let's unpack this.

The first part of echo-logics is the echo. In acoustics, an echo occurs when acoustic waves are reflected off a surface which delays its perception by the listener. An echo is always out of sync with its source. It is sound delayed, redirected, and distorted. Echoing technologies such as sonar are even able to transduce the echo into other media such as visual displays. In literary forms, an echo is an imperfect repetition. It can be a repeated piece of a dialog produced from a different source with or without the same intent. Or, an echo can be a repetition in form but lacking key qualities found in the original.

The echo in echo-logics draws on these properties. The echo is out of sync and of a different quality to the original sound event. These properties limit and free the way the listener engages with non-human sound. To manage this, the echo has two senses. First is the recognition that the listener is perceiving the echo of the non-human's sound world. Second is that the listener has the responsibility to create further echoes.

Attending to the sound worlds of non-humans as echoes places the listener in an important relationship with the sounder. The echo is a recognition of the barrier between the listener and the sound producer. Non-human animals produce and perceive sounds in their world as they interact with each other and their environment. This creates a particular context and a constellation of meaning for the non-human which the human listener can never fully comprehend. Take for example the "songs" of baleen whales. The whales produce their calls to communicate and coordinate actions between conspecifics who may be kilometers away. They are not produced for the aesthetic enjoyment by human beings. The human listener is always listening in to these other sound worlds. Because of that, it is difficult for humans to communicate with non-humans through the same familiar modes in which we communicate with each other. As of now, humans are not fully able to understand the communication systems used by whales.[20] We can only listen and infer. The echo respects the imbalance of this relationship by acknowledging its out-of-syncness. This means that all echo-logical listening begins as anthropocentric.

Anthropocentrism in this case is a critical anthropocentrism and concerned with communicating to other humans. It is a recognition that listening is limited by the affordances

[20] Current research is attempting to do just that and decode humpback whale songs, but the final results are still far off. For more information, see earthspecies.org.

of the human body and that attempts to uncritically extend beyond the human risk violating the non-human's being. Acknowledging the human limits of listening, the listener is relieved of responsibility to generate objective truth. This freedom allows listeners to play, experiment and regularly reform their understandings of other sound worlds. It is an acknowledgement of the unavoidable imperfection and incompleteness of such knowledge which allows echo-logical practice to be generative and respectful.

Within this echoed relationship, the listener begins to takes on certain responsibilities. If the listener cannot dialogue—engage in a clear, reciprocal communication channel—with the non-human, then the listener takes on the responsibility to echo on the non-human's behalf. In order to practice echo-logics, one must affirm that they listen so that they may echo. This means that the listener takes on the responsibility to bring the sound worlds to the public. Where echo-as-barrier provide a constraint on sonic relationships, echo-as-resounding opens those relationships up to creative possibilities. Because the echo is already out-of-sync, then the response can work creatively with sounds to carry the intended impact.

Logics

Where does the responsibility to echo lie? It is the second part of echo-logics that structures the response. This logic is a way of thinking and acting which is shaped by the echoed relationship. What can be said about the non-human's sonic world when the listener recognizes those boundaries that separate the human and non-human bodies? How does the listener shape a further echo given the affordances of any venue or the transductions needed to make the sonic perceptible to human sensing?

As an echo-logical practitioner begins to work with the echo, they start to move from an anthropocentric to a relational position via critical anthropocentrism. Listening in this manner encourages the listener to acknowledge the subjectivity of the non-human. Through processes illustrated in this thesis, the listener begins to catch glimpses of the non-human's world. Such interactions build or reinforce more-than-human values and politics in the listener.

The transition to rationality lies in the ontological politics (Stengers 2018) of listening. Through the practice of echo-logics, listeners are making a political choice to echo. Echo-logical practitioners find a moral need to work with and advocate for non-humans. It is a recognition that we must live in a world with other beings, and the logics one follows attempts to find an appropriate way of living.

Echo-logics also finds its actions in conservation biology (Soulé 1985) and the ethics of public dissemination. What good does listening in on the non-human animal do for the creature if action ends at listening? It is the listener's responsibility to use echoes to engage the public in creating a positive change in the non-human's sonic world. The goal of echo-logics is to close the gap between the scientific, the public, and the political. LaBelle (2018) affirms the political power of the echo through the "echo-subject" which can amplify or transport a voice and give it power.[21] Echo-logics intends to create echo-subjects from non-human sounding in order to make their sonic worlds more hearable, visible, and touchable.

There are many modes of echo-logics, dependent on the context that the practice is intended to address. Some may choose to utilize report writing and expert witnessing in order to effect direct political change in legislative bodies. Others may facilitate online streaming or provide public lectures in order to educate the public. The more creatively inclined practitioners may produce artistic works in order to inspire affect in listeners. These practices are forms of reaching out, but they also allow the practitioner to further explore their relationship to and understanding of other sounding beings. In short, as I will demonstrate in the context of underwater noise, echo-logics pulls the participant through possible sonic worlds (Voegelin 2014) in order to come to a respectful recognition of the sound worlds of non-humans.

The Dive Plan

As I have already noted, this thesis presents multimodal sound. You will find audio recordings and images of sound throughout the text. This thesis is designed to augment and amplify the argument of synesthetic sound and listening. I learned to hear underwater noise pollution through listening to sound and I present these sound recordings to help develop your ability to listen. As such, I highly encourage you to listen to the audio when prompted and to follow any given instructions.[22] At times, the audio links directly to the content of the text while at other times the audio acts as a sonic vignette. I also highly encourage you to treat visual representations as sound recordings rather than images. Doing so will help you keep a frame of mind that will assist you in your reading. Hopefully, by the end of this thesis, you will have developed an improved listening practice.

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[21] See Chapter 6 for more on echo-subjects.
[22] Direct instructions on how to listen to the audio recordings are given in a special note on page xiii.

Throughout this thesis you will be introduced to people and creatures that are highly involved in the marine sound world. Consequently, many of the (human) individuals I work with are also primary sources for marine sound research. In order to clarify what information I retrieved through participation and interviews and what information came from published sources, I have chosen to use first names for personal interactions and last names for publications.[23]

In the following chapters, I explore how different, interlinked communities have come to hear and understand underwater noise pollution. The following chapters are presented in a loose chronological order of my fieldwork. This is done to reflect my own process of learning to hear noise in the Reef. Each experience has allowed me to grow and refine my own sonic sensitivities, and I can think of no better way to impart that information on to you than to structure this thesis around my own research-driven arc of learning how to hear and, in turn, to resound as a modest practitioner of my own echo-logics.

In between these chapters, I have added four interludes. These spaces allow for an extended meditation of key philosophical discussions that are threaded through this thesis. In the first three, I explore transduction, phenomenology of non-humans, and ontological politics. In the fourth interlude, I discuss how those threads come together to drive echo-logics.

In Chapter 2, I outline the current state of knowledge on underwater noise pollution. I review historical developments in the concept of underwater noise pollution through key scientific and governmental documents. This chapter demonstrates how increased knowledge of the hearing sensitivities of marine animals has led to a growing concern for the impact of acoustic energy via shifting scientific and legal definitions of noise.

In a return to Helmreich's scientific object (Helmreich 2014) and moving athwart theory (Helmreich 2016), underwater noise becomes both an abstracted force in the form of guidelines and measurements as well as physical phenomenon through the actual impact of acoustic energy on the health of marine life. This moving back and forth is demonstrated through public outcry and revisions of marine noise policy in the wake of mass whale death. The tracing of relationships between the abstract and the concrete continue through the

[23] There is one exception, Dr. Deborah Giles (Chapter 5), who prefers to go by—and is almost exclusively known by—her surname.

growing inclusion of non-mammalian species into the category of sounding beings sensitive to noise exposure.

Interlude I meditates on the philosophy introduced by Gilbert Simondon and expanded upon by Helmreich and Sterne. Transduction here is used to refigure the relationship between humans and technical objects in a way that deviates from earlier phenomenologies of technology which proposed a utilitarian relationship with the technical object. The transductive relationship is more dynamic, continuously shaping both the technical object and the user. In this interlude, I propose that approaching technical relationships through the philosophy of transduction can provide new pathways to technological sensing.

Chapter 3 introduces the sound worlds of recreational divers. It takes place onboard the dive vessel *Passions of Paradise III* as I journey with the crew on regular Reef visits. To some degree this chapter replaces the traditional methods chapter as I wrestle with the shortcomings of utilizing established phenomenological techniques to listen to marine sound. Through the activity of diving, I push against the bodily limitations of underwater hearing and explore how divers use sound to navigate and communicate. To compensate for my desensitized hearing, I also introduce the method of listening via hydrophone.

The difficulties in hearing marine sound highlights the discrepancies between the sensory abilities of terrestrial and marine animals. These differences are what, in part, makes marine noise so isolated and inaccessible. Using Nagel (1974), I argue why a multispecies approach to sensing sound requires a move away from established phenomenological practices and towards a transductive approach. This enables the rejection of a sound study of only aural practices in favor of a multisensorial, synesthetic study of acoustic energy.

In Interlude II, I elaborate on the difficulties of attempting to understand the sensory worlds of non-human beings. Chapters 2 and 3 have signaled to these challenges, and it is in this space that I fully explore the historical development of thought on this subject. In reviewing the contested (and at times opposing) positions in the area, I suggest a compromise. This middle ground position is purposed not to resolve the tensions in the field, but to allow a way forward for my work while acknowledging the limitations and potential overreach in any study which proposes to reach across the species divide.

The relationship between the oceanspace and virtual space become the focus of Chapter 4. In this chapter, I examine the practices of acousticians working in the Reef as they seek to create accurate models of noise propagation in the environment. Such modeling requires the reduction of complex variables to make the model manageable while also maintaining referential associations to maintain model validity. To demonstrate this, I look to how acousticians use tables, charts, maps, and formulas to recreate a world in miniature and how those references were created through connection to physical properties.

The transformations from referent to reference in scientific practices are a recurrent theme in works of Bruno Latour (Latour 1987, 1999, 2013; Latour and Woolgar 1986). It is through his guidance that I come to understand the process of model making as a form of speculation. Models become a type of scientific fiction, not in that they make up fantasy worlds, but as constructed objects which allow us to probe the worlds we live in. Through speculation and careful construction, model making demonstrates an intense connectedness to the environment rather than the distancing many social critics have accused it of.

Building from the previous two interludes, Interlude III explores the politics of taking on a multispecies project. Here, I examine the growing literature on ontological politics and allied programs. Ontological politics proposes a non-hegemonic political discourse that allows for the intersection of multiple life-worlds. Through my examination of this form of political discourse, I demonstrate the difficulties of integrating new political views into the current Australian political framework for governing environmental concerns.

Chapter 5 sees this thesis leaving the Reef in favor of cooler waters. During a period of little activity in acoustic monitoring in the GBR, and I found myself compelled to find a comparative field site. At the suggestion of my supervisors, I took the opportunity to investigate the noise pollution management techniques being employed in the Salish Sea, on the border of the United States and Canada, specifically in relation to orcas. While the Pacific Northwest seems a far cry from Tropical Queensland, this move was further encouraged by Australian researchers looking to import some of those techniques to the marine park.

The plight of the declining orca pods in the Salish Sea has generated many different listening practices in the area. Riffing on Grasseni's (2004, 2007) notion of skilled vision, I develop skilled listening as a way of describing these practices. While skilled listening retroactively applies to those practices described in the previous chapters, I present it here because the concept only started to make sense to me in the context of the Salish Sea.

Bringing transduction, non-human experience, and politics together, Interlude IV fleshes out the practice of echo-logics which I have briefly described above. The previous three interludes introduced aspects of echo-logics which combine together here into a coherent argument for an echo-logical practice.

Returning to the Reef in Chapter 6, I reflect on the politics of resounding through artful practice. I speak of resounding as the politics of presenting echoes. In doing so, I explore how art may act as an alternative pathway to state politics. As part of my participation in sound art, I present and reflect on a collaborative sound artwork which attempts to make obvious the urgency of the sonic reef world to the public.

Westerkamp (2002) and Voegelin (2010, 2014) help me to formulate an understanding of sound art, allowing it to become a tool for understanding sonic relationships. This chapter treats sound art as a skilled practice for listening and responding to the sonic world. It is through artful practice that room for other worlds can potentially be built. While imperfect, the use of sound art demonstrates alternative tactics for resounding that engage in other forms of knowledge.

Chapter 7 concludes this thesis with a summary and reflection on the ethnographic material. As part of my conclusion, I address some of the questions and concerns of Reef stakeholders, especially those of GBRMPA. I also make a few recommendations towards the management of underwater noise pollution and future projects. It is through reimagining the human/non-human relationship and structures for sensing and scaling environmental management policy that we may come to responsibly manage the Great Barrier Reef during the age of the Anthropocene.

Chapter 2: Underwater Noise Pollution

In 1953, Jacques Cousteau and Frédéric Dumas proclaimed "the sea is a most silent world" (131). While Cousteau and Dumas's comment on underwater sound (or lack thereof; see pages 131-133) seems contradictory to what is now know about sound and sea life, I find it noteworthy how long these sentiments persisted (and still do) in the scientific literature, public policy, and legal documents. However, given the mounting evidence, scientists should no longer be able to naively state, "I doubt whether the explosion [of dynamite] is anything more than a dull, insignificant noise to [the sharks]" (133). Underwater noise pollution is now an internationally recognized environmental hazard (Unclos 1982), with growing, if uneven, support from national governments and international organizations. When and how did researchers buck the "silent world" model of the seas to grow underwater noise into a global pollutant?

In this chapter, I will begin by examining the component parts of underwater noise pollution that allow it to emerge as a distinct substance. Once established, I explore the epistemological turns in underwater noise research, starting at a nexus in the mid-90s when research, funding, and policy making began to coalesce. From there, I will trace backward and forward in time, uncovering the roots and ramifications of the sonification—and noisification—of the world's oceans. Through this structure, this chapter outlines the growing concern for underwater noise pollution which motivates the actions described in the rest of this thesis.

Underwater, Noise, Pollution

Underwater noise pollution as a concept has not been adopted as enthusiastically as other maritime environmental threats by environmentalists and research scientists. Ocean acidification, oceanic dead zones, and alien species are more salient terms in marine ecology, being readily used in conference papers, articles, and books. One reason for this, I suggest is that underwater noise pollution, based on its component parts (i.e., "underwater", "noise", and "pollution"), is distinct from other marine pollutants and hazards because it drastically shifts normal, human experience and demands sympathetic relations with other beings living in radically different sensory worlds. These elements are lacking in other pollutions and hazards which are detectable in gradual environmental shifts, with observable impact on organisms both in the lab and in the field (except for heat and light pollutions which are kindred to noise in that they are energetic pollutants and can cause stress but may not leave noticeable effects when at low levels).

Placing noise pollution "underwater" is the first major shift in how humans normally experience the environment. As I have described in the previous chapter, humans are not well equipped to sense underwater sound. Underwater, sound travels faster and further and, since the body has a similar density to water, sound passes through humans quite easily. Sounds without sources become ghostly phenomenons for divers, and the marine environment is filled with cryptic noise. Merely becoming submerged is an arduous and disorienting process for most people. It requires special equipment, skills, and funds to spend any significant amount of time underwater. It is a place that we humans are unaccustomed to and, therefore, are unaccustomed to think about. People from Western industrialized nations tend not to give too much thought to the push and pull of currents, shifts in the thermocline, or changes in buoyancy that marine life sense in the day-to-day. Nor do they concern themselves with the propagation of acoustic energy underwater.

"Noise" itself is a problematic term partially because it is such a common word in the English vocabulary. While there are many interpretations of noise, for my purposes, I will focus on the bifurcation of noise into two approaches that reflect the noise pollution literature. The information approach utilizes Claude Shannon and Warren Weaver's (1949) definition that figures noise as a distortion added to a signal as it is conveyed through a medium. Either through the deletion, addition, or alteration of information in a signal, noise becomes a disrupting force. It pulls the receiver away from a faithful transmission. The second approach to "noise" figures on the experiential reception of noise. In this figuration, noise is unwanted acoustic signals that can annoy or injure the receiver. This position has been enthusiastically taken up by authors of sound studies (see Novak 2015 for a keyword on "noise"), who have demonstrated the impact of noise on human society. Noise in this sense pushes rather than pulls the receiver from the center, as being at the center of noise becomes too dangerous.

Both approaches describe an innate relationship between the noise producer, the medium, and the receiver. But in the case of defining or determining noise pollution, a secondary, important, relationship forms: that between the observer and noise perceiving organism. The observer must in some way sympathize with the organism's ability to perceive. This sensuous sympathy enables the observer to recognize the organism's capacity (and limits) to sense and to model what the organism might be experiencing (its *umwelt*).

Returning to Cousteau and Dumas, these oceanographers were unable to fully sympathize with sharks' ability to hear and, thus, failed to see them as perceiving noise. An even deeper level of sympathy is required to evaluate the *impact* of noise. The observer must recognize *both* the sensuous and emotional state of the other in the presence of noise to judge its impact. The failure to sympathize on this level leads to broad conclusions and poor policy (the implications of which will be discussed later).

Pollution and noise are intimately bound concepts. "Pollution" has long been a category of anthropological concern. Opposed to the pure and the sacred, pollutants are corrupting substances that poison or harm through the excess of the pollutant. Discussing the difference between the sacred and the polluted, Claude Lévi-Strauss (1966) has stated that "it could even be said that being in their place is what makes them sacred for if they were taken out of their place, even in thought, the entire order of the universe would be destroyed" (10). Mary Douglas (1966) developed similar thought in *Purity and Danger*, identifying the origins of pollution in the order of things themselves. For Douglas, things that disrupt order become identified as pollution. Her famous definition of dirt as "matter out of place" (35) positions pollution as an invading force, putting things in places they should not be.

Pollutants, unlike natural disasters or disease, are almost always attributed to human causes. Douglas identifies pollution as transgressions against the social structure. Sacred systems are implemented to maintain social systems in what Barth (1969) argues as boundaries of significance made of overt signs and value orientations. As Western society moved away from supernatural systems of signification towards rationalization during the Enlightenment, nature and natural kinds became the new locus of the sacred (Latour 1987). Around this time, "pollution" begins to be recognized as a disruption of the natural order. The sense of pollution as an environmental contaminate developed in the mid-1800s, but did not become commonly used until a century later (Harper n.d.-b). This shift corresponds with the solidification of a nature/culture dichotomy that saw the incursion of the cultural into the natural as both progressive and destructive (Latour 1987). Variations of these sentiments are still prominent in the natural sciences, including conservation and ecology (Helmreich 2016; Latour 2013).

Underwater noise pollution severely shifts and alienates the human experience of sound. Pickering and Rice (2017) apply Douglas' (1966) definition of dirt to noise and conclude that noise *is* sonic dirt. Riffing on Pickering, Rice, and Douglas' formulation, I suggest that underwater noise pollution exists when human sounds are out of place and distant from human hearing, which then allows the pollution to proliferate further. The sound is out of place because it disrupts the ecological soundscape in which marine organisms have evolved an thrived (Krause 1992). Submerged in an environment that distorts the sensorial experience, it can be difficult for a human listener to distinguish between endemic and introduced sounds. The crackle of snapping shrimp throughout the tropical and subtropical coastal waters may not be readily identified as zoogenic noise to the casual diver and the low hum of the dive boat might be barely perceptible over the sound of the diver's own breath. These factors isolate humans from the marine soundscape. It is through this isolation that humans fail to sympathize with others. For Cousteau and Dumas, the underwater world was silent because of *their* auditory deficiencies, not those of the *fish*.

Constructing Sonic Beings

I have described how the components of "underwater noise pollution" alienates the human experience and problematizes multispecies relationships. Now I will explore how "underwater noise pollution" as a bound concept begins to re-frame human listeners and normalizes other marine listeners. Rather than starting at the emergence of underwater sound research, which is fragmented, I will begin at the point when research, technology, and government policy begin to intersect.

Two events occurred in the mid-1990s in the United States that brought underwater noise pollution to the forefront of environmental policy. The Marine Mammal Protection Act (MMPA) of 1972 was scheduled for reauthorization in 1992, which led the National Research Council (NRC) to commission a study on the known impacts of low-frequency sound (NRC 1994). Around the same time, the Acoustic Thermometry of Ocean Climate (ATOC) experiment proposed using low-frequency sound to measure the change in water temperature in a large area of the Pacific Ocean. ATOC found itself embroiled in a highly contentious public debate that folded back to inform the NRC report. The fallout from these events would cement underwater noise pollution as a real and legitimate policy concern, first in the United States and then in other industrialized countries.

The Marine Mammal Protection Act (MMPA) was part of a wave of environmental acts that swept through the US congress in the 1970s. The MMPA was one of the broadest of these acts, establishing all marine mammals in US waters as protected species. This effectively stopped the hunting, killing, and trading of marine mammals as well as introduced new regulations for maritime activities that might bring harm. The intent of the MMPA was to maintain stable populations of marine mammals, which were experiencing a general population decline. As is typical for this period, underwater noise was not mentioned in the original wording of the MMPA.

Twenty years later, in 1992, noise could no longer be ignored. An increase in ocean traffic, an intensification in mineral exploration, and new sound-based research projects were increasing the ambient sound levels of the world's oceans. The Third United Nations Conference of the Law of the Sea (UNCLOS III) in 1982 had recognized introduced energy as a marine pollutant which included underwater noise, making it no longer feasible for regulating bodies such as the Marine Mammal Commission to ignore underwater noise pollution. Two reviews examining the known factors of underwater noise and marine mammals were commissioned by the National Research Council (NRC 1994) and the Minerals Management Service (MMS; later published as Richardson, et al. 1994). Both reviews found the literature lacking. Data on the hearing abilities of marine mammals were mostly available for aquarium staples like pinnipeds (i.e., seals and sealions) and odontocetes (i.e., toothed-whales, dolphins, and porpoises). Data on mysticetes (i.e., baleen whales) were almost non-existent as their size and migratory nature made it near-impossible to test their hearing range in controlled conditions. For my purposes, I will focus on the NRC 1994 report as it also offers a critique of the MMPA's restrictions and enforcement. Many of the points made in the NRC report are also reflected in Richardson, et al. (1995).

The recognition of underwater noise pollution is generally traced back to Roger Payne and Douglas Webb's 1971 study of acoustic signaling among migrating fin whales. Payne and Webb briefly acknowledge the impact of increased shipping on the fidelity of low-frequency signaling among baleen whales. The NRC report also cites a handful of publications predating Payne and Webb (1971) which mostly report on the acoustic sensitivity of various species, or the ambient noise of the ocean. This report therefore situates the genesis of scientific underwater noise research in the late 1960s to the early 1970s. The NRC report, however, completely ignores other sources such as anglers who have acknowledged the impact of anthropogenic noise on fish behavior at least since Izaak Walton published *The Compleat Angler* [sic] in 1653. This omission reinforces the separation of scientific and other knowledges that persists in the field. This pedigree establishes underwater noise pollution as a scientific/mathematical problem.

The scientific/mathematical orientation of underwater noise pollution has certain effects on subjectivity of both sound and listening bodies. As scientific objects, both acoustic energy and listening beings become quantified, abstracted things. Through quantification, these things can become subjects of management bodies and legal doctrine which thrive on objective, quantifiable parameters.

Audiograms play a prominent part in the quantification of animals and their sensory experiences.[24] These U-shaped charts display an animal's hearing threshold, the lowest energy level (measured in decibels) needed to detect a given frequency. Producing an audiogram most often requires a cooperative, captive animal. For this reason, audiograms on dolphins, seals, and sealions could be generated at this time, while complete audiograms for baleen whales did not exist. The NRC report did suggest the establishment of a "Stranded Whale Auditory Test (SWAT) team" (1994: 48) composed of scientists ready to conduct auditory evoke potentials (AEP) tests on sick, stranded, or injured whales. AEP tests are invasive tests that use implanted or attached electrodes to measure brain responses from auditory signals which can be used to produce an audiogram (Richardson, et al. 1995). The SWAT team would essentially convert physical, dead and dying whales into abstract data points. As of the NRC's follow-up report in 2000, the SWAT team had not yet formed, and there is no evidence that it ever did. Instead, researchers had to continue to rely on observational data on the behavior of the whales in response to sound sources in the oceans.

The properties of audiograms and whale observation data produced two linked schemas of underwater noise pollution: noise pollution was any signal that a protected species could hear, and exposure to noise pollution caused adverse behavioral changes. It was this black and white mentality to noise pollution that the NRC report directly critiqued.

The "120-dB criterion" is one of the best examples of rigid threshold schemas as a source of poor policy. The 120-dB criterion derives from two studies of gray and bowhead whales summering in the North Pacific and Arctic oceans respectively (Ljungblad, et al. 1988; Malme, et al. 1983, 1984; Malme, et al. 1988; Richardson, et al. 1985; Richardson and Malme 1993; Richardson, et al. 1986, 1990). These studied observed behavioral changes of the migrating whales when exposed to low-frequency sounds with a perceived energy value of 120 dB in water (re 1 μPa at 1 m).[25] Following the established logic, policy makers in the National Marine Fisheries Service of the U.S. Department of Commerce determined that broadband signals at or above 120 dB could be detected by whales and should be regulated (NRC 1994). Regulators found the 120-dB criterion to be such an effective, though informal,

[24] See Chapter 4, page 95 for a visual representation.

[25] Read as: referencing one micropascal at one meter. This is the normal reference for sound pressure levels measured in water. The reference for sound pressure levels measured in air is 20 micropascals at one meter.

tool that they attempted to apply it to nearly all marine mammals, regardless of hearing thresholds for specific species. As the NRC report argues, “that the 120-dB number is considered to be such an important regulatory criterion is testimony only to the paucity of our knowledge about marine mammals” (1994: 20). Part of this “paucity of knowledge” is a lack of data on how much energy is needed to produce temporary or permanent threshold shifts (i.e., loss of hearing; TTS and PTS respectively). Workplace safety regulations target energy levels that can cause TTS in humans (90dB in air re 20 µPa at 1 m), but underwater noise regulations do not recognize the difference between perception and harm in marine mammals. The 120-dB criterion becomes even more problematic because many marine activities, including research, operate at 120 dB or more.

A large part of the NRC critique of the 120-dB criterion and the MMPA centers on the definition of a key regulatory term: “take.” The regulatory power of the MMPA lies in its ability to limit or prohibit the “taking” of marine mammals. The MMPA defines “take” as “to harass, hunt, capture or kill, or attempt to harass, hunt, capture or kill any marine mammal.” In relation to underwater noise pollution, the NRC found fault in the MMPA’s failure to define the scope of harassment. Regulators took a conservative approach because of this, identifying any change in an animal’s behavior as harassment. Compounding problems, commercial fisheries were exempt from MMPA regulations as long as they reported the number of animals accidently killed, while scientific research projects were under strict scrutiny if it was likely the research would take marine mammals. The NRC argued that the regulations on taking by scientific research need to be relaxed. Otherwise, underwater noise pollution research could not be advanced as such research would necessarily cause a great deal of taking. It is precisely the confusion on taking that lead to the controversy surrounding the ATOC experiment.

The Acoustic Thermometry of Ocean Climate (ATOC) experiment proposed to measure ocean temperatures using high-energy acoustic pulses. The experiment was funded by the Strategic Environmental Research and Development Program, a swords-to-plowshares initiative created to convert defense infrastructure into environmental research tools (Potter 1994). ATOC was already benefiting from decades of defense research on underwater acoustics. Since the advent of sonar and the submarine, the world’s navies heavily invested in vast hydrophone arrays and detailed research on the propagation of sound in water. Now, in the post-Cold War era, these hydrophone arrays were freed for general scientific research (Schwartz 2016). ATOC was not the first experiment of its kind, being preceded by the Heard

Island Feasibility Test (HIFT). The HIFT was a pilot study that sent a one-off acoustic pulse from the sub-Antarctic island through the world's oceans to test if the pulse could be detected by various hydrophone arrays scattered around the globe. Late in preparations, the researchers became aware of the MMPA (Potter 1994). It is at this point that "take" became a key issue.

Due to the MMPA's low threshold on what it considered to be a take, the HIFT researchers were advised to include all marine mammals in the surrounding region as potential takes (Potter 1994). This encompassed several hundred thousand animals and meant that the permit could take up to a year to process. The HIFT researchers were ultimately able to apply political pressure to get the permits within time for the test. The HIFT experienced opposition from environmentalists who doubted the objectiveness of the permit evaluation process. Learning from the HIFT, ATOC lowered the energy level of its acoustic pulses and implemented an expanded marine mammal observation program. When it applied for permits, ATOC followed the same advice given to the HIFT and declared a potential take on a significant portion of Pacific marine mammals. ATOC hoped that its risk reduction would allay the concerns of environmentalists. It did not.

A February 1994 post on the "Marmam" (marine mammal) listserv made by population biologists Lindy Weilgart and Hal Whitehead questioned the validity of ATOC (Potter 1994). Weilgart and Whitehead's post warned the scientific community that ATOC proposed to transmit sounds 10 million times louder than levels that cause pain in humans. This claim was a severe misunderstanding of the properties of sound in air versus sound in water. ATOC researchers in the listserv tried to explain the project, but failed to contain the situation as others began to spread the message to other listservs and Weilgart and Whitehead became more adversarial. By the time of the permit's public hearing, Weilgart had convinced the *Los Angeles Times* to cover the ATOC controversy which lead to an article presented almost completely from Weilgart's stance. The story was then picked up by several other news sources and sparked public outrage. Much of the outrage centered on the public's misunderstanding of "take." In the public's imagination (spurred on by secondary news sources) "take" was equated to "killing" or "maiming." Under such interpretations, it was, of course, more than reasonable to be upset at an experiment which proposed to kill a large portion of the Earth's marine mammals.

The fallout from the ATOC controversy resulted in two US Senators strongly opposing the experiment, six additional years of environmental impact research, and millions of dollars spent (NRC 2000; Potter 1994). Importantly too, the ATOC controversy brought underwater noise pollution into the mainstream consciousness. The resistance to ATOC and the resulting publications, particularly the original *LA Times* article "Undersea Noise Test Could Risk Making Whales Deaf" (Paddock 1994), highlights the discrepancies between the public and the scientific understandings of noise pollution. The *LA Times* article portrays the oceans as a pristine, untouched environment, which played on the public's naïveté to the amount of anthropogenic sound already being pumped into the seas. ATOC proved that oceanic researchers not only had to contend with governmental and scientific constructions of underwater noise pollution but had to consider the public's construction as well. It also problematized environmentally motivated research, which now must balance the monitoring of one environmental problem with the possible introduction of new pollutants.

A series of events in the new millennium brought underwater noise pollution to public attention once again. In 2002, 17 whales beached themselves in the Canary Islands following NATO exercises (Dyer 2002). Similar events occurred in the Bahamas in 2000 and the Greek islands in 1996. All stranding events coincided with naval exercises. Investigative research identified low-frequency active sonar, which produced high energy, low-frequency pulses to detect submarines at long range, as the probable cause. These stories were picked up by the mass media and articles like "Death Knell" in *The Guardian* (Dyer 2002) caused a public outcry. The result of this public awareness was a system of international and regional agreements that have limited the use of active sonar in certain environmentally sensitive regions (Scott 2004).

During this period the formulation of underwater noise pollution focused particularly on observable harm, mostly to charismatic animals. The hearing abilities of some of the largest animals in the oceans were only beginning to be understood, which produced an anxiety over new sources of harm. A lack of data and conservative policies associated noise pollution with the most visible signs of distress in marine mammals. This period also often treated noise pollution as an event. Pollution was produced through scientific research or naval activities and most commonly through low-frequency pulses. The exclusion of fishing and shipping from the MMPA suggests that noise from industrial shipping and fishing were not considered significant pollution. This period also saw the advent of a nascent public recognition of the existence of underwater sound and noise pollution. These interlinking themes and concerns persist in current research areas, particularly marine mammal research (André, et al. 2009).

Constructing Sonic Spaces

If the late 20th century and first decade of the 21st were marked by the growing recognition of marine mammals as sonically sensitive beings—and with this a growing concern to prevent individual harm—the past ten years have been marked by a shift to an ecological model, partially through the recognition that other marine animals are also sonically sensitive. This newer wave of research also shifts focus from specific sonic events such as ATOC or geological surveys to the general and local rise in ambient noise in the oceans. In this section, I will explore these new sonic spaces being formulated in the scientific literature.

The move towards an ecological approach to underwater noise pollution is rooted in the growing recognition of hearing beings outside of the class Mammalia. A review by Popper and Hastings (2009) traces the study of the effects of underwater sound on fish to the mid-1970s, but the material is so sparse that they supplement the review with "grey" literature, reports produced by industrial research not peer-reviewed. The lack of data was identified in the NRC (1994) report which called for more research on organisms that supported the marine mammals' food web. A review by Williams, et al. (2015) indicates that while marine mammal research dominates the field, fish and invertebrate research has greatly expanded since 2000 (marine reptiles remain understudied). As more aquatic animals were acknowledged as reliant on and/or sensitive to underwater noise, a web of sonic connections was traced between species and in association to human activity.

Facilitating this transformation was the development of soundscape ecology. As described by Pijanowski, et al. (2011), soundscape ecology is dedicated to the study of the combination of biological, geophysical, and anthropogenic sounds as well as the change in the soundscape due to certain stimuli. The goal of soundscape ecology is to demonstrate how one sound event can impact another and how organisms adapt to changes in the soundscape. Soundscape ecologists also argue that the health of an ecosystem can be measured by the amount and diversity of biological sounds being produced (Servick 2014). The founding principle of soundscape ecology is the acoustic niche hypothesis proposed by Bernie Krause in 1992. The acoustic niche hypothesis suggests that ecosystems evolved in such a way that different species communicate at different frequencies and during different times of the day, so all communications are as clear as possible. These principles have made their way into marine sciences and play a key role in the new trajectory of underwater noise pollution research.

A good place from which to explore this newer configuration of underwater noise pollution is Slabbekoorn, et al.'s 2010 review titled "A noisy spring." A play on Rachel Carson's (1962) *Silent Spring*, "A noisy spring" reviews the available literature on the effects of rising sound levels on fish. Slabbekoorn, et al. was one of the first reviews to tackle the general rise in ambient noise on fish ecology. The authors recognized the need to move the focus of research away from short-term acoustic events and towards continuous sound generators, "although sonar, piling and explosions typically attract most attention, it is reasonable to argue that the greater impact on fish will be from less intense sounds that are of longer duration and that can potentially affect whole ecosystems" (Slabbekoorn, et al. 2010, 424).

Two years after Slabbekoorn, et al. (2010), the United Nations Environmental Programme (UNEP) published their own report on underwater noise pollution (UNEP 2012). The UNEP report is interesting because it demonstrates a move towards diverse environments, organisms, and noise sources. Unlike other national and international reports (e.g. NRC 1994), the UNEP report incorporates a variety of marine ecosystems. Previous scholarship tended to treat the ocean as one holistic system. This may be due to the focus on cetaceans and pinnipeds that often occupy open marine environments. UNEP localizes the sonic environment to include enclosed areas such as bays and estuaries as well as differentiating between coastal zones, reefs, and open oceans. By doing this, UNEP recognizes that stressors impact different regions unequally.

In terms of noise mitigation, UNEP recognizes two broad categories: noise control at the source and spatio-temporal restrictions. Noise control at the source has been a consistent mitigation practice since the 120-dB criterion and NRC (1994). UNEP raises the source limits to 180 dB for cetaceans and 190 dB for pinnipeds following changes made previously to US regulations, but the principles remain the same. The spatio-temporal restrictions are more interesting here as they represent a broadening understanding of underwater noise. While a few spatio-temporal restriction recommendations can be found scattered throughout earlier reports, the UNEP report demonstrates a stronger emphasis on this form of mitigation. The advent of exclusion zones and marine protected areas reposition underwater noise as a spatially distributed pollution. Temporal exclusions based on the migratory and nursing patterns of whales also frame noise as a temporally sensitive pollutant, with risk of harm fluctuating in certain areas throughout the year. These spatio-temporal restrictions force noisy activities to sync with annual patterns occurring in the natural environment (or at least patterns of culturally important species).

Popper and Hastings (2009), Slabbekoorn, et al. (2010), Pijanowski, et al. (2011), and UNEP (2012) do something interesting to the acoustic space of the submarine ecosystem through their syntheses. The space begins to transform into a true soundscape. Space continues to be defined by its three dimensions of longitude, latitude, and depth in addition to the fourth dimension of time. What these authors do is add the quasi-dimensions of frequency and sound energy level. Sounds begin to interact with each other as they spread through the environment at specific frequencies, masking lower energy sounds. Hints of this spacing dynamic can be found throughout the history of underwater sound studies, but when the research focus was on sonic events and direct harm to organisms, the complexity of a complete soundscape took a backseat to more pressing matters. By integrating acoustic dimensions into the geometric landscape, the acoustic band becomes a resource used by humans and other organisms. Underwater noise pollution in the former trajectory caused harm by directly impacting an organism's physiology or behavior. In this new trajectory, noise pollution overrides a necessary resource used by populations for communication, danger avoidance, and mating.

It is now recognized that underwater noise can taint the entire soundscape, causing adverse effects in individuals. While stress caused by noise has been recognized in previous research (e.g. NRC 1994), persistent stress emerges as a real concern in this new trajectory. One groundbreaking study linking underwater noise to stress occurred by chance as whale researchers were collecting data in the Bay of Fundy in September 2001 (Rolland, et al. 2012). Scientists were collecting sound data and whale fecal matter from shipping lanes when terrorists attacked New York. Following the 9/11 attacks, shipping traffic temporarily decreased on the Atlantic coast of North America, causing a decrease in noise. Stress hormones found in whale fecal matter showed a corresponding dip in the stress levels of right whales in the area.

As the science is now making clear, stress from underwater noise can impact marine organisms both big and small. The recent shift in noise pollution studies to include non-mammals has revealed fish are also stressed by noise (Wysocki, et al. 2006). Continuous stress in fish can cause impaired growth, lower reproductivity, and impaired immune systems. Simpson, et al. (2016b) has shown that stress from boat noise can also impair predator avoidance responses, leading to increased mortality. The impact of noise-induced stress on fisheries is still largely unknown.

The impact of noise on key species is at the heart of the soundscape ecology approach. Whale researchers have become attuned to the effects that noise has on prey species that support the large cetaceans (e.g. André, et al. 2011). However, the subtle impacts of noise on species populations is only beginning to be addressed (Stanley and Jeffs 2016). One reason for this is that the impact of noise is not as obvious as the die-off resulting from other pollutants such as chemical run-off or oil spills. Instead, underwater noise pollution should be interpreted as an amplifier of other environmental stressors. Noise can lower the overall survival rate of marine animal populations that support a larger food web. While the impact of noise alone is limited, it can intensify the effects of other stressors such as global warming and ocean acidification.

Paying attention to larger webs of interaction means that noise researchers are entering more key marine ecosystems. Coral reefs live and die on the currents of plankton, heat, and sound flow. Noise in the reef is ambivalent; it can help build up reefs or tear them down. As Kennedy, et al. (2008) has shown, a noisy reef is a healthy reef. A reef rich in zoogenic noise is an indication of a thriving ecosystem able to support multiple species of reef fish, invertebrates, mammals, and reptiles. Reef fish live complex sonic lives, singing in morning and evening choruses and dividing the sound space among species to optimize communication (McCauley and Cato 2000). All this noise helps young reef organisms locate and settle reefs including the larvae of fish (Tolimieri, et al. 2000), crustaceans (Montgomery, et al. 2006), and even coral polyps (Vermeij, et al. 2010). Zoogenic noise is so important to maintaining the diversity of a reef system that a decrease in the crackle of snapping shrimp caused by ocean acidification, for example, results in lower species complexity (Rossi, et al. 2016, 2017).

This new research moves the scientific interests away from individual animals and towards local ecologies. The key themes in this research are that submarine spaces possess certain sound qualities, and that changes to the soundscape are known to impact more and more species. The type of sound under review also changed. Continuous and reoccurring sounds have become more important than isolated sonic events. These changes allow sound to be understood as a resource in the local ecosystem rather than an intrusion. Noise became inescapable, leading to policies more focused on mitigation than prevention of noise.

Contesting Noise

Throughout this chapter I have presented underwater noise pollution as a phenomenon continually reshaped by the combined efforts of governments, industry, and the scientific community. While cooperation between interest groups has been important to this process, I would like to remind the reader of the tensions between groups in defining the dimensions of this phenomenon. The space within these tensions is ultimately where future developments in underwater noise pollution will occur.

Underwater noise pollution is not a constant among the various interest groups outlined in this chapter. Underwater noise pollution did not even exist before Payne and Webb (1971) tied it to fin whales if one follows Bruno Latour's (1999) summation of the historicity of substances. While marine animals had perceived and reacted to *anthropogenic sounds* before 1971, *underwater noise pollution* is a human construct. What constitutes noise pollution, as I have demonstrated, is dependent on systems of human values and interpretation. Naming the phenomenon also bounded it.

Underwater noise pollution has primarily been the product of the industrialized North. Most legislation has originated in the United States, Canada, and Europe (Erbe 2013). Approaches to legislation vary between regions. North Americans, with an abundance of territorial waters have relied more on national-level regulations and have been broad in their inclusion of hearing beings and noise producers. Europe, meanwhile, has relied heavily on multi-national treaties pertaining to shared bodies of water.[26] European restrictions have mostly focused on fossil fuel exploration and maritime construction (Erbe 2013). In the southern seas, Australia and New Zealand have developed comparatively little underwater noise pollution regulation. While these countries participate in international treaties such as the United Nations Conference of the Law of the Sea, what regulations exist are weak. In Australia, the Great Barrier Reef Marine Park Authority and the Australian Maritime Safety Authority have both been developing underwater noise pollution guidelines, partly in line with their international obligations. Underwater noise pollution (like many other environmental stressors) has come under the jurisdiction of individual states or government

[26] A few European treaties include The Helsinki Commission (HELCOM), OSPAR Convention, The Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), and The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOMBAMS).

authorities rather than management efforts being led at the federal level. This has led to an uneven approach across the country.

Variations between countries on what constitutes underwater noise pollution can be linked to valuations of noises, noise producers, and noise perceivers. The regulations outlined in the NRC (1994) report demonstrates that not all sound producing activities are valued the same. While the geological surveys and marine construction were heavily regulated, the US Navy and the US fishing industry received clearances. In the case of the US Navy, sounds produced from sonar and naval exercises became essential to national security, while the nation's fishing fleet is perceived vital to local and national economies. In the view of governmental policy, the role of pollutants is often underestimated or ignored when the pollutant is the byproduct of a highly valued activity.

Due to the unevenness of governmental regulations and the initial lack of scientific data, industry often had to take the initiative for noise pollution mitigation. The reliance on "grey" literature in Popper and Hastings (2009) is indicative of the contribution of industrial research. Still, the global maritime industry has its priorities and limits to its resources (both time and funding). This has led to industrial research continuing to focus on noise events and direct harm. When underwater noise pollution is considered in most environmental impact assessments, it is evaluated for the likelihood of the sound source to displace local fauna or cause direct damage to mostly fish and mammals. The resources needed to evaluate and mitigate the impact of noise at the ecosystem level are too great, especially if the government has yet to implement policy.

Research scientists working on the noise pollution phenomenon have tended more towards calls for conservation than government bodies and industry groups. When I refer to research scientists, I mean researchers working in academia, government, and the non-profit/advocacy sector. These scientists have little investment in increased maritime industries and natural resource exploitation, but are heavily invested in preserving the natural environments and the key species they work with. Williams, et al. (2015) demonstrates a trend since the 1990s in an increase of publications and citations focused on conservation. This may differ drastically with the mindset of industrial scientists whose focus is primarily on exploration and management of marine resources.

Williams, et al. (2015) has also shown a steady regime shift among research scientists. Early work on aquatic sound was dominated by acousticians working primarily on naval research (Schwartz 2016). The transformation of aquatic sound into underwater noise pollution in the late 1980s and early 1990s saw an influx of biologists into the field. Around the time of the ecological turn in noise pollution research, Williams, et al. shows an additional increase in the number of publications in biological and ecological journals, as well as the expanding number and variation of species represented in those publications. The downside to this regime change is that while biologists may be experts on the bioacoustics and behaviors of marine animals, they may not be fully trained in acoustics. The controversy surrounding the ATOC experiment serves as a good example of how the knowledge gap between biologists and acousticians can lead to conflict.

As I have gestured to throughout this chapter, the development of marine noise and sound research has been led predominantly by North American and European researchers.[27] The Southern hemisphere has received far less representation, including contributions from Australian institutions. While some Australian research and some research on Australian ecosystems have appeared in this chapter, the overall development of noise research in this region has been slow. Historically, acoustics programs—especially those focused on underwater acoustics and bioacoustics—have been sparse in the Australian university system. Recently, focus has started to shift towards marine noise with notable research being conducted out of James Cook University in partnership with the Australian Institute for Marine Science, Griffith University, and Curtain University.

Noticeably absent from this account is the public, except for a few cases that managed to gain media coverage. Few public advocacy groups have formed for the regulation of underwater noise. This is in stark contrast to the sheer amount of support for noise regulations in the terrestrial and human environment (Stewart 2011). As I discussed at the beginning of this chapter, underwater noise is alienating and difficult to access. The lack of public investment into the issue may result from the general public's ignorance of the pollutant and its impact to the environment.

Looking forward, partnerships between government, industry, research scientists, and environmental advocacy groups may be the next stage in defining and managing underwater noise. Programs in Canada have already shown the effectiveness of these partnerships (McPherson 2014; Williams, et al. 2015). Research is also starting to examine the impact of small vessel noise on reef ecosystems (Holles, et al. 2013; Radford and Simpson 2014; Simpson, et al. 2016a; Simpson, et al. 2016b). As research interest and public interest begin

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[27] At least in the available English-language literature. I have not been able to review the body of research coming out of Asia which is primarily published in Chinese or Japanese languages.

to intersect, as in maritime recreation, public interest in underwater noise pollution may increase.

Continued growth in research, regulation, and public interest may finally add some continuity to “underwater noise pollution” and its related terms. With increased attention to the phenomenon, terms used to describe and discuss the pollutant may become better standardized. Giving shape and boundaries to invasive, anthropogenic sound in the marine environment has made the phenomenon more humanly accessible. It is also through empathizing with affected organisms that humans have begun to comprehend the impact of underwater noise pollution. The field has moved a long way from the “silent world” of Cousteau and Dumas but there are miles of open ocean left to explore.

Interlude I: Transduction

Ghost Radio (Track 2) [01:58]

Thursday, 7 September: My hydrophone broke. It was not a catastrophic break which would cause a complete signal disruption. This break was caused by a short in the cable. The audio kept cutting in and out. I did not think there was much of the 20 minutes recording worth salvaging, but I played it back in Adobe Audition the next day. Where the audio cut out, there was a prominent, continuous signal at 10 kHz and another at the 20 kHz harmonic. I also noticed some wisps of sound near the bottom of the spectrogram which looked like speech to me. After some amplification and equalization, I was able to educe the ghostly voices. While breaking, my hydrophone managed to pick up radio!

The 7 September recording was what I do not hesitate to classify as a bad recording. I made quite a few of those. It turns out, producing a high-quality recording is difficult. Many factors can degrade a recording, from strong currents which bang the hydrophone against the boat to the cable rubbing against the deck. Under actor-network theory, such recordings could be explained as a break down in the actor-network or a sudden and disastrous inclusion of other actors. I, instead, want to approach the actor-network from a different angle. I want to examine how the signal transforms as it passes through actors and circulates within a network. I want to, as Helmreich (2007) says, “think transductively” (633). I see how the history of the instrument has shaped the circuits in which marine sound becomes recorded sound and other noise is shielded when I examine my recording transductively.

Making Good of Bad Recordings

What makes a recording *bad*? At the level of the specific, a bad recording is one with a lot of introduced noise or low signal fidelity. I will explore those issues more in Chapter 4, where such properties influence the applicable use of sound recordings. For now, I am more concerned with what makes a recording abstractly bad.

Badness is a subjective value judgment. There is no objective measure which determines if something is *bad* or *good*. We mostly base our judgment of *badness* on how far something deviates from certain cultural expectations. Michaels (1994) provocatively identifies *badness* in Aboriginal art through its deviations from contemporary art or traditional norms. Aboriginal art was *bad* in the artworld if it did not to conform to certain rules of style, medium, or content[28] while Aboriginal communities would judge such art *bad* if it failed to comply with certain traditional styles, semantics, or rights of use. One artwork could be judged as *good* in the artworld but *bad* in Aboriginal communities (or vice versa). Such an analysis could also apply to my recording as it challenges standard notions of what counts as *good* audio recording.

Bad/*good* value judgements can best be understood through schema theory. A schema is an organized and generalized collection of attributes which a person uses to classify something or make a decision. D'Andrade (1995) summarizes that most of our schemata formed from our cultural or social lives (such as the competing schemata for judging Aboriginal art). When something like art or a recording matches attributes of that schema, it is considered *good*. But when its attributes do not match, it can be judged as *bad*. Schema theory would suggest that these value judgements therefore have a teleology.

Teleology has long been a point of concern for STS and the anthropology of technology. Pfaffenberger (1992) has identified an erroneous "standard view of technology" which includes—among other things—a teleology to technological development. Callon and Latour (1981), Latour and Woolgar (1986), Law (1987) and others have also regularly critiqued the notion that technology serves a predetermined end. Teleological arguments like those espoused in Heidegger's (1977) phenomenology of technology, start to unravel when analysis is directed towards the use of technology by social outsiders. For those who have not subscribed yet to certain schemata of, are alienated from, or harmed by technological use, technical objects lack a specific use case. They instead possess a multitude of possible actions. Hammers stop seeing everything as a nail. Teleology then becomes the result of backfilling a schema as the standard use of a technical object becomes settled.

I had decided that my recording was *bad* because I was applying it to a pre-formed schema of what a recording should be (clear audio of fish croaks and snapping shrimp crackle). If I instead throw off the schema and deny the recording a teleology, I am directed

[28] These norms often derived from colonial ideas of primitive art mixed with modern tastes.

instead to pay attention to how the recording emerges from its parts to become its own being. This process in which something emerges not from preordained rules but from the relation of its parts is what Simondon (1992[1964], 2017[1958]) identifies as transduction.[29] Through transduction, I can reconsider what unexpected sound reproduction can mean for my studies.

Transduction, Transducers, and Choice

Simondon (1992[1964], 2017[1958]) first identifies transduction as a process in the individuation of the being. He suggests that an individual is not a pre-defined, permanent state, but one that continuously emerges from a pre-individual sate through self-organization. The pre-individual state is comprised of components with many possible potential configurations, but which have not yet been organized. Transduction begins to occur as the components' possible configurations begin to organize and lock into place. Each instance in individuation resets the relations between the individual and the pre-individual milieu so that the individual develops through immediate associations of its parts and the un-organized components rather than through pre-established rules. Transduction is the movement of components from one state (the pre-individual) to a new state (the individual) and the subsequent changes that movement effects onto other neighboring components. Importantly, transduction only ceases when the individual ceases to exist because there is no teleology to individuation.

Simondon's individuation and transduction can be identified in the development and evolution of biological organisms as they solve a series of emerging problems in their environment. Adaptation occurs as associations of pre-existing biological components exist in a population in response to an environmental pressure,[30] rather than through intentional modification. More importantly for this thesis, Simondon extended the application of transduction to the formation of the psychic individual. We continue to identify our own individual selves through interactions with the world which challenge our identity. In doing

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[29] While Simondon (2017[1958]) identifies teleology in the evolution of a technical object, he does not apply teleology to the emergence of technical objects from transduction.
[30] Interestingly, the technical use of transduction in genetics applies to horizontal gene transfer where viruses can donate snippets of DNA from one bacterium to another.

so, we can intuitively identify other individuals. This sets up the ability for individuation and transduction to occur at multiple scales, including the development of the transindividual.

The *transindividual* becomes key to Simondon's (2017[1958]) development of a phenomenology of technology that radically reconfigures the technical relationship. The transindividual:

> can be understood as a relationship that does not relate individuals by means of their constituted individuality separating them from one another, nor by means of what is identical in every human subject. . .but by means of this weight of pre-individual reality, this weight of nature that is preserved with the individual being, and which contains potentials and virtualities. (253)

It is a heterogenous collection of individuals which share a pre-individual root and a potential inertia. In this way, technical objects retain connection to those who produced them and thus each constitutes the other in part. The transindividual can be read as a collective individual or an individual extended through a collective. The transindividual human extends past the skin and flows through technical objects they use in a proto-cyborgian manner. Simondon uses transindividuality in order to resolve the experience of technical alienation of work. He argues that alienation is felt because technical objects[31] developed after social structures had solidified the idea of work. People and technical objects were already fully individuated and separated under this framework which then pitted the two against each other. Alienation could then be solved through the primacy of transindividuality of humans and machines which transduced the social structure of work. Humans and technology would develop together to constantly reshape what work is rather than beholden to a rigid definition of work. Such a world would collect around knowledge, technique, and invention rather than utility. [32]

Simondon's work on individuation and transduction would go on to influence other technical thinkers including Deleuze, Massumi, Stengers, and Latour. His impact is most obvious in the development of network theories which elaborate on individuation. In the field of anthropology, Helmreich has further refined Simondon's philosophy and spearheaded a movement for transductive anthropology.

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[31] Technical objects in this case can be understood as complex industrial machines or automated processes.
[32] This is in direct contrast to Heidegger's phenomenology of technology that positioned technical objects as tools to be used by humans.

Transduction holds the most promise for anthropologists of all Simondon's concepts. Transduction as a process of relations indicates the importance of social and cultural practices which complement the biological and psychological analysis contributing to individuation and transindividuality. Coming to Simondon from sound studies, Helmreich (2007, 2009) takes this project and forms it into an analytical framework. A transductive approach would be to envision a society as a system through which signals and information move. Unlike earlier attempts of allying cybernetics[33] to society, the transductive system is only partially formed, and remains dynamic. As signals move around, they create relationships and structures. But the transductive society is full of structural impedances which require active work to push through. The development of new relations changes the context of the social milieu as each component changes those around it.

Helmreich (2007) states that "to think transductively is to think from inside the infrastructure that supports transmission of the information across media" (633). A transductive anthropology not only accounts for the changes made to the signal. Thinking from inside the infrastructure is to consider the logics that enable transformation. Unlike ANT's focus on how structures change through actor-networks, transductive anthropology draws attention to why those transformations happen and why they are possible. It is an approach that combines historic and ethnographic elements. All of this aligns with Simondon's concept of the allagmatic—theory of operations—in which structures take form and change.

As Helmreich indicates, to fully understand the potential of a transductive anthropology requires a sidestep from Simondon's metaphysical transduction to technical transduction. In the engineering fields, transduction is the process of changing energy from one form to another. A microphone transforms mechanical acoustic energy into electrical energy while a lamp changes electrical energy into light. These technical objects are transducers. Simondon (2017[1958]) mainly discusses transducers through the lens of information science rather than through a social analytical lens. This leaves Simondon's theory of transducers underdeveloped. Helmreich therefore turns to sound and technology historians like Sterne (2003, 2012) to better assess these agents.

[33] Simondon was greatly inspired by Weiner's cybernetics and his argument was against the implied teleology in Weiner's application of cybernetics to human societies and not to the general field itself.

Sterne's histories of sound technologies identify transducers as cultural artifacts that have solidified notions of sound, hearing, and humanity before launching a series of new relations. Transducers become cultural bottlenecks through which relations of energies are formed and transformed. The tympanic transducers of early sound technologies reconfigured how we listen to and produce audio (Sterne 2003) and the digital transducers which have led to the MP3 format have once again reoriented the position of sound in our daily lives (Bull 2007; Sterne 2012). Mechanical transducers have also been in the middle of cultural shifts: water mills and windmills restructured agriculture, the steam engine facilitated the Industrial Revolution, and the generator has birthed our modern electric life.

On the physical level, transducers behave as a sort of alchemist's gate for energy. Energy moving through the gate is transformed into another type, but the gatekeeper determines what energies can pass through. The transducer becomes the embodiment of technical relations between notions of energy and work. The transducer is also the point at which those relationships are at the most risk. No matter how strict a gatekeeper, the transducer always lets in some amount of noise into the system. Signal noise, friction, or heat, unwanted energy is normally controlled for through the continual evolution of the transducer.

The transducer is therefore developed through a series of choices as to how to structure relationships. The movement of energy or work through a series of transducers forms the logic of operations which produces the structure. Helmreich's transductive anthropology critically examines the development of that logic while also recognizing that the anthropologist is contributing to forming a structure as well.

It is when the short in the wire opens up new modalities that the hydrophone becomes a transducer of electromagnetic waves. As the signal transforms, it comes up against my own choices as to how the system should be structured. I adapt to the changing sound by trying to tweak the short back into place and re-establish a clear signal.

The recording was a product of my series of choices coming up against the choices embedded in the hydrophone. What I learn from the recording is the expanded possibilities of the hydrophone and the choices I make to reign those in. I have developed a certain technical aesthetic and technical practice to this relationship as I sought to create structure. The hydrophone was later fixed so that that aesthetic could be maintained, but the recording remains as a reminder of the structure I impose and forces a moment of self-reflection.

There is a Politics Here…

If transducers direct the process of transduction—of individuation and the formation of structures—then they can be said to engage in some form of politics. I am not referring to a state politics of control. Instead, the politics of transduction is in making decisions as to how the milieu will take on structure. The transducer determines which possible channels to make real, thus negating others. In technical objects, transducers do not form all on their own, they are placed in circuits by the volition of a human agent. My hydrophone had the possibility of transducing marine sound or radio waves, but I am the one who places value on the former and directs the hydrophone to transduce that pathway.

Politics are already present in Simondon's writing, even though they may be a little subtle. After all, he wrote about the alienation of the technical object through labor as well as the relationship between technics and oppression.[34] His challenge to traditional philosophy of technology spurred a political shift in social relations between humans and technology by inspiring a new wave of science and technology thinkers. The politics are there again when Helmreich writes about "impedance and resistance in cyborg circuits" (2007, 633). Those resistances are not just technical. Social, personal, and political forces also impede certain flows for signals because of intentional will to obstruct or inability to envision other possible structures. These resistances are, in themselves, valueless. Some resistances create positive structures for certain users (like the resistance of radio transduction in hydrophones), while other can create negative structures (inability to transduce subsonic or ultrasonic waves). Overall, positive and negative structures formulate the mode of engagement with any technical object or its output.

A transductive politics may reframe how we think about the activities of technicians. Rather than acting as neutral agents, technicians become political actors shaping our technological relations and the structure of our lived experience. Under the utilitarian

[34] See Simondon (2017[1958]) pp. 159-163 for his most cogent political argument against Norbert Weiner's recommendations for the use of cybernetics in government and society (see Weiner 1961[1949], chapter 8; 1954[1950], whole book).

model common in continental philosophy around the end of WWII,[35] technicians had lost some aspect of their humanity. To use a utilitarian tool, one had to behave in a utilitarian fashion. Decisions were seen to be made based on the best logical use of a tool. The technician had become more machine-like. But, once humanity is returned to the machine, technicians can recover their lost creative humanity. Technicians are now engaging with machines through transduction and establishing a transidentitive relationship. They become recognizable as active shapers of the world with intentions, goals, and agendas.

For the acousticians and other sonically engaged practitioners in the following chapters, transduction and transductive politics allows for a greater appreciation of their work. Thinking transductively about their activities enables me to see how social and political institutions, technical histories, and personal ethics direct their actions. Their operations to create knowledge exist within a greater context which they also attempt to restructure.

Thinking transductively also makes me reflect on my own politics as an ethnographer. “The ethnographer as a kind of transducer” (Helmreich 2007, 633) makes certain decisions about how to convey their fieldwork. I make decision about what I present on these pages which shapes the potential narrative. Some of those choices are deeply rooted in cultural norms and disciplinary standards while others are subject to personal taste. I choose *good* recordings to play to the reader which hides those resistances which have frustrated my research. Yet now I see that these moments of impedance in my fieldwork help to challenge the infrastructure I am investigating and demonstrate the ongoing transduction of the field I am studying.

[35] Heidegger’s (1977) phenomenology of technology is a notable example of the utilitarian model while Pfaffenberger (1992) provides a clear description of this model in his critique of the Standard View of technology.

Chapter 3: Diving In

In 2017, I began my fieldwork onboard *Passions of Paradise III*, a dive boat running day trips out of Cairns to several sites on the outer reef. My intent was to study how recreational and professional divers related to the Reef and its denizens through—among other things—sound. I saw divers as a potential alternative knowledge community outside of formal science networks and deeply emmeshed in the daily happenings of the local marine environment.

I also started diving for my own phenomenological investigation. I had the sense that if I were to write about the Reef, I should immerse myself in it. What does it sound like and feel like to be in the marine environment?

While well intentioned, much of this fieldwork was a productive failure. Whether it was the location of the dive sites, the employee turn-around in the industry, or the limits of the human body in an aquatic medium, this way of going about things tended to hit dead ends if not break all together. In a way, this chapter is an anti-methodology chapter intent on challenging preconceived notions of what sound research is. By reflecting on my methods of phenomenological inquiry, a new question emerges: why is marine sound such a troublesome subject to interrogate?

Finding those boundaries and breaking points in phenomenological attempts at grasping non-human and sonic worlds demonstrates the difficulties in doing anthropology underwater. It demonstrates why a first impulse of immersion can only go so far when trying to develop an inter-species intersubjectivity in this context.

Phenomenology and its limits

Sound-as-an-experience is a running theme in most sound studies research. Saeed Hydaralli (2012) argues that noise is fundamentally phenomenological (in that it is experienced within the greater sonic context) and “always reflexively determined” (232) (*see also* Voegelin 2010). Phenomenology also forms the basis of many methodologies of sound studies. R. Murray Schafer’s (1977) soundwalks, which require the practitioner to move through an environment while listening closely to (and ideally recording) the changes in sound, has been an inspiration for many sound studies. Steven Feld’s (1990[1982], 1996, 2015) acoustemology added an anthropological framing to sound research and is heavily based in methods of recording and collaborative editing. Even Stefan Helmreich (2007), the most science-focused of the sound anthropologists, relies on phenomenological techniques when discussing sound in submersibles, although he does place more emphasis on the role of technological mediation in perception.

For sound studies and the anthropology of sound, the phenomenological approach has mainly focused on auditory practices.[36] This is especially true of environmental sound and noise research. One of the first academics to promote an auditory methodology for examining this phenomenon is composer R. Murray Schafer (see Schafer 1977 for best example of his work) who established the World Soundscape Project (WSP) in the 1960s. One method devised by Schaffer and the WSP to record the environmental soundscapes around Vancouver, Canada, was the soundwalk. Hildegard Westerkamp (1974), a member of the WSP described the soundwalk as "any excursion whose main purpose is listening to the environment." A soundwalk typically involves waking quietly through an environment alone, or in small groups. Westerkamp recommends first paying attention to the quiet sounds of the walker's body and then moving outwards to the qualities of the local environment. A more methodical variation utilized by the WSP is to include recording equipment to document the walk for later analysis. This method has been utilized by many sound researchers including anthropologists working on communicative ecologies (e.g. Vokes 2007) and practitioners of the burgeoning new field of acoustic ecology.

Another commonly employed auditory method is the practice of deep listening, as developed by composer Pauline Oliveros. According to Oliveros (1998), "deep listening is listening in every possible way to everything possible to hear no matter what you are doing" (3). It is a practice of listening with a focus on lengthy emersion in a sound field. The practitioner listens intently and tries to identify the various qualities of the soundscape and the effect the environment has on those qualities.

Armed with these methods, I attempted a phenomenological approach to listening, starting off with some soundswims. The soundswim was supposed to mirror the soundwalk method. I would participate in a dive and take notes on sound experiences and changes in the soundscape in a waterproof notebook. I even entertained the idea that once I developed the method, I could train other divers to join in.

It didn't go so well. First, as I will describe later, it was not difficult at all to listen to my own body. The problem was moving beyond those sounds. Overtime, I did learn how to

[36] Merleau-Ponty (1962) and the phenomenology of perception, body, and experience remain the basis of most phenomenological sound studies with equal measure being given to general musicological approaches of listening. Together, these phenomenologies present sound as a primarily sensual experience of the ear.

hear around my respirations, partially by controlling the rhythm of my breathing. I was able to pick up more sounds and identify the presence of others (mostly other divers) around me. But we were constantly on the move and our presence in the area was too noticeable to the other sea creatures who would change behaviors or hide away. Additionally, there was no practical way for me to audio record these swims, meaning all listening and notetaking had to be done in the moment; a difficult proposition when half my mind is already committed to maintaining my survival. There was also the matter of my physiological limits to hearing underwater sound[37] that further decreased my auditory perception.

My methods had been based on the phenomenological approach which has been the go-to for sensory anthropology: if one is to study a sensory experience, then one should experience it first-hand (Feld 1996; Picken and Ferguson 2014; Pink 2009). Soundwalks and deep listening are deeply rooted in this philosophy. These phenomenological approaches assume the human body as an adequate instrument for perception. It is precisely this preoccupation with experience that leads to methodological breakdowns when confronted with a phenomenon that exists on the periphery or outside of sensation.

Most of the influential works in sound studies find their roots in music theory or environmental issues of noise from industrial activity (Attali 1985; Schafer 1977; Stewart 2011). Musically inclined theorists, including ethnomusicologists who continue to drive the anthropology of sound, have contributed to the growing knowledge of sound production practices through to practices of consumption (Bull 2007; Larkin 2008; Novak 2013; Novak and Sakakeeny 2015). Overtime, these theorists have joined with media studies to expand their analysis to other sound media such as radio, television, and film (Bessire and Fisher 2012; Bull and Back 2004; Cox and Warner 2004; Fisher 2016; Ginsburg, et al. 2002; Goddard, et al. 2012; Samuels, et al. 2010). Conversely, environmentalists have focused on sounds which are forced on the listener. Most theorists in this field have been critics of industrialization and, thus, have set the built environment as their subject. Both traditions have started with the assumption that sound is primarily an auditory experience perceived by human bodies, one that can be studied through auditory methods.

There are two problems with this approach. First, with primacy on aural listening, these methods tend to ignore acoustic activity beyond the listener's sensory abilities. Scholars, such as Helmreich and Friedner (2016), working with Deaf culture have attempted

[37] See section titled "Multispecies Listening" in this chapter.

to expand sound experience to include its tactility, a move that is more in line with the marine experience of sound but continues to limit sound to the margins of sensorial capacities. This is partly the result of the terrestrial bias in sound studies. Helmreich (2016) is once again the exception in scholarship, which otherwise is greatly lacking in consideration of sound manifesting in aquatic or geologic media. Sound studies end up without a general body of theory for considering the changes of sensory capacities and new forms of synesthetic hearing produced through different technological media.

To further illustrate the affordances and limitations of an aural-centric, experiential phenomenology, I turn now to my fieldwork onboard *Passions*. An extended inquiry of diving and listening practices will demonstrate how sound fits into Reef encounters and how I might move beyond my limited sensorial abilities.

Traditions of Knowledge

I had chosen to include divers in my study because they represented a potentially underrepresented but important group in underwater noise research. Most of the published documentation on underwater noise comes from scientific, governmental, or industrial bodies (see Chapter 2). Divers seemed to be an alternative source of knowledge to the established, legitimized networks.

My thinking followed Barth's (1993) concept of traditions of knowledge: that rather than being a cultural monolith, "knowledge" is fractured and situated among various social groups and individuals. If knowledge is "what a person employs to interpret and act on the world" (Barth 2002, 1), then a diver's knowledge should be different from that of a scientist or an ecosystem manager. Moreover, if "a person's stock of knowledge structures that person's understood world and purposive ways of coping in it" (2002, 1), that would suggest that divers could contribute new modes of interfacing with the marine ecosystems and soundscapes that have been overlooked by traditional research methods. These new modes of interfacing include sensual and experiential knowledges, following assertions made by Simondon (2017[1958]) and Ihde (2010) that phenomenological experience is structured by learned skills and is not universally regular.

Academic research on marine noise has the benefit of being backed by the academy and its long history of complex, sophisticated theory, access to advanced technologies and computation, and pool of funding (Downey and Dumit 1997; Latour 1987; Latour and Woolgar 1986; Law 2002). But, academic interaction with marine spaces is periodic and structured around fieldwork seasons, grant cycles, and other academic duties. Professional divers lack many of the resources that the academy can provide, and their knowledge tends toward the practical and experiential; they are in the water continuously. My approach was informed by an assumption that the tradition of knowledge supported by professional divers could enlighten environmental managers to the more mundane, quotidian, and local phenomena that are important for reef beings and industries but are potentially missed by academic research.

To understand the professional diver's tradition of knowledge and how it enables the diver to access (or is unable to access) marine sound, I now turn towards daily dive practices as observed during my fieldwork.

Control and Communication

Passions III is 30-metre-long sailing catamaran, the newest vessel of the Passions of Paradise dive company. Debuting a few weeks before I started my fieldwork, *Passions III* increased the company's daily customer capacity from 85 to 120 passengers while also extending the vessel's range. A daytrip on *Passions* involves a journey to two dive sites and the options for snorkeling, introductory diving (first-time dives with an instructor), and certified diving (guided dive tours for trained divers). As I was interested in diver's knowledge of the underwater soundscape, I tended to participate in certified diving, often acting as an unofficial assistant to the divemaster.[38]

Diving is for healthy bodies only. Due to the physical strain and the effects of increased pressure from diving, many potential divers are excluded due to epilepsy, asthma, certain medications, or recent surgeries. Temporary congestion in the sinuses or ears can also disqualify a person from diving due to the risk of a painful pressure imbalance known as a "squeeze." Diving is also primarily for wealthy bodies. Training, travel, and equipment are all expensive, meaning recreational divers mostly originate from prosperous countries. These healthy, wealthy bodies comprised the diving companions who would explore the Reef with me. They also comprised the target demographic for ecotourism, seen as more likely to be university educated and more receptive to ecological education (Fennell 2008). Many of the passengers I met held postgraduate degrees, were studying at university, or were educators.

[38] "Divemaster" and "dive instructor" refer to two higher-level industry certification classes. A divemaster is sufficiently trained to lead groups of certified divers while dive instructors can train and certify new divers. I use the term divemasters here collectively since this job only requires the lower of the two levels of certification.

In contrast, the same assumptions cannot be made for the crew. While all the divemasters and instructors can be assumed healthy enough to dive, their socio-economic position and education varied. For them, diving was not a hobby but a means to earn an income and possibly travel. Most of the crew were young, seeking employment out of high school rather than entering university. While higher education was not off the books, it was something for later. Despite this lack of a formal education in marine ecology, one of their responsibilities is to educate the tourists about the Reef. Their lived experience with the Reef as part of their daily lives and the supplementary education provided to them through companies like Reef Teach make the crew great stores of knowledge of the ecosystem and its threats.

While it can be assumed that the professional divers support a tradition of knowledge among themselves, the same cannot be said of the recreational divers who come aboard *Passions III*, who represent a spectrum of ability and cultural background. Part of the challenge for the divemasters is to reconcile the various traditions of knowledge represented in the recreational divers with their own so that all can properly communicate and remain safe. That reconciliation involves coordinating embodied knowledges and preparing the recreational divers (particularly those newly certified) for the sensorial experiences of diving.

The first step for a day of recreational diving is to attend the morning dive briefings. Normally held on the dive deck, this daily ritual lays out the safety procedures and introduces the divers to their equipment. The dive briefing is also the time when the divemasters establish their underwater communication system. Speaking underwater is highly impractical—though not impossible—and most facial cues are obstructed by masks and scuba equipment. Therefore, divers rely on a set of gestures and sonic signals. Signaling allows the divemaster to dictate the way that the group interacts with the marine environment in a manner that is both safe for the divers and the ecosystem. It is also the means by which divemasters attempt to transmit environmental knowledge *in situ*.

Dive signs, a series of agreed upon gestures, can be broadly broken up into three categories: directional, state, and zoological. Additionally, "you" or "I" is indicated through pointing and any statement can be turned into a question with a simple shoulder shrug.[39] Directional signs instruct other divers where to go. Pointing with the thumb can signal a diver to descend, ascend, go left, or go right. Twirling the index finger signals "turn around" and

[39] Alternatively, one can also curl the index finger to imitate a question mark.

outfacing palm signals “stop.” There are also signs for orientating towards the boat, finding dive buddies (diving partners responsible for providing each other aid), and for the three-minute safety stop at five meters (a precaution against decompression sickness). State-related signals convey the divers internal state or the state of the dive equipment. The most ubiquitous is the “ok” signal to communicate that everything is alright (do not use the “thumbs up” as this is an order to ascend). Tapping two fingers on a flat palm inquires how much air a diver has in their tank, to which they respond by holding up the appropriate number of fingers. Rocking the hand from side to side signals, “something is wrong” and then is often followed by the diver pointing to an injured body part or malfunctioning piece of equipment. Finally, the zoological signs are used to identify or draw attention to marine creatures. These signs often replicate the animal or identifiable parts. Placing the side of the hand vertical to the forehead indicates a shark while stacking one hand flat on top of the other with thumbs sticking out, twirling, is the sign for a turtle.

Hand signaling is a less-than-perfect mode of communication. It is rudimentary, coarse, but effective. Signaling anything outside of the limited lexicon can seem like a quick game of underwater charades. On many dives, I have watched the divemaster invent new signs for marine species, and I have done so myself. This on-the-fly means of communication, lacking clearly established signs for many sea creatures, can hinder the formation of new understandings of unfamiliar beings. Signaling relies on a pre-established knowledge of marine life. If the divemaster makes a pull-and-pinch motion to signal a pipefish, the other divers must already be familiar with that animal to translate the signal properly. If a diver points to an animal and shrugs her shoulders, she is unlikely to get any satisfying response since she could not identify the organism to begin with. Divers are also limited in their syntax when trying to communicate complex information. During one dive, the challenge was great enough that the divemaster borrowed my dive notebook instead of attempting to signal the reason why we had to surface. All of this relies on face-to-face communication, so divers must first use sonic signaling to attract each other’s attention.

At the safety briefing the divemaster primes the cohort of recreational divers to respond to certain sounds. Most divemasters carry some sort of sounding device with them on a dive. The most common are the tank banger – a metal bar used to rasp on the air tank – or a modified jingle bell. Divers may also hit the palm of one hand against the side of a fist or yell through their regulators to attract someone’s attention. These signals say, “look at me” and are most often employed if a diver needs to be told to ascend or descend to the proper depth or if a popular animal such as a turtle or shark is passing by. Two other signals are much more specific, but far less common. A pattern of three rasps and a pause emanating from the dive boat or the sound of the dive tender[40] circling overhead are the typical emergency recall signals. Something is wrong and everyone needs to return to the boat immediately. While these signals are rare, experienced divers are aware of them.

Maintaining signal clarity is important for diver safety. Too much environmental noise can mask the reception of important sonic signals from the dive boat or divemaster. Additional noise can also hinder navigation since the unique sound signature of the dive boat can help orientate dive groups. This is why divers surface when the environment becomes too noisy due to anthropogenic activity.[41] Inversely, it is the diver's inability to make highly complex sounds that places importance on standardized hand signals. The diver thus experiences a paradoxically deafening and ensonifying space.

The safety briefing provides divemasters a platform to reorient the recreational divers to one shared system of communication in which to convey their experiences. In so doing, they create a knowledge framework that prioritizes which sensorial experiences to attend to. Sound becomes a medium of inter-diver and diver-boat communication, but one that must be reinforced with visual gestural communication. Under these circumstances, the sonic experience becomes utilized rather than becoming part of the aesthetic experience valorized by Attali (1985) and Schafer (1977).

Signaling is a great means by which to coordinate divers, but it is rather limited in terms of transferring more general knowledge. For multispecies interactions, dive signaling can only convey identification at best. Complex relationships between the environment, the creature, and the diver cannot be relayed in the moment. Instead, the diver must rely on bodily experiences to sense these relationships. That is, after all, one of the appeals of diving: to feel (and see) what is like to be a marine being (Cousteau and Dumas 1953; Picken and Ferguson 2014). Developing that embodied sympathy requires major technological interventions. For that, I will now turn to the technologies of immersion and the immersive experience.

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[40] The dive tender is a small rubber vessel with an outboard motor.

[41] It is common practice to surface when it becomes too difficult to navigate underwater. Many of the divers I worked with described surfacing in the presence of noise or other navigational obstacles like low visibility when orientation became too difficult.

Immersion

Paradoxes abound in recreational diving. I find it strangely both a highly social and isolating activity. Sinking below the surface, my sense of space dramatically contracts while my sense of self expands to include my equipment. Entering the inhospitable aquatic environment requires the modification of the human body. The scuba equipment transforms me into a cyborg, a merging of human and machine regulated by cybernetic loops. Donna Haraway (1991) identifies the cyborg as a bodily paradox where technology and biology continually merge and separate. The cyborg is patchy and imperfect—as it should be—otherwise it would be all human or machine. It is also dependent on its parts to maintain its existence and any break in relationality could fracture its identity. The paradoxes of diving are a mixture of the cyborgic relationship between diver and dive gear as well as the transformative nature of other mediums on the human sensorium. Therefore, it is unproductive to discuss one without the other when examining sensorial experience underwater.

Stefan Helmreich's (2007) work on the anthropology of sound and oceanspace points towards the need to recognize the cyborgic self. In his call for a transductive anthropology he declares:

> to think transductively is to attend to the earache, to imbalance, to all the **embodied capacitances** of the ethnographer—and to the work necessary **to place oneself in particular networks**, machinic and social. To think transductively is to pay attention to **impedance and resistance** in **cyborgic circuits**, to **the work that needs to be done** so that signals can link machines and people together, at a range of scales, from the private to the public. (emphasis mine, p.633)

While Helmreich's works stems from his participation onboard a deep-sea submersible, it is useful to apply his thinking to diving. Through its ability to support human life underwater, the scuba equipment alters the ethnographer's "embodied capacitances" as well as introduces new impedances in the form of self-generated noise. Because it affords the submersion into a new medium, the scuba equipment mediates a new ethnographic ear.

The primary components of dive equipment are the mask, fins, weight belt, buoyancy-control device (BCD), air tank, regulator, air gauge and dive computer. The mask (with snorkel) and fins are provided to each passenger as they board *Passions*. Everyone receives a set and they become the primary means for all to interface with the water. For divers, the other equipment is introduced during the dive briefing, after the signaling lesson. The dive belt and BCD are used to regulate buoyancy and maintain dive depth (sometimes the belt is integrated into the BCD). The dive belt laces through lead weights and is placed around the diver's waist to assist the diver in descending from the surface. The BCD is an inflatable vest that can counteract the dive belt when on the surface and make up for changes in buoyancy due to pressure and the loss of air in the air tank over time. The air tank is strapped to the back of the BCD and provides breathable air to the diver via a hose and the regulator, a device that sits in the mouth of the diver. The air gauge and dive computer are integrated in *Passions'* equipment and monitor how much air is left in the tank (measured in bars, pressure), dive depth, dive time, and non-decompression limit (amount of time left to safely dive at that depth without having to use a decompression chamber).

Becoming an aquatic cyborg has a learning curve. Managing the dive equipment effectively is a skill that takes time to develop. A good example of this is buoyancy management. Controlling one's buoyancy is necessary for maintaining a proper depth. A novice diver will sporadically inflate and deflate their BCD to adjust their buoyancy, while an experienced diver learns to adjust buoyancy by holding more or less air in their lungs and only adjusting the BCD occasionally to compensate for lost air or major changes in depth. Novice divers also tend to kick and swim into things more often. This is exacerbated by the reduced field of vison caused by the mask, affecting a diver's sense of awareness. It takes a while for the self to map these new changes.

While the scuba cyborg may offer the possibility of a new ear, in practice, the equipment does little to amplify the sensorial experience and can even encumbor auditory sensing. As Picken and Ferguson (2014) note in their sensual ethnography of novice divers, most listening is oriented towards monitoring internal states rather than external sources. The body and its expanded cyborgic system make all sorts of noises. As pressure changes, gasses shift and change volume. Most new divers concern themselves with monitoring their breathing rates to best conserve air and ensure that the supply system is working correctly. I have found myself listening for tell-tale cues of air escaping my mask through a leak in the skirting so that I can fix the issue before my vision is flooded. The internal soundscapes of a novice diver are so powerful that they mask environmental soundscapes. The process of becoming an effective cyborg can be overwhelming and can insulate the diver further from transducing outside sound.

So how could diving generate new, phenomenological knowledge of noise pollution if divers were not attuned to underwater sound? When I asked GBRMPA how my work could best assist their efforts in assessing the impacts of underwater noise pollution, they suggested I look at its effects on the sound amenities[42] of the Reef. After conducting my fieldwork, it seems likely for the great bulk of introductory and newly certified divers, those amenities are not perceivable. New divers are unlikely to be aware of what a healthy reef soundscape should sound like and are probably not going to learn it through diving. Ultimately, visiting divers are more interested in communication channels remaining clear.

The crew of *Passions* fare much better at perceiving the Reef's soundscape. Through training and experience, they have learned to listen beyond their internal states. Sound, for them, has become another tool for monitoring their surroundings and for navigation. An experienced diver can begin to recognize the sizzle of rain hitting the surface, the munching of parrot fish and triggerfish, or the respirations of another diver just outside of the field of view. The divemaster may even signal these audio cues to the rest of the group, but it is unclear if the other divers actually hear it.

Intriguingly, one sonic experience was independently reported to me by multiple divers. While each event was singular, the general pattern of those reports goes as so: a diver is underwater when they suddenly experience a strong increase in noise and a strong vibration. The diver would latter describe the sound as being like a helicopter landing on their head or some other illustration. The diver is unnerved enough by the noise that they surface only to notice that a large ship was passing by several kilometers away! Even though this story was not uncommon, what was striking was that almost none of the divers I worked with connected that experience to underwater noise pollution. On almost every trip out to the dive sites, we could see a cargo ship passing through the lagoon shipping channel. It was obvious that shipping was occurring within the Reef and that those ships were most likely making noise, but no one was making a link between that noise and the health of the ecosystem.

The inability of the divers to connect their own experiences with the overall impact of noise pollution on the Reef may have to do with location. Dive sites are chosen by companies like Passions of Paradise for their remote and pristine condition. Most sites are found within protected zones in the marine park, well away from the shipping channels. Even the noise produced by the dive boats is often imperceptible to divers since the greatest amount of sound output occurs when the boat is approaching or leaving the reef—a point in time when no

[42] Amenities refers to any pleasurable quality that would support or be encountered during recreational activities.

divers are in the water. Live drops—when divers jump from a slowly moving vessel and then head to the mooring—are one of the few times divers may be exposed to anthropogenic noise. In addition, it was never clear to me if the divers' experiences with anthropogenic noise occurred in the Great Barrier Reef or some other location. As stated above, divers are a highly mobile and youthful workforce. Many divers have trained and worked in multiple countries (mostly in the tropics) and see diving as a means for world travel. During my time on *Passions*, there were divemasters from the Netherlands, South Africa, Jamaica, New Zealand, Hong Kong, and Japan. High mobility may make it difficult to translate an environmental impact in one location to another. Each environment has its own unique mixture of stressors and the well protected waters of the GBRMP are less impacted by anthropogenic activity than for example, Thai dives sites, which are known to be close to small vessel traffic. Unless it is experienced repeatedly at multiple sites, divers may consider those stressors to be a local and not a global problem.

The movement across species is also difficult. Once again, the problem of sympathizing with beings much different from humans arises. Although there might be sonics experiences that disturb human divers, the divers are often unable to translate that to the fishes' experience. Nagel (1974) has previously argued that the conscious experience of one species is not fully accessible to another. Humans, Nagel argues, are unable to fully comprehend what it is like to be a bat, for instance. The further away one gets from primates, mammals, or terrestrial fauna, the harder it is for one to comprehend the life of another being. For divers, it is easier to assume that the fish are deaf to most noise than it is to comprehend how a being can hear in a manner complete different to the human experience. Comprehension can be improved with education. As my fieldwork progressed, the crew of *Passions* developed—through my conversations with them—their understanding of the ability of marine species to detect acoustic signals. However, their level of comprehension is hard to assess without a more systematized metric than I was using. Suffice to say, without any direct education on the sensory perception of aquatic life, divers are likely to be unable to sympathize with these beings to a level where they can identify sources of pollution.

Multispecies Listening

Given Nagel's (1974) quandary, would more marine education actually spark a sympathetic affect among divers? So far, I have outlined how divers might use sound and are affected by it in the practical activities of diving. These experiences build up a knowledge set of sounds for diving and indicates an aural phenomenological experience of diving. But, when considering sound in relation to the experience of other beings (thus detecting noise experiences beyond the human), does a human phenomenology overlap with a fish phenomenology?

The human animal is, fundamentally, terrible at hearing underwater. Our reduced hearing capabilities are a result of biology and physics (Hollien and Feinstein 1976). Humans evolved on land, and so did our mammalian ears. The structure of our ears is designed to channel the vibration of the air through the ear canal to the tympanic membrane, the ear drum. The vibration of the membrane is then transferred to the ossicles, the middle ear bones, which then tap on the cochlea. The cochlea is a helical fluid-filled organ which contains small sensory hairs that convert the vibrations in the fluid into a nervous impulse which becomes sound when it reaches the brain. This entire system relies on the difference in density between air and the tympanic membrane in order to generate those vibrations. Unfortunately, soft tissue of the human body is approximately the same density as seawater and acoustic waves mostly bypass the entire system. Instead, those waves are picked up by the bones of the skull and channeled to the cochlea in a process called bone conduction. Because of the rigidity of bone, hearing sensitivity and range are greatly reduced and favor lower frequencies. In addition, the speed at which sound travels through water (about five times faster than through air) disrupts the listener's ability to tell from which direction the sound came. While some localization is possible (Bovet, et al. 1998; Hollien, et al. 1986) the human brain's capacity to detect the delay between the two ears is greatly limited, and decreases as the frequency rises.

This change in hearing capacity is dramatic enough that trainee divers are warned about sense alteration. Dive training organizations like PADI (Professional Association of Diving Instructors) prepare new divers to be particularly aware of the loss of directionality underwater. A new diver will be unable to identify where a sound is coming from and should stop and look for the source of strong or strange sounds. If a diver is searching for the dive boat by listening for it, PADI suggest that they should orientate based on changes of sound intensity. Orientation by intensity rather than directionality is a useful skill to master, though it is still disconcerting when one might hear a fellow diver to the left, but she suddenly appears below, on the right.

What I did start to sense was the haptic qualities of sound. The whine of the dive tender as it passed overhead or the rumble from *Passions'* bilge pumps when close to the hull would vibrate my entire body. Due to the higher density of water, sound could be felt more readily, like standing in front of a bass speaker or marching band drumline. And, due to the phenomenon of bone conduction, most sounds felt as if they were originating inside the body. A heavy rain on the surface felt like carbonated bubbles popping in my head. Not all experiences are so innocuous. For the professional cleaners that accompany *Passions* regularly, the vibrations can be downright disruptive. The cleaners clear the hull of dive vessels while they moor at the dive site to reduce drag on the boat and prevent debris from accumulating in the harbor. The cleaners dive below the vessel and then hold on with suction cups while they scrape off barnacles. All goes well until the team reaches the area around the bilge pumps. The racket from the machinery violently vibrates the cleaners' bodies. Smaller boats like *Passions* are manageable, but the vibrations from the larger vessels limit the time the cleaners can be around the pumps to a few short minutes. Such experiences helped me to understand that underwater noise is as much felt as it is heard. For the divers who experience a cargo ship pass by, it was as much the bodily vibrations as the loud sound of the vessel that sent them to the surface.

The haptic sensations of sound have often been underreported in phenomenological studies on sound, with notable exceptions in Deaf studies (Helmreich and Friedner 2016), research on noise music (Novak 2015; Voegelin 2010), and underwater music (Helmreich 2016; Kahn 1999). For me, the haptic qualities of sound were the first indication that I might do better approaching underwater sound and haptic qualities' relational potentiality through sound by figuring it as acoustic energy. After all, it is these energetic properties of sound that also enable a fish to hear.

While there is no one structure for the fish ear, generally speaking, all fish sense sound through particle motion (Popper and Fay 2011). I will explain it to you as it was explained to me. Imagine the fish is one big particle in the water. Since the fish's flesh has a similar density to water, it moves in sync with the liquid as sound waves pass through it. Inside the fish's head are small, hard objects called otoliths (literally ear stones) which are denser than the fish's body and causes it to vibrate out of sync with the soft flesh. The otolith pushes and pulls on the sensory hairs inside the fish's ear, causing the fish to hear. Fish can also sense particle motion through their lateral line, a string of sense organs running down a fish's side, and some fish have air pockets around the otolith or in the swim bladder that can pick up sound pressure as well.

Humans can only gain an inkling of how marine creatures experience sound. In this project, I had set out to understand how people grasped the sonic worlds of marine beings, but the phenomenological approach can only examine how people *experience* the sonic worlds *containing* marine beings. Even our mammalian relatives have special adaptations to listening underwater. Dolphins are able to hear by bone conduction through a thin section of their mandible (Hughes 1999). It is unlikely that diving could ever allow a human to develop a complete empathy for non-human sonic experiences. We are too imprisoned by bodily imaginations as Nagel suggests. But the inkling, no matter how small, does open the door to understanding how marine creatures might experience sound. From there we can begin to reorient our search for sensory experiences and start to develop sympathy. But to do that, I would need to find a new way of listening.

Learning to Hear

To overcome my physiological limitations, I turned to other technologies of listening. I had acquired a quality hydrophone—underwater microphone—and I listened in from the bow[43] of the boat after dives. This device was capable of picking up acoustic energy and transducing them into audible sound. I would sink the hydrophone down to a depth of around eight meters—if it was too shallow, I would run into the phenomenon known as the Lloyd's mirror effect[44] which resulted in the silencing of low frequencies near the surface. The hydrophone forced me to consider the various mechanical energies interacting in the surrounding water including the reflection of acoustic waves on the surface and the movement of water particles against the instrument. Once I put on my headphones, a new sonic world opened up. This cyborgic configuration offered another avenue in penetrating the reef environment, an augmentation that allowed for greater acoustic clarity.

Dive Site Sounds (Track 3) [01:30]

The hum of *Passions'* pumps and compressors were still present, but I could hear more of the action on the vessel. During early recordings I would pick up the 1kHz pulse of a malfunctioning water pump which one crew member described as sounding like a "robot giving birth." The pump was later fixed, but I could still hear the movements of various mechanical devices as well as human movement below the waterline. These sounds formed

[43] Port (left) bow was the furthest point away from the bilge pumps which dominated my early attempts to record from the duckboards (low diving platforms at the aft).

[44] Lloyd's mirror effect is caused by interference of low frequency waves reflecting off a surface and cancelling each other out.

the acoustic signature of *Passions* which I learned to differentiate from other vessels in the area. The low buzz of the boat formed the sonic floor to all my recordings.

Everything above 500 Hz in the audible range was dominated by the crackle of snapping shrimp. Occasionally, I had the opportunity to hear the grunts and chirps of fish. Or, at least I thought I heard them. The primary deficit of using a hydrophone is that the listener is only partially transported underwater. While I could listen in, I rarely was able to see what I heard. Later, I learned that this was a perpetual problem in underwater bioacoustics. Unlike bird calls, there is no generally available resource to learn fish communication. There are limited databases of fish sounds and most focus on ecologies of the Northern temperate oceans or freshwater ecosystems. Without a functioning database, marine auditors must rely on visual confirmation to identify most sources. The only time I could be certain of the origin of a call was when a trio of batfish took interest in my hydrophone and auditioned[45] before it.

Mostly, I would hear the sounds of human activity. The respirations of introductory divers, the whine of a BCD inflating, or the *clang clang clang* of a tank banger were common. Snorkelers jumping in and splashing about could be heard above and below the waves. Then there was the dive tender: a small rubber dingy that would patrol the area and assist any passengers needing aid or occasionally tow divers to remote dive sites. The whine of the motor could be obnoxiously loud. I had experienced the noise while diving, but It was even worse with the hydrophone. Yet the fish did not seem to mind, at least as far as I could tell from listening in. On the few occasions when I did continuously hear fish grunting, the presence of the dive tender did not appear to affect their behavior.

Apart from the dive tender, very little anthropogenic noise pollution could be detected. It was not just the deadened sense of the divers; noise was not seeping into these dive sites. There was one exception: Towards the end of August, on Flynn Reef, one of the larger dive boats in the area left and came back to its mooring while I had my hydrophone in the water. Its departure from and return to the reef were gradual but noticeable above the typical reefy soundscape. Its maneuvers to position itself at the mooring were the largest sources of noise. For each maneuver, the boat's propellers would spring to life and explode with sound, producing noticeably higher sound levels in the lower frequencies.

[45] "Audition" is the technical term used by bioacousticians to describe the process of directly recording the sounds made by animals.

[Dive Boat Moving (Track 4) [2:13]]

Hearing does not have to be in the moment of listening-in. Most of the time I was recording off the boat, I was too concerned about maintaining the equipment or monitoring what was going on around me. Many sounds I could not hear until I listened to the recordings again back at my desk. The day or so after a trip out to the Reef, I would replay my recordings using Adobe Audition. Not only would the acousmatic (sound without a visible source) listening allow me to focus on individual elements, the computer program also generated a spectrogram (Figure 2), allowing me to *see* sound.

A spectrogram is a temporal graph with frequency on the vertical axis and duration on the horizontal. Each sound is color-coded for intensity with purple being the least intense and yellow the most. The low sounds of *Passions* form a thin yellow base to the spectrogram and the clicks from the snapping shrimp striate the graph in thin, broadband lines of varying colors. Upon this background, other sounds begin to appear. A BCD inflating takes the form of a gradually ascending line while tank bangers form decaying triangles. Most fish sounds produce a percussive series of dots near the bottom. Here, the effect of noise becomes visible. As anthropogenic noise increases, the fish chortles and grunts begin to blend in and become indistinct from the sounds of engines as they become masked.

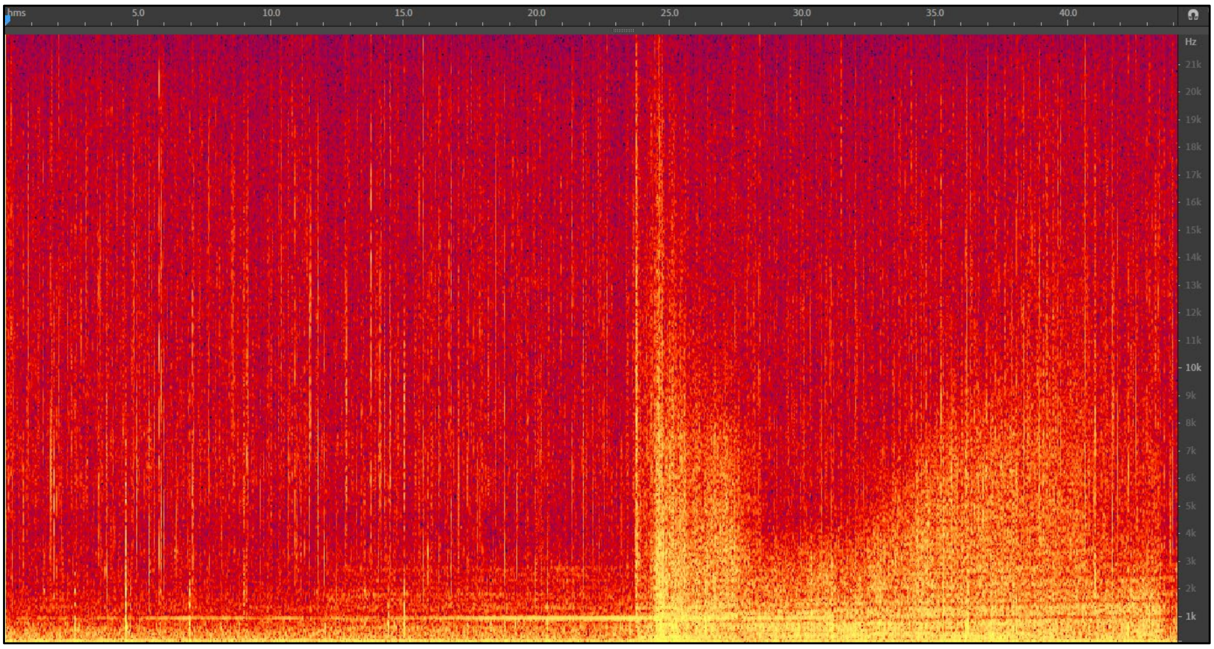

Figure 2. Spectrogram from recording of moving dive boat. Time on top axis, frequency on right axis

Making Others Hear

Integrating sound into the tourist Reef experience is a constant challenge. Among all the other stressors to the ecosystem and the demands from tourists, noise does not seem so important. The average Reef visitor has a superficial level of knowledge about the Reef ecosystem mostly drawn from popular documentaries, news reports, and guidebooks. Few of which seriously considers the soundscape.[46] Noise, to most visitors, blends into all the other bits of information about the aquatic environment. It was less notable because it was less noticeable, say compared to coral bleaching. The crew must cater to the educational needs of the passengers and so they focus on more approachable topics of identification and the life cycles of popular creatures.

Heading home from the Reef, the crew would hold their daily marine life talks. Just about every boat going out to the Reef presents this type of talk. It is a brief lesson on coral, reef ecology, key reef species, and conservation. As part of my agreement with *Passions*, I added my own segment about sound. This was the final attempt of the crew to drive home any environmental or educational message and my last opportunity to get the passengers to hear noise.

Using tablets, one of the divemasters started to explain the size of the marine park, the anatomy of coral, and how to identify various types. Then it was time for my contribution. Using my own tablet and a small speaker, I introduced the audience to the sounds of the Reef, playing either that day's recording or another recent one. Passengers were often shocked that the crackle of the Reef is not produced by foraging fish, but by little shrimp. They also seem to enjoy recordings of fish choruses and whale songs. Once I finished, the presentation returned to the crew member who then starts identifying popular fish species. The anemone fish receives a generous amount of attention here, spurred on by the popularity of Disney Pixar's *Finding Nemo* (although the skipper has told me before that it is now mostly the adults who understand the reference). To round out the presentation, there were segments on turtle and shark conservation. Closing out the marine life talk, the instructor promoted Passions of Paradise's conservation efforts and allied programs.

The question and answer session came next. Depending on the audience, this can be either lively or non-existent. Some passengers wanted to know what type of fish they saw. They will often try to describe the animal's color and size or its location. There were rarely

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[46] One notable exception is the inclusion of a segment in *Blue Planet II* which features fish communication.

any pictures and we would keep guessing until we stumbled across the correct species or the passenger gave up. Some passengers wanted clarification or more information about some part of the presentation, or they wanted to know more about my research. Then there is The Question. The one we always dreaded and sighed before answering: Is the Reef dead? Since the 2016 mass bleaching event, there has been the popular myth that the Great Barrier Reef is dead. It had been a constant struggle for the crew and me, as “Scientist Matt” (“anthropologist Matt” was too confusing for the passengers). Answering this question always made me feel a little bit gross, like I was denying climate change. “No, the reef is not dead. The Reef is healthy. It is in trouble if we do not do anything, but it is surviving.” It was hard for us to find the balance between alarmism and optimism. Such a balance can be difficult to find in the Anthropocene. Faced with multiple crises to the environment, interpreters like ourselves have to find ways of generating action without causing panic and hopelessness.

Moving Forward

One afternoon on a return from the Reef we were forced to wait outside of Trinity Inlet with all the other dive boats. A cruise ship visiting Cairns was on its way out to sea and taking up the entire channel. As we waited, the skipper drew my attention to the sonar screen. What was generally an orderly and minimal representation of surface objects around the boat was suddenly striped with ribbons of color. The skipper explained that the cruise ship’s sonar was much stronger than *Passions’* and was creating interference. The stripes were an artefact of the interplay between the two signals.

The sonar artefacts are one example of anthropogenic noise well outside of human audibility (but not necessarily outside the hearing range of some marine species) and still detectable. Sonar is a sound-based technology which does not require the operator to listen to the audial signal. Instead, it translates sound into a visual representation of the environment but is still susceptible to noise. These artefacts indicated that marine sounds were not solely heard through aural listening devices. They could be seen and felt as well. In this moment it became clearer to me that to truly listen to underwater sound and noise required moving beyond my own body and the phenomenological orientations it afforded me, towards a technological synesthetic listening practice.

I needed to extend my thinking beyond the approaches pioneered by Feld (1990[1982], 1996, 2015), Feld and Brenneis (2004), Attali (1985), Schafer (1977), and the like and move towards theorists including Sterne (2003, 2012) and Feaster (2012) for whom sound is meshed in technological and biological networks. The phenomenology of perception that supports much of the former work proved to be too anthropocentric and hid the energetic nature of sound. While it worked well for studying most human sonic behaviors, the transition to the marine space proved that such a phenomenology was not capable of surviving the transition to other media and beings. Sound in the latter works is able to be held and transmitted across media and in multiple forms outside of the aural. While they focus on particularly human technologies, their approach to sound might be translated in part to the study of the non-human world. I walked away from the marina that day excited to think this could be a path to a new synesthetic anthropology of sound.

Interlude II: Phenomenology of Non-Humans

How can we ever possibly know the experiences of other creatures? This is one of the thorniest questions at the root of my investigation. If any one concern is likely to keep me up a night, it is this one. How can we effectively or ethically manage noise—or more generally find ways to respectfully co-exist with other creatures—if we cannot know how they experience the world? The stakes are high because if we do not critically engage with how we live with non-human animals, we risk carelessness and cruelty (Almiron 2016; Puig de la Bellacasa 2017).

As Nagel (1974) has pointed out, we will never know what it is like to be a bat, let alone a batfish. We are limited to our own bodies and experience, which means that any insight we may get from other beings is always tinged with our own anthropocentrism.

What Is It Like to Be My Dog?

Thinking about phenomenology of non-humans makes me think about my dog. He is a dachshund who joined our family when I was in high school. He must have been terrified when we brought him home as a pup. When we gave him free roam of the house, he immediately scampered under the dining room table. For the next few hours he would peek out at us from under chairs until he built enough courage to stand at the threshold to the family room. Finally, with enough coaxing, he crawled into my lap and fell asleep.

Pet owners are familiar with reading the experiential state of our animal companions. We know what they like and dislike, can anticipate their needs, and judge their emotional states. At least we think we can. This kind of knowledge is what I will call *folk phenomenology*. I use folk in the anthropological sense of referring to the way people understand and organize the day-to-day world around them. Folk phenomenology does not draw from any specific philosophical school or from the latest in psychological theory. Instead, folk phenomenology springs from regularly being around humans and non-humans.

Folk phenomenology is a powerful tool for navigating our interactions with non-humans. It enables us to share space with other creatures. But folk phenomenology is strongly biased towards experiences we as humans might share with other beings. This uncritical anthropocentrism can result in an unproductive anthropomorphizing (I will return to this later). While I know my dog has higher sensitivities to smell and sound, I cannot smell the same scents he smells nor hear the same sounds. Thus, I often only consider experiences in which our senses overlap.

Such biases have led to inappropriate assessments of non-human (including doggy) intelligence. As de Waal (2019) has noted, tests for markers of non-human intelligence use humans and human perception as the baseline. The mirror test, which measures self-awareness, relies on the non-human to visually identify itself which is not my dog's forte. His visual perception is weaker than mine, but he is far more capable at identifying his scent than I am. When presented with a scent test, dogs are shown to be just as self-aware as humans (Bekoff 2014). At the other end of the argument, Key (2015) suggests that anthropomorphism has generally skewed the field of non-human consciousness as researchers attribute phenomenological experiences (he uses pain) to animal behavior even though such experience is not neurologically supported in certain species. Pushing even further, Toadvine (2007) argues that the foundation of phenomenology itself is corrupted by notions of human exceptionalism which greatly limits the possibilities of experience.

I may wonder what it is like to be my dog, but does my dog wonder what it may be like to be me? Udell, et al. (2014) surmises that he may be looking at me as a companion or for comfort. He knows I can do things he cannot do (he asks me to open the door for him to go outside). I doubt that he sees me as a human (as I perceive myself) nor as a fellow dog (since I behave and smell differently). He may be theriomorphizing me, seeing me as another beast living with him. Critically asking this question forces me to consider myself through his *umwelt*, his perceptual world. Could doing so help negate some of the anthropocentric limitations of phenomenology as Horowitz and Hecht (2014) propose?

The Ontics of a Triggerfish

I was diving with Passions on Australia Day when I was attacked by titan triggerfish, twice. We were swimming around Saxon Reef when two triggerfish started to swim towards us. They harassed each party member, nipped at the divemaster, and then turned their attention to me, since I was in the back. As I swatted at them with my dive notebook, I started to ascend in the water column, which only antagonized them more. I luckily escaped the fish without being bitten. Unfortunately, we had to pass by them again on our way back. Again, they attacked me, and again I made to mistake of rising higher. Still, I came away uninjured.

Triggerfish are generally amicable Reef co-dwellers, but they can be aggressive in the summer during their breeding season. Male triggerfish will build a nest in the sand flats and fiercely guard the territory that radiates out from the nest in an inverted cone. They will charge and bite at any invader, which can leave some divers and snorkelers with minor wounds (Randall and Millington 1990).

My trouble with the triggerfish resulted from my inability to properly assess their worlding. While I considered the surface as a safer place to be—and my ascent as a retreat towards my own domain—the triggerfish saw me further invading their precious territory. That the triggerfish recognizes a certain space as being its territory and distinguishes organisms as threats or non-threats depending on their proximity to the territory would suggest that triggerfish have some way or ordering their world. Borrowing from Verran (2001), Tsing (2017) refers to this world-ordering in non-humans as "ontics." She describes ontics as "practices in which modes of being are enacted" (15) without having to burden such practices with the philosophy of being in ontologies. But that ontics is difficult for humans to access because it has been composed through the phenomenological experiences of the fish within its *umwelt*.

The concept of the *umwelt* was introduced by the German biologist Jakob von Uexküll (2010[1934]) and repopularized by Hungarian-American linguist Thomas Sebeok (1979). Von Uexküll's observations of animal behavior led him to theorize that animals experience individual worlds shaped by their perceptual capacities. This *umwelt*, or perceptual world, incompletely overlapped with the physical world the animal shares with other creatures. A world may be simple in the case of microorganisms or complex for vertebrate animals including humans, but each *umwelt* is complete to the organism. For the triggerfish, its *umwelt* is composed through its visual, audial, olfactory, and other senses to construct the space of its conical territory and identify invaders. The inability of my own *umwelt* to construct space in a similar manner placed me in direct confrontation with the fish.

The recognition of species particular *umwelts* opens still more questions about the experience of a fish; particularly, if the *umwelt* indicates that fish are capable of having experience. The link between *umwelt* and phenomenology was complicated by the writings of Heidegger (1973) who expanded upon *umwelt* while adding the concept of *Dasein*, the uniquely human experience of being. Heidegger had argued that since only humans could access *Dasein*, then they were the only known beings that could fully access the world. Animals, who lacked the ability to self-reflect on being were poor in world.[47] Later philosophers (Hinchliffe, et al. 2005; Marder 2014; Morton 2017; Toadvine 2007) have challenged this assertion on the grounds that not even humans perfectly experience the world. If my experiencing of the world is lacking (I cannot hear like a fish or smell like a dog) why should I set myself apart from other beings? Philosophers working on phenomenologies of non-humans find some vindication in Merleau-Ponty (1962) who re-obscures the boundary between humans and other creatures and allows for the consideration of non-human experience (see Toadvine 2009).

Echoes of the *Dasein* divide in the phenomenological experience can be felt in the biological and psychological sciences, particularly in the field of ethology. Ethology concerns itself with observing animal behavior. It should therefore be the most beneficial science to the development of a phenomenology of non-humans. That development had been set back by the prominence of Skinner (1938, 1974) and behaviorism. Skinner's theory saw all actions by an organism as a response to a stimulus. Under his radical behaviorism, Skinner even put forward that consciousness was just an illusion which emerged from conditioned responses. When taken up by ethology, animals were less and less treated as agential actors and more as reactionaries to their environment. While behaviorism has fallen out of favor generally, its mark can be seen in non-human cognitive research. Ethologists and other biologists are more likely to attribute consciousness to closely related non-humans (mainly mammals) than they are to more distantly related creatures. Key (2015) suggest that fish, due to their neurology, are unlikely to feel pain nor do they possess a phenomenal consciousness. Such arguments would imply that while I experience the episode of invading the triggerfish's territory, the fish unconsciously reacts to my presence with aggression. While the cohort of animals which can experience the world may have grown, there still appears to be some threshold for experience imposed by ethologists.

Not all biologists agree with such a limited view of consciousness. Other researchers are more willing to attribute consciousness to a wider range of creatures including bees and

[47] "Poor in world" is a Heideggerian term referring to a lack of connection to the world.

worms (Dawkins 2000; Griffin and Speck 2004). Dawkins (2000) best states the issues still currently at play for all non-human animals:

> Strictly speaking, therefore, consciousness still eludes us. It is my personal view that emotional states defined in the way I have described (using reinforcement value) does imply subjective experience—a conscious awareness of pleasure and pain that is not so very different from our own. But that should be taken for what it is: a personal statement of where I happen to stand, not a view that can be grounded in empirical fact. It is just as valid (and just as open to challenge) as the more widely held beliefs that consciousness ''kicks in'' with the ability to form abstract concept or plan ahead or use a language. (887)

The nature of consciousness still eludes Western science. We know humans have it, are pretty sure elephants, dolphins, and the great apes have it too, but we remain unsure for every other organism.

If conscious action is so difficult to identify, does it even matter? Philosopher Timothy Morton (2017) argues that, "world doesn't depend on consciousness. It's not about *knowing* that there is a world. It's about getting on with stuff, going about your doggy, or spidery, or whaley business" (emphasis original 92). Morton's notion of getting on with stuff is the crux of his argument. Getting on would require that an organism would have some sort of ordering of the world (an ontics[48]) and be able to experience worldly interactions (phenomenology). It does not matter if the organism reflects on how it is getting on. *Umwelt* becomes all that is needed for phenomenological experience, and *Dasein* is just one of many modes of experience (if *Dasein* is messy enough to exist at all).

I have once again returned to *umwelt*. However, *umwelt* as I want to claim it here is slightly different than the concept put forth by von Uexküll. Due to the detour through Heidegger, Skinner, ethology, and biology, this expanded sense of *umwelt* has been able to shed some of the anthropocentrism which has hampered our understanding of non-human perceptual worlds as well as identifying the human exceptionalism in other philosophies. In a way, it is like my experience with the triggerfish. Confronting the *umwelt* of another being assaults my assumed order of the world. Attempting to understand how the triggerfish

[48] For Morton, a follower of object-oriented ontology, all world orderings are ontologies, but I continue to use ontics here because I find it more appropriate.

experiences the environment puts me in a new, confusing territory which I do not know how to navigate. The second time around, I am more prepared. I can know what I can expect from the fish and how it might perceive me. I still make mistakes, but I can better take the triggerfish on its own terms. But I cannot *become* a triggerfish nor can I make someone else into one. How could I effectively communicate about their perceptual worlds? Can I only speak of human phenomenology if I wish to avoid anthropocentric presumptions and mistakes?

Critical Anthropocentrism

In the winter of 2018, Cairns hosted the Reef Restoration Symposium which brought some of the top coral and ecosystems scientists together to discuss a possible restoration project for the GBR. On the last day of the Reef Restoration Symposium, we were scheduled to take a trip out to Fitzroy Island to view an experimental coral farming initiative. Before we boarded the ferry, we were invited onto the COTS Control boat. Crown-of-thorns starfish (COTS) are a significant stressor on the Great Barrier Reef. The large, spiky sea stars eat coral polyps and can destroy entire reef ecosystems if their populations become too large. In the time of the Anthropocene, their populations are decidedly not in check.[49] The COTS Control Program is an attempt to reduce the number of mature COTS in the marine park in order to prevent a destructive outbreak. COTS Control divers (whom we affectionately called COTS kids on *Passions*) inject each animal with a substance that causes an allergic reaction resulting in the sea star breaking apart. On that day, we were given a live demonstration of the process. One COTS diver removed a large specimen from its plastic container and then proceeded to inject the creature. My fellow guests watched in fascination, but I felt sickened by the execution. I was horrified for the sea star even if it did not know what was happening to it. Fortunately, we were spared the sight of the animal breaking apart, but I wondered what it would be like to slowly disintegrate.

I know I am anthropomorphizing. The *umwelt* of a COTS is relatively simple. It does not have a centralized brain for higher-order thought and it probably does not feel pain as we think of it. It is unlikely that the sea star is frightened of its inevitable demise or even

[49] While COTS are native to the GBR, their populations have bloomed due to increase run-off of nitrogen based fertilizer.

aware of its own mortality. I know these things, but I still want to project onto it my own way of sensing. I have been warned against the dangers of anthropomorphizing, yet I cannot fully prevent myself from doing it. Is there space for anthropocentrism in the phenomenology of non-humans?

To be clear, anthropomorphism is a consequence of anthropocentrism. If the entire world is only understood through human experience, then radically other beings must be transformed into near-humans for us to make sense of their experiences. We attribute even the most neurologically simple organism with complex inner lives so that we might understand their motivations. We ascribe gender and familial norms to animal relationships. We moralize the actions of predators, going so far as villainizing creatures such as COTS who do not possess their own moral framework. These are arguably ethically dubious practices which set up a faulty substitute for the organism itself. Rather than creating a representation of the creature, we have "humans in animal drag" (Toadvine 2007, 39).

But we cannot seem to stop from anthropomorphizing. Even among the most careful scientists, non-human experience is often described through analogy. In part, it is a result of the shortcomings of human language to describe non-shared experience. But the issue is more deeply rooted. Even non-linguistic forms of communication transduce non-human experience into anthropocentric formats. Whale songs are sped up to be made audible to human researchers and infrared light is made visible so that researchers might "see" a snake's ability to perceive heat. Those who attempt to remove any trace of anthropomorphism through the use of purely technical language threaten to succumb to mechanomorphism (Karlson 2012), an equally dubious position.

Anthropomorphism and anthropocentrism places us in a double bind. We try to remove it all together and risk negating non-human subjecthood, or we could lean into it and risk unethical representation. The third way out could be to engage in a critical anthropocentrism[50] which recognizes that all phenomenology of non-humans are *attempts* to escape our own subjectivity which must continuously fail in some manner. This way risks

[50] I would like to acknowledge Karson (2012) for developing critical anthropomorphism in animal ethics and contrasting it to critical anthropocentrism. Critical anthropomorphism pertains to how non-human phenomenological experience is written and communicated in an ethical manner while critical anthropocentrism takes one step back and pertains to how phenomenology of non-humans can be ascertained, studied, engaged with, and communicated. While critical anthropomorphism generally applies to ethics of academic writing, critical anthropocentrism is applicable to many forms of engagement with non-humans.

both subjectivity and unethical representation if done haphazardly, but it seeks to gain an honesty about the phenomenological project if done with sustained attention. It reduces the burden of creating fact from a scientific quandary that may never be satisfactorily resolved.

Whether a dog, a fish, or a sea star, I will always be limited by my imagination in assessing their phenomenological experiences. There are things I cannot directly experience and there are things that imperfectly overlap. By placing the critical focus on the limits of my abilities, I do not risk projecting those limitations onto non-humans nor do I further a sense of human exceptionalism. Anthropomorphism then becomes a tool to use sparingly in order to understand phenomenology of non-humans though analogy. Analogies become things to think with without being mistaken for fact. We use such analogies when we experience empathy. We make critical assumptions about the similarities between our experience and the experience of another. When that other is non-human, the analogy becomes more strained, but the tension remains bearable if the differences between the human and non-human are acknowledged.

Building Towards Echo-logics

I want to return now to folk phenomenology. When I consider the experience of my dog, I do not debate whether he has consciousness, nor do I trouble myself with the ethics of anthropomorphism. There is an often-implicit recognition of a shared *umwelt* in folk phenomenology. When my dog sits up and tilts his head, I ask him what he hears even if it is inaudible to me. Folk phenomenology has been the way humans have engaged with non-human experiences well before we began to write down non-human phenomenological philosophy.

We should be wary of cordoning off the phenomenology of non-humans to philosophers, biologists, and psychologists. To do so would be to invoke a scientific chauvinism which delegitimizes all other attempts. What a shame that would be! Art, literature, film, music, and other non-academic outputs have made wondrous attempts to communicate non-human experience. Take J. A. Baker's (2010[1967]) lyrical writing in *The Peregrine*:

> The peregrine's view of the land is like the yachtsman's view of the shore as he sails into the long estuaries. A wake of water recedes behind him, the wake of the pierced horizon glides back on either side. Like the seafarer, the peregrine lives in a pouring-away world of no attachment, a world of wakes and tilting, of sinking lanes of land and water. We who are anchored and earthbound cannot envisage this freedom of the eye. (46)

Baker continues to contemplate what the bird truly knows and sees. Are his meditations not worthwhile because he has not trained in the biological sciences or philosophy?

Echo-logics is a recognition that each form of non-human phenomenological inquiry has merit as an attempt to apprehend *umwelten* that sit beyond our own embodied, perceptual and cognitive reach. Adopting a critical anthropocentrism may temper our worst natures to project our own sense of exceptionalism onto other creatures, but it also reminds us of just how limited and human such pursuits can be. We are like the proverbial blind men feeling an elephant for the first time. Each chosen perspective—biological, philosophical, or folk—gets at only a portion of experience. We will never get anywhere if we cannot recognize that we are all blind and perhaps probing the same thing.

I still struggle with these questions of knowing which seem necessarily unresolvable. Nonetheless, these notions of *umwelt* and critical anthropocentrism provide a way to self-consciously stumble forward though my research. They also help me to understand how others are stumbling around with me. Through the rest of my journey, I meet people of all sorts struggling with the phenomenology of non-humans (explicitly or tacitly) as they try to manage marine noise pollution. None of us will get it all right, but the attempt, and the ethical openings and sensuous orientations that are fostered in the process, I will argue are nonetheless worthwhile and vital on their own terms.

Chapter 4: Animat Aquarium

Geoff is a stocky, Australian bloke enjoying semi-retirement in Far North Queensland. One of his eyes had been damaged a while ago in an incident involving a knife, but he is still able to do delicate electrical work with fine wires. I have watched him several times connecting gossamer threads of copper together in just the right way to make fickle technology work. He will often have me—as a young, adult, male—listen through a pair of headphones to the chirps and swoops of an acoustic calibrator. I still have most of 20Hz-20kHz[51] range and can more readily identify any extraneous noise. He has lost a decent portion of his range thanks to the curse of age.

I have visited Geoff at his house several times. There is a constant chirping emitting from a repurposed dolphin alarm meant to keep echolocating bats away, but the sound does not bother him since he can no longer hear the high-frequency pulses. Additional thumping from a dugong acoustic alarm discourages sucking insects. His garage/workshop can, at times, be filled with chirps and buzzes from other electronic devices on his workbench. Tucked away in plastic bins are meters of cable, hydrophones, wires, and insulation. On some visits, various electrical components, heat guns, and wire were scattered on and around the kitchen table. The house shows all the hallmarks of belonging to an electrical engineer.

Geoff did not start out in electrical engineering. He was originally trained in marine biology and began his career in Queensland Fisheries in the mid-1970s working with prawns, later moving on to life histories of pelagic fish and stock assessments. Then, in the mid-1980s, the “Taiwanese Wall of Death” fishery, a network of offshore gill nets, appeared on the Australian shelf. Within 3 years, 14,000 dolphins were killed in the nets. Geoff was nominated as the tuna biologist to work on the bycatch issue. Dolphins’ use of biosonar had been described less than a decade before and Geoff moved to studying the acoustics of bycatch communication. Similar research was developing in the North Pacific among American and Japanese scientists. It was during this time that he made his professional connections and switch to acoustics.

In this chapter, like Geoff, I must make a switch to acoustics. In Chapter 3, I described how divers become sensually submerged in the soundscape of the oceanspace and how those experiences were limited by the affordances of the human body and produced

[51] 20 hertz to 20 kilohertz (20,000Hz) is the stated standard hearing range for a healthy human adult. This ranged is reduced, particularly in the higher frequencies as an individual ages.

limited sympathies for marine beings. In this chapter, I will explain the ways that acousticians move between the oceanspace and other spaces through the generation and manipulation of knowledge and data in the form of model-building for government assessments or marine industries.[52] Through this transductive process, new relationships form between the acousticians and other spaces, other species, and other disciplines of knowledge.

Sometimes this moving between these spaces can be confusing and jarring for the layperson. Few Westerners have been properly taught to think in acoustics or even marine spaces. The field that I am laying out exists at multiple layers of abstraction and within multiple scales. As I will identify, it is difficult for others entering the field to become firmly oriented. If you, the reader, feel a sense of confusion, frustration, or vertigo from the constant movement between layers and scales, know that you are not alone. Many newcomers, including myself, have felt this same sense of disorientation before we learned to think in sound.

DIY Hydrophones

If I were to assign one sacred[53] object to the submarine acoustician, it would be the hydrophone. I have already discussed the use of hydrophones in the previous chapters, but they take on more meaning as technical objects when used by acousticians. The hydrophone is the main mediating technology that the acoustician uses to interact with underwater environments. It is the primary technology for the acoustician's data collection. Once networked into a sound recorder and, perhaps, a pair of monitoring headphones, the acoustician can begin to transduce the ocean soundscape into predictive models and policies.

Terrestrial microphones cannot work properly in marine environments. Like the mammalian ear, a microphone uses a vibrating diaphragm to pick up and transmit acoustic energy. Due to the need to waterproof the device as well as the distortion and loss caused by movement of acoustic energy from a high-density to a low-density medium, microphones are useless for transducing underwater sound. Instead of a diaphragm, hydrophones contain a piezoelectric material in their waterproof bulb which produces an electrical signal when pressure is applied (DOSITS n.d.).

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[52] Acousticians are commonly contracted by marine industries and government bodies to conduct acoustic modeling in order to complete environmental impact assessments (EIA).
[53] I use sacred to refer to objects that hold a special function similar to key-points which Simondon (2017[1958]) identifies as places where technical objects contact to privileged locations or times (originally drawing from Gestalt theory of figure and ground).

A hydrophone can easily be purchased from any one of dozens of online marketplaces, within a wide range of price points, but it is often up to the buyer to make the device work for their system. That is often the reason why I visit Geoff's house. Early in my project I had bought a used hydrophone from him to listen in to the Reef from the side of *Passions III*. He had to attach a ¼-inch audio jack and 9-volt battery snap connector to the end of the 40m cable of the hydrophone I had chosen so that I could connect to my Zoom audio recorder. These system-making activities are common with hydrophones. Depending on the data to be collected, the hydrophone could be hardwired into a waterproof recorder for long-term underwater sound recording, or it could be networked with other hydrophones in an array towed behind a vessel for seismic mapping. Each configuration therefore individuates new technological relationships which allow for different forms of transduction (Simondon 2017[1958]).

Hydrophone housing must also be improvised. Water movement past the hydrophone's bulb creates a similar noise effect as wind blowing past a microphone. While commercial cages are available to reduce flow noise, many acousticians find it more efficient to make their own. Geoff showed me a housing made of PVC piping and fly screening. He cut three long holes in the pipe and then wrapped it with the fly screen, attaching the latter to the former with zip ties. The material here is important: both the pipe and the fly screen are made of PVC, a petroleum-based plastic that is sonically invisible underwater. Since PVC has a similar density to sea water, acoustic waves pass through the material while the screen disrupts the movement of water particles. I also attempted to make my own cage from a used Powerade bottle and fly screen, but the amateurishly connected cage kept knocking at the hydrophone.

One rarely discussed issue with deploying hydrophones is that marine life seems to be interested in any new addition to their environment. Fish, in particular, are attracted to the device, most likely thinking it is a food source. The best way for them to tell whether the thing is edible is to take a bite. The continuous scrapping of small fish can turn a recording into a muddled mess, so Geoff provided me with wire insulation to wrap around the cable. A flow noise reduction cage also doubles as a fish screen, preventing the animals from trying to eat the instrument.

Do-it-yourself interventions rarely (if ever) appear in the literature. Methods sections lack any discussion around optimal PVC pipe thickness or length. Results clean up any messy bits caused by fishy curiosity. These omissions create a false black box to encapsulate the hydrophone for any outside reader such as regulatory agents or other scientists. Blackboxing in a Latourian sense,

> …refers to the way scientific and technical work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one needs focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become. (Latour 1999, 304)

The internal complexities of the hydrophone are continuously made apparent to the acousticians as they tinker with the device and augment it. Unfortunately, the language of the field allows no means of expression for these activities. For the outside reader, a hydrophone is a stated fact that exists to describe oceanspace. It listens and reports objectively. For the uninitiated, it becomes another data-in-data-out electronic scientific measuring instrument like the mass spectrometer, MRI machine, or seismometer. With no recognition of the flexibility of work a hydrophone can perform, the device and its data become alienated from the reader (Latour 1987; Simondon 2017[1958]).

I call this type of blackboxing false because the described actions in print sources do not match the observed relationships in the field. The blackboxing has been done through the writing and revision of the event, not through the daily thinking and practices of the practitioner. It offers a productive break in the chain of knowledge. The heavy steel cage sitting in Geoff's closet dissolves when oceanspace is reproduced in print. The affordances and constraints such a device provides can be, and are divorced from, the data collected. So too are the errant radio signals[54] a hydrophone can pick up, or the gnawing of fish. They are not data, they are noise.

Here is the first contact with noise. Which noises matter and how. The flow of particles, curious fish, and radio waves create an artefactual noise, "elusive and transitory substances" (Latour and Woolgar 1986, 60) which must be eliminated. From a technical sense, this noise is added into the system through inefficiency (Shannon and Weaver 1949). The signal is described by its *fidelity*, its loyalty, to the recorded subject. The more noise, the less loyal the recording. Noise, therefore, must be controlled, first by removing it as much as possible through the modification of the recording device, and then again by removing it from the written record. After all, the acoustician must remain loyal to their clients and not

[54] See Interlude I.

distract them. What is left is the objective noise: the noise targeted for recording. The noise that can be transformed into data, manipulated, and presented to regulatory bodies, peer-reviewers, and corporate boardrooms.

That is the thing about sacred objects: they reconstruct worlds. Morton (1987; 1989) argues that sacred objects are things with “their own independent subjectivity” (Morton 1989, 294) while also objectifying other subjects. Sacred objects can redirect human potential by constructing and reconstructing different worlds as the object transforms those things it comes into contact with. The hydrophone is more than a mere tool for listening into and recording the marine soundscape. It augments the listeners’ ability to hear while, in turn, the listeners augment what the device can transmit. Through continuous augmentation, the acoustician can transduce the recorded world, removing the messy bits and creating a productive fiction through replication. The complexities of the marine environment have been reduced to a soundscape that the acoustician can work with.

From Oceanspace to Log Space

> “If you don't understand logarithms and log space maths and what you can do in log space and what you need to do in linear space and then convert back to log space … that's where so many mistakes, I've seen mistakes, made constantly where people combine things they shouldn't be combining to get to certain points.” *(Acoustician,*[55] *interview)*

Space figures prominently in an acoustician’s configuration of sound and noise. This makes sense as acoustics is the field of *physics* which studies the movement of *acoustic energy* though *space*. The story of any sound signal is one of energy traversing a space. To fully understand the work of the acoustician, I must start with the spaces they move in.

Sitting at the university café, drinking coffee, Geoff explains to me why the Great Barrier Reef is such a difficult space to do acoustic research. Most research is conducted for seismic surveys which predominately occur in open ocean, with consistent seabeds hundreds of meters below the surface. The inshore waters that comprise the lagoon (and main shipping channel) of the Great Barrier Reef average only 35m in depth with seabeds ranging from sand to mud, to limestone.[56] And then there is the coral. The thousands of coral reefs lining the continental slope, skirting islands, and forming cays and patches in the middle of the lagoon

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[55] Many of the acousticians I am working with are currently active in the field and/or are employed in industry. Therefore, at their request, these individuals will not be named.
[56] http://www.gbrmpa.gov.au/about-the-reef/facts-about-the-great-barrier-reef

can do weird things to sound. They may act like large blocks and create quiet sound shadows opposite the source, or they can create channels for sounds to traverse and pop up in unexpected places. As the outer reef gets closer to the shore in the Far North, sound can start to echo in the narrow channels. Geoff's point is illustrated by the asymmetrical shape of the building's atrium. The sounds of other patrons and students bounce around the walls and bits of disembodied conversations can be picked up from across the room.

Acousticians need to once again reduce the variables to make the space manageable. They need to make a *model*. A model is a representation of the physical world, simplified enough to allow the model maker to easily manipulate it. Data come from the outer, physical world but much of the acoustician's work is done in the modelled world. Models are useful because they allow for multiple futures to emerge. Emergence is a future-directed orientation grounded in the present and "populated by enduring physical structures, invested social institutions and habitual cultural categories" (Otto 2018, 1). I will return to the future-making possible in modelling. For now, I will direct my attention to the population of enduring physical structures that enables future emergence.

Models are formed through a chain of references to the wet oceanspace. Latour (2013) states, "the work of references, as we now know, relies on the establishment of a series of transformations that ensure the discovery and the maintenance of constants: continuity of access depends on discontinuities" (107). Latour uses the difference between a map and a mountain as an example.[57] A map is not the mountain, but a mountain can become a map through a series of transformations. The scales are shrunk, elevation is transformed into contour lines, trails become squiggles, and a host of structures become little icons. Each transformation is qualitatively different from its source, but the continuity in relationships is maintained. These transformations are important in deciding what to keep, what to leave, and what to alter and reduce in order to make the model accessible but valid through the changes in scale (physically and temporally).[58] Latour suggests that these transformations can be dangerous. They form the weak points where the work of reference can fail. To strengthen the transformations, acousticians will recruit data from other fields and draw upon other models. They cannot possibly be expected to produce all the necessary data points. At the

[57] The relationship between maps and territories are by no means original to Latour. Latour is borrowing from a rich tradition of noting such relationships which has spanned science, art, and literature.

[58] Anthropologists, too, must construct models of people. We must scale the real human beings we work with down to make them manageable. I for, one, have jettisoned many facets of these humans to make my model of acousticians. These transformations can be just as dangerous, and I hope to have done them justly.

same time, they remain aware of where the data are lacking or missing. Many of the acousticians I have worked with readily identified which sources did not meet the required standards and where more studies were desperately needed from other fields. The knowledge networks of acousticians (like all other sciences) are not linear, but rhizomatic. They reach out and pull from other fields as they give back.

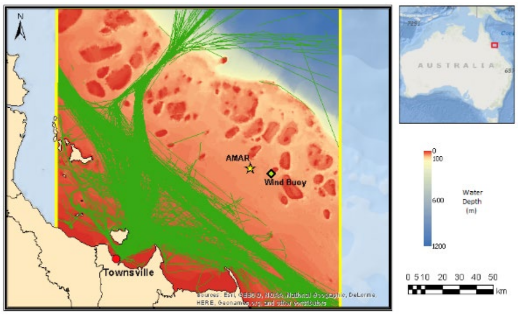

Figure 3. Bathymetry and vessel tracks from Wheeler Reef area (originally in MacGillivray et al 2014, 2)

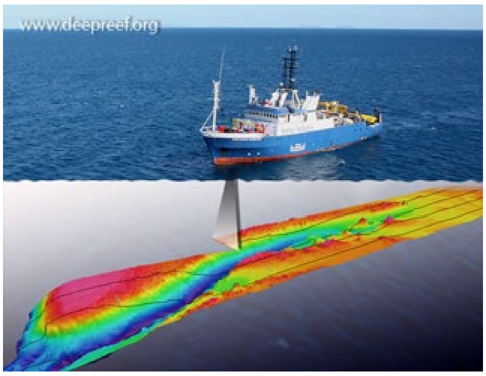

Figure 4. Illustration of sidescan and multibeam sonar mapping by the JCU Deepreef Exploration Project (originally in Beaman n.d.)

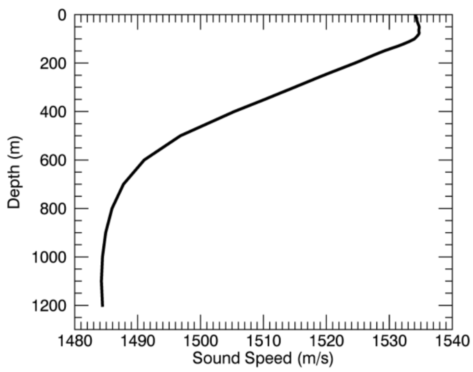

Figure 5. Speed of sound (m/s) per depth (m) for GBR region (originally in MacGillivray et al 2014, 4)

Notice how acousticians model the sonic marine space in 25,000 km^2 of reef off the Queensland coast, around Townsville (MacGillivray, et al. 2014). Listen to who is drawn in and look for what is pushed out. The project was in response to the increased shipping in the Great Barrier Reef Marine Park (GBRMP) through the North-East Shipping Channel. A private acoustic consulting firm partnered with a university fisheries center “to characterise the baseline acoustic environment, including shipping noise, at Wheeler Reef, off the coast of Townsville, Qld” (MacGillivray, et al. 2014, 1). The scientists chose not to rely on hydrophone data due to the large spatial and temporal scales of the project. Instead, they pulled together geologic, biologic, and technological datasets to produce their model. The *bathymetry* (Figure 3) (shape of the sea floor) was taken from the JCU Deepreef Explorer Project, which used acoustic energy from sidescan and multibeam sonar to generate its maps (Figure 4) (Beaman n.d.).

The acousticians then had to construct the rules by which sound moved through the environment. Figure 5 describes the speed of sound per meter of depth for the Reef. The data for these rules were taken from the Global Digital Elevation Model’s (GDEM) database for ocean temperature and salinity developed by the US Navy. As the depth of the ocean increases, the speed of sound drops, but the composition of the water is not the only thing that would inform the movement of sound. For that, the acousticians turned to publications by geologists to understand the composition of the sea bed. They found good data for the inshore waters around the reef (mostly various sediment covering limestone[Figure 6, regions 1-4]) but they suddenly lacked data for the deeper waters. Here, they had to pull data (mud over basalt [Figure 6, region 5])from other places (and studies of the Reef) to create a complete model of the ocean floor. Figures 5 and 6 do nothing to sound until they can be related together. Another model had to be enrolled (the ORCA normal mode model) to marry the sound data with the seabed data. The end result was a transmission loss table (see Figure 7 for sample at 30-45 m [the average depth of the Reef] in region 3 [of Figure 6]). Now they had a model of the Reef that sound could exist in.

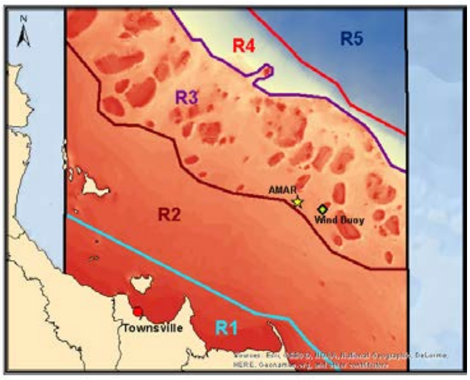

Figure 6. Geological regions of the Wheeler Reef area (originally in MacGillivray et al 2014, 4)

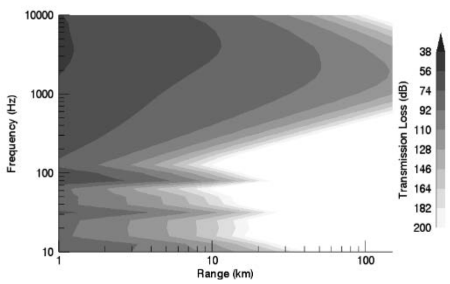

Figure 7. Transmission loss table for sample at 30-45m in region 3 (originally in MacGillivray et al 2014, 5)

The acousticians labored to build this computational aquarium, a reef-in-miniature, and give it the tables which animates the sound. They had to extend their knowledge networks beyond their own institutions. The acousticians borrowed data from geologists, physicists, technicians, and foreign navies. When they found broken links, they had to reach out to other seabeds in other parts of the world. If one transformation failed, then the whole model would break. It would no longer reference Wheeler Reef, but some other, fictional reef. To an extent, the model itself is a fiction. No real, wet reef would be so well behaved. But this fiction is made to matter through reference. Each transition was justified by connecting the acousticians' knowledge with other knowledge networks they believe to be true. As long as the trust in those connections remains, to the acousticians, there is fidelity in this model.

The Decibel

Now that the acousticians have a model, it is time to make it sing. But before they populate it with sonorous beings, I would like to turn briefly towards the nature of sound itself. A model is worthless if there is no consistency in the inputs or agreement on how to interpret the outputs. The acousticians must also be cognitively aligned so that they do not make mistakes and undermine their whole endeavour. Because of that, I will discuss the problem with decibels. Dear reader, I warn you that there is mathematics up ahead. If it has been some years since you have dealt with complex math, I implore you, do not get hung up on the numbers but pay attention to the relationships, for they are what matter.

The decibel is the fundamental unit of acoustics. It describes the relationship between the pressure of any acoustic energy (the sound pressure level) and the lowest pressure the receiver can sense (the threshold of perception). The formula for such a measurement is:

$$dB = 20 \log\left(\frac{P1}{P2}\right)$$

where P1 is the sound pressure level and P2 is the threshold of perception. Each portion of this equation is not solely a piece of data for the output of a decibel value. It is a symbol that encapsulates the acousticians construction of sound. 20 log, P1, and P2 informs the world view of the acoustician.

I will start with P2, the threshold of perception. It is a sanitary name for such a visceral element. P2 is often substituted by 10^{-12} W/m^2 or one trillionth of a Watt per meter squared or – again – a magnificently small amount of energy hitting a one meter square surface. But what is that surface? Why, the human eardrum, of course. 10^{-12} W/m^2 is the lowest amount of energy that the human ear can detect, anything less energetic is silence. Therefore, P2 stands in, most often for the human, but it could be altered for whatever is listening. This will become important later. For now, P2 becomes the stand-in for the listener, or more precisely, the listener's ear.

Now for something that P2 can listen to. P1 is the placeholder for whatever sound is traveling across the medium – the sound pressure level (SPL). SPL is itself a complicated concept. How best to measure a complex phenomenon such as acoustic energy which is hardly ever transmitted as a consistent wave?[59] It turns out, there are multiple ways of measuring acoustic energy, and knowing which way it is measured matters. There are three principle ways of measuring acoustic energy: *peak-to-peak*, *zero-to-peak*, and *root-mean-square*. Peak-to-peak (p-p) measures the "difference of pressure between the maximum positive pressure and the minimum negative pressure in a wave" (André, et al. 2009, 10).

[59] A consistent wave or a *sine wave* would produce a pure tone at a consistent volume.

Zero-to-peak (0-p) measures highest maximum pressure from zero. Root-mean-square (RMS) is a more complicated. It is the square root of the mean of the squares of a set of peaks within a signal.[60] Essentially, RMS is the mean of a series of peaks. RMS is no longer used anymore, but it is important to understand this measurement for its historic useage.

Each type of measurement does its own work and is appropriate for different types of signals. A 0-p or a p-p is appropriate for pulses such as the pop of a snapping shrimp while a RMS is more appropriate for complex signals over time, such as the accumulated pops of snapping shrimp in the environment. Knowing how each signal is measured is essential for interpreting and comparing levels so acousticians will include the method onto the decibel measurement so that it reads $dB_{0\text{-}p}$, $dB_{p\text{-}p}$, or dB_{RMS}.

A second amendment to the sound measurements is the *reference*. The medium through which sound travels also matters. Air is less dense than water, so sound behaves differently in each medium. Generally, sound in air is measured at a reference of 20µPa (micropascals) at one metre from the source and sound in water is referenced at 1µPa at one metre. Where did 20µPa and 1µPa come from? Well, each is the amount of pressure needed to generate 10^{-12} W/m^2 in the given medium, circling back to P2. Therefore, P2 could be replaced with 20µPa (or 1µPa if in water) instead. These references will be written as re 20µPa (or 1µPa) at 1m. All of these amendments let the acoustician know, at a glance, the nature of the measurement he or she is working with. "$dB_{p\text{-}p}$ re 1µPa at 1m" reads as a sound level measured using peak-to-peak in water (probably a pulse signal such as a shirmp snap or sonar ping).

With the ratio properly established between P1 and P2, it is now time to deal with 20log. Decibels exist on a logarithmic, not linear, scale. Each increase of ten decibels is ten times as energetic as the tenth before. The human mind has difficulty dealing with the vast scale between power levels. For example, the sound of the human voice is somewhere around 60dB which equates to one millionth (10^{-6}) of a watt. Compare that to the one trillionth of a watt for the threshold of hearing. Working In logarithms makes these scales manageable. Placing sound energy into a logarithmic scale gives the acoustician one bel, but humans are able to distinguish between changes in energy at the decibel level, therefore we multiply 10 to log. But that gives us 10log, not 20log. Why?

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[60] $x_{RMS} = \sqrt{\frac{(x_1^2+x_2^2+\cdots+x_n^2)}{n}}$

If you, the reader have been paying attention, you will notice that we have been measuring sound in two units: watts and pascals, or energy and pressure. A decibel is a measure of sound *energy*, but energy is hard to get at. Think of the particles in the medium hitting the ear, microphone, or hydrophone as if they were balls being thrown at a surface. The more energy one passes to the ball, the harder it is thrown and the harder it hits the surface. This causes more pressure to be applied to the surface hit by the ball. This pressure can be measured. Happily, the two measures are related. Simply square the pressure to get the energy, or multiply by 2log (trust me, the math works). This gives us the final product of 20log.

Within one measurement are entwined the worlds of a particular sound and an acoustician. It encapsulates method, medium, and scale. It ties up the listener with the sound-maker and the environment that they inhabit. All of this is readable to the acoustician as long as the labels are there. But decibels may not be comparable. Fear not, the acoustician has one more trick: the *sound exposure level* (SEL). An SEL is "the level of pressure of a constant wave which, if it is maintained for one second, will generate the same acoustic energy to the receptor as the studied sound" (André, et al. 2009, 10). Here is another transformation, another fiction that matters. It shrinks or grows a sound signal to a uniform size for uniform comparison. It may not work with all signals, but it is a start. Now that the acoustician has a model aquarium and rules to govern the sound by, it is time to add in some sonorous beings.

Populating the Aquarium

At Wheeler reef, the acousticians listened to ships traverse the Reef lagoon. They had a hydrophone in the water (the little yellow star labelled AMAR in Figure 3), but it could not hear every boat that passed by or tell of the experience of other reefs in the area. How then do the acousticians shrink those massive, complex ships into something that can fit inside their model?

First, the acousticians must know what ships are in the water and where they are going. For that, the acousticians used the Automated Identification System (AIS) which records the position of every comercial vessel at a regular time interval. The system was set up by the International Maritime Organisation (a subdivision of the UN) and is required on almost all commercial vessels (IMO n.d.). Those data are freely available, although, as one acoustician pointed out to me, the data alone are not complete enough for acoustic modelling. It is still too coarse. At best, the acousticians now know where the boats are going (the green lines in Figure 3), just not how fast and what class the ships are.

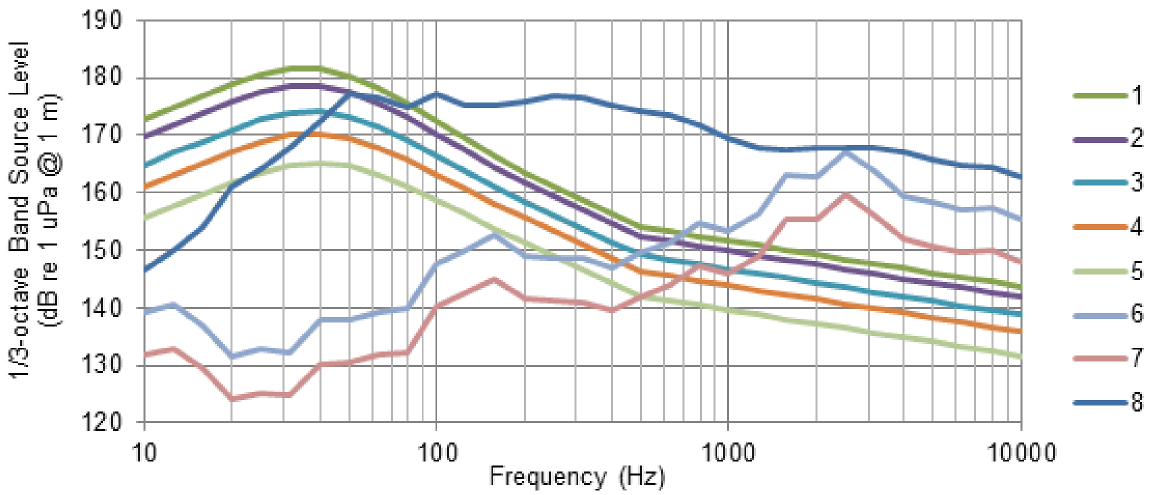

Figure 8. Acoustic signature of 8 categories of marine vessels in the Wheeler Reef area (originally in MacGillivray et al 2014, 4)

The AIS data did show the overall length of the ships. From those data, the acousticians divided the ships into seven categories based on length and one category for tugs "which were categorised separately because their source levels are uncharacteristically high for their size" (MacGillivray, et al. 2014, 3). Drawing from another acoustician's model, they characterized noise for vessels over 50m long (categories 1-5) using the "power-law model":

$$L_s(f,v,l) = L_{s0}(f) + c_L \times 10\log_{10}\left(\frac{l}{l_0}\right) + g(f,l)$$

While of imprantance to the acousticians, the maening of each variable does not really matter for my purposes. What is important is that these vessels were so easily transformed into an equation. That equation is then represented as a sound profile, the typical SPL for each frequency band the vessel produces. The transformation becomes apparent when compared to the other three groups with sound profile characterizations being drawn from earlier studies by the acousticians in Alaska (as visualized in Figure 8).

Once again, the model is filled with abstractions, fictive references that remain contiguous because of the strength of their transformations. The many ships plying the coastal waters have been reduced down to their sonic profile, but the reference held. The larger ships were transformed through an equation the acousticians thought valid, thus the connection between ship and profile became vaild.

The other set were made by use of hydrophones and the acousticians' own skilled research in Alaska. They would have recorded the noise of different vessels using a calibrated hydrophone at a set distance. Then, and this is important, they had to *back propagate* the sound. The acousticians needed a *source level* from the vessels, but sound is unevenly distributed throughout a ship. Using what they know about the movement of sound, they had to trace the signals to an artificial point. This is one of the most dangerous transformations. This is what the acoustician quoted at the beginning of the previous section meant about log space and linear space. The sound moves logarithmically out from the source, not linearly, but many individuals poorly trained in the art of acoustic modelling fall for this trap. These acousticians were well trained and successfully navigated log space. Their references remained intact. The profiles also became mobile. The Alaskan vessels' profiles were able to be moved from the Arctic to the tropical Australian waters as stand-ins for similar, but unmeasurable objects.

Now the model vessels had life. The acousticians knew where the ships were going, how much noise they made and how that sound travelled across the Reef. So they animated it. Figure 9 shows the movements of the model boats through the model reef. The little balls of yellow and red represent the ships with sound radiating out and being blocked by coral outcroppings. In other places outside of this thesis, this image is shown as a short video clip so that the viewer can watch the ships passing and the noise filling the environment. Many transformations were needed to get to this one compelling image. Many other actors had to be recruited. But the transformations are not done yet.

The model reef lacked one vital element: living beings. The only things plying those computational waters were the acousticians' toy boats. The model in Figure 9 would remain

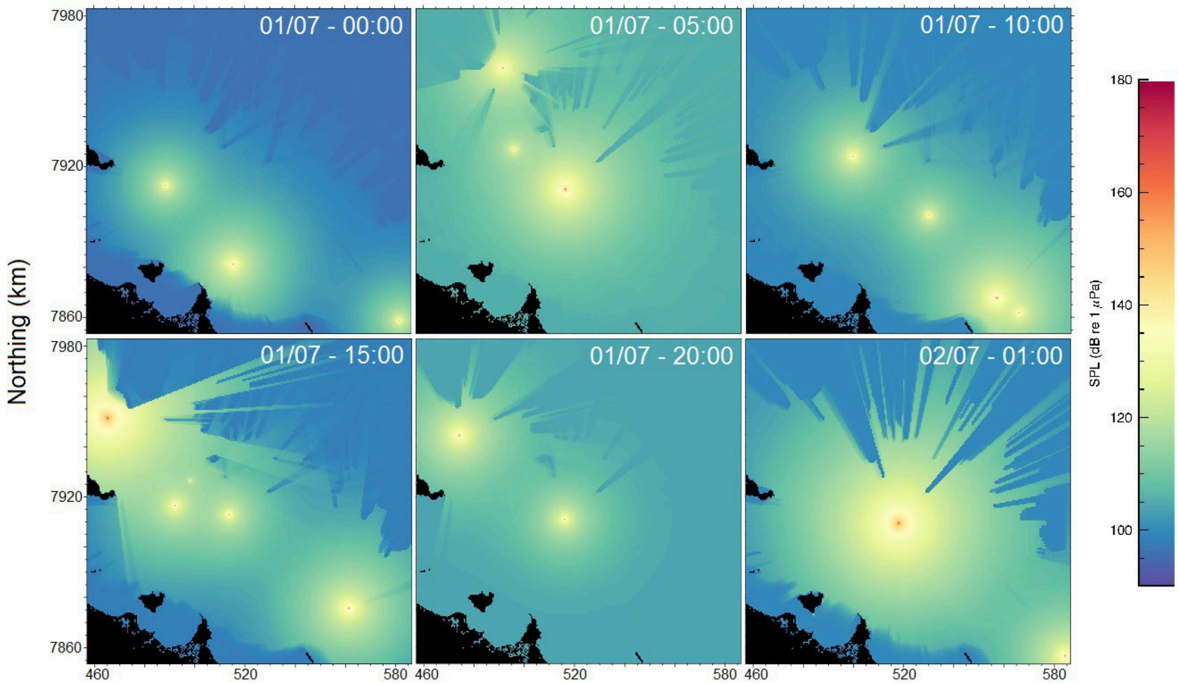

Figure 9. Sample frames from the time-lapse animation model of vessel noise in the Wheeler Reef area (originally in MacGillivray et al 2014, 7)

sterile, for the authors had completed the task they set out to do. But not all models are so lifeless.[61] Some contain their own menagerie of fictive beasts: the animats.

Animats, short for animal materials, are computer models of marine life (almost always marine mammals) that swim through a modelled environment, collecting and reacting to noise. After a set simulation time, an acoustician can check how many animats received an unacceptable *accumulated SEL* or *peak pressure* which can cause death or injury to a flesh-and-blood animal.[62] While animat modelling is still relatively new technology and has yet to become industry standard, its use is increasingly being requested by governmental agencies (particularly in the United States). Being a new technology at the extreme end of animal modelling, activities around animats can illuminate the relationship between acousticians and marine life that are forged or broken in model making at multiple levels of complexity.

Generating Animats

To build up an animat, we must first break down the animal, although "animal" may be too broad of a term. Almost all animats model marine mammals (an issue I will discuss later), with a heavy focus on cetaceans.[63] Marine mammals have been subject to considerable, global, protective legislation, resulting in a plethora of biological data.[64] The intensity of legislative and scientific focus means that marine mammals have established a data granularity which allows their bodies to be quantified, broken apart, reconfigured, and rebuilt into model beings.

This process starts with the ear. No matter how simple, a model must be able to hear in order to measure sound. Historically, this been the starting point for every marine animal modelling in noise pollution studies. A species hearing range is typically depicted as a U-shaped graph called an *audiogram*. Figure 10 shows the audiograms for select odontocetes.[65] Each point on the graph represents the quietest possible level for each frequency the animal can hear. I have added the green field to highlight the effective hearing range of the harbor

[61] In an animate version of this model, an animat whale was added.
[62] Accumulated SEL and peak pressure are the duel criteria required by the US National Oceanic and Atmospheric Administration (NOAA) for assessing marine mammal sound impact. Accumulated SEL can cause hearing fatigue, increased stress, or other ailments caused by continuous exposure to loud sounds. Peak pressure can indicate that an animal has experienced a traumatic, possibly deadly, event from an acute exposure to an extreme pressure change.
[63] Whales and dolphins. Cetaceans are further broken up into mysticetes (baleen whales) and odontocetes (toothed whales) (see Chapter 2).
[64] See Chapter 2 for a historic perspective a marine mammal research and sound.
[65] Beluga whale, bottlenose dolphin, harbor porpoise, and false killer whale.

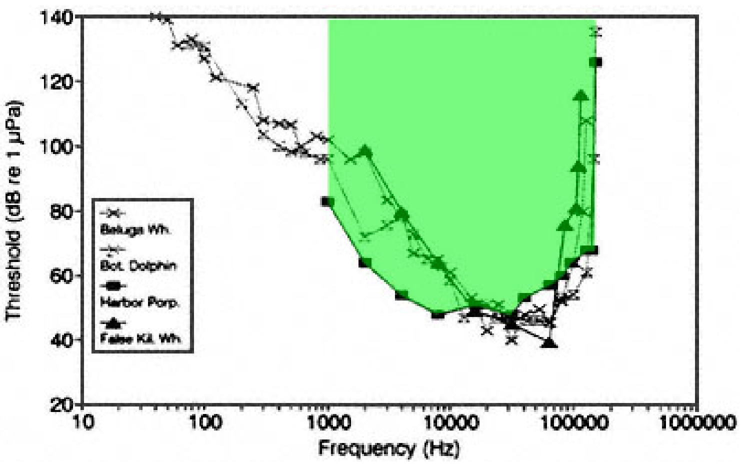

Figure 10. Audiograms for beluga, bottlenose dolphin, harbor porpoise, and false killer whale. Green field added Buttacavoli to highlight audiogram for harbor porpoise (originally in NRC 1994)

porpoise. Theoretically, a healthy porpoise could hear any sound that would be graphed within that field (for example, 12,500 Hz at 80dB re 1µPa at 1m).

Through an audiogram, the entire animal can be reduced to the ear. An entire whale becomes an elegant curve. But, this seeming simplification allows the acoustician to complicate things elsewhere. Perception is the name of the game in acoustic monitoring, and not all sounds are heard the same. Sounds within an animals more sensitive ranges (20 to 30kHz for the harbor porpoise) are perceived to be louder than sound of the same intensity in their less sensitive ranges (1kHz for the harbor porpoise). This means that the threshold for pain is lower in more sensitive ranges. Remember that the decibel is a *relational* measurement. The acoustician can never fully move away from fleshy beings, and must now make another transformation to reinforce these relations. They do this by *weighting* the signals based on frequency to adjust the decibels to their *perceived levels*.[66]

There is one major problem in this. Recall back in Chapter 2 that an audiogram is difficult, if not impossible, to get from most large marine mammals. How then is the acoustician supposed to model such creatures, who also happen to be the most at risk from underwater noise?

To create an effective model, the acoustician must be willing to abstract. Over the years, enough data has been generated through observation of living animals and experimentation on dead ones to create generic audiograms. These frankenwhales, puzzled together from many different species, are adequate substitutes for the real thing. Southall, et al. (2007) have established the standard for these generic weightings, both for cetaceans and for pinnipeds.[67]

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[66] Technically, the weighted units are called *phons*.
[67] Seals, sea lions, and walruses.

Typically, sound is weighted using an *A-weighting* (represented as dB(A)) based on the human audiogram (in air). Southall et al. established a series of *M-weightings*; three weightings for cetaceans based on their typical hearing ranges (see Figure 11) and two pinniped weightings depending on if the animals are listening in water or air. Southall et al.'s M-weights further abstracted the animal into something that acousticians could work with.

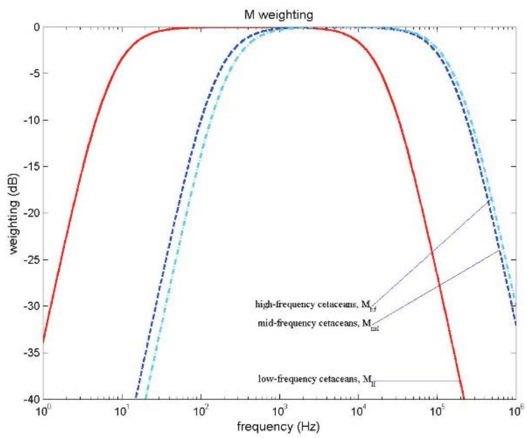


Figure 11. Chart of M weightings (originally in Southall et al. 2007)

The M-weighting has typically been the terminal transformation for marine mammals in acoustic modelling.[68] Select a distance from the sound source, apply the correct weights, and do the appropriate mathematics. This modelling can predict accumulated SPL of an animal traveling on a linear path or located at some distance from the sound source, but the flesh-and-blood animals rarely behave that way. The abstraction can be too abstract, the transformation incomplete for a satisfactory outcome. The model may hear like a whale, but it does not behave like one.

Behavior is key for true animat modelling as "an animat is just a simulated animal in space" (Acoustician, interview). The Marine Mammal Movement and Behavior (3MB)[69] software (Figure 12) is a leader in animat modelling. It works by taking published material about observed mammalian behavior and converts each animal into a set of probability tables.

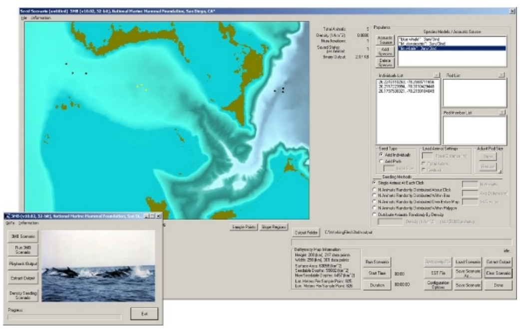
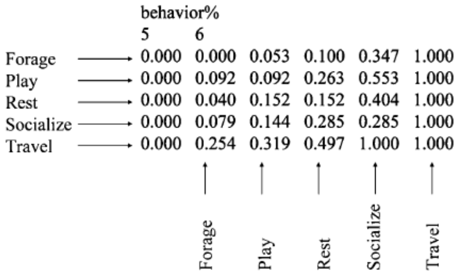


Figure 12. Sample of 3MB interface from nmmf.og/3mb

Houser (2016), the creator of 3MB, provides eight different parameters to set the "species definition": behavioral state, directional movement, horizontal speed, vertical speed, diving depth, reversals, and surface intervals (77). Tables, like the behavior state table in Figure 13, predict the likelihood that the animat will transition from one state to another. The results of all the tables then inform the

[68] For fish, the transformation ends at other weightings if they are lucky enough to even be considered.
[69] http://www.nmmf.org/3mb-release.html



behavior%	5	6				
Forage	0.000	0.000	0.053	0.100	0.347	1.000
Play	0.000	0.092	0.092	0.263	0.553	1.000
Rest	0.000	0.040	0.152	0.152	0.404	1.000
Socialize	0.000	0.079	0.144	0.285	0.285	1.000
Travel	0.000	0.254	0.319	0.497	1.000	1.000
		Forage	Play	Rest	Socialize	Travel

Figure 13. Behavior state table (originally in Houser 2006, 78)

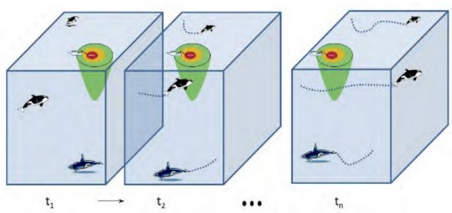


Figure 14. Illustration of animats reacting to noise (originally in Zeddies, et al. 2015, D-28)

animat's behavior and where it will be positioned in the next cycle of the model. These tables produce a simulacrum of marine mammal behavior, enough to provide a decent reference for what the animals will do in the water. Through other mathematical means, they are given direction so that they do not aimlessly wander about.

Zeddies, et al. (2015)—who uses JASCO's Animal Simulation Model Including Noise Exposure (JAMINE) software—asks the reader to imagine animats as if they were the orcas in Figure 14, swimming freely around their little cubic aquarium. In reality, the visualization for 3MB (much like other modelling software) depicts these animats as small dots moving around a bathymetry map (see Figure 12) playing, foraging, and sometimes scurrying away from the sound source. Ultimately, neither of these images matter to the acoustician, the visualizations are there solely to communicate the model to the client. A complete study would include too many creatures and the time scale would be too great for any visualization to run. The acoustician cares about the outputed numerical data. How many animals received too much sound, were harmed, or scared away from the area.

This is the true goal of any model, to arrive at some actionable data. The modelled environments are temporary structures and the animats are temporary beings, brought into existence to speak for the greater world. Once again, they are references. That is why these transformations matter. If the model is to truly reference the outer world, then the transformation of all of its elements must be robust. Otherwise, the model would be fantasy, a fiction divorced from the logic of the physical.

Inside the Virtual Aquarium

It can be argued that the aquarium of the model is a virtual space. It is a bounded space protected from the tyranny of physics which we experience in the actualized world. According to Deleuze (1991[1966], 2002), the virtual is a product of material relations that enable access to a realm which is real but not quite anywhere in particular. The virtual is notable in the flexibility of space and time which it affords. Unlike the actual world we experience daily, space and time in the virtual world are not rigid. For the model, this means that space can expand and contract, time can be rewound and fast-forwarded. It is the flexibility of space-time which makes the model useful for acousticians.

Still, as Deleuze notes, the virtual world is tethered and limited through material attachments to the actual world. Virtual worlds do not just appear. They are generated by computers and computer programs and made accessible through output devices like monitors and speakers. How fast the virtual aquarium can run through a given scenario depends on the technological limits of the machines it runs on, the elegance of the programming, and the granularity of the data.

We can think of the virtual aquarium as a complex transducer. Through its assemblage of technical objects, the model is able to convert a multitude of data points into graphical or synthesized outputs which make the modeled environment sensible. This sensibility also has great flexibility as changes to the technical assemblage, data set, and transductive pathways can produce new sensory data. Not only do the spatial and temporal boundaries of the model have the ability to shift, contract and expand, the perceptual self, embedded inside the aquarium, morphs along with the data.

It is the morphing perceptual self which builds a bridge to between human and non-human experience. If the virtual aquarium is a great transducer, its orienting goal is to transduce non-human perception to make it accessible. Animats become virtual diplomats that tell us what their reference might experience so that the actual animal might never experience harm. Yet, animat diplomacy is a strange form. The diplomat is nominated (and built) by us, not the whales. It becomes a best guess diplomacy in which the acousticians can never be quite sure if they have successfully represented the whales.

The virtual aquarium can never fully substitute for the actual oceanspace, nor do we want it to. Its flexibility gives it power so that we may sense new possibilities in the rigid actual world. If the model is to be useful, it must instead be speculative, a what-if that convincingly predicts possible futures. In the next section I will outline the future making possibilities of models and what is preventing perfect prediction.

Imperfect Futures

Throughout this chapter, I have presented model making as a type of fiction. The use of the term fiction might be unfair, given the genre's connotations with deception, arbitrary invention, and fabrication. But it would also be unfair to call these models facts for two reasons. First, the models contain too many strained transformations in themselves to be comfortably embraced as true references to the greater world. Second, these models reference a future that has yet to occur.

Latour (2013) reminds us that the map of the mountain is *not* the mountain, just like the model of Wheeler Reef is *not* Wheeler Reef and a blue whale animat is *not* a blue whale. These references have become too flat and too small to be the refered to thing. The acoustician knows this and attempts to *validate* the model by continuously tracing it back to the wet oceanspace. Now we return to that sacred object: the hydrophone. By taking readings at select points during an exact point in time, the acoustician (via the hydrophone) can confirm that the predicted measurements are accurate, thus securely linking the model to the environment. The acoustician can never truly leave the physical world behind as the models need constant validation. The hydrophone has transduced the subject into the object and back again. With hydrophone in hand, the acoustician repeatedly traces the links between the two spaces. Those points then anchor the reference to the referred space. If the anchors are solid, then the model works across the board.

The acoustician can be confident in the transformations that allow for the model to reference the oceanspace. They are experts in acoustic propagation and can continuously reaffirm those ties. But, the further the model moves away from their expertise, the less confident they can be with the transformations. The main frustration for acousticians is not in understanding material from other disciplines—they are very comfortable working with such information—but with the dearth of data available. As I have indicated throughout the model-making process, many of the data that the acousticians enrolled from other fields were incomplete and needed supplementation. Validation becomes near impossible, straining the relationship between the reference and the referred.

The Wheeler Reef model will remain sterile for the foreseeable future. This is not because the real reef is devoid of life or of marine mammals. Migrating humpback and minke whales pass by the Northern Queensland coast every winter while smaller odontocetes (as well as dugongs) live in the shallow lagoon year round. Unfortunately, these populations have not been quantitatively studied sufficiently to generate useful animats (with the sole possible exception being humpback whales). Their population sizes, movements, behaviors, and distributions simply are not available for modelling.

The animat problem intensifies when interests extend outside of class Mammalia. Currently, there is no available modelling software to create fish, reptile, or invertebrate animats. The vast wealth of the sea is unmodelable. This lack of modelablity extends to the marine mammals who prey upon those creatures. Some acousticians have questioned the usefulness of animat models that cannot properly account for the movements of prey species. For instance, a sperm whale is not likely to spend time around a sound source that repulses or kills the squid the whale likes to eat, irregardless of whether or not it is receiving dangerously high doses of acoustic energy. These issues are repeated throughout the other disciplines that the acousticians attempt to collaborate with. Either through a lack of funding or the siloing of knowledge, the data acousticians need to create robust transformations are incomplete or nonexistent.

These strained transformations can make forecasting difficult, especially in a complex environment such as the Great Barrier Reef. But even with all the data an acoustician could possibly want, modelling would still be imprecise because it is playing in future-making. The future is inherently unstable because of the overwhelming abundance of entangled present variables that compose the future. The future is emergent because it is unpredictable, it is more than the sum of the parts that compose the present. Too many unknown and unexpected interactions conspire to create the future. It is a tall order, then, for the acoustician to predict the future sound-state of ocean.

Speculations may be a better word than fictions to characterize model-making. Speculation is a type of fiction (most notably in the speculative fiction genres such as fantasy and sci-fi), but it is a fiction grounded in the present and looking towards the future. The acoustician works hard to create a *valid*, *high-fidelity* model, anchored in oceanspace. This model becomes a platform from which the acoustician can speculate about the future. The model offers possible futures while closing other avenues. Tweak the model and new futures appear and then disappear. It is the acousticians' ability to manipulate and finesse these not-yet-realized futures that underlie their value.

Speculation is neither complete fact nor fiction. The speculation is valid *if* the model is valid. The model is valid *if* the transformations are robust. The transformations are robust *if* the data are good. The data are good *if* the fidelity is high. At all the levels of these nested contingencies the acoustician works hard to maintain connections. Noisy data are controlled, weak transformations are strengthened as much as possible by enrolling others, strong transformations prop up models, and models are continuously validated. Acousticians can claim the speculation is near-fact even in imperfect futures because they have done the work to maintain the chain. The acousticians are not naïve. They realize that their speculations are never solid, they could bend and break with every new revelation or change in the environment.

Sonic Sybils

I met Geoff once again at the university café a week before I had to leave for Denmark. I would be away in Europe for some time so I called the meeting to catch up. He started telling me about the progress being made on some ill-conceived reef project that threatens to dump more noise into the environment (all in order to save the Reef). It is not uncommon for us to talk about potential projects and threats to the Reef soundscape. Geoff will often call me if some news breaks or if something came up in a meeting he had. A few weeks before, he had called me asking, “Did you hear the news?” I was on the dive boat heading out to the Reef. No, I had not heard the news. The project we had thought was going nowhere (the same one we would discuss at the café) had just advanced, to the shock of many interested parties, without a thorough acoustic assessment as part of the environmental impact study.

It is clear that Geoff cares about the future of the Reef, as do all the other acousticians I have spent time with. They also share a frustration with the lack of acoustic assessments and noise management on the part of the Commonwealth. Throughout this chapter I have shown how acousticians work through abstractions and transformations, but I do not want to imply that this distances them from the field. It is easy to criticize scientists for using abstractions to isolate themselves from the grittiness of the physical world. I would argue the opposite: acoustic modelling has enabled a deeper relationship to unfold between the acousticians and the underwater environment. The acousticians attend to sound as what Helmreich (2014) calls scientific things, pheomena like waves that are equally material and abstract.

Through the process of measuring, modelling, and validating, acousticians reorganize complex phenomena to allow for new perspectives. They create for themselves an object that can be manipulated and interrogated in order to better comprehend the oceanspace and foretell its future. In this case, the reference can allow for such manipulation because it is abstracted away from a more rigid, physical space. It allows the acousticians to think in futures. Future forecasting is a positioned project, there is some ideal or feared future state of the environment. It is that feared future state that motivates such forcasting. Whether it is concern for for the environment on behalf of the acoustician or regulatory concerns from the government or contracted company, future forcasting through modeling helps to direct the acousticians’ actions. In the next chapter, I explore how environmental urgency has put acousticians in contact with other sonically interested groups as marine listeners attempt to improve the lives of orcas in North America.

Interlude III: Ontological politics

Geoff McPherson has been a fierce advocate for noise pollution management in the Great Barrier Reef World Heritage Site. His fight has taken him beyond acoustic monitoring and assessment into direct activism with the Australian Government. In 2014, Geoff submitted a voluntary submission to the Australian Senate which laid bare the state of underwater noise pollution from shipping in the Great Barrier Reef and the Commonwealth's international obligations to reduce shipping noise impacts (McPherson 2014). He later sat as an expert witness to the Senate Environment and Communications References Committee's inquiry into "the adequacy of the Australian and Queensland Governments' efforts to stop the rapid decline of the Great Barrier Reef" (Commonwealth 2014, preamble). More recently, he has assisted GBRMPA in writing an underwater noise guidelines (McPherson, et al. 2016). For all that effort, Geoff still feels silenced.

As mentioned in Chapter 4, many of my conversations with Geoff circled back around to the ways that marine noise and sonically sensitive species went uncared for. If he was attempting to make noise about noise, it was into a veritable anechoic chamber where the political absorbed all sound and refused to yield any echo. Speculation on why marine noise pollution was being willfully ignored was common among many of my interlocutors, but much of it was difficult to verify ethnographically. This is a common problem in anthropological research. We are rarely able to get a full picture of the decision-making mechanisms used by state politics, which are often far removed from our field sites. It is not unusual for anthropologists to be cut off from government bodies and large corporations, leaving us with local rumors and the odd bits of published material. But, even with those scraps of policy documents and press releases, we can get an idea of the world views attempting to shape the local environment.

As my research progressed, what began materializing for me was the existence of competing world views that enabled or prevented the sensing of marine noise. How could I start thinking (transductively, perhaps) about these competing views? Maybe there might be some insight through ontological politics (de la Cadena and Blaser 2018; Gibson-Graham 2009, 2011; Haraway 2008; Stengers 2005) which have sought to generate new political possibilities through difference.

A Politics of Worlds

In 1970, Roger Payne—the man who first document the songs of Humpback whales with his then wife Katy Payne and later documented the first know effects of shipping noise on right whales with Douglas Webb—released the album "Songs of the Humpback Whale" with Frank Watlington (O'Dell 2010). Watlington and Payne's album was released with the specific purpose of generating a sympathy for the whales who were still being hunted at the time. Through persistent effort, Payne managed to convince radio stations to play his recordings and the album soon sold thousands of copies, making it the most successful field recording album to date. The popularity of "Songs of the Humpback Whale" sparked the "Save the Whales" movement which helped to end international whaling (Toop 1995). Excerpts where later added to the golden disk on the Voyager spacecraft, making the whales non-human diplomats for any lucky extraterrestrials who might stumble across the probe. Listening to the recordings, it is possible to hear the development of a new politics which begins to recognize the complex worlds of these leviathans. Watlington and Payne's work can be viewed as an early sonic example of applying ontological politics to non-humans.

I wish to start out with Stengers' (2018) politics in order to understand such actions. Here we have a politics of competing worlds who are mutually respected, not just tolerated. Developed from her earlier cosmopolitics (Stengers 1997) which sought to recognize the intersection between political discourse, scientific practice, and non-humans, her ontological politics expands upon those topics to the point where they no longer intersect but continuously clash with one another. Not only does techno-scientific discourse happen in front of those upon whom it will impact, but it must now include them as interlocutors. Hers is an ontological politics that has developed out of the European interest in science and technology studies which makes it the most appropriate for my own work.

The world of Western techno-science[70] does not rule all in ontological politics, but must share space with Indigenous worlds, religious worlds, and non-human worlds. These politics create a *pluriverse*, a world of many worlds (de la Cadena and Blaser 2018; Escobar 2018). In the pluriverse, multiple worlds sit beside each other. They do not have to agree on how the pluriverse should be ordered, but they must reach a temporary accord. The politics

[70] Latour's Moderns which Stengers also takes up.

of the pluriverse are set in motion by equal senses of urgency and care, partially as a result of on-going inequity originating from colonial violence and Modernist domination of the environment. For more-than-human politics, the urgency of environmental change threatening the world during the Anthropocene has revealed the defects in the current status quo in a world of one world. The dangers ahead have formed new allegiances between different worlds. These allegiances are ones of caring in order to stave off the worst of the effects from the Anthropocene, which opens an ethics of care (Puig de la Bellacasa 2017). In Birmingham, UK, it is care towards finding spaces for water voles and Peregrine falcons to live in the city (Hinchliffe, et al. 2005; Hinchliffe and Whatmore 2006). While in Australia, it is caring for an ecosystem which supports flying foxes as much as we care for ecosystems that support us (Rose 2017). It is through caring that Stengers (2013, 2018) proposes that politics of worlding and belonging start. Through caring practices, beings are given political agency and the pluriverse enables a proliferation of subjects who were once objects.

Stengers' and other's politics are built around a multispecies and multicultural approach. Within it, von Uexküll (2010[1934]) and Simondon's (2017[1958]) influences can be seen. Ontological politics tacitly recognizes the phenomenological experiences and ontics of other creatures as being constitutive of ontologies, although it is made more obvious is some scholarship (Haraway 2003) than in others. Such a positioning is reinforced by Jackson (1996) who finds ethical and political knowledge in the phenomenological experience. There also appears to be more focus on shifting, emerging relationships that echo Simondon's individuation. Ontologies and their interactions with each other unfold from moment to moment rather than maintaining set relations. They become dynamic structures as they act and react to other ontologies. They are no longer subject to the pressure of the authentic world found in Heidegger (1973) as there no longer exists one world, or one *Dasein,* which has authority over the others.

Research into ontological politics is both observational and practical. On one hand, ontological politics and pluriversal researchers seek to document the ways in which ontological politics is being enacted such as through the Zapatista declaration which has inspired the Latin American scholarship (de la Cadena and Blaser 2018). They desire to show

how such politics are already being enacted in opposition to totalizing state politics.[71] On the other hand, these writers are attempting to practice the pluriverse as an emerging politics. By showing how worlds can interact, they are demonstrating how they wish ontological politics to develop. Rather than an intellectual exercise in documentation, ontological politics research is an assessment and provocation for developing possible futures in the age of the Anthropocene and post-colonial politics.

While the worlds of non-humans are a part of this future making, their place within the political arena (or the political space which is viewed as legitimate by state actors like the Commonwealth of Australia) is questionable. Or, maybe the political arena itself is questionable. This is my greatest stumbling block in comprehending ontological politics: the shifting scales of politics and care do not appear to be of the same structure. At best, I see two arenas. The first is at the level of daily, intimate politics in which I recognize non-humans as political actors. We each try and structure how the day should unfold. I react as much to the will of non-humans as they react to mine as we try to live together in the same space. I contend with weeds, ants, birds, and trees as I, at times, try to enforce my ontology through removal, extermination, and cultivation while I occasionally concede defeat to their ontics when they successfully claim a garden bed, infest a bag of sugar, or build a nest in an ornamental plant. But at the level of governmental politics, the non-humans tend to fall away as agentive beings, at least in ways that can be recognized by human political structures. A whale does not walk into parliament and demand legislation. The whale does not *know* what parliament or legislation is and would it care if it did? As we get into to the complexities of managing or governing ourselves, we seem to transition into a tighter pluriverse of human worlds. It is a trade-off: in order to focus on collective and structural organization, some participants must fall away.[72] It is a difference of generality and specificity directed by unbridgeable differences in *umwelt*. A relationship also exists between the two arenas in that actions in intimate politics are often directed by actions in social politics. How I interact with non-humans is shaped by legal and social protocol.

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[71] While not specifically framed as such, Australia's Native Title doctrine demonstrates some ontological politics through the recognition of Indigenous land management and social structure.

[72] In a countermove, some non-humans are gaining legal personhood status and rights such as the Whanganui River in Aotearoa New Zealand, the Ganges in India, and Lake Erie in the United States. Pointedly, these are new political practices which currently still require the use of human spokespersons for these entities.

Now, if I accept that ontological politics occurs in two related arenas, then I have something anthropologically interesting. I can start seeing how shifting relations in one arena are impacting the other. It also helps me to see more clearly how Stenger's strand of politics fits into the politics of scientific knowledge. Through the writings of Latour (1987), Law (2002), and Mol (2002), we can see how non-humans become enrolled and represented by individuals or institutions. In the cases examined in this study, "representative" may better replace Latour's "spokesperson" as the representative goes beyond speaking for the non-human to making actions that he or she thinks will benefit the non-human. Political wrangling in the sciences often occurs when two groups believe that they are the best representatives of the same non-human or when actions on behalf of non-humans are in conflict. Those representatives/scientists have brought the knowledge gained from their intimate politics with non-humans (fieldwork or experimental research) to inform political/scientific debate. This sort of politics is recursive as the representatives constantly move between arenas (we have transduction once again!).

This might be the frame in which I could observe political action towards non-humans. Politicians, scientists, and activists are all acting as representatives of non-humans in the social political arena. The politics here are about how the representatives attempt to structure non-human worlds through building managerial and legislative frameworks to direct state action.[73] In terms of noise pollution policy, the politics come out through the way representatives like Geoff and the other acousticians bring other species to the negotiation tables through representation in order to more respectfully divide up the marine sound space. It is also how those representatives reposition themselves after going back and assessing their intimate politics. It is that moment of transduction I want to home in on because it is only possible through the mediating structures which connect the two areas.

Ontological Machines

I am struck by just how many *things* there are in the space between the intimate and governmental political arenas. There is a materiality to ontological politics. I am not talking

[73] I would like to differentiate my thinking on representation from Latour's (1993) spokesperson in the Parliament of Things. While I see the usefulness of PoT, I feel that these representatives are doing more than acting as a spokesperson for non-humans. They are actively attempting to shape non-human worlds.

about the things that make up worlds. I am fascinated by the things between worlds that connect worlds. The interstitial tissue of the pluriverse. These things help to connect worlds through relations while continuously transducing actions and reshaping them. I think I will call these things *ontological machines*[74] for now. I like the use of "machine" because the machine, in a Simondonian sense, is an assemblage of things, techniques, and people engaged in a process. A machine is also modular and can change and do other types of work if it is allowed. It mediates actions across ontologies. The ontological machine is an assemblage that facilitates the interactions between ontologies in a pluriverse while also shaping those ontologies.

Ontological political writing is brimming with these machines. Corsín Jiménez (2018) writes about paintings and conceptual furniture (specifically, a table) as traps (might trap be a type of ontological machine?). Verran (2018) includes text books, English primers, and school houses. Law and Lien (2018) discuss fish farms, fishing rods, and genetics labs. Mol (2002) is filled with medical machines. This thesis has hydrophones, scuba equipment, and virtual models. In each case, these machines allow information to flow between ontologies, like transducers. They make ontologies knowable across difference and separation. These machines are not Stengers' world destroying hegemonic machine, but a multitude of little machines building and tying together worlds.

Thinking with ontological machines makes sense to me mostly when considering non-humans in politics. Machines are *necessary* to access the ontics of the non-human in order to represent them in the political arena. Hydrophones and models are essential to acousticians in understanding how noise might impact marine species. At the same time, our interactions with non-humans help to shape future iterations of those machines as seen with the continual development of more sensitive monitoring equipment and more powerful modeling software packages. We become reliant on those machines and we will lose in the arena if the other side refuses to take them up.

What I also like about ontological machines is that they can be altered. Like all other machines, ontological machines are susceptible to confiscation by the hegemonic state. They can be broken or levered for the benefit of the powerful. But they can also be

[74] This is not to be confused with Object-oriented Ontology.

subverted through their own design. Pfaffenberger (1992) writes about how technology is coopted and altered by the disenfranchised through creative action. He calls the political dimension of this cooption “technological drama.” When the powerful take away access to a technology, the fringe will always find a way around the system through reconfiguring and reinventing the technology. Political actors can also use technological drama to refashion ontological machines to subvert hegemonic control. New funding, new institutions, hacker collectives, and public platforms can all put ontological machines back to their work of mediating ontologies.

Ontological machines enable potentially collaborative projects. They are built through diplomatic processes and structuralize an agreement on how information and action should flows between ontologies. Alternatively, ontological machines can be broken and become obstacles when one group no longer wants to cooperate. Funds stop flowing, equipment is no longer accessible, and recordings are not played. Much can be learned from these shattered ontological machines. They can illustrate the force of logics and entities which oppose pluriversal practices. In the next section, I will demonstrate how these ontological machines break down and stymie the politics that Geoff and I are trying to pursue. In doing so, I wish to spotlight the difficulties facing the project of ontological politics.

Science Inaction

The politics of marine noise in Australia, or the lack thereof, demonstrate the resistive nature of ontological politics and the potential failure of ontological machines in the face of opposition. While much of the writing on ontological politics have focused on successful case studies, the inverse is just as important in order to understand the difficulties of dealing with a pluriverse.

When it comes to noise pollution (and potentially many other environmental stressors) scientists are forced to represent non-humans in what they experience as a rigged system which favors the political status quo that supports shipping and resource extraction over environmental integrity. Within this system, it is the self-appointed task of scientists like Geoff to take information from the field and transport it to Parliament. Each arena—the field and Parliament—has its own sets of structures and rules (methods, ethics, codes of conduct) but the real rigging occurs in the transference of that information from one arena to the other. The current political system for reporting scientific information has legitimized certain ontological machines while delegitimizing others. Those impedances have a critical effect on how politics plays out. The form that that structure takes in Australian marine science and policy will exemplify this argument.

In *Science in Action* (1987) Latour makes it clear that governmental funding plays a major role in how science gets done. Without that money we wind up in a state of science inaction, especially for resource heavy fields like marine research. Funding has long been a source of fuel for ontological machines. As I have indicated in chapters 2 and 5, government money and policy are substantial drivers for the development of environmental research. So much is known about whale audition and communication because many countries around the world have actively sought to protect them from acoustic harm (e.g. MMPA, UNCLOS, ASCOBANS, etc.). But when funding dries up, ontological machines are no longer able to transduce worlds. The level of political will which supported cetacean research does not exist for protecting the greater marine environment from sonic intrusion. To get access to those funds, marine researchers would have to demonstrate that there exists an urgent matter which needs political intervention. To prove that that the urgency exists, marine researchers need their research to be funded.

And here is the policy paradox: politicians want scientific evidence of an ecological crisis before they release funding, but those researchers need the funding to produce scientific evidence. The paradox is indicative of a system that relies on a static world which denies the dynamism of the environment and stifles the development of new ontological machines. For many potential environmental stressors, the paradox can be resolved through well-established institutional networks that have been collecting the necessary data either intentionally or incidentally. Ocean temperatures, fishery catches, and rainfall had all been collected for other purposes before those data were needed to prove an ongoing crisis to the Reef. Few pre-existing hydrophone arrays are available for marine noise monitoring, with most of those arrays being naval installations whose longitudinal data remained classified until the end of the Cold War (Schwartz 2016). To start collecting the appropriate data would require investing in, and installing monitoring equipment.

Several scientists I spoke with specifically expressed dismay that currently policy is driving science instead of the reverse. For a student of science and technology studies, the link between science and politics may have been apparent for some time (see Downey and Dumit 1997; Haraway 1991; Latour 1987, for some examples), but many in the natural and physical sciences are only now recognizing the impact of politics with the current rise of conservative and populist governments. While in the past, scientists had more maneuverability in their research, the current level of policy driven research can feel restrictive. This is especially true for government institutions and government funded research which is also becoming more politically driven.[75] Through such funding policy, governments are able to control which ontological machines transduce which worlds, thus directing the flow and legitimacy of knowledges.

Part of the reason that researchers in Australia have felt their academic autonomy narrowed has been due to changes in the universities. As Western university systems have seen an increase in rationalization, access to funding has become more difficult. Australian universities have seen an increased push for research which can contribute to the economy and an increased reliance on government grants (Keller 2015). As Bromham, et al. (2016) has indicated, those funds can be particularly difficult to access for interdisciplinary projects like marine noise pollution research. The increase in competition from a shrinking pool of funding is threatening to further isolate academic departments and increase the siloing effect of knowledge production. The scientific disciplines in many Western university systems are already fractured kingdoms with each discipline developing its own unique culture according to Knorr Cetina (1999) which can make developing an interdisciplinary program an uphill battle. The fight for funding will only widen those divides.

While the above indicates structural barriers to representing noise pollution, it would be remiss to discount the work of active oppositional agents who take advantage of these barriers. Opposition to environmental legislation is not new to the Commonwealth or Queensland governments. The mouths of at least three Queensland Parliament Members on record have oozed the phrase “land rights for gay whales”—Mrs. Beryce Ann Nelson (Aspley) (Queensland Queensland 1983, 3697), Hon. Peter Richard McKechnie (Carnarvon) (Queensland Queensland 1985, 656), and Mr. John Joseph Hegarty (Redlands) (Queensland

[75] Environmental monitoring agencies in the US such as the National Oceanic and Atmospheric Administration have seen drastic budget cuts since the start of the Trump presidency which ran on a platform of climate change skepticism.

Queensland 1997, 1492)— a statement unique in being racist, anti-environment, and homophobic in the same breath. It was deployed as a slippery slope argument that saw no room for queer, indigenous, or non-human worlds within Queensland legislation. While such outright speech has become rarer, the current political climate has produced such flagrant environmental denialism as One Nation Senator Pauline Hanson's infamous Great Barrier Reef swim (AAP 2016)[76] or Former Cairns Mayor Kevin Byrne's call for the Reef tourism industry to oppose environmental research (Allen 2019). These politicians show no taste for a more-than-human worlding project that threatens their own political future.

This behavior from government leaders has worked to undermine the public's will for action by making clear the politicians' intent to disrupt any attempt at ontological mediation. Such opposition has not been publicly launched at anthropogenic noise pollution in Australia and it is unlikely to happen due to noise remaining a niche issue. Nonetheless, it is hard to see opponents of other environmental issues such as climate change or coastal run-off suddenly supporting marine noise abatement. Marine noise is often tied to other environmental fights such as coal shipping and the recognition of noise in the Reef would be a *de facto* recognition of noise from other marine activities such as seismic surveying in the south.

Essentially, the Australian government has put in place an ontological filter (or should I say transducer?) between the two fields that removes any subjectivity or framework which does not conform already to its worldview. Excluding purposeful obstructionists, this filter does not appear to be actively malevolent. Most of the structural resistance derives from hegemonic ideas of what counts as knowledge or evidence and an ontology which does not account for a multitude of other ontologies. Neither is the filter neutral. There is a clear bias for human exceptionalism and modern, neoliberal economic values. I, as an anthropologist and critic, must put my foot down and denounce such biases. They enact systems that are non-transductive and are harmful to efforts attempting to create a more respectful politics towards those outside of the hegemonic social order.

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[76] In 2016, One Nation Senator Pauline Hanson attempted to demonstrate that the Great Barrier Reef had not been significantly damaged by coral bleaching. Hanson invited her fellow senators and the media to survey a section of the Great Barrier Reef off Great Keppel Island. Her stunt was generally derided by conservationists and coral scientists, in part because she chose to survey a particularly healthy reef.

Resistance and Rebellion

Geoff perseveres. He may be frustrated with such a system, but he is not deterred. He finds allies within government bodies, the media, and the academy to help him subvert the system and get the information about noise out there. In some important ways, I too have become an ontological machine in service to Geoff's politics through my own advocacy and writing.

Like many environmental scientists, Geoff is engaged in ontological politics even if he does not know it because his intimate politics with the world is entangled with non-humans. His ontology which includes respect for non-human ontics gives him the political traction to push for a sonic pluriverse. Rather than be silenced by such rigid systems, Geoff and scientists like him are mobilized to find non-traditional means in which to subvert them.

There is some hope here that I might start to understand the politics of underwater noise. Ontological politics and ontological machines are starting to help me see the relationships and competitions forming in my fieldwork. I know better now why Geoff has become so frustrated with the process. He is working with broken machines in a broken process. As I continue my research, resistance and open rebellion to the hegemonic system is becoming more visible to me. Ontological politics requires more than standard political or scientific practice to open up for the pluriverse. It will require non-traditional warfare with a wide range of allies to chip away at hegemonic systems. I, as yet, do not know how to subvert those obstacles, but I have the hope that it is possible.

Chapter 5: The Salish Sea Movement

Mother and Child Orca Communication (Track 5) [01:26]

Now listen to Dr. Val Veirs, who captured the above conversation, discuss this recording:

Val Veirs on Recording Orca Conversation (Track 6) [04:26]

This chapter explores the sonic relationships between communities of sea life and a community of skilled listeners in the Salish Sea. I was drawn towards the Salish Sea—a narrow inland sea between the mainland coasts of Washington State, US, and British Columbia, Canada, to the east and Vancouver Island to the west—because of the potential for a comparative case study of noise pollution mitigation practices to the Great Barrier Reef. Due to the large shipping ports of Seattle and Vancouver, the Salish Sea is highly susceptible to underwater noise pollution which may be negatively affecting its iconic wildlife. But what would attending to orcas[77] have to do with corals and tropical fish? What I found in the Salish was an established community where I could better attune my listening practices to the marine realm. Because these listeners, scientists, and community activists have the ability to focus on this one animal, their practices of listening and echo-logics began to reveal itself to me. Rather than ship slowdown trials[78] or passive acoustic monitoring, it is these practices that interested me.

Scientific and other action around underwater noise was more intense in the Salish, mostly because of the Southern Resident Killer Whales (SRKW)[79] and the urgency to save the population from extinction. What could these relationships teach me about modes of listening? What lessons could I bring back to the Great Barrier Reef to form more meaningful listening communities? During my brief fieldwork in the United States and Canada I learned about the cultural history of the orcas in the area and how a community of skilled listeners developed around these beings. By paying attention to the practices of a specifically focused

[77] I prefer to use orca when possible instead of killer whale for *Orcinus orca* for two reasons: (1) orcas are more closely related to other dolphins in the family *Delphininae* and (2) it lacks the connotations embedded in the name 'killer whale'.
[78] In the slowdown trials, cargo ships receive financial rewards from the port authority for keeping the ship's speed below a certain limit while in the Salish Sea. The intent is to reduce shipping noise in the region.
[79] While I prefer orca, Southern Resident Killer Whales is the most commonly used name for this population in the scientific literature. Therefore, I will use this designation.

listening community, I furthered my own notions of how phenomenology of non-humans, transduction, and ontological politics work together in the field.

Before travelling to North America, the Salish Sea had lingered in the background of my fieldwork, always at the periphery of the conversation. The discoveries I made when I finally took this journey have ramifications for how I think about listening to sound and deserve this space of contemplation. Several of the audio files in this chapter act as sonic vignettes. They may not be directly linked to the context they are imbedded in, but their stories allowed me to reflect on my experiences.

Skilled Listening

In the Salish Sea, I found a community of listeners engaged in a practice directed at developing meaningful modes of listening in the here and now. The listeners introduced in this chapter can be considered as members of an orca listening community. They are all linked to the same key institutions (e.g. The Whale Museum, Washington State University, University of Victoria, Port of Vancouver, etc.) and share information and practices. This listening community is not homogenous, but Barth (1993) indicates that few seldom are. These communities are defined by their intensity of action and active relationships rather than interpretive agreement.

I call the practice this orca listening community engaged in skilled listening. A driving theme of this thesis has been documenting practices of listening to marine spaces. I began in Chapter 2 with a formulated practice of listening structured by policy documents and scientific papers. These practices placed listening, while highly disciplined, at such a distance that they bordered on practices of hearing instead. Then, I demonstrated in Chapter 3, such attuned listening does not arise naturally from a few instances of exposure. Listening practices ranged from unskilled (among novice divers) to developing, but mostly utilitarian (among diver masters). Chapter 4 indicated a more useful direction. The acousticians are active, skilled listeners but their processes of modeling are such an advanced mode of sensing that that discussion obscured the basics of skilled listening. I have chosen to develop skilled listening now because the Salish Sea community practices in the middle ground between the divers and acousticians. It is here that the practices of skilled listening are the most apparent due to urgency of mitigating noise in this precarious ecosystem.

I base my theorization of skilled listening on Cristina Grasseni's (2004, 2007) discussion of skilled vision. Grasseni posits that vision is not the result of detached, unaffected viewing. It is, instead, an embedded way of looking that is akin (rather than opposed) to the intimacy of the other senses. Grasseni developed her notion of skilled vision through her ethnographic project on Alpine Italian cattle farming and breeding. She noted how the cattle farmers learned to recognize desirable phenotypical traits in the animals and passed that knowledge and aesthetic appreciation to younger generations. Skilled vision must be learned because it is structured within an ecology of practice. Though expert-apprentice relationships, professional communities, and established institutions, the specifics of a skilled vision are circulated and standardized. Ultimately, skilled vision becomes the background that imparts meaning on watching activities.

Grasseni (2004) makes one final "call [that] 'sensuality' in anthropological scholarship should therefore contain recommendations to maintain close attention and discernment of the actual techniques and apprenticeships thanks to which embodied knowledge emerges, documenting how different ways of knowing are embedded in social practice and in an ecology of aesthetic and practical standards" (53). Following Grasseni, I take skilled listening as the learned practices of listening within a particular ecology of knowledge. Given that this thesis is mostly organized around scientific, academic, and educational practices, ecologies of aesthetic and practical standards make way for ecologies of interpretational and educational standards. Skilled listening is also reliant on technological ecologies and standards.

Skilled listening practices, like skilled vision, are supported by a network of institutions, technologies, arts, and other cultural elements that define and enable traditions of knowledge (Barth 1993, 2002). Communities of listeners formed up as standards of practice are circulated through these networks. Through these communities listeners construct and share schemas of listening, much like how other knowledge communities generate particular practices and artifacts (Latour and Woolgar 1986). These communities are shaped as much by the institutions and artifacts that support them as they are by the biographical histories and orientations that community members bring with them.

Skilled listening is audible in Val's interpretation of the orca conversation. He has learned how to listen to the orcas through audio technologies and how to interpret those calls through institutionalized standards of orca acoustic behavior. Even the context of the recording was a part of an apprenticeship-like exercise for imparting knowledge to university students. Throughout my fieldwork, I came across many stories of skilled listening and became entangled in those networks myself. Tracing those relationships allowed me to grasp this concept, and so I present those tracings in the rest of this chapter.

Before I do that, one final note: I distinguish skilled listening as aligned with, yet separate echo-logical practice. Skilled listening does not require engagement with phenomenology of non-humans or political ontology. It does engage with transduction in as much as all listening practice requires transduction of some kind. It so happens that in the Salish Sea, skilled listeners are engaged with orca ontics and politics, and thus skilled listening is also linked here to a practice of echo-logics.

A Cultural History of Southern Resident Killer Whales

Orcas are socially and linguistically complex animals. Like other cetaceans, they are incredibly vocal. They use clicks, whistles, pops, and squeaks to coordinate, socialize, and admonish each other. In track 5, an attentive listener can identify two orcas exchanging calls with each other. Both animals are members of the Southern Resident Killer Whales population living in the Salish Sea.

The orcas of the North American Pacific Northwest are generally divided into three ecotypes (Saulitis, et al. 2000). Starting outward are the offshore orcas who spend most of their time away from the coast eating fish and sharks. These orcas rarely, if ever, come into the Salish Sea. Next are the transient—or Bigg's—orcas who are often found in the Salish and hunt marine mammals. This population has the largest individuals and often travels in small social groups of just a few animals. They are known to range widely, traveling between Alaska and California. Then there are the resident orcas.

Resident orcas are highly social populations who subsist on fish and tend to stay within or continuously visit the same large territory throughout the year. Resident orcas can be divided into genetically and socially distinct (endogamy-like) populations called communities. The Salish is home to the Southern Resident Killer Whale community. Communities can be further divided into vocal clans (Bigg, et al. 1990; Ford 1991; Yurk, et al. 2002) who share a common vocal dialect. The SRKW have only one clan while the Northern Residents have multiple. Clans are further broken down into pods who share similar vocal accents and comprise closely related individuals. Southern Residents belong to one of three pods: J, K, and L. Finally, each pod is comprised of closely related matrilines, the base social unit in orca societies. Resident orcas tend to spend their entire life traveling and socializing with their mothers, grandmothers, aunts, and cousins. These types of social structures means that resident orcas form genetically distinct populations who do not socialize or mate amongst each other or with the other ecotypes. As a result, the SRKW population has been declared highly endangered.

The decline of the SRKW is the outcome of an intertwined history of humans, orcas, and salmon. The salmon fishery has always been important to the local economy due to the abundance of spawning rivers and streams which historically support salmon runs in the millions (Ohlberger, et al. 2018). The salmon are vital to the Indigenous Salish societies living around the sea (Thornton, et al. 2015) and continued to be harvested in large numbers by the Euro-American settlers. The salmon are also vital to the SRKW, specifically Chinook salmon which comprise about 80 per cent of their diet (Ford, et al. 2016). However, Chinook salmon populations have drastically fallen in the region due to overfishing and anthropogenic activity (e.g. industrial development, damning for hydroelectric energy) on their spawning streams. In the historic competition for salmon, orcas were cast as the villain. Partially due to a drastic overestimation of their population, orcas were viewed as pests and killed by fishermen until the mid-20th century (Colby 2013). Later, as perceptions around the animals changed, the SRKW were captured for aquariums due to the population's smaller body size and social nature. Live capture further reduced the local orca populations, which has helped precipitate the group's decline into endangered status. A history of heavy metal and chemical pollutants running into the sea from local industrial centers further sicken and weaken the orcas that are left.

At the beginning of 2018, the population of SRKW was 76 individuals. On 17 March, Washington State Governor Jay Inslee established the Southern Resident Orca Task Force through executive order 18-02, which also initiated a recovery plan. The purpose of the task force was "to identify, prioritize and support the implementation of a long-term action plan for the recovery of Southern Resident orcas to ensure a healthy and sustained population for the future" (SROTF 2018, 4) . Two incidents in the summer would garner international media attention and further underline the urgency. First, in July, the orca named Tahlequah (J-35)[80] was spotted pushing around her dead newborn calf for 17 days before abandoning it. Then in September, Scarlet (J-50)—a three-year-old who was being actively monitored for starvation—disappeared and was presumed dead. By the time I arrived in Seattle in October of that year, the population was at 74.[81]

[80] Each SRKW is given an alpha-numerical designation denoting its pod membership and lineage and a name.
[81] The current population is 73 individuals as of the last published count taken in on 1 July, 2019.

From Pest to Icon

The Southern Residents once thrived in the Salish Sea. Before European settlers, the orcas and indigenous peoples of the Pacific Northwest lived at a respectful distance from each other. Being too big and agile to be hunted by humans, the orca people in indigenous cosmologies lived separate, parallel lives from humans (Colby 2013). Although orcas are often used as clan icons, the salmon people in cosmology are integral to the cultural lives of the Coastal Salish people.[82,83]

Perceptions of orcas changed when Euro-American settlers began to industrially harvest the fisheries of the Salish Sea. Settler cosmology envisioned the orca as a bloodthirsty beast and a pest.[84] Further, orcas were seen as being in direct competition with the fishing industry. As such, fishermen in the US and Canada were permitted to gun down any orca on sight (Colby 2013). The resident orca populations were hit particularly hard by this practice due to their subsistence on fish and their increased likelihood to depredate the fishermen's catch.

Mindsets began to change with the first live capture of an orca off Saturna Island, Canada, in 1964.[85] Sam Burich was commissioned by the new Vancouver Aquarium to sculpt a lifelike replica of an orca, an animal then considered too dangerous for captivity. In order to create an accurate model, Burich planned to collect a specimen. In July, a small team including Burich harpooned a male orca from the shore of East Point on Saturna Island. The harpooning failed to kill the animal and his struggle for life (with the assistance of his kin) won over the artist. Instead of dispatching the beast, the team towed him to Vancouver where he was kept in a flooded drydock. He was named "Moby Doll" through a radio survey (having been mistaken for a female).

The live capture of Moby Doll generated tremendous social and media interest until he died of skin and respiratory infections a few months later. The short period of time researchers had with Moby Doll radically accelerated their understanding of these animals. A few years earlier, John Lilly's (1961) work on dolphin communication had changed how

[82] Salmon are such an important resource for the Costal Salish that clans living in the United States are guaranteed access to salmon through treaties.
[83] Some information provided by the Burke Museum, University of Washington, Seattle WA.
[84] Europeans have a long history with these animals that reinforced this view. "Killer whale" is commonly believed to be a reference some ecotypes actively hunting baleen whales while "orca" is derived from *Orcus*, Latin for Hell, and also used as a name for sea monsters (etymonline.com).
[85] Some information about the Moby Doll story comes from the Saturna Island Heritage Centre, Saturna Island Marine Research and Education Society, the Moby Doll Symposium, and Colby 2013. See also Leiren-Young 2017.

scientists thought about cetacean intelligence. Moby Doll's relationship with his human captors reaffirmed this paradigm shift that reframed orcas as intelligent beings.

In the following years, resident orcas from the region were captured for display in aquariums around the US and Canada (Colby 2013). The Pacific Northwest was now linked with the orca. While greater interest was shown for orca conservation and research, the resident orcas were exploited until 1975 when live capture was banned. The naming of the resident orcas was an attempt to humanize the animals and make live capture more socially unacceptable. More recently, the captive display of orcas has become unpalatable for many people around the world and emphasis has been placed on seeing these animals in the wild.

Noise and the Current Decline of Southern Residents

Vessel Noise (Track 7) [02:30]

The US and Canadian governments now acknowledge noise as a principle stressor on the Southern Residents. Anthropogenic noise is being studied in the US by Washington State's Southern Resident Orca Task Force and in Canada through the Port of Vancouver's Enhanced Cetacean Habitat and Observation (ECHO) Program. These programs are responses to the heavy industrialization of the Salish Sea and the precipitous decline of the SRKW. Most orca research or advocacy organizations in the region are currently engaged with one or both programs.

The churning of vessels large and small continuously encroach on the sonic space of the orcas. The Port of Vancouver,[86] Port of Seattle, and Port of Tacoma[87] attract a massive amount of Pacific shipping, with merchant vessels sharing narrow waterways with local marine life. Population growth in the past two decades in Seattle, Vancouver, and Victoria have seen increased ferry traffic, recreational boating, and marine tourism. And as people seek out non-captive orcas, it is becoming more difficult for the animals to find space unaffected by human action.

Vessel noise (and other vessel impacts) were identified by the task force (SROTF 2018) as one of three interlinked stressors impacting the health of Southern Residents. It is believed that vessel noise is reducing the range of the orcas' biosonar as well as the effective communication range for orcas and other cetaceans. As noise in the higher frequencies

[86] While the Port of Vancouver is managed by the Vancouver Fraser Port Authority, the entire enterprise is popularly referred to as the Port of Vancouver.
[87] The Port of Seattle and Port of Tacoma are jointly managed by the Northwest Seaport Alliance.

increases, it is becoming increasingly difficult for orcas to identify the dwindling stocks of Chinook salmon through echolocation. Broadband exposure to vessel noise can be uncomfortable and disruptive for social orcas and intense instances of noise exposure can cause the orcas to change from feeding behavior to avoidance and traveling behaviors.

The dwindling stocks of Chinook salmon and the decreasing ability for orcas to hunt their prey has led to increased starvation and malnutrition among the SRKW population. Starvation is believed to have been the cause for most of the recent SRKW calf mortalities. Starvation is also compounded by the metabolization of polychlorinated biphenyl (PCBs), polybrominated diphenyl ether (PBDEs), and dichloro-diphenyl-trichloroethane (DDT)[88] have built-up in their blubber. These legacy toxins from the region's recent industrial past leave the animals prone to disease and infection. This was most likely what caused the demise of Scarlet (J-50).

While the Southern Residents have been one of the most intensively studied orca populations in the world, much is still unknown about their relationship with anthropogenic sound. There are a few questions the task force is trying to solve. First, it is not abundantly clear if the orcas are responding to noise or the mere presence of vessels. Orca-vessel interaction is a developing research avenue, with recent progress being made due to the ECHO Program. That raises the question: if they are responding to noise, do the orcas need an overall reduction in noise, or an increase in periods of quiescence?

Initially, through structuring my object of study as "underwater noise pollution," I had wanted to treat it like other pollutions: something to reduce and mitigate. Discussions around marine plastics, agriculture run-off, and legacy chemicals all frame action around the reduction of the amount of material entering the environment. However, considering noise pollution in this way subjected me to the same cognitive trap famously described by Benjamin Whorf (1997). Sound and other energy pollutants behave differently from material pollutants in that most sources can be completely turned off. Hearing and thinking about quiescence was a mode of skilled listening that I picked up in the Salish. The relationship between sound, intensity, and time were already present, but this was the first time that the temporality of quiet[89] became apparent as an important factor. While reduction in overall sound intensity could help, it may be that the environment could cope with the interference if

[88] PCBs were used in many building materials, PBDEs are used as fire retardants, and DDT was a notorious pesticide.
[89] Quiet here refers to periods of little to no anthropogenic sound within a given area.

given adequate and complete rest periods during ecologically vital times. A similar technique. has been implemented for light pollution during the hatching periods for sea turtles (Longcore and Rich 2004). My exposure to hearing quiescence was an indicator that I had a lot more to learn about hearing and relating from the community of skilled listeners in this region.

Skilled Listeners

Scot Veirs on Sailing the Salish Sea (Track 8) [04:45]

Scott Veirs first came to the Pacific Northwest to study underwater volcanoes. As an environmental science major, Scott was pulled to marine science and oceanography by his interest in the human dimensions of ecological change, coupled with his formative ocean experiences of sailing and diving, and participation at the Hopkins Marine Station at Stanford. He did not start listening to the SRKW until his father, Val Veirs, bought a house on San Juan Island in anticipation of retiring there to be close to his children. Val is a particle physicist and tinkerer and he started to throw instruments, including a hydrophone, off his porch and into the water. That is when Val and Scott first heard the Salish Sea. Val had been bringing his students from Colorado College to study the environmental issues of the region and Scott was contemplating how to connect his math and science skills to actual human problems of the Northwest. Translating his skills in seismographic physics to marine acoustics, Scott helped teach Val's students. Since then, Val has retired, and the pair have concentrated their efforts on listening meaningfully to the Southern Residents and noise.

The processes that transform an individual into a skilled listener are idiosyncratic. Mediated forms of skilled listening—such as marine listening—have few established developmental pathways as they have typically required heavy technological investment and training. As the biographical vignettes in this section indicate, each listener finds their own way into this field. Although each story is unique, one common pattern among this group is the interconnected sociality of their journeys.

Grasseni's (2004) work on skilled vision focused heavily on the social relationship between the master and apprentice viewer. These social connections allowed for the exchange and standardization of knowledge traditions. The growth and proliferation of these relationships make skilled listening a dynamic process. Orca listening poses some issues to traditional master-apprentice relationships given that the field has only developed in the past few decades. Scott and Val form a co-skilling relationship by bringing together their separate knowledge histories to help each other orientate to orca sounds. Given that marine listening is a multidisciplinary and multimodal practice, skilled listening in these circumstances tends to be more emergent. In the following two biographies, more traditional apprenticeship relationships are revealed—although the pathways through which these relationships develop through show signs of emergent processes.

Jason Wood studied acoustics in graduate school, but in an environment far removed from the Salish Sea. He was not specifically interested in acoustics but was looking for a way to return to Africa after previous visits to the continent. His supervisor was working with African elephants and Jason developed a fascination for behaviors and things that were outside of human perception. From airborne acoustics, Jason shifted to substrate-borne acoustics as he focused in on the elephant's ability to transmit low-frequency sound through the earth. When he married his wife, he moved to San Juan Island, where he now works on underwater acoustics for an environmental consulting firm in conjunction with The Whale Museum.

It was because of Jason, his wife, and his supervisor that Deborah Giles (or simply Giles as she prefers) moved into orca research. She had loved orcas since she was a child and took every chance during her early adulthood to visit San Juan Island and the Southern Residents. Giles knew she wanted to work for the SRKW and was going to study law until she met the trio during an undergraduate course. Through them she met Kari Koski at The Whale Museum and became a part of the Soundwatch Boater Education Program. Kari put her in contact with nearly every researcher in the area which allowed her to develop a monitoring technology and led to a PhD. She is now an investigator on multiple orca monitoring projects out of the University of Washington's Friday Harbor Laboratories.

A network of institutions is equally vital for the development of skilled listeners. For Grasseni's (2004) cow watchers, national associations and agricultural fairs are part of the process of developing skilled vision. According to Barth (1993, 2002), institutions act as centers where knowledge can be deposited and redistributed. Institutions also become places that organize and coordinate skilled activities, as fairs organize and standardize the practice of watching cattle. In the Salish Sea, institutions have the added role of supporting and providing access to technological mediators.

The most traditional of knowledge institutions, the university, clearly plays the role of supporting the master-apprentice relationship. They are places that legitimize the development of skilled listening through coursework and degree training. A university also acts as one of the few institutions that can continually support skilled listening practices through their ability to afford such budgets and provide needed technological and material aid.

The Whale Museum in Friday Harbor is another central institution to these skilled listeners. Aside from its role as a knowledge dissemination center (the most publicly known role museums play), The Whale Museum supports research, public initiatives, and a hydrophone network (see below). It also acts as an effective organizer since it requires only partial membership. Unlike more formal institutions like universities, which demand some level of fealty from its students and employed academics, the museum allows for fluid, temporary relationships. All the American skilled listeners I worked with in the field were associated, or had been associated, with The Whale Museum in some form.

Institutions have ways of standardizing and then normalizing traditions of knowledge in a manner that can dilute the dynamism of skilled listening but they also relieving the listener of redundant work (Downey and Dumit 1997; Latour 1987; Latour and Woolgar 1986). Institutions allow the skilled listener to develop the minutia of the listening practice by supporting the weight of what Kuhn (2012[1962]) described as “normal science.” Because of their position, institutions also can maintain connections to each other and outwards to other actors in the network. As the next biographical vignette demonstrates, skilled listeners within the institution must also reach beyond its borders to further develop listening practices.

Lauren McWhinnie was trained as a marine biologist in her native Scotland. There she became familiar with European governance of marine noise. Her move to the Salish was long in the making. Lauren has an uncle living in the area. When she was a little girl visiting him, she saw the orcas from the ferry. Someone had told her, "if you want to work with killer whales you have to become a marine biologist." When she finally returned to British Columbia, she took a position at the University of Victoria in oceanography. In a new discipline, she had to a develop a new skill set to interact with the human elements of the novel network. Lauren has since taken on more responsibility for community outreach and scientific research.

No matter which social relationships or institutions supported the skilled listener’s development, they needed an anchor for their listening. The crux of a skilled community of orca listeners is that the orcas are themselves members. Noise is inherently perspectival and to listen for marine noise that impacts the SRKW, these skilled listeners introduced in this chapter had to learn to listen *with* the orcas. I use ‘with’ in two senses here. First, skilled listeners learn to listen through the animals by means of behavior and physiological studies and through technological mediations which attempt to measure acoustic properties (see Interlude I, and Chapters 2 and 4). As this listening practice becomes normalized, the listener then listens with an orca's virtual ear to the best of their ability. The listener now listens in a more-than-human relationally that situates humans and orcas as co-listeners. This becomes and engagement in phenomenology of non-humans. Listen again, if you like, to Val Veirs' account of hearing the conversation between Oreo (J-22) and DoubleStuf (J-34).

Val Veirs on Recording Orca Conversation (Track 6) [04:01]

Central to this re-emergence of the sensitive animal in the human scientific imaginary is the nature of noise. So far in this thesis, noise has been characterized as a legislative/scientific object (Chapter 2), glitches in the human-machine network (Chapter 3), and an information/mathematic disruption (Chapter 4). Now, I want to revisit the idea of noise as dirt, as first mentioned in Chapter 3.

If I sincerely adhere to Pickering and Rice (2017) and not treat noise *like* dirt, but instead view noise *as* dirt in accordance to the dirt theory presented in Douglas (1966), then new social relations emerge for interrogation. Pickering and Rice (2017) argue that dirty noise is sound that transgresses and disrupts a sonic order. It is anomalous or ambiguous, disruptive or dangerous, and needs to be negotiated, dealt with, or tidied up. While Pickering and Rice (2017) and Douglas (1966) firmly place noise/dirt as cultural relationships, the elements of dirty noise are vague enough to pertain to any being with a sensory imaginary, regardless of symbolic thought. If orcas can have sensory imaginations and desire certain experiences (it makes no evolutionary sense to assume these abilities only developed within *Homo sapiens*), then it makes sense that certain sounds should disrupt those imaginations and run counter to those desires, being either anomalous or ambiguous, disruptive or dangerous. Orcas should experience noise.

Skilled listening within the Salish Sea community is an attempt to grasp the sonic structure of the orcas' sensorium and to perceive disruptions as an orca would. Here again we encounter Nagel's (1974) dilemma as orcas and humans have different sensory capabilities. It is true that we may never be able to fully hear like an orca, but that does not negate the best attempts to grasp some aspect of hearing. The skilled listener learns to use technologies and develop and augment listening practices that acknowledge the species divide, but also identify those pathways which allow the listener to get effectively close enough to the orcas' *umwelt*.

So far, most of those pathways have been traced through skilled listeners who developed their practices within academic institutions. Deep engagement in these networks is not the only way of developing skilled listening. Some listeners develop their skill through more tangential relationships to academia. These listeners come and go from institutions and form more casual relationships with other listeners. Because they enjoy more distance from normalized practice, they have freedom to explore multispecies relationships.

Jeanne Hyde on Detecting Sonar (Track 9) [03:43]

Jeanne Hyde has been developing her skilled listening practice for over a decade. She moved to San Juan Island in 2004 and has been engaging in skilled listening on a scale far greater than the scientists. Jeanne, a non-academic, enjoys a deep relationship with the Southern Residents. Using the Lime Kiln hydrophone, she listens to the orcas day and night, even as she sleeps. Over the years, she has become sensitive to the vocal variation between the pods and can identify the downward inflection of J pod, the mew of K pod, and the upward tick of L pod. Her constant listening has also made her the front line for reporting the presence of animals entering Haro Strait, and of ships not complying with sound mitigation programs. She reports these to the proper authorities and was the first to identify some rare whale calls.

Jeanne has served as a volunteer at The Whale Museum and enjoys a close relationship with many of the American researchers, but she does not have a formal training relationship through apprenticeship or institution. Since Jeanne's listening practice did not develop inside academic programs which place more emphasis on the human-animal divide, she has cultivated a different type of relationship with the orcas. She does not shy away from personification and has been called the "TMZ[90] of the Southern Residents." She documents the daily episodes of the SRKW family drama on her blog, although recently, she had to take down most of her posts because someone was stealing her images. In Jeanne's view, the orcas are another type of people who deserve equal dignity and respect. To steal those images and post them without context was akin to stealing the orcas' identities. She sometimes finds herself at odds with local scientists over her tendency to anthropomorphize the orcas, but she feels that it must be done both to respect the animals and to educate the public. She was at Lime Kiln when Tahlequah (J-35) passed by with her dead calf, a deeply emotional moment

[90] TMZ is a popular American gossip publication known for documenting the daily lives of celebrities.

that Jeanne considers a gift to the world for showing the mounting problems in the Salish Sea.

Jeanne's practice may not always align with scientific understandings of orcas, but that does not invalidate it. Her long, focused listening coupled with observation has enabled Jeanne to develop a set of skills that sometimes exceeds those of orca scientists. This practice, unburdened by a scientific ontology, may be better able to attend to the effect of the animals and their interpersonal relationships. There are no clear boundaries that delineate a multispecies phenomenology, and to place those arbitrarily at the borders of scientific practices would do a great injustice (and violence) to other ways of knowing. The existence of listeners like Jeanne draws attention to the limits of a scientifically skilled listening, and the respect she receives from other skilled listeners (although, notably, not from larger institutions) demonstrates the intrinsic value of her skill.

Hydrophony and Echo-logics

I have discussed the hydrophone as an object central to perception of underwater noise in the previous chapters, and it has appeared again in the Salish Sea. I now focus on the practice of hydrophony rather than on the technical object as it relates to skilled listening.

Orcasound

The first day I met Scott Veirs he was launching his new Orcasound web app. Orcasound was created in partnership with Scott's father, Val, and networks many of the hydrophone arrays scattered around the Salish Sea. Originally Orcasound provided a web platform that allowed listeners to tune into the hydrophone arrays using a RealPlayer plug-in. The website also included educational material aimed at university students to orientate their listening. In addition to the website, Scott and Val had designed listening installations at the Seattle Aquarium, the Port Townsend Marine Science Center, and The Whale Museum. Orcasound's newest redesign jettisoned the RealPlayer plug-in in favor of a web app that makes the network more accessible on mobile devices.

Scott envisions Orcasound as his way of creating engaged listeners and mobilizing them to assist with research. From the start, the new web app received widespread support. Using an online crowdfunding platform, Scott noticed funders coming from around the country and internationally. That trend continued in his user data, challenging the notion that the sounds of the Salish Sea were of mostly local interest. Ultimately, Scott hopes to mobilize these listeners into a research tool. Currently, Orcasound only streams hydrophone audio, but he hopes to soon start streaming the spectrogram as well and create a reporting feature. Some current hydrophone streams in the area offer a comment board that allows listeners to report novel signals, but Orcasound would be the first to automatically include the useful metadata as well.

Making real time data on SRKW publicly available could have one major downfall. Private boaters and whale watchers could use the hydrophone streams to locate orca pods and harass the animals. The Port of Vancouver is concerned enough to not make the real time data public, but Scott thinks the fear is overblown. Still, he identified recreational boaters as one group under-scrutinized by Washington State's orca task force. A sub-set of boaters, whom Scott refers to as "yahoos," are opportunistic whale watchers and likely drive too close to, or through, orca pods. These careless listeners are likely to disrupt the orcas' behavior or even strike one with their boat, making their boating behavior a great concern. Remarkably, the same arrays that might be used by the yahoos also act as a monitoring tools for other listeners to identify poor boating behavior and report it to the authorities.

Lime Kiln Hydrophone

The Whale Museum has established a research station in the Lime Kiln Point lighthouse to study passing cetaceans and their communications. As part of the project, the museum has installed a hydrophone array at the lighthouse. A nearby board allows visitors to listen in with a push of the button to the passing orcas or the croaking rockfish. Visitors can also tune into the hydrophone feed on radios or stream it online.

Jason Wood inherited the management of the Lime Kiln hydrophone from the Veirs. According to Jason, almost all the work at Lime Kiln has focused on the orcas. There are three reasons for this. First, most of the government funding is connected with the current endangered status of the orcas. Then, as Jason states, local researchers are spoiled with access to these creatures and any research they do is easy to sell to the public. Third, other marine mammals in the area tend to be quiet underwater,[91] though recently, the hydrophones have been seeing new use in tracking fish populations.

It is also through the Lime Kiln Hydrophone that Jeanne listens to the orcas. She records the hydrophone stream when she is out of the house and listens to those recordings for important sounds when she returns. She will keep any recordings of orcas or other

[91] Pinnipeds on land are well known for being noisy, particularly the sea lions. As for the cetaceans, the various hydrophone arrays have only caught the calls from humpbacks and sperm whales on occasion.

interesting marine life and dump the rest. When volunteering at the state park, she gives educational talks in front of the hydrophone listening station. It was partially the hydrophones that made the episode with Tahlequah (J-35) so impactful. As the pod passed the lighthouse, the bystanders could hear the mournful lament of animals playing from the speakers.

SIMRES Hydrophone Array

Over the years, Saturna Island Marine Research and Education Society (SIMRES) has benefited from enthusiastic community support for marine noise monitoring, resulting in community members donating state-of-the-art hydrophones. One hydrophone is deployed at East Point, near where Moby Dolls was originally harpooned. Just south of the lighthouse, a thick, black cable snakes up the sea cliff and into a private residence. The homeowner had donated a portion of his basement to be used as a field station for the hydrophone equipment. The entire system is supported by Oceans Network Canada, and some local monitoring firms rent the data. A second array floats just offshore of Monarch Head. The data has now been made available to SIMRES members, who can stream the spectrograms and will soon also be able to listen to the audio.

Lauren McWhinnie manages the hydrophone data in her role as Science Director for SIMRES. The hydrophone data contributes to her research on the impact of small vessels on the SRKW, and other researchers are looking to use that data to study various sonic phenomena in the area. SIMRES is looking to expand their network and hope to add a third hydrophone across Boundary Pass so they can triangulate sound sources. This, in turn would help them to locate noise makers.

These practices of listening to hydrophone streams are able to network technologies, modes of knowledge, listening communities, and beyond human worlds. In each case, listening to the hydrophone is meant to shift the listener's perspective in some way that would lead to new knowledge. These unique technological practices merit their own term: hydrophony.

In many ways, the properties of hydrophony mirror practices of radio listening. Aside from the technological networks that hydrophones and radio broadcasts share, the practices of hydrophony and radio listening invite distant locals into the proximate, give voice to subversive subjects, and create a virtual community of fellow listeners (see Bessire and Fisher (2012) for radio listening). Listeners like Jeanne have become such avid practitioners of hydrophony that, like radio, the audio has moved to the background texture of domestic life (Tacchi 1998). Through Orcasound, such practices are able to be adopted by an increasingly larger community at greater distances from the Salish Sea region, similar to spread enabled by internet radio (Black 2001).

What is notable about hydrophony are the particulars of the local voices and community that it enmeshes. Hydrophony not only asks listeners to attend to a novel environment, but to do so through sensing that is beyond human, and to learn a phenomenology of non-humans. Orcasound provides pages of information and teaching guides for listeners to become skilled, while other hosting sites, information panels, and skilled interpreters also encourage such perspectival shifts. Additional visual listening skills are needed to fully engage the spectrograms that are a part of—not different from—hydrophony.

This shift of sensing and perspective is all in service of the non-human voice. It is by no means a stretch to affirm that the Southern Residents have a voice, and it is these voices which the hydrophone networks were designed to tap. But, like radio, hydrophony does something more to the voice: it gives subjectivity back to those who have become marginalized (see Fisher (2016); O'Connor (2006) on voice and radio). Through hydrophony, orcas become complex agents breaking from Cartesian theory. Vessels, too, are given a voice (very literally in the case of Jeanne's account). Their voice is like the politician's voice caught on a clandestine recording and broadcast for all to hear. Hydrophony is able to transmit what the vessels say in secret to the aquatic world and hold noise polluters accountable.

No doubt, hydrophony has enabled the orcas to become part of the community. But they remain unaware of their participation, unlike all but the most questionable radio broadcasts. Neither are they listened to for purely aesthetic pleasure. Hydrophony in the Salish Sea emerges as form of echo-logic practice. In fact, it was this practice that inspired me to formulate echo-logics in the first place. Through the networks of hydrophones, speakers, and web apps, a unique transductive structure forms. The goal is to make as much marine sound audible to as many people as possible. The hydrophony structures are designed so that listeners around the world could connect with the Southern Residents.

Embedded within these structures is an ontological politics for sharing the Salish Sea with the orcas. All participating parties are driven to find solutions that maintain the SRKW population while allowing for the continuation of human activities in the area. The first step is to make the boundary between human and orca communities fuzzy. Hydrophony allows the orcas to enter the human social space, but it also pulls humans into the orca world. Once our worlds become joined, these echo-logical practitioners can begin additional political work.

Extending Communities

Lauren McWhinnie on Onyx (L-87) (Track 10) [03:50]

Extending the listening community out beyond the small circle of skilled listeners is embedded into the echo-logics of the Salish Sea hydrophones. Each case speaks to how hydrophony is not only utilized by skilled listeners but extends listening practices out to the wider network of concerned, curious publics. By allowing the marine sounds to echo around public spaces, the hope is that these hydrophones can create public action and pressure on governmental bodies to act in favor of the Southern Residents. These new listeners are in the process of skilling, though some might never reach the stage of being skilled.

That ethos is clearest in Orcasound. Scott's vision for the network involves skilling listeners to identify sources of noise or novel aquatic sounds. It sits well within the frame of citizen science, the practice of enrolling non-academics into the process of data collection or analysis. Instead of using humans to monitor the marine environment for noise, Scott is hoping to use the data to skill another type of listener: the computer. As Scott explains, machine learning and listening is good at identifying repeating patterns,[92] but humans are much better at identifying novel signals. By mobilizing the listeners, Orcasound would create a citizen science project that meshes human and machine listening to better characterize the Salish Sea soundscape. Computers, too, must be taught how to participate in hydrophony.

On Saturna Island, extending the listening community is not done to create a network of semi-skilled listener and computers for monitoring. Instead, it is used to encourage the island population towards engaging an economy around science research and environmental action. Founded in 2013, SIMRES is a savvy community-run organization for leveraging the island's unique benefits. Given its remoteness, Saturna does not receive anywhere near the number of summer tourists as the more accessible islands. What it does have is a prime location directly on Boundary Pass, the main shipping channel for the Port of Vancouver and a popular migratory route for large cetaceans heading for the Strait of Georgia. The hydrophone array has been SIMRES' cornerstone for their bid to attract marine researchers. It

[92] This is evident in Val's use of computer software to clean up the orca conversation recording. The computer was able to identify the difference between the orcas' calls and the ambient noise in order to reduce the environmental sound and amplify the orcas.

has been enthusiastically embraced by Saturna's residents who tend to be older and well-educated. Vessel noise has become a cause célèbre for the islanders. Some island residents go so far as to protest and harass whale watchers from shore.

Extending communities has a great effect on the researchers. SIMRES provides scientists like Lauren hope and support when the prognosis for the SRKW (and the greater environment more generally) seems dark. The tools provided by SIMRES allows Lauren to bypass institutional obstacles for funding or bureaucratic red tape for deploying instruments from government land.

This endeavor also forces researchers to adapt. To properly engage and extend a listening community and to continue to receive support from them, researchers must relearn public communication skills. All the researchers I worked with in the Salish Sea were involved with public engagement in some manner, either through institutions like The Whale Museum or through their own initiatives. Soundwatch and Lauren's work with fisherpeople and whale watchers require effective and empathetic communication on noise impacts. Not only do they need to deliver information to non-skilled listeners, they also must undo years of social damage and mistrust between boaters and academics. If not directly a part of echo-logics, an ethics of non-alienation and the maintenance of good community relations seem to underpin echo-logical action.

Part of extending listening communities and engaging ontological politics involves turning politicians and government agencies into listeners. All these researchers have participated in some way with either Washington State's orca task force or the ECHO program out of the Port of Vancouver—most have participated in both. For Giles, an adamant follower of Michael Soulé's conservation biology (Soulé 1985), working with governments and policy is part of her responsibilities as a researcher. This mindset is a direct challenge to the old ivory tower model of academia and part of the reconfiguration of scientific institutions. In an era of prominent science-sceptic politicians, many scientists are awakening to the reality that science is and always has been political. Giles is quick to point out that while policy is political, a good relationship between scientists and government offices means that policy does not need to be mired in party politics. In truth, she suggests that scientists have an ethical responsibility to act, declaring, "the planet does not have time for scientists to not get involved!"

Extending listening communities as part of an echo-logical effort is a process of generating listeners beyond the small community of skilled listeners. If echo-logics is to be a more-than-human form of engagement, then space must be created for orca sounds to echo within public, social spheres. Orcas must be allowed to reverberate among networks that enable and carry out political action. It is part of the mediation and attention to the echo. The skilled listener becomes the transducer of the orcas and allows the orcas to be a part of the listening community without having to directly participate at every node. By not extending the community, the skilled listeners risk re-alienating the orca as an object of study.

As the above examples demonstrate, practices of extending community to machines, publics, and politics requires significant work from the skilled listeners. They have produced a surplus of texts, webpages, sound installations, cartoons, images, and artworks as well as intangibles such as speeches, lectures, and advice. Like Smith (2015) has argued for historical acoustemology, the media of sound in echo-logics extends well past electronic recordings.

Listening Beyond Orcas

Humpback Whales, Bigg's Orcas and Vessel Noise (Track 11)

This chapter has been, if nothing else, orca-centric. Noise pollution, as it is constructed, in the Salish Sea *is* orca-centric. But this does not necessitate that all concerns for sound and noise needs to be focused on the SRKW. A large community of listeners, both skilled and unskilled, practicing echo-logics can begin to listen outward to a greater sonic ecology.

The orca as central focus for ecological action or as a regional mascot was never ensured in the animal's innate being. It was made such through a long, networked history. Already, growing attention is paid to the sonic worlds of other beings. Using the infrastructure in place for listening to orcas, researchers are beginning to consider studies involving midshipmen, rockfish, and herring. As the supporting literature on non-mammalian sonic worlds increases, other creatures may rise in importance to public and political listeners. The networks and communities presented in this chapter exist in the ethnographic present, as a snapshot of things as they existed during my field work at the end of 2018. That is not a guarantee that they will remain in stasis. One large oil spill could potentially wipe out the Southern Residents. What then? If they were to continue to listen, this community of listeners would have to listen to something else. Arguably, they already must listen to more than the orcas to more fully appreciate the ecologies that the orcas inhabit. This chapter has shown how people listen *in*, listen *with*, and listen *to* the orcas. Now it is time to extend listening practices more broadly and to think how people might further engage with sound.

What can we take from this case about skilled listening as practice that can help in other contexts?

In the next chapter, I return to the Great Barrier Reef, away from the charismatic Southern Residents. I will interrogate how others might engage marine sound in different, creative echo-logical practices. I will explore how sound art might work alongside hydrophony and skilled listening in Australia and beyond.

Interlude IV: Echo-logics

The idea for echo-logics has its origins in my struggle to describe what I witnessed in the Salish Sea. The level of engagement with sound and the orcas was something that had no correlation to anything I could readily identify in my literature. There were some aspects I could recognize through Feld (1990[1982]) and Schafer (1977), but they were each generally limited in their applicability. No one had yet written about such broad sonic environmental engagement. The practices in the Salish Sea went well beyond that of acousticians and marine managers. Community groups and a broader interested public had now become involved and I had the task of finding commonalities between institutional and public skilled listeners who often worked together to push for noise moderation.

One standard view has been to treat such sonic practices as eavesdropping, or *écouterism* as Weis (1999) calls it. This calls attention to the act of listening in on conversations (most often in secret) analogously to voyeurism, the act of watching. Much like voyeurism, eavesdropping is passive with no direct engagement with what is being heard. Analytically, what is done with the information overheard is second to the pleasure or horror felt through the process of eavesdropping. Yet theories of voyeurism and eavesdropping are products of cinema and art studies and reveal themselves to be limited when applied to activist projects. Relying on such concepts cuts off avenues for analyzing how images and sound continue to engage and be transformed through networks of practice.

The relational attunements of acoustemology (Feld 2015) seemed closer to the approach I had been searching for, but in the context of this research, I could not find a satisfying critical or material edge here either. Acoustemology is primarily focused on developing an epistemology through sound. It works well as a descriptive tool for identifying sonic knowledge, it is less useful for considering the political use of sound. While Feld fully acknowledges the place of audio technology in his fieldwork methodology, the production and reproduction of sound through technology is often under-examined in acoustemological analysis.

For me, echo-logics became a way of discussing the practice and process of engaged listening that extended beyond the moment of listening, expanding the analytic attention to considering the potential consequences of that engagement. Echo-logics is less about what is known through sound and more attuned to the processes of knowing and sharing knowledge through sound. It is also more narrowly focused on interspecies and environmental action.

In chapter 1, I provided an outline of the structure of echo-logics. I deliberately held off further elaboration until I could provide examples of echo-logical practices. The previous interludes have provided a theoretical orientation towards the concerns from which I have come to understand echo-logics, enabling me to now demonstrate how phenomenology of non-humans, transduction, and political ontology drive the practice of echo-logics—while also situating it within context.

Echoes of Echoes

Nets can be dangerous for dolphins. They can easily entangle and drown marine mammals if the animals run into them. For dolphins traveling the Reef at night, nets do not make good echolocation targets either. There is very little surface area to produce an echo so a dolphin passively echolocating might miss the structure. The solution: acoustic warning devices—also known as "pingers." These devices alert the dolphins and other cetaceans to the presence of some object in the water and, as a result, the animals are more likely to avoid the nets. That is the theory, anyway.

Acoustic pingers seem uncontroversial, but the death of a juvenile humpback whale due to entanglement with shark nets installed off of Gold Coast beaches recently brought the devices into question (McElroy 2017). Activist groups used the incident to point to pingers being ineffective and to call for the complete removal of shark nets from the beach. Geoff McPherson was not having any of it. He pointed to something else in the environment. At the same time the whales were migrating south, the Gold Coast was dredging sand close to the beach. Likely, the noise from the dredging masked the pingers and prevented the whale from identifying the net. So, was it ineffective pingers or dredging noise that caused the whale to run into the netting?

Geoff and I have had many conversations on these sorts of issues and on how to communicate to the public the relationship between marine animals and acoustic technology. It takes a double effort to not only ensure that the pingers work with non-humans but also that the public is aware of the role the devices play in marine acoustics. This type of work requires an engagement with the echoes of pinger technology and the echo-logics of their use. The pinger as an echo-logical tool will become handy in describing the drivers of these engagements.

Fundamentally, all echo-logical practice starts with the recognition of the need for a consideration of the ontics of non-humans. It starts with recognizing that animals experience their worlds rather than mechanically react to stimuli. The experiencing animal requires an ethical engagement that has not been present under the mechanical schema. The reactive animal relationship which dominated Western thought since the enlightenment (Simondon 2011[2004]) is only as complex as the relationship between the stimuli and reaction. It is a mechanical relationship. There is little ethical concern for the animal's welfare because a creature that runs on programming does not have welfare. This frame has been used to justify violence towards non-human animals from industrial slaughter of livestock to widespread extermination. It is an anthropocentric mindset that positions humans as exceptionally able to meaningfully entangle themselves into their environment. Because the reactive animal only reacts to stimuli within its environment, it remains at some distance from its environment and is incapable of becoming entangled. It becomes an interchangeable part which can be moved, removed, or substituted without any great harm.

The experiential animal is embedded in a complex relationship to its environment. It makes decisions based on the state of multiple elements in the environment as well as its own internal state. Any action towards the animal will potentially change its internal state, which includes senses of satisfaction, stress, and happiness. The experiential animal has welfare and requires critical engagement to ensure that welfare. It is an engagement not solely directed at the animal itself, but one which considers then environment which the animal is entangled in. This orientation towards other creatures becomes the basis for echo-logical practice.

The pinger could have been developed in two ways. Designing for the reactive animal, the pinger could have been made to produce a signal at the right frequency and intensity to repel a dolphin. These devices do exist as acoustic repellants attached to fishing lines in order to prevent depredation of the catch, but they are rarely used on nets (despite what is popularly believed) because they can disrupt natural behaviors like foraging and can potentially cause damage to the animal. Instead, the pinger was designed for the experiential animal. They were designed to send out a ping at a frequency that would alert a cetacean without frightening it, allowing the animal to make its own decisions on how to approach the obstacle. Such a development required a deep knowledge of how dolphins and whales sense and interact with their environment.

Not all echo-logical practitioners or echo-logical projects come to this sort of ethical engagement with non-humans through the same pathway. Some come to their projects with an inherent sense of responsibility developed through previous engagements, while others grow a sense of responsibility through honing their practices of skilled listening. Echo-logics emerges in either instance when the practices of skilled listening converge with a sense of responsibility towards the non-human being. Such a convergence occurs as the skilled listener starts to move from an anthropocentric position to a relational position to the non-human.

Part of that transition from anthropocentrism to relationality is in the development of the echo described in Chapter 1. First, the echo is removed from its spatiotemporal context through the use of technological sensors. Then, a new context is built for the echo as it returned to networks of listening. This is a process which carefully disentangles and then re-entangles the echo. If done from a non-critical anthropocentric position, it threatens to erase all continuity with the non-human being, but done from an echo-logical position, it has the potential to further develop relationality.

I am starting here with the process of developing the echo instead of establishing a set of values and ethics because, as I see it, growing responsibilities is something acted out by echo-logical practitioners within the structures built by the echoic process. Those structures, built through the echo, are best understood by way of transduction.

For now, I will take the process form of transduction in which one thing changes to another and precipitates more change (Simondon 2017[1958]; Sterne 2003, 2012). Of this form of transduction, there are two circuits to consider, the technical/sensing/input circuit and the action/design/output circuit.

The input circuit of echo-logical transduction is the structures which capture the initial signal. Input circuits tend to be highly technological as they rely on instruments to capture, convert, and store signals. Once captured, a signal becomes an echo-in-network. I do not mean to construct "echo-in-network" as some new grand term. Instead, I use it for convenience sake to distinguish the unique properties of any information caught in a technological network. The echo-in-network gains some material qualities in that is can now be transformed, manipulated, and stored in physical media. The echo (and it is an echo at this point as the signal is physically and temporally distanced from the source) shifts from an experience to an object for a short time in the network.

The process of capturing an echo—or, in other words, sensing—is vital in determining all other future echoes and so the technological transduction becomes a vital point of inquiry. Both paths of transduction and resistance are responsible for shaping the echo-in-network. When designing the pinger, cetacean hearing and vocalization data had to be captured. The accuracy of that echo capture had to be highly accurate, otherwise an effective pinger could not be produced. Such issues appeared in some acoustic repellants which, being based on poorly captured data, should more accurately be called dolphin dinner bells because they attracted more dolphins to the catch than they repelled. In echo-logical practice, the process of capturing an echo that has continuity with the sounding source is essential. This also means that the context in which an echo is captured is part of the input circuit. The resistances from signal masking to funding structures further transduce an echo as it limits or colors the nature of the sound after it has left its source.

In and of itself, the input circuit has tremendous potential for anthropological and STS inquiry. Skilled listeners take great pains to control echo capture. The technical practice involved reveals certain assumptions and values that practitioners hold about sound. I shield my hydrophone from electromagnetic waves because I value marine sound over radio. Marine biologists calibrate their instruments to pick up high-frequency sound because they assume that the orcas will hunt using echolocation. It is these practices which differentiate echo-logics from acoustemology, partially because echo-logics is an implementation of acoustemology into a process.

The output circuit kicks in when the practitioner transduces the echo-in-network to an echo of an echo. It is the process of putting the echo, changed, back into the world as a sensory experience. Unlike the input circuit which relied on highly technical transduction and technical practice, the output circuit opens up for a wider variety of creative practices and social transductions.

Clearly, there is still abundant room for technical transduction when the echo-in-network is transformed into an output signal and played through some sort of audio system. But audio can be just one of many outputs for the same echo. Environmental mangers can convert the echo-in-network into texts, graphs, and orations or activist groups can use those echoes to create social action.

The echo-logical structure built through transduction can also produce a certain social order through the output circuit. For instance, the pingers do not only output a warning signal, they establish the boundary between dolphin and human territories. They enforce a certain distance that would be dangerous to the dolphins otherwise. Pingers, like other echo-logical practices produce social and technological structures in tandem.

Community or relationality are key outputs of the transductive structure, going back to Simondon's (2017[1958]) use of transduction with human-machine relationships. Transduction moves away from humans as individuals and in opposition to non-humans, to humans in relationship to non-humans and part of larger human/non-human networks. By establishing a transductive structure through developing the echo, echo-logical practitioners fundamentally establish themselves within a greater community. Pingers could not exists outside a wider community of dolphin and human stakeholders, nor could any of the other echo-logical projects featured in this thesis exist without the communities they circulate within.

Now that I have established the transductive structures which echo-logics moves within; it is time to turn my attention to how responsibility is grown through echo-logical practice. To do so, I will now look at the logics or thought processes that drive echo-logical transformations.

Logical Transformations

The pingers on the Gold Coast shark nets exist because a group of humans felt the need to structure the built environment to the needs of another being. They did not want cetaceans drowning in the nets, so they invested in the acoustic warning system. Objects may have agency (Latour 2005), but they do not have so much agency that they can self-assemble into systems without someone putting them in association. Through iteration and awareness, those structures continue to transform to become more relational.

“Logic” has its etymological roots in thought, idea, and speech (Harper n.d.-a). When I consider the tailing half of echo-logics, I reflect on how thought and action are shaped by the echo and are caught in its reverberations. When one is forced to consider carefully all the changes one makes to a signal in a transductive network, as skilled listeners do in their practices, then one can generate new knowledges about that signal. These are knowledges gained through action rather than observation. Such knowledge practices resemble what Gatt and Ingold (2013) refer to as correspondence. Correspondence, in their usage, is the continuous exchange and response between the anthropologist and those they work with. “To correspond,” Gatt and Ingold say, “…is not to describe it, or to represent it, but to *answer* it” (144). For echo-logical practitioners, direct correspondence with the non-human being might be difficult or impossible, but the sentiment still holds. Practitioners may choose to correspond with a virtualized non-human (for instance, modeling), with the concerned public (as demonstrated in the Salish Sea), or become more aware of our interactions with non-humans (such as improvements to noise mitigation efforts as described in Chapter 2).

This knowledge through action is different than other scientific knowledges because it does not conform to formal logics. It does not seek to describe the properties of an object. Instead, it strives to find new possibilities in subjectivity. Once again, I turn to transduction to understand how this knowledge is generated. While transduction is more commonly used in psychology as an explanation for poor logical reasoning among young children, Simondon (1992[1964]) saw a different use (one similar to the current use of transduction in artificial intelligence). To be clear, Simondon made specific mention that transduction is not formal logics because it does not generate a conclusive proof. I argue that transduction is not a logic for generating representational knowledge, but instead it is a logic for designating a course of action whose validity does not derive from a proof formula but from its continued practice.

The logical (or psychic) form of transduction is presented by Simondon as an intuition which finds solutions within the problem at hand. Essentially, transductive reasoning considers all the elements and relationships within a problem and intuits possible structures. It is an *ad hoc* solution which only applies to the context and the here and now.

It is also reiterative as any structural solution will change the context and produce a new problem at hand in which to apply transduction.

To further elaborate on transduction, I will contrast it with another transformative logic: translation. Unlike transduction, translation transforms based on *a priori* rules. It is a systematic and regular movement from one state to another. Simple transformations from one language to another, for example, rely on formal sets of rules such as word equivalence and grammatical structures. Therefore, to solve a problem through translation requires identifying the underlying general rules and applying them to the context. Transduction, conversely, has no general rule for transformation. Each transformation must be structured at the time of the problem at hand.

For the Gold Coast beaches, the problem at hand consisted of cetaceans, shark nets, sharks, people, and geography. Creating an action response through the use of pingers satisfied the problem at the time. When the sand dredge appeared, it changed the context of the problem and the pingers no longer worked as a solution. Other echo-logical practices from acoustic modeling with animats to the creation of hydrophone networks derive themselves from the best judgments of the practitioners, the resources at hand, and the target for action. Valid action continues in practice while invalid action ceases in the face of resistance. No one action can solve all the problems which catalyze echo-logical practice.

In the case of the Gold Coast, the echo-logical project of the pingers placed engineers, marine animals, infrastructure, and the public into a correspondence. Each answered the others' actions in their own way, creating new, emergent possibilities and problems. The echo-logical practitioners engaged in this correspondence had to rely on transductive intuition to respond appropriately.

Bringing It All Together

Earlier, I stated that echo-logics forms when practices of skilled listening converge with sense of responsibility and I would like to now turn to those mechanisms that bind the two through practice. I will not focus on how responsibility is first established, because that is highly variable, depending on the individual. Instead, I will emphasize how values, responsibilities, and ethics are grown and reinforced through the transductive processes of echo-logics.

The move towards echo-logics begins with the technical transduction and output of the echo. I will assume at this point that any potential echo-logical practitioner aims to maintain continuity between the sounding being and its echo. Those who wish to completely decouple the sound from its source for whatever reason can safely be removed from the pool of echo-logics. This then suggests that these skilled listeners must consider the ontics of the non-human being throughout the transductive process. Technological networks of listening force skilled listeners to consider each moment in which the echo is transformed in order to maintain a connection with the original sounding beings. This ensures that the ontics of that being is actively considered. As listeners increase their skills, they become better able to conceptualize the world of the non-human, reinforcing a relationality to that being.

As I have stated in Interlude II, recognition of an animal's ontics does not necessitate the recognition of its subjecthood. In echo-logical practice, the link from ontics to subjectivity is made through action. Knowledge of ontics gained through observation allows for the non-human to be objectified as the observer can resort to describing aspects of the *umwelt* as features. No more engagement is required. But, knowledge through action—especially through iterative actions which are a part of transductive transformations—reinforces the subjecthood of the non-human being. As echo-logical practice requires correspondence with multiple entities, the practitioner must continue to work with subject rather than reproduce objects.

It is at this point which the convergence between practice and ethics occurs in echo-logics. Once the subjecthood of the non-human—and the assumed human's sense of responsibility towards it—are reinforced through knowledge practices of skilled listening, then the practitioner's actions become engaged in ontological politics. The echo-logical practitioner not only must consider the world of the non-human through listening practices but must then place that world in relation to human worlds when the practitioner rebuilds a context for outputting the echo. The practice of echo-logics, first through the transduction of the signal and then the transduction of action, implies a pluriverse. It is then through the pluriverse that the practitioner finds new ways of knowing through relationality.

The continued awareness that has remained a theme here aligns with Stengers (2013) slow science. Stengers proposed slowing down of science as a means to counteract the totalizing force of industrialization which have quickly converted the landscape into economically productive space through the use of scientific intervention (pesticides, geological engineering, monocropping, etc.). A slow science would encourage scientists and related stakeholders to consider more broadly the effects of their actions. Slow science does not imply that scientific projects must be brought to a screeching halt. Instead, science should be slowed down *enough*, to be considerate to other, less powered beings. Echo-logics does this by forcing continued awareness of the non-human being's subjectivity. Fast science gains its speed through objectifying and disentangling everything before it. By reinforcing the multiplicity of subjectivities within the pluriverse, echo-logics can aid in slowing down science enough to consider non-human beings without jeopardizing the urgency which the Anthropocene crisis demands.

Not everything in this thesis is echo-logical practice, but those who do not practice echo-logics do contribute to it. Echo-logics was created to fill a lacuna in sound studies. It may be imperfect, but it provides a cognitive anchor for discussing a range of behaviors. Echo-logics sits beside scientific practices and acoustemology. They are meant bolster each other rather than echo-logics acting as an alternative analytical form.

Because echo-logics as developed within this research project is still a developing conceptual gesture, its boundaries are porous. Public hydrophone networks are safely echo-logical practice, but is acoustic modeling echo-logical? Modeling requires extensive prescriptive actions, but the results are emergent and constantly shifting as further actions take place. Modeling is meant to spur action (or inaction) through the transformation of sound data. Alternatively, project reports require extensive transformations and interpretations of the data, but they often take highly prescriptive forms and do not encourage further action. The point of defining echo-logics as I have done is not to create a clear-cut category for describing certain ethnographic behaviors. Echo-logics is, instead, designed to be a tool for understanding sonic engagements in a different way.

Echo-logics does not only ask what is out there, today. It inquires what is possible tomorrow. How will echo-logical practice change our sonic relationship with the wider ecology of the planet? What will drive echo-logical practice in the future? Who will become the next cohort of echo-logical practitioners?

Chapter 6: The Reef Resounding

The orcas encountered in Chapter 5 are not objects but have become subjects through human practices of listening. They have names, families, and personalities. The orcas have become political participants as they move public opinion through heart-wrenching displays of loss and mourning. Industries have started to accommodate the orcas' needs, treating them as members of the Salish Sea community. While not yet a success story, the orcas provide a glimmer of hope as to how marine soundscapes can be managed.

Conversely, the corals, fish, and invertebrates of Great Barrier Reef communities are still treated as objects. Policy makers and managers strategically decide what lives and dies based on fishery stocks, ecosystem services, and public amenities. Few Reef beings are given the privilege of being sensate subjects (cetaceans, turtles, and dugong excepted), which has ramifications for marine park management. While fish and invertebrates are categorically treated as a natural resource, marine mammals and turtles are provided welfare protection under Australian Law (Cao 2015).

The Salish Sea orcas benefit from being large, expressive mammals who can be individually identified, giving them certain charisma. They need little transduction beyond hydrophony to encourage subject-making. It seems that Reef beings, in their multitudes of alien bodies, have less chance of attaining subjecthood in the human psyche, either collectively or individually. This has frustrated the acousticians and other noise management advocates who have seen their efforts continuously drowned out by other marine stressors such as heating oceans and agricultural runoff. The Reef needs help if it is to become a subject and if there is any hope of echoing the management lessons learned in the Salish Sea.

In this chapter, I explore resounding as a form of echo in echo-logics that pays attention to the creative political use of sound. Rather than focus on how sound might be heard in the halls of state politics—as I have done in previous chapters—I will explore how resounding to public audiences may generate new political possibilities. In doing so, I will examine the role of sound artists in creating possible sonic worlds and sonic subjects as alternative ways of knowing. This will include a reflection on the production of a collaborative sound piece between several sound artists and myself.

The Politics of Resounding

What do I mean by resounding? To resound is to fill a place with echoed sound. To resound is also to respond or to celebrate. Resounding transforms space and time to recreate, recontextualize, or reimagine. It is a willful act which often begs for a response.

Resounding is an intentional political act. It makes a claim as to what we should hear in specific spaces; in echo-logics, there are many ways to produce an echo—as I have gestured towards what we should attend to in the previous chapters—and resounding is one such method with its own logical uses. These public presentations of sound or sound data are shaped to argue for how soundscapes should sound and who should be a sounding subject.

Resounding is also a highly creative process for echo-logical practitioners. Resounding is commonly employed to respond to novel or nascent political questions of how to order the world. Resounding forges ahead to create new relationships between subjects. With few guides to go by, this form of ontological politics requires creative effort. A creative practice in resounding can be a stumbling, trial-and-error struggle in the human attempt to connect to other beings, but it can also be rewarding to engage a politics beyond ourselves. The pluriverse of resoundings is equal parts a creative and a political act, continuously recreating and transforming all those who participate.

A pluriverse of resoundings creates what LaBelle (2018) calls "echo-subjects" (114). The echo-subject is a voice that is echoed and amplified for political ends. LaBelle gives the example of the People's Microphone used during the Occupy Wall Street protests in 2012 in which the crowd repeated the words of the individual to amplify political speech. While LaBelle's conceptualization of the echo-subject remains on the collective, non-technic amplification of voice, his description points towards a transductive action to create a heard subject. The intent is to bring sounding subjects on the periphery into the middle of the political field. I consider technologically and socially transduced marine sounds as echo-subjects as the strategy and intent remain largely the same. Notably, the creation of non-human echo-subjects are a way of bringing these creatures into human political discourses. They are enrolled as subject-participants in human worlds.

The Salish Sea is one place where echo-subjects are emerging through echo-logical practice. Resounding the orca in aquariums, museums, state parks, and private residences brought the orca's sound world into the political arena(s). Through the hydrophone networks, both regional and distant listeners become engaged in the management of the marine soundscape including compliance in, and monitoring of, the ECHO program ship slowdown trials or the activism demonstrated by SIMRES and Saturna Island residents. Transducing the orca into an echo-subject propelled it from being a marine being to a sonic being. The orcas became subjects in multiple worlds from those of sailors, to activists and politicians. Their sensory world experience was taken seriously by the Washington State and Canadian governments and new management plans were developed to respect their lifeworld.

The effectiveness of this logic of echoing remains contingent on the social history of the orcas. Through the long history of research, display, and monitoring that included individuals like Moby Doll, research by Lilly (1961) on dolphin communication and cognition, and institutions such as SeaWorld, orcas have become an animal-with-a-voice. Voice plays a crucial role in LaBelle's echo-subjects. The people he writes about already have the capacity for voice, though that voice may be quieted or silenced. A new problem arises when the potential echo-subject is thought to lack a voice, like the non-white and non-human bodies of 19th century Colombia about which Ochoa Gautier (2014) writes. These echo-subjects were made echo-objects through colonialism; their sounds transduced into noise. As noise, the sounds of the echo-objects are not treated as vital parts of other sound worlds which create meaning beyond Western human imaginations. Echo-objects become something to be quieted, lessened, or tolerated through objective rules that have no consideration for their sound worlds.

For resounding the Reef, it is not sufficient to only echo the strategies used in the Salish Sea. Unlike the orcas, the Reef does not easily present as an echo-subject. The geography of the Reef has prevented the establishment of hydrophone networks that worked so well in the Salish, and the sounds of the marine life remain indistinct and foreign to most listeners. Work must be done to develop a space in which Reef subjects are taken seriously by other political bodies (in this case, the Commonwealth Government of Australian and the Queensland State Government). That work is two-fold: the space-time of the Reef must be transformed so that it is accessible to human world makers and the Reef must be recognized as a sonorous subject.

While the context of echo-logics in the Great Barrier Reef is different than that in the Salish Sea, there is some wisdom we can potentially gain. As practice in the Salish has shown, public engagement is paramount for initiating government action. Public participation in noise management plans is strong because marine sound was made accessible and resounded plainly. The public was not likely to be mobilized by reports and studies—even if those documents were vital for generating management plans—but could be engaged through listening technologies, both online and strategically placed throughout the region. This two-pronged attack with scientific documents directing state action while creative resounding generating public sentiment may be the best option for developing effective noise management policy for the Reef. While I have outlined how scientific data has begun to shape government action, far less engagement has been occurring at the public level. Having learned from the "orcaholics" (as some residents of the Salish area have dubbed themselves), public engagement will be a key factor going forward.

Artful Resounding

Creative practice is a time-honored strategy for engaging politically with the public, outside of the mechanisms of state politics. It is through creative practice that the politically engaged push the boundaries of modern politics and society. They find the cracks in those boundaries that can be exploited to insert new orderings of things. Creative practice can generate ontological politics among the public, in a grass-roots movement to enact such relationships in state politics. I turn my attention now to consider an artful approach to this issue (following Jennifer Deger in Miyarraka Media 2019).[93] Artful practice differs from creative economies (Gibson-Graham 2009; Gibson-Graham and Roelvink 2011), technological innovations (Ingold 2001; Pfaffenberger 1992), or other creative practice by turning to skillful creativity to explore and build possible worlds. Artful practice is both playful and methodical in testing the relationships among worlds and attempting to recast them.

An artful resounding has been intertwined with the practice of ecological soundscape recordings since the founding of Schafer's World Soundscape Project (WSP). The impetus for WSP was to draw attention to noise pollution and the environment through both recording and artistic practices. The project's inaugural album *The Vancouver Soundscape* (1973) combined field recordings made around Vancouver with more playful compositions of environmental sounds. The WSP would make several more soundscape albums in Canada and Europe before the research group disbanded.

One of the more prominent members to emerge from the WSP has been environmental soundscape composer Hildegard Westerkamp. Her work goes beyond the

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[93] I owe my understanding of artfulness to the guidance of Jennifer Deger, who has incorporated artful practice into the development of the Visual, Digital Material Research group co-supervised with Ton Otto, of which I am a member.

presentation of field recordings. She augments, rearranges, and speaks over her sonic material to build a relationship between the listener and the environment. Westerkamp's form of resounding is less concerned with the veracity of the presentation to the soundscape and more toward a truthful communication of sentiment.

Westerkamp's *Kits Beach Soundwalk* (1989) composition best characterizes this form of resounding. Softly, Westerkamp talks over her recording of Kitsilano Beach in Vancouver, describing first the current conditions of her recording before turning to the sounds of barnacles feeding which "trickles, and clicks, and sucks, and…". These sounds, she acknowledges, are magnified by the recorder as she first pulls back to more truthful levels and then amplifies the background sound of the city to mimic the noise as it interferes with her listening. "Luckily, we have band-pass filters and equalizers," and she smoothly turns off the cityscape to focus all her attention on the "tiny sounds." She dreamily drifts to associations between the barnacles and other sonic imaginaries, pulling other sound works in and out until she can finally face the monster of the city noise and end the piece. Through her sound play, she pulls the attention of the listener to the sounding of the barnacles and gives meaning to an animal that most would not consider worth listening to. Through artful associations, she sets up multi-species relationships that contain the potential for ecological action.

Ecological relationships at the heart of Westerkamp's conception of sound art helped me conceptualize how sound art may resound the Reef. *Kits Beach Soundwalk* builds the world of the barnacles. These small, hard-shelled invertebrates are much like the coral polyps. Their vital nature easily misunderstood as geologic. As Westerkamp learns to appreciate the lives of small barnacles on the edge of Vancouver through artful practice, I too learn how to make room for other, alien beings.

More recently, Westerkamp (2002) has wrestled with defining soundscape compositions and her struggle has ramifications for ecological sound art more broadly. Soundscape compositions emerged as a genre with—or at least meaningfully organized through—WSP and have been linked with a larger practice of listening and documentation. As the genre gained popularity and its own tradition, some have wanted to place soundscapes under the umbrella of *musique concrète*. Westerkamp has rightfully recoiled from such ordering that would position soundscapes as a musical genre, but has been forced her to declare her own positioning. She draws a link to acoustic ecology, which harkens back to WSP and how soundscape compositions emerge from the same processes as acoustic monitoring. "So, once we have accepted the acoustic ecology arena as the basis from which soundscape composition emerges, one could perhaps say that its essence is the artistic, sonic transmission of meanings about place, time, environment and listening perception" (Westerkamp 2002, 52). In this definition, Westerkamp imagines the soundscape composer as a kind of acoustic ecologist who produces artistic forms rather than reports. I would add that under these guidelines, acoustic composition becomes the resounding arm of acoustic ecology directed towards the public.

Westerkamp's stance suggests a wider reorientation for ecological sound art. While difficult to precisely define, sound art can be considered any creative practice orientated towards sound and sonic phenomena, whether it is a performance, installation, sculpture, or text. This definition intersects with music but includes many non-musical practices. Ecological sound art are these practices focused more specifically towards ecological sounds and sounds of the environment. Westerkamp resists the label of *musique concrète* and Pierre Schaeffer's (2004) *objets sonores* (sound objects)—sound divorced from all causal and visual context and experienced through pure aesthetics. She does so by re-ascribing meaning and connection to the recorded sound, claiming a position close to Feld's (1990[1982], 1996, 2015) acoustemology. *Kits Beach Soundwalk* constantly reminds the listener of the context of the recording as well as the associations of meaning that emerge from Westerkamp's listening experience. These ecological soundscape compositions are about considering and exploring relationships between the ecology and the listener, exhibiting what I call echo-logics. If I assume Westerkamp's understanding of ecological sound art (which I am inclined to do), it would mean a denial of an *objet sonore*[94] and an embrace of the echo.

Relationships are important in this echoing process. The vitality of the artwork is the most tenuous relationship, but it is not the relationship between sound and the body (Chapter 3), the actual and the modeled (Chapter 4), the environment and the listener (Chapter 5) or the representatives and the politician (Interlude III). Instead, the resounding relationship is between the artist and the audience. Ecological sound art continues to contain meaning and diverts from *music concrete* if artist and audience achieve "resonance"[95] with each other and the recorded environment.

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[94] Importantly, I do not deny the validity of *objets sonores* or *musique concrète* in artistic practice, only that I do not find these to be appropriate for ecological sound art.

[95] Westerkamp uses resonance to indicate the relationship between artist and audience that enables meaningful communication.

The relationship between the artist and the audience is central to sound art critic Salomé Voegelin's (2014) sonic possible worlds.[96] She asserts that a possible shared world exists between the artist and the audience in the moment of listening. This world is constructed through the experiences each party brings: the experience that shapes the artist's creative process meets the experience that shapes the audience member's reception and interpretation of the art. The shared world creates a temporary ontology for the artist and audience around which to organize things. If I situate sonic possible worlds in conversation with actor networks, most aptly with Law (2002), then the robustness[97] of those worlds depends on how much of that experience is shared. That robustness depends partially on the flow of transduction and the presence of resistance. A robust world will smooth over most obstacles that block the artist or audience from perceiving it. Finally, if I reintroduce Westerkamp (2002), then *ecological* sound art depends on those experiences being derived from environmental observations rather than other shared schemas.[98] The more robust the shared world is, the more likely it is to have an effect on lived worlds once that temporary ontology is resolved.

Voegelin's use of possible worlds hints at the world of many worlds in the pluriverse. Possible worlds become the first step into generating awareness of actual worlds. Possible worlds allow the audience to recognize the possibility of other ontologies that can sit next to their own. The audience participates in art by accepting the temporary incursion of other ways of beings into their experience. Artistic practice makes these worlds approachable through shared elements. And it is through those shared elements that art can connect the audience to other actual worlds when the art experience finishes.

While there are many possible orientations and interpretations for what sound art and an ecological sound art are and can be, these provide a workable frame from which a possible echo-logical sound art can emerge. A resounding through the artistic arm of echo-logics would assert that sounds are inherently connected to their source and to our systems of meaning imbedded in them. It is the artist's challenge to entice the audience into a possible world of shared experiences rooted in the environment. An echo-logical artist does not need

[96] See Chapter 1.
[97] Or *nearness* in the parlance or possible world logic indicating how many logical propositions must be made to transform the actual world into the possible world.
[98] For example, due to the practice of replacing a bald eagle call with the cry of the red-tailed hawk in film, the schema for the sound of a bald eagle may be greatly shared but is not based on environmental observation.

to be fettered to the veracity of the sound world but must attend to the relationship between themselves, the audience, and sounding subjects.

Acoustic Ecology and Underwater Spaces

Acoustic ecology and soundscapes compositions have been embraced in Australia. There are annual meetings for acoustic ecologists as well as research positions in multiple universities. This appetite for acoustic ecology follows the same energy behind the environmental humanities and multispecies movements (see Kirksey 2014) seeking to buck the trend of discipline-specific research schemes. Spurred on by Australia's contested reputation as an environmental leader, it is unsurprising that there is an interest in listening to Australia's various ecosystems.

Interest from non-indigenous Australians in the continent's sonic ecology is relatively new. Jane Belfrage (1994) identified the historic presence of the Great Australian Silence as "the experience of strangeness and displacement felt by many nineteenth century 'white' Australians… It was 'silence' because no sound was recognizable or culturally known" (1). This contrasted with the acoustically rich worlds of Indigenous communities who hear the land ringing with song (Molnar and Meadows 2001). It was out of this dichotomy that sound artists like Ros Bandt found space to make art which incorporated Indigenous knowledge with soundscape ecology (Bandt and Barclay 2017). It was Bandt's work *Voicing the Murray* (1996) that helped to inspire sound artist and acoustic ecologist, Leah Barclay.

Leah is a researcher, artist, and composer with the Queensland Conservatorium Research Centre at Griffith University. Much of her work has focused on the aquatic environments of Australia, both riverine and marine. Leah's reef-inspired productions include *Listening Underwater* (2018a)[99] at the Horizon Festival on the Sunshine Coast and *Requiem for the Reef* (2018b), performed at the Australian Anthropological Society Annual Meeting in Cairns. Leah's interest in underwater sound and hydrophonic practices has led her to collaborate with marine scientists and acousticians as she continues to learn about the aquatic soundscape.

These close relationships between artistically and scientifically inclined listeners produce a particularly energetic push for world building. It enables Stengers' (2013) slowing down of science. "Fast science," for Stengers, is an ontology that concerns itself with

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[99] Winner of the 2019 Queensland Award for Excellence in Experimental Music.

building more scientific knowledge. The modernization of science has dismissed other worlds not conducive to self-perpetuation. By slowing science down, Stengers hopes to reform the scientific ontology so that it can sit beside other worlds. Doing so might lessen the likelihood of producing unexpected, adverse effects.[100]

Artistic practice is able to slow science because it forces collaborating scientists to focus on extra-scientific matters. Artists are not solely focused on creating more scientific knowledge. Instead, their practice explores philosophical, ethical, aesthetic, and affective knowledges in addition to, or to the exclusion of, the scientific. Through collaboration, scientists are pushed to consider other knowledges diverging from a focused pursuit of science. By giving science and scientists room to breathe, artistic practice allows them to reassess their position within a more-than-human entanglement. At the same time, the artist has the ability to engage in scientific research and import new knowledges into scientific practice.

Leah's work is a good example of this. Not only does she present recordings through artistic installations, but she works closely with scientists to create tangible impacts to the environment. Currently, the research side of her work has focused on acoustic monitoring programs for Australian rivers and marine environments (Barclay, et al. 2018). Unlike traditional monitoring and population measurement techniques, acoustic monitoring provides a non-invasive method to measure ecosystem health. Additionally, monitoring feeds can be broadcast for public consumption and generate new forms of caring. This combined with her artistic work forms the basis of her activist position, one that is normal within Australian acoustic ecology.

Following the lead of artists like Hildegard Westerkamp and Leah Barclay, I endeavoured to attempt my own resounding. I collaborated with a team of musicians and fellow anthropologist, Sebastian Lowe, to create an underwater sound piece that plays to the heart of acoustic ecology and the Australian tradition.

[100] Stengers (2013) uses geoengineering as a potential example, but one can simply refer back to Rachel Carson's (1962) *Silent Spring* for a thorough example of the precariousness of fast science.

Echoes from an Uncertain Reef

Echoes from an Uncertain Reef was designed as a collaborative work inspired by the *Cities and Memory* project.[101] Four musicians (Anna Jalving, Adam Purdy, Ingibjörg Yr, and Jeremy Mayall) were sent a clip of one of the hydrophone recordings I made on *Passions III*. They were then asked to create a response incorporating elements of the soundscape recording. Submissions speak to the emotional qualities of the sounds, draw out hidden elements, react to the subtleties and fragilities of the environment, and play with this novel soundscape. We envisioned this project as an academic exercise in which we could critically reflect on the process of creation. These four musicians were chosen because they were also involved in academic pursuits and would be able to engage with theory, including environmental inquiry.

The piece was played at James Cook University (JCU) over the Listening Post sound installation in The Cairns Institute and made available on the Listening Post's Soundcloud account.[102] We originally commissioned the piece as part of ongoing experiment with anthropological and ecological sound art practice within the university. It was not intended to be an exploration of echo-logical practice. During the early consultation and design process we were exploring what an anthropological/ecological/artistic conceived collaboration could be. As the process developed and we began to hear the submissions, I started to consider how this project might be an echo-logical practice.

This project was a practice in play. Play is an underexplored gift of transduction. If structure emerges and transforms through ever changing relations, then the milieu is open for playful exploration. Play is a unique and ubiquitous form of engagement where practitioners can explore and tests the boundaries of practice. The participating artists were asked to play with the sound recording. Without having clear goal, they could explore sonic potentials and could learn through failed attempts rather than be deterred. In terms of ecological interventions, play becomes a refreshing change from the high stakes management practices with no room for failure.

The intent of this play was to explore how a collaboration with artists could reveal new pathways in which the public might come to hear underwater sounds. The use of art and

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[101] citiesandmemory.com

[102] Sebastian Lowe and I had been tasked with curating the content for the Listening Post, a new sound installation at JCU consisting of a domed speaker suspended via a pole over a wooden drum which houses the electrical components. *Echoes* was our second sound work.

artistic collaborations to promote science communication has been on the rise for the past decade (Harvey 2018; Lesen, et al. 2016). With science/art projects becoming more frequent, new questions are emerging as to how these collaborations can further public engagement. Alan Friedman (2013) has some particularly useful insights into the emerging art/science relationship. After reflecting on three successful science/art productions, Friedman comes to the conclusion that the power of art is not to neatly bundle and deliver scientific data to the masses but to generate an affective response to the subject matter. The artist is not the spokesperson Latour (1987) describes, nor are they solely representatives in ontological politics. Rather than represent non-humans as scientific instruments, the artist interprets the scientific process or its outcomes into a form that encourages the audience to care or generates a sense of urgency. This assessment aligns with Stengers' slow science although Friedman's analysis focused more towards the communicative aspects of these collaborations rather than the reflexive process Stengers describes.

The affective relationship between the public and the scientific subject is one of the core components that Lorimer (2007) identifies in establishing non-human charisma. Creative practices, as Friedman (2013) notes, may be in the best position to do just that. One way may be through the use of pathetic triggers. Voegelin (2010) defines a pathetic[103] trigger as "an affect that initiates the action of perception through which its sensation is realized" (177) and later suggests that these triggers are what draws the audience into possible worlds in Voegelin (2014). Returning to *Kits Beach Soundwalk*, Westerkamp does not contain her monologue to objectively presenting the sounds of water flowing over feeding barnacles. She continues to draw deep associative connections to those sounds and generates an affect that can work as a pathetic trigger that draws the listener in to her Kits Beach and generates a connection to that environment. I highlight *Kits Beach Soundwalk* for another reason. Unlike the orcas who also reside along the coast of Vancouver, the barnacles are not creatures with immediate mass appeal. Through the pathetic triggers in her soundwalk, Westerkamp is able to facilitate a relationship between the barnacles and the audience. Might sound art then facilitate a relationship between coral reefs and an audience? This is not the only way art can engage with the science or the environment, but the literature suggests the focus on establishing affect and attending to connections has viability as an echo-logical practice.

[103] Voeglin borrows the concept of the "pathetic" from Victorian art critic John Ruskin (1903).

I invite you now to listen to *Echoes*:

Echoes from an Uncertain Reef (Track 12) [19:02]

The structure of *Echoes*, as we have curated the artists' submissions, is meant to attract the listener and produce pathetic engagements through the four compositions so that when the listener finally listens to the field recording, they hear more than the acousmatic sizzling, grunting, churning sounds. In that process of engagement, I hear at least four interrelated themes: contact, globalism, temporality and the role of creativity and the senses in focusing our attention.

Contact

Anna Jalving invites the listener, first in Danish and then in English, to enter into the water and make contact with the marine realm. Her poem is both intimate and distant in relation to the underwater world, perhaps mirroring many listeners' relationship to the ocean. "Come," she initiates the possibility of contact. But as she finally breathes the water in, the audience is confronted with the first respirations from Adam Purdy's track. As the respirator punctuates the next three- and one-half minutes, the listener is not allowed to forget that entering the Reef domain is an embodied and technologically mediated experience.

The field recording I sent to the artists is not purely a nature soundscape. There is no illusion of the disembodied ear swimming through a pristine reef. The recording of Shark Mountain is sonically situated off the side of a dive boat, with its rumbling, churning innards, jiggling and clanking, and the occasional diver catching a breath. I had chosen this clip specifically to emphasize that the submarine world remained a cultural space with cultural activities and human agencies as well as an ecological space for non-human beings to resound their continuous existence. This sense of contact is exhibited from Jalving's invitation through to the child's voice reading climate change headlines in Ingibjörg Yr's track—restating the contact between anthropogenic forces and the Reef ecosystem at scale.

Globalism

The first voice in *Echoes* to greet the listener is not English but Danish. Only about one third of all spoken word in this work is in English—Icelandic counting for the other third in Yr's contribution. This was an international collaboration. I am American while Lowe, Purdy, and Mayall are New Zealanders, Jalving is Danish, and Yr is Icelandic. This diversely located team deliberately reflects something of the global interest in the Great Barrier Reef. It is also reflective of the global environmental movement that has sparked protest and activism around the world in 2019.

As a child, I was mesmerized by the Great Barrier Reef I saw in nature shows and picture books. The Reef, in my novice imaginary, represented all tropical reefs and marine environments. While the Reef has become an icon of Australianess (Deloitte 2017), there exists a global fascination and concern with the GBR. We made the curatorial choice to highlight these global relationships of imagined Reefs and remind the listener that impacts to the Reef are an international concern.

The global Reef is best represented in Yr's track. Through the child's voice and the whales' calls, she ties together tropical Australia and subarctic Iceland. A child's voice reads out headlines describing climate impacts to the Great Barrier Reef and occasionally the listener can identify a familiar word in the Icelandic monologue. It is a reminder that global activity feeds into the impact on the Reef. The child is slowly joined by the calls of humpback whales and dolphins whose antipodal cousins visit the GBR lagoon every austral winter.

Temporality

In *Echoes*, as the artists shift senses of spatial scale, they also shift senses of time. It starts in Purdy's track as he attempts to represent the long time of the Reef. As he told me, he builds up the piece to signify the vital complexity of the ecosystem, before bringing it crashing down to a silence reflecting the bleak outlook for the future Reef. Yr orients to another future perspective through the child's voice. Yr highlights the intergenerational responsibility for protecting this ecosystem and calls to the uncertainty of what space the next generation will inherit.

Mayall literally plays with time in his piece. But instead of examining the macroscale of time, he provides a microscale exploration of sound events. By taking a recording of only a few minutes and stretching it to a few hours, Mayall enables the listener to hear the sounds between each booming implosion of the snapping shrimp sizzle. The track meditates on the intimacy of the sound, much like Versluis, et al.'s (2000) highspeed photography of the snap that opens Chapter 1 (Figure 1).

Attention

At the end of the sound work, the listener is returned to the continuous sizzle of the original, unadorned field recording. Hopefully by now the sounds of the Reef are not an undisguisable wall of noise, but an intricate interplay of minute sounds. The sizzle pulls through the pieces like a sonic thread. It picks up context and connections. It becomes a pathetic trigger.

Each contribution seeks to draw attention to the nuances of underwater sounds. The breath of the scuba diver, the grunt of the fish, and the snap of the shrimp build together to form a sonic Reef, a possible ecosystem accessed only through sound. It is also meant to inspire attention to the living Reef. We want the listener to inhabit the sonic possible world of the Reef and reflect on what that inhabiting means. During that process, each artist had to focus their own attention to the field recording in order to echo that attention. I would like to turn now to that process of learning to listen through the creative practice.

Listening through Creation

The process of creating sound art requires skilled listening. The artist must first attune to nuances of the sound event before they can artfully echo them. It is a type of skilling that Oliveros (1998, 2015) has called deep listening, a focused attention to sound that probes its movements and interminglings. The skilling also requires the artist to determine their relationship to the sound event, to guide how they may engage with it. This type of skillful practice generates a knowledge through creation. Knowledge is obtained here through the construction of possible worlds in which each relationship must be tested and explored. This contrast with the scientific modes of knowledge, which acknowledge only one world that is already actual with pre-established relationships identified. Creative practice therefore represents a form of transductive logic for organizing relationships. It is a relationality that iterates upon itself as each new relationship forces the artist to reassess all other relations. Relationships build and dissolve through the work of the practitioner. I had the chance to discuss with each artist their process of creation.

As described throughout this thesis, hearing the Reef takes skill. In this instance, listening to the field recording requires a specific capacity to focus and draw out those sonic moments on which to pin the artwork. For Anna and Jeremy, the skill of listening to underwater environments was already developed. Both had previously worked with underwater recordings and had an idea of what could be done. For Adam and Ingibjörg, there was a stronger cognitive clash between expectation and experience of the sound. As Adam stated, he was expecting a dynamic recording, but what he got was something more continuous and fragile. It upended his plans for possible composition. Ingibjörg, too, remarked on the surprising mundanity of the soundscape. While she was expecting a build-up to some climax—that the piece was "going somewhere"—further reflection revealed that our expectations for exciting sound experiences often negate the sound beings' right to just be.

There is a surprise of the ordinary in listening to environmental soundscapes. Mediatized sound has taught us to expect dynamism from the sonic experience, whether it is from the rise and fall of musical compositions or the narrative-focused soundings of film and television. The apparent monotony of the environmental sounds goes unattended. We have been trained to hear dynamic life, not continuous life. Westerkamp (2002) warns against forming too many expectations, as soundscape compositions must emerge from the listening. "Environmental recordings," she indicates, "never give us sound objects, i.e. isolated, singular sounds recorded in a quiet studio environment, they give us sounds within a context of other sounds" (54). The dynamism is built through listening and editing process.

Most of the listening that I have documented in the previous chapters were attempts to hear the actual sounds of facts or possible facts. It is a listening that can be indexed, cited, and mathematically described. These artists instead listen, as Jeremy put it, musically. It is a listening focused on the rhythms and textures, a listening out for those pathetic triggers. Notably, Jeremy describes musical listening and ecological listening as coexisting. One does not negate the other. The artist emphasizes one listening practice depending on the project. Westerkamp would agree. Like the integration of science and art described by Friedman (2013), musical listening complements ecological listening by attending to the affective components of the soundscape.

How each artist chose to transform their listening into a sonic piece was highly variable. Anna's poem is notable for its lack of any sonic adornment. No shrimp sizzle in the background nor waves lap against the ear. She first tried to create something without words but could not produce something she found meaningful. Anna is very aware of noise and noise pollution in her own practice, and without a connection to the Reef, she felt anything she created would remain noise. That is when she turned to her poetry. The lack of environmental sound makes echo-logical sense in Anna's sound politics. She is able to speak to the Reef and wider marine world without improperly speaking for it.

Ingibjörg creates connection in a different way. Fond of soundwalks and sound recordings, she wanted to create a sonic picture. Hers is a sonic picture of the plight of the ocean during the Anthropocene. Ingibjörg was inspired by a collection she came across online of cries produced by whales as they were being hunted. The mournful lament of the dying whales could echo the dying of the Great Barrier Reef. Unfortunately, Ingibjörg was unable to obtain those recordings but did manage to contact a marine biologist who shared another collection. These more common calls of whales and dolphins intertwine with the daily crackle of the Reef and highlight what could be lost during the current climate crisis.

The listening experience not only directs how the sound is presented (or not) but can also affect the structure of the piece. Adam's electronic music, produced under the name Bluesleep, is typically supported by a strong beat. He intended to incorporate that same support into his track. His efforts were stymied by the relentless continuity and fragility of the recording. Any beat would disrupt the integrity of the sound. Conversely, Jeremy created as he disrupted. His practice included a reflexive listening as he stretched and then augmented the sound, finding new musicality in each step. Jeremey interrogated the sound event at a microphonic[104] level to create a deeper engagement with the field recording.

Reflection

As curators of *Echoes*, Sebastian and I were tasked to place each piece into relation with others; to establish an order. We took five possible worlds and created one world in which the listener could follow the string of relations and contradictions to the end. The order we chose was structured to invite the listener to build an aesthetic knowledge so that they may come to respect the final possible world, Shark Mountain, which was the closest to the actualized Reef.

This project was about exploring relations and contradiction within ontologies of the Reef. To do so, we had to create possible worlds. Here, I would like to emphasize that the possible worlds of sound art are intentional creations that are both of their source world as well as intentionally separated from it. Simondon (2017[1958]) describes aesthetic objects as mediators between two forms. Often one form is easy for humans to grasp while the other is of a higher order, such as through connection to the divine or moral exigency. Applied to possible worlds, objects become the mediators between our world and other worlds. Possible worlds as aesthetic objects provide a vantage point to access and develop respect for other worlds. In this way, the aesthetic choices made by the team generated aesthetic knowledge of the links between sound worlds. As Simondon says, "the world of art re-establishes a reticular universe at least for perception" (192).

[104] As an aural equivalent to micro*scopic.*

The potential for possible worlds is still reliant on humans identifying those links to other worlds. When we provided the project brief to the musicians, we gave them freedom in deciding what to present through the source sound file. They were not instructed to produce a comment on underwater noise pollution, but I did make them aware of my own research topic. Even though anthropogenic sound and boat noise are clearly evident in the source sound file, not one musician directly took up the issue of noise. Only Jalving's track addresses noise pollution, although this is through her ethical decision making rather than explicitly through its production. The reasons for these decisions are complex but they may signify two general sentiments. First, as Jeremey suggested, noise (in general) is so prevalent in our lives that it becomes more interesting to ignore it and focus on other elements in artwork. The other sentiment may be that even skilled listeners trained in aesthetics can miss the ecological noise or noise can be overwritten by other, more public stressors.[105] There is potential for both to contribute to the artist's intent.

It is important to consider separately the echo-logical practices of the artists and my own goals of communicating noise pollution. It would be unfair to judge *Echoes* based on a goal that was not the focus of the initial project brief. But a practice does not need to be intentionally echo-logical to be an echo-logical practice, and I recognize how echo-logics develops from artful considerations.

Echo-logics as a tool for understanding a variety of sonic engagements does not necessitate intentionality to adhere to echo-logical principles. It can be engaged with in degrees and in kinds. It is up to the critic, analyst, or scholar to comment on *how* a practice engages in echo-logics, as they would assess engagement in an art form or ethical relationship. From my perspective, *Echoes* shows the signs of echo-logical practice. The project respectfully considered the sonic worlds of other beings and attempted to instill such awe and respect to an audience. Through the process, the participants were realigned with the sonic environment, allowing them to navigate new pathways for encouraging attention to the ongoing troubles of the Great Barrier Reef.

Echoes is driven by dual interests in transduction and ontological politics. It is transductive in its structure, both technically, as it transforms signals through technical networks and creatively, as it attempts transform relationships between sonic elements in the milieu. It acts with ontological politics as each participant seeks to challenge conventional

[105] In this case, the threat of climate change and reef die-off were of more concern to the musicians.

structures of building sound worlds and including more non-human beings in that process. *Echoes* is less driven by phenomenology of non-humans, although this appears intermittently in the project. This illuminates an affordance of echo-logics. Not all echo-logical practice must be driven equally by all three elements. Such flexibility allows echo-logical practice to address different questions within the same domain. *Echoes* engages less with phenomenology of non-humans than the Orcasounds hydrophone network, but it also asks more challenging ontological questions than the Salish Sea project. Both practices remain engaged in echo-logics.

It remains that *Echoes* does not speak well to noise pollution specifically. I had thought that artists would be attracted to such challenges, but that difference in expectation and practice may have resulted from an underlying bias in my skilled listening. By the time we developed the *Echoes* project, I had grown particularly sensitive to underwater noise pollution. Through such focus, it became more difficult for me to understand why other skilled listeners were not hearing the same things I did.[106] This is an important reminder to not be critical of other echo-logical practices solely because their goals are not aligned with your own. A diversity of echo-logical practices can be helpful to the overall movement. While *Echoes* did not mediate on noise pollution, it generated a new engagement with the sonic reef in general. Likely, both engagements (and more) are crucial for spurring public action and new practices can emerge through iteration and creative associations. When one allows for such diversity, surprising connections start to develop.

Echoes sought to generate an aesthetic knowledge of connections. One of those connections was between spaces the emerged through that performance of the Listening Post. Due to its location and the structure of the building, sound from the Listening Posts bounces around the atrium, ensonifying the place. The space of the Reef and of the possible worlds were woven into the lived space of the Cairns Institute. The building transformed into a world of many sound worlds. Artful practice has a unique way of tangibly demonstrating how worlds overlap and intersect. This is not the purview of scientific practice. It is exactly this that makes artful resounding an echo-logic. Artful resounding succeeds in demonstrating possible ontological politics which scientific practice has difficulty doing. It is arguing for those worlds that gives artful resounding its political edge.

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[106] It is easy to remember that unskilled listeners have not been trained to pay attention to sound, but it is often harder to remember that there is a diversity in skilled listeners who have trained their attention to one or another aspect of sound.

Reflecting on that knowledge, future versions of *Echoes* could focus on noise pollution policy and generate a call to action. This would require greater integration with scientific knowledge. In addition, I would like to acknowledge the importance of Indigenous voices in future *Echoes* projects. The Indigenous perspective is not only missing from this work, it is absent from most of the broader conversation in Reef and noise pollution management.

Echoes of Resoundings

Resounding is a declaration of existence. It is therefore a political act. It is an ontological politics which declares the existence of another world and a demand to be respected. But resounding is also a creative act that creates ties between worlds.

In this chapter, I presented creative attempts at resounding that embody echo-logical practice. These practices are few of a countless multitude of possible engagements. I used them to demonstrate the various possibilities for echo-logics and the kinds of questions they can generate. The artful practices in this chapter engage in a very different manner than other echo-logical practices outlined in this thesis. These practices not only reach out to the audience, they also inspire the continual development and refinement of the artist's practice.

Unfortunately, the threat of the Anthropocene is looming. Left unchecked, the Anthropocene threatens to wipe out all worlds. In troubled times, doing anything seems difficult. But that is why we also need artful echo-logics. Through artfulness and play, we can temporarily suspend the threat of the Anthropocene. Protected by a possible world, the artful practitioner can play without fear of failure. It is a quality not afforded to those who are locked in critical engagements with actual marine life. Freed to critically play, the artful practitioner can slow down science enough to ask important questions about relatedness and responsibility.

All the practices in this thesis are challenging, but when working together, they help lift the load. I have demonstrated varied echo-logical practices and how they can work together. No one field of knowledge has a monopoly on sonic engagement, nor can one domain answer (or even ask) all the relevant questions. We must begin to consider the different ways people listen and resound the sonic environment of the Reef. If we only listen to one group, we threaten further harm and further alienation. At stake is the future of our world, and we can only begin to solve the issues of the Anthropocene if we maintain a multitude of voices.

Let this not be a guidebook on how to practice echo-logics. Instead, treat these examples as brief glimpses of what echo-logics can be. As these practices continue to transduce our multispecies relationships, they will inevitably generate new and surprising formations that cannot be forecast.

Chapter 7: Coda

Standing on the beach, I look out across the water and see a cruise ship moored offshore. Whenever I see these large vessels—cruise ships, cargo ships, tankers—I can no longer ignore their submersed sonic presence. I may not hear them on land, but I can sense them with my mind's ear. They echo in me because I cannot forget about the other worlds they occupy.

The skilled listening, echo-logics, and politics that have built up throughout this thesis have snared me in the many worlds of non-human beings. Perhaps this is what Corsín Jiménez (2018) means when he refers to anthropology as a trap. Through my fieldwork I am pulled into close association to other worlds and I do the same to you, the reader, through my writing. Having been drawn together, it becomes difficult (maybe even unethical) to forget about those worlds. If I no longer listen to the Reef, those echoes begin to fade like their nymphic namesake, but they will never fully go away.

Corsín Jiménez's traps are not killing traps. They are analog to catch-and-release traps used by coral fish scientists back in chapter 2. The anthropological trap must release the anthropologist or the reader back into their world at the end. I see these traps working like a piece of music. The musicians draw in the listener into a sonic world until all there is is the song. But then, the orchestra must release the audience back into the concert hall. This last movement towards release is called the *coda*. Perhaps I am mixing metaphors at this point, but I am also attempting to mix worlds. I have entangled trappers and prey and music and noise. Now I must release those entanglements back into the world.

The ensnaring process of intimating listening practices break down the conventional politics and scales of the environment once the listener is released. Having listened closely to snaps and croaks of coral reefs or the squeals and whistles of orcas it becomes difficult to scale up to national or global proportions of sound. How does someone listen to the entire ocean? One can only listen to small parts of the ocean, one at a time. This trouble is a part of the overall patchiness of the Anthropocene (Tsing, et al. 2019). While the overarching threats of the Anthropocene are global, they manifest unevenly and in particularly local configurations. Tackling the politics of underwater noise pollution requires paying attention to these patches of marine soundscapes while attending to how these sounds play into larger national or global structures. It is an attentiveness which I hope to have fostered through skilled listening and echo-logics. These practices allow listeners to build up a piecemeal scale that shift between patches of sound and the structures which support governance and commerce.

Reflecting on the troubles of environmental politics and the patchiness of listening, I must find new meaning to those questions I started this thesis with: how does sound become noise, and according to whom? How is noise detection and management on the Great Barrier Reef mediated through listening technologies? How can we learn to hear in a respectful and careful manner towards noise and non-humans? In doing so, I want to make some suggestions on how noise might be managed in the future through a sense of respect for other sound worlds. I do not have all the answers, but I wish to provide what insight I can.

Becoming Noise

Pickering and Rice (2017) were right when they stated that noise *is* sound out of place. Throughout my fieldwork, I encountered instances of sounds which would never have occurred in those environments without human intervention. Rumbling ships, exploding air cannons, and pinging sonar are increasingly finding themselves in places where they are unwelcomed by the non-human animals who have evolved to thrive in specific sonic ecologies. Marine sounds become noise through unique processes as noise is assessed through a more-than-human phenomenology.

Terrestrial noise management has greatly centered on the human experience. The Queensland Environmental Protection (Noise) Policy 2019—which ostensibly covers Queensland waters—is focused primarily towards noise in the built environment. When it does apply to undeveloped spaces, threshold levels are vaguely described as "the level of noise that preserves the amenity of the existing area or place [or marine park]" with amenity being further described in S6(c)[107] as "the qualities of the acoustic environment that are conductive to protecting the amenity of the community." The policy mainly relies on human valuation as well as acoustic measurements weighted to human ears. Queensland's policy generally falls in line with noise policies from other state governments and even stands out for its inclusion of biodiversity and ecosystem concerns. While the vagueness of ecosystem assessments does leave room for parks to set up their own thresholds, the inflexibility of assessment criteria does indicate a lack of consideration for non-human beings.

[107] The definition given for "community amenity" in the policy's dictionary (Schedule 2) actually reads "means the environmental value mention in section 6(c)," leading to a circular and vague definition.

This tact has generally followed the trend set by sound studies research into noise. Attali (1985) and Stewart (2011) have both directed their critiques towards noise within human environments as it impacts the health, safety, and integrity of the human being. Even environmentally focused writers such as Schafer (1977) tend to gear their analysis to how humans engage with noise in ecologically diverse places. The natural sciences have not fared much better since noise studies in community ecology only emerged recently (Chan and Blumstein 2012).

My own motivations for this research were originally along this track as well. Early in the development of this project my interest was in how sound and noise impact diver navigation. I too was unaware about the impact of noise on reef species because I did not know how acoustically sensitive they were. That started to change once I read the Reef 2050 Long-Term Sustainability Plan (Australia 2015), and I began to conduct my initial literature survey.

As I explained in chapter 3, that focus on human experience of underwater noise was muddled at best. While humans have likely been listening and reacting to underwater acoustics likely since humans first took to the seas, the amount of human exposure to modern anthropogenic noise is generally limited. Noise was not a principle concern for the divers I worked with, although it could have the ability to acutely disrupt them in specific contexts. Unlike air traffic or industrial noise, marine noise is not going to be successfully managed through the lens of human wellbeing. Instead, understanding marine noise requires a more complex set of relationships.

From my work with divers, I began to work off a preliminary model for how sound becomes noise: a set of skilled humans detect underwater acoustic signals and then compare them to observed or modeled data from non-humans. The humans then make the determination between the acoustic signal as sound or noise. The non-human is given some agency in the decision, but it is not the final arbitrator. Human beings must act on behalf of the non-human and act as transductive agent. Sound and noise are human categories after all.

This model is supported by my observations and fieldwork present in chapters 2 through 5. Legal regulations and management schemes of marine noise are filtered through an increasing array of non-human datasets. What started with cetacean behavioral data has now expanded to include other mammals, fish, marine reptiles, and some crustaceans. Still, it is hard to completely decenter the human as they remain the organizing agents through which policy and non-humans pass.

Such a model enables the creation of global and regional noise distribution maps. Those map data can be transformed into large scale models which become visual substitutes for what we are incapable of sensing aurally. But in doing so, noise becomes flattened into threshold values. Intimate relationships between sound, information, and noise are lost in favor of scalability. This model of noise useful for managing large regions, but it does not trap the listener, and therefore does not force humans and non-humans into intimate sonic relationships. The subtlety of sound is not given time to manifest. This model alone appears insufficient for underwater noise pollution management.

On that note, I propose a second model of underwater noise: a set of skilled listeners learn to listen to underwater sound with non-human beings acknowledged as the subjects for whom this really matters. The humans start to notice the relationships between themselves, non-humans, and the ecosystem. The humans then begin to see how relationships break down in the presence of certain sounds. Humans interpret non-human behaviors to the best of their ability and label those sounds as noise. Those classifications get further refined through continued listening.

In this model, noise is never a solid category. Humans remain as the central interpretive agent, but those interpretations are allowed to be unsure. Noise can still be understood scientifically as a set of properties contingent on an everchanging context. Noise is no longer a solidified fact. Under this model, it may be more appropriate to consider noise as a prediction. Like climate change or evolution, scientists can predict what noise may do or what form it may take, but noise will continue to surprise in its actuality. There is precedent for this in chapter 4. The acoustic modeling already carried a sense of uncertain possibilities. Animats were never confused with the fleshy whale, but they could be a tool to help think through the experience of noise.

The second model of noise can help loosen up rigid noise management and mitigation policy into intimate policies for patchy ecosystems. Under such policy, noise is taken as a potential to cause disruption to non-human relationships. The focus is no longer on “take,” on causing harm, but on the livability of specific environments. The trade-off here is reversed: noise becomes difficult to scale, but it traps humans and non-humans into sonic entanglements. Noise gains context through relationality but loses its ability to scale up. As such, there is a higher valuation on predictive modeling and continuous monitoring working in tandem. Policy through this model would also remain flexible enough to adjust for seasonal variations in the life worlds of non-humans or to shifting understanding in terms of multispecies relationships. Such policies are already evident in the Salish Sea with the Port of Vancouver slowing down shipping or potentially changing shipping routes in coordination with the Southern Residents orcas. Such policies can be implemented in the Great Barrier Reef if there is a strong political will for it.

Establishing a two-model approach to noise management would potentially allow managers to address issues of patchiness and scale. Rather than choosing between models, managers should adopt both. The use of the first model can help generate national and international guidelines while the second model can address the context of specific sites and species lifecycles. Rather than being concerned with scaling, managers can focus on points of transition between local and global concerns. It keeps the relationship between humans and non-humans troubling, but in ways which produce more careful attention which further informs management practices. Each model covers for the others shortcomings and a skilled manager could find synergy between the two.

Instruments of Detection

Where would this thesis be without the hydrophone? It has been my primary means of hearing the marine soundscape. It is a treasured possession for many of the humans with whom I have spent time. I have written more about hydrophones than I have about fish, whales, or snapping shrimp. I care so much about the hydrophone because it is fundamental to hearing marine noise not just for me but for all my interlocutors and marine management organizations.

The hydrophone has a storied past which I have mentioned in previous chapters and briefly recap here. The first hydrophones were used during World War I to detect enemy submarines, with further deployment during World War II and the Cold War (Schwartz 2016). It was not until the easing of tensions in the 1980s that the hydrophone became a predominantly scientific device. During the time of military hydrophony, the sounds of the ocean were literally classified—made inaccessible to the public. This history has ramifications for how we listen to underwater sound. First, the majority of World War II and Cold War era hydrophones are distributed around the northern hemisphere skirting North America, Europe, and East Asia. Second, these hydrophones are placed in militarily strategic locations rather than ecologically important ones. Third, with much of the sound data from these hydrophones still classified or in the process of declassification, it is difficult to construct historic patterns for shifts in ocean ambient sound levels.

The early history of hydrophones meant that the Great Barrier Reef was not a listening priority. Reef listening had to develop through the initiative of enterprising scientists, acousticians, and artists. Those of us who use hydrophones value them as our second ears for listening underwater, but we are also a privileged few who have them with access to specific key localities. Unlike the Salish Sea, there are no institutionally supported hydrophone arrays accessible to the public in the GBR. Skilled hydrophone listeners become gatekeepers to marine noise in practice because of limited technological access.

Those same listeners have assemblages of other listening technologies in connection with hydrophones to aid in the management of the Reef. Acousticians rely on modelling and animats to convert hydrophone data into actionable information for management bodies. Sound becomes transduced into probabilities, charts, and recommendations. Artists, on the other hand, utilize speakers, smartphones, and online streaming platforms to amplify Reef sounds and play them in public spaces.

Environmental advocacy has often focused on visceral contact. Environmental education has long placed an emphasis on physically being in the environment.[108] What gets lost in praxis is the realization that almost all of these instances of contact are technologically mediated. This is particularly true of marine experience given that the ocean is hostile to—and sensorially incompatible with—the human body. As I write this chapter in Australia, I am listening to the Orcasound hydrophone feed. I can hear the squeals and clicks of the Southern Residents in Haro Strait and they bring me "joy, sometimes dolorous joy, but joy indeed" (Stengers 2013, 179-180). I am connected to specific listening points (the lighthouse at Lime Kiln State Park in this instance), but they also generate a more global sense of listening.

Hydrophony can connect us to specific points of listening as well as instill a more global awareness of marine sound when we place ourselves inside its transductive networks. Rather than feeling alienated by technological mediation, listeners can become engaged in this sonic transplantation when they allow themselves to become a part of the technological structure. Simondon (2017[1958]) introduces his work by declaring:

[108] I have even argued for the need for being in the water as part of Reef education (when possible).

> we would like to show that culture ignores a human reality within technical reality and that, in order to fully play its role, culture must incorporate technical beings in the form of knowledge and in the form of a sense of values…the opposition drawn between culture and technics, between man and machine is false and has no foundation; it is merely a sign of ignorance and resentment. (15)

Simondon was speaking against the view of technology as a tool humans use and saw this position as the origin of the myth of alienation through mechanized work. He called instead for a recognition of the entanglement of humans and machines which produces work. While he speaks mostly towards technological labor, his argument can apply more generally to all technological activities.

By recognizing the humanness in technology and its entanglement with our culture activities, we can generate another mechanism for slowing down science. Inside the technological networks or hydrophone listening, the skilled listener becomes hyperaware of their extended sensing. Working with technology to mediate our environmental interactions enacts Haraway's (1991) imperfect cyborg where the human and the machine are in constant negotiation in their assemblage. Listeners must wrestle with the distortions produce by human or technological forces. The illusion of listening like a fish or whale disappears and forces a reflection on how listeners are part of the *process* of listening.

The mediatized sensing also destabilizes senses of locality and scale. The location of the hydrophone becomes both distant and intimate through the process of listening. When I listen to hydrophone streams, I am made aware that they present a soundscape from a specific place and transmit that experience over vast distance. I also become entangled with the environment and with mediated non-humans as I allow the hydrophone to become an extension of me. By connecting to more and more hydrophones, I can scale through a bricolage of soundscapes. It is an imperfect scale of patchiness, but it is one of the few options available to my aural ability.

The extended Reef community of researchers, managers, activists, and visitors can use listening technologies to better manage noise pollution. An attempt at transductive technological mediation would make obvious the necessity of listening technologies to hear the Reef. Hydrophones, models, and playback devices would become partners in identifying and mitigating noise. Listeners who negotiate with listening technologies would be made aware that they are listening from their perspective and not as another reef being while also gaining a sense of connectivity to place.

Echo-logical Lessons

The echo-logical practices that I witnessed throughout my research demonstrated a form of slow science which may be beneficial to marine noise management and mitigation. Echo-logics was not a deliberate practice by my interlocutors. Instead, I have taken the emerging practices, Which I noticed during my field research, and presented a possible model for further slowing them down. Echo-logics emerged precisely because my interlocutors, as skilled listeners, were responding to the effects of fast science. Geoff McPherson witnessed the depletion of fish stocks in the Great Barrier Reef caused by transportation vessels while the orca scientists and SIMRES community members reacted to the explosion of shipping in the Salish Sea. Sound artists like Westerkamp and Barclay take time to listen to the environment in the face of the rapidly expanding city. Most of these skilled listeners wish that ships and boats would literally slow down, as slower vessels produce less noise. They also want a slowness to allow research and knowledge generation to catch up to the demands of industry.

The Salish Sea already demonstrates how echo-logical listening can slow down marine management to produce more careful policy. Through long-term, intimate listening, researchers and community members have been able to build a corpus of knowledge on how Southern Resident Killer Whales and other cetaceans interact sonically within the environment. By forming such a detailed survey, policy makers could then recognize how noise interacted with other stressors facing the SRKW population. Without echo-logical listening, management may have solely focused on salmon fisheries which would have led to under-performing management strategies as well as increased public opposition. By including noise mitigation, the Washington State and Canadian governments have potentially reduced some pressure on the fishing industry. Echo-logical resounding through hydrophone streams, films, and exhibitions have also garnered public support for noise mitigation initiatives such as the ship slowdown trials.

The Great Barrier Reef is in early days of producing a body of echo-logical practices in relation to underwater noise pollution, so it is still too soon to see any policy-based results. Noise research and sound art installations are beginning to generate some attention to the sonic lives of Reef denizens, but they will need more institutionalized support if they are to reach a mass audience. A slowdown of policy through echo-logics may even be what the Reef needs as concerns around global warming are causing a speeding-up of totalizing technological interventions to the marine park. Drastic interventions such as genetic manipulation of coral or cloud brightening may help save the Reef in due time, but they do not force us to confront our own impactful relationships to the environment. Echo-logics and other slowing practices produce experiences which encourage greater behavioral change which may prevent the compounding impacts that have led us to the crisis we are now in. Taking such an approach may speed up our response to Anthropocene crises as slowness can prevent unintended adverse effects from stacking.

The patchiness of echo-logics and the difficulties of scaling such listening practices become a benefit rather than an obstacle in these instances. The context-specific relationships between listeners and non-humans generated through these listening practices makes it difficult to implement generalized, holistic solutions and instead forces managers to think locally. Such a move has the potential of giving back some control to local communities and grassroots organizations. The slowing down effect provides time for the public to organize and educate themselves to engage democratically with the management process.

Slowing science is essential for creating a respectful and careful management system for the Reef. Carefulness implies a thoughtful and deliberative practice. Slowing down the process in which we react and respond to emerging crises allows us to consider the impact to all living beings, not just humans. Such carefulness has been enshrined in policy making through the precautionary principle (COMEST 2005). Under the precautionary principle, if there is a reasonable suspicion that an action would have a negative consequence, then that action is suspended until further research can be conducted. All action in UNESCO sites should be following the precautionary principle and GBRMPA does do so to the best of their ability. But, there continues to be gaps in the principle's overall application. Noise is one such gap since the principle relies on a manager's ability to identify potential risks. As I have demonstrated throughout this thesis, underwater sound is often out of mind to even management teams. Slowing down would not only mean slowing the application of fraught environmental intervention such as invasive reef restoration projects, but also slowing down our interactions with the ecosystem and letting our time connecting with them linger in order to begin sensing new phenomena and creating a new form of "common sense."

The shifting subjecthood of humans and non-humans through echo-logics also enables the dissolution of human and natural boundaries. For a long time, the culture/nature divide has legitimized a human domination of non-human environments, particularly where those environments are highly productive to human needs such as the oceans. Legal stewardship of natural spaces, where they exist, often ends at the shoreline or within the skirting waters around nation states. Most of the oceanspace is considered public commons and tragedy has befallen it (Seto and Campbell 2019). Echo-logics helps to bring about an acknowledgement that culture does not stop at the sea's surface. We are as much a part of the ecosystem as the whales and sharks. This is a scale recognized by most non-Western maritime cultures but has been lost in Modernity. This reconfiguration of the scale of human interaction with more-than-human environments forces a revaluation of which spaces are open for environmental management. The management of so-called disturbed or reclaimed environments increase in importance as more ecosystems begin to exhibit what Bubant and Tsing (2018) call "feral dynamics"— "anthropogenic landscapes set in motion not just by the intentions of human engineers but also by the cascading effects of more-than-human negotiations" (1).

If we wish to carefully manage the Reef and other ecosystems, we must find practices which slow down decision making process to a speed which fully considers the complexity and specificity of the ecosystem. This can be done, in part, through realignment of humans with the more-than-human environment. Artful practice can assist with this, but so can government and educational institutions. Considered slowness must be integrated into the language and programming of management bodies like GBRMPA.

Possibilities, Potentialities, and Policy

I want to return to the question that GBRMPA asked at the start of my research: what are the sound amenities of the Great Barrier Reef? A decisive, clear-cut answer is hard to come by. As was shown in chapter 3, most Reef visitors do not hear the underwater world well. At the same time, there are some unique marine sounds associated with the Reef by people who have learned to listen. The difficulty in coming to a definitive conclusion arises from the current moment in underwater sound perception where listening practices are still emerging. Identifying sound amenities and managing the marine soundscape needs to focus more on potentialities and future possibilities (even more so as the Reef is likely to change due to Anthropocenic pressures).

As I have been arguing in this chapter, noise pollution policy in the Great Barrier Reef should transition to one that acknowledges possibilities and potentialities rather than certainties if it is to be effective. Fundamentally, noise is not a quantifiable phenomenon precisely because it is contextual. Noise is relational and is constantly transforming based on the context it is sounded in. Acousticians can measure and model noise through quantifiable elements, but that only leaves the possibility for noise. There is nothing wrong with making policy based on possibility either. In fact, it may be the more responsible and careful route to take. Public health, economic, and weather-related policies are all built on possibility rather than certainty. The only drawback (for some) would be that noise possibility policy would most likely error on conservative responses, but this what is already being called for in international environmental treaties.

The best lessons from the noise mitigation practices in the Salish Sea are how to construct effective, flexible policy around potential noise impacts on marine life. Augmenting shipping behavior and activity based on the possibility of negatively effecting orcas during vital biological processes has shown to be more supported than establishing universal thresholds. If enough data can be generated for the Great Barrier Reef, policy structured on possibilities could help GBRMPA mitigate noise without completely disrupting vessel activity in the region. The benefits of such policy structure extend beyond noise mitigation and can potentially benefit the management of other stressors too.

This type of management policy also requires changes in educational and outreach policy. Management only works through the cooperation of resource users. This is where the problem with sound amenities comes back in. Sound amenities for the Reef are not fully formed yet, because there are few ways for the public to access them. It is best to think of them as potential sound amenities. They are amenities that need to be cultivated. This can be done through the development of public-access hydrophone arrays or through support of sound art projects. As hydrophony in North America has shown, these types of engagement not only increase public awareness, but can even convert public listeners into environmental monitors.

Back to the Studio

This marks the conclusion to my thesis. I have made my argument about how underwater noise is constructed and how it constructs our relationships with marine non-humans. Now it is time to consider what may come of it.

There is, of course, the obvious need for more scientific research which I have called out through this work. The body of knowledge on sound reception and the impact of noise on marine species is woefully lacking. These are the problems for the marine biologists and acousticians working in the field, but they need more monetary support if they are to assess this issue.

From a social science perspective, there is so much more we still do not know. First, there has been no systematic survey to measure the public's knowledge of noise pollution nor gauge their support for noise mitigation practices. Additionally, many cases of blatant obstruction by policy makers or industry organizations were presented to me in the course of my research, but these claims have not been validated independently and the reasons for such obstruction have not been studied.

I would also like to acknowledge the lack of Indigenous representation in my fieldwork. For me to complete my research within a timely manner, I had to set boundaries. I had chosen to only focus on the practices of the people Latour (1993) has called Moderns: the Western, industrial, highly scientific people who colonized much of the world. Respectfully including Indigenous communities would have required a time and resource commitment I did not have. These communities should and must be included in future projects. Integrating Indigenous knowledge into academic and management systems has been difficult, and I am currently unconvinced that most of those efforts have been effective. Indigenous world views have been tolerated, not respected, in science-led fields. Future research on marine sound and Indigenous knowledge has a potential to develop new means of including such knowledge in Reef management.

All these research possibilities sit alongside the future needs to develop quieter technologies, new strategies for boating around reefs, and whole changes to economic patterns in order to decrease reliance on shipping. Managing noise in the Great Barrier Reef requires a multipronged approach that is often tied to other environmental stressors. There is plenty of work for all branches of scientific inquiry.

As I end my current investigation, I am left with a multitude of new questions. I wonder what new relationships will unfold as we begin to listen more intently to marine beings. I also am curious about overall efforts to better understand the sensory life worlds of non-human beings. I can only begin to comprehend these questions because I have become a skilled listener. My listening practices throughout my fieldwork have guided me in thinking about worlds beyond my own unmediated sensory abilities.

Hopefully, this is also true for you, dear reader. With that said, I would like to consider one last listening. Reflect how this track has been mediated through technologies and learned practices, and meditate on the relationships it can facilitate through echo-logical sentiments. What can we gain from learning to hear the complex relationships between human and non-human sounds, and how might that change how we interact with the more-than-human environment?

Coda (Track 13) [03:29]

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