Hand in Fin: Exploring Reciprocity Between Humans and Fishes Through Music

Sarah Kelly (She/Her)

University of British Columbia

ABSTRACT
The relationship between fish and humans in the sonic realm is one that has yet to be explored in an anthropological context. Exploring this relationship provides us with an important new understanding: there is a reciprocal sonic relationship between humans and fish which must be considered in both biological conservation efforts and when understanding the lives of fish-adjacent peoples and communities. I provide a brief overview into the complex and diverse systems that fish use to hear and how noise influences their lives, and examine findings from biological studies that describe how fish react to human-generated noise. Then, I delve into a select few cases that describe how fish and fishing appear in human music and the meanings that these songs communicate. This research reveals that just as humans have the potential to have deep, yet poorly understood, impacts on the aquatic realm of fishes through our sound and music, changes in fish and fishing appear in our sound and music.

1. Introduction

Well, I love her, but I love to fish.
-Brad Paisley's "I'm Gonna Miss Her"

Most people can conceive of a reciprocal relationship between fish and people, usually based on us eating them and trying to be considerate of their habitat to preserve our food source in the process. As we transition into an unprecedented time of threat to marine and freshwater fish, we must consider our relationship with fish beyond the physical nutrition they provide. Fish play important roles in the aquatic realm, they are key participants in underwater ecosystems and have long held important spiritual and cultural meanings for humans. Often left behind in discussions of fishes' environments is their sonic realm, yet research in this field increasingly demonstrates that fish exploit and contribute to a complex underwater acoustic environment. One must recognize the impact of anthropogenic noise and music in understanding the auditory world of fishes.

Just as humans influence fishes through noise and music, fish and fishing appear in human music across time and space; these songs reveal the interlinked relationship between humans and the marine world. Using music, one can understand that humans are inextricably linked to fish and vice versa. We sing songs about fish, and our songs and noise can profoundly impact fish: a sonic reciprocal relationship. Western conceptions of music strictly delegate singing and music-making to the human realm, but other cultures suggest that the fish may be singing back should we listen carefully enough.

2. The Fish are Listening

Auditory reception is critical in providing fishes' non-visual information, often from great distances. Sound is used for communication between fishes, detecting predators and prey, mating behavior, and migration and habitat selection (Fay 1988; Popper 2019). Fishes generally are restricted to low frequencies (800–1000 Hz) compared to marine or terrestrial mammals, although this is highly dependent on species (Sand 2008). Fishes generally have a greater ability to discriminate between sounds of different amplitude and frequency, as well as calls that differ in timing characteristics (Popper 2019) compared to other hearing animals. As sound plays a significant role in the lives of most fishes, it is crucial to understand how fish detect and process sound.

Fishes exist in an aqueous medium, which means they cannot detect sound using the vibrations of a tympanum as tetrapods do. None of the fishes, including teleost fish that have a developed bony skulls, have developed a tympanum (ear drum) on the outside of the body or in the middle ear because no net movement exists between the medium (water) and the animal's body (Fritzsch 1992). However, this certainly does not mean that fishes cannot hear. Almost all fish have some auditory reception capability, and some groups have further specialized their ability to hear using accessory structures. All bony fishes have otoliths, a calcium carbonate structure that sits in the auditory capsule, and are thus capable of some noise detection. To do so, the fish's brain analyzes the otoliths movement striking delicate cilia, small hairs attached to the auditory capsule, in the capsule relative to body movement to provide information about the auditory environment (Popper 2019). In these cases, fishes are not detecting pressure changes striking a membrane (like tetrapod auditory reception), instead they are detecting particle motion[1] (Schuijf & Hawkins 1976). This method of auditory reception is more akin to standing next to a loudspeaker and feeling the sound as it vibrates your skin rather than hearing the loudspeaker. Sensing particle motion limits the frequency of sound that can be detected and the range at which sound can be detected, but likely increases the ability to detect minute changes in directionality of sound (Nedelec 2019).

At least a third of all teleost (boney) fish have developed a far more sensitive auditory detection apparatus that functions similarly to the tympanum in tetrapods, relying on compressing air rather than compressing water, as air is more compressible than liquids. There is much diversity and variation of the type of air-filled chamber and its position in the fish. Sometimes this chamber is the swim bladder, like in cichlids or squirrelfish, or it may be another gas-filled chamber, like in labyrinth fish (Ladich & Schluz-Mirbach 2016). Regardless of position, these air-filled chambers are compressed and moved by vibrations in the water, and the movement of these walls is transmitted to the inner ear (Schuif and Hawkins 1976). Some fish have associated accessory structures that improve sound transmission, such as the Weberian apparatus; these fish are typically termed "hearing specialists". Additionally, around 800 species of fish can create sound by rubbing specialized groups of muscles called sonic muscles against the gas bladder; the muscles recruited to generate sound differ between taxa but have convergent functions (Bass et al. 2008). Just as some fish are hearing specialists, some are noise-making specialists. Similarly to the diversity in hearing structures, fish produce noise in myriad ways.

3. Do Fish Bay at the Moon?

While we typically associate nature's intricate auditory environments with choruses of birdsong in the forest or perhaps the ultrasonic screech of bats, many fishes are also just as capable of creating complex noise. Often, fishes generate noise during mating season. Those who have spent time on British Columbia's Sunshine Coast may be familiar with the low grunting, growling, and humming noises that can be heard above the water in late spring and early summer, a sound that has been likened to an “an orchestra full of mournful, rasping oboes.” (Pearlman 2014). These are the vocalizations of the planefin midshipmen (*Porichthys notatus*), and are the fish equivalent of putting a Barry Manilow record on. Midshipmen produce these noises using sonic muscles attached to their swim bladder (Forbes et al. 2016). During the breeding season, the females undergo a modification of an accessory sensory organ in the inner ear called the saccule that likely helps them hear the males' vocalizations more clearly, encouraging them to rise off the benthos and mate (Sisneros 2007). Enticing your mate with sound is particularly important to avoid predation while trying to fertilize eggs.

Cusk-eels (*Ophidiidae*), a pelagic marine fish, also produce sound by rubbing sonic muscles against their swim bladder and have specialized forked bones that

[1] For a more thorough discussion of particle motion detection in fish, see Nerelec (2019).

wrap around the swim bladder, forming a connecting bridge to the inner ear (Picciulin et al. 2019). In Cape Cod, the male cusk-eel times its song with the setting sun. Noise production begins just before sunset and peaks about an hour after sunset. The calls are the loudest when there is no moon (Roundtree 2002). This is likely because the female cusk-eels lay their eggs in open water, and the eggs float in the water column in a mucilaginous conglomeration for a week before dispersal. The eggs are at significant risk of predation during this period, so males must balance enticing females to lay eggs with the threat of alerting predators to the presence of a newly available snack (Mooney et al. 2016) By singing in the dark, the male cusk-eels can encourage egg laying without letting predators know eggs are on the menu. Here, we can see a prime example of fish exploiting the sonic realm to communicate with other members of their species to increase the chances of their young survival. Just as fish use sound to communicate within their species, fishes also likely analyze their sonic environment to understand the other species in their habitat more closely.

The impact of fish song on other animals is poorly understood, as there are many challenges to measuring environmental noise. However, one recent study suggests that fish "music" may contribute to a healthy reef environment. As the oceans face unprecedented levels of reef degradation, much effort has been put into restoring reefs by replacing the coral or spreading larval coral (de la Cruz et al. 2017). While restored reefs may have coral cover, they often are missing other invertebrates and fish that contribute to the overall health of the reef. Mooney (2016) suggests that diverse organisms do not flock to restored reefs because of the lack of sonic familiarity.

A healthy reef has a rich sonic environment, with diverse noise generated by fishes and invertebrates. Recent research has suggested that these "reef orchestras" are vital in guiding the recruitment and settling of reef organisms, particularly larval stages with limited sight (Montgomery 2006). Recall that most fish cannot sense noise from great distances as they detect particle motion rather than sound waves, so noise may be more impactful when selecting an ideal spot on a reef rather than finding the reef in the first place. For example, some damselfish (Stegastes) species live their entire lives in a single square meter of reef. Damselfish produce a distinctive "pulse" sound and a small "jump." Studies of closely related species (*Stegastes* spp.) have shown that each species produces a unique sound and can discriminate conspecifics from heterospecifics (Mann 2006). This distinctive pulse noise may encourage the pelagic larvae to settle in the area of their species rather than competing species or predators. Further research using equipment sensitive to particle motion is needed to understand the mechanism these larvae exploit to understand the directionality of sound.

By playing the songs of healthy reefs at loud volumes, humans can encourage recruitment of species to reefs that are being restored. A small project in Maui that used speakers demonstrated that the reef that plays "reef music" had greater biodiversity than the reef without music. Additionally, researchers used sonic diversity to measure biodiversity on the reef, which proved particularly useful for detecting the presence of cryptic and nocturnal organisms (Temessco 2020). Through human manipulation, we can understand that fish-generated noise impacts the health and lives of fish.

Fishes contribute to and interpret an underwater acoustic environment, but how can human noise impact fish? Because sound is so essential to fish, it is of the utmost importance that we understand the impacts of anthropogenic (human-generated) noise on fish and, thus, behaviour in health. By acknowledging the reciprocal relationship between human noise and fish livelihoods, humans can regulate and attempt to mitigate negative impacts of anthropogenic noise.

4. Sonic Stress: Impacts of Anthropogenic Noise

While there has been some recognition in the past several decades of the impact of anthropogenic noise on marine life, most research has focused on marine mammals, particularly whales (National Research Council 2006; Peng et al. 2016). Unlike whales, the impacts of anthropogenic noise on fishes are best understood on the scale of populations and local environments rather than individuals.

Existing studies suggest that noise impacts depend on the type of noise and the species of fish. The sounds added by humans into aquatic environments (both marine and freshwater), include those from shipping, dredging, sonars, seismic airguns used for oil and gas exploration, underwater explosions and construction, including pile driving, and many other activities. Some of these sounds contribute to "chronic" noise (such as the low hum of a ships engine), and some acute, such as the sharp pulse noise generated by underwater pile driving. As seen above, fishes use sound to engage in various life-sustaining activities, it follows that anything interrupting the auditory environment generated by fishes may have deleterious effects on their communication and health.

While it is generally assumed that anthropogenic noise will be more impactful on "hearing specialist" fishes, this may not always be the case. Comparisons of laboratory responses of Zebrafish (*Danio rerio*) and Lake Victoria cichlids (*Haplochromis piceatus*), the former having more sensitive hearing, demonstrated that both showed similar and immediate reductions in swim speed when exposed to a continuous loud noise (Shafiei et al., 2016). This indicates that anthropogenic noise may concern more fish species than initially thought, but also confounds our current understanding of how fish sense noise. More research is needed to explore the relationship between hearing specialists and "regular" fishes concerning anthropogenic noise and possible harms.

Many fish produce a short single pulse rather than sustained call (Wilson et al. 2004.) Of particular concern to fish health are "pulse noises", which have a high amplitude and low frequency, like those produced by oceanic pile driving. Pile driving produces many of these noises and has been shown to have acute near-field effects on hearing specialist and non-specialist species. Fishes generally avoid areas with active pile driving and will rapidly leave once the "noisy" portion begins (Bruintjes 2014).

Additionally, some fishes subjected to close-range noises similar to pile driving in laboratory settings showed short-term damage to the cilia in the inner ear that affected hearing ability for several days following noise exposure (Enger 1963). Taken together, this likely means pile driving noises can sonically injure fish at very close ranges and mask fish communication at longer ranges. Deckling (2016) points out that while we can make assumptions about anthropogenic noise in the range that fishes can hear and possible adverse health impact, there are large gaps in our knowledge of auditory reception via particle motion and underwater anthropogenic noise that make it challenging to understand the impacts of human noise on fishes fully.

5. Do Fishes Enjoy a Human Tune?

Very few studies have been conducted on how human music affects fish (as opposed to non-musical noise), but those that have concluded that music can either calm or harm fishes, depending on the volume, type of music, and the species of fish examined. A study examined the impact of the Ultra Music Festival® in Miami, FL, USA on Gulf toadfish (*Opsanus beta*) cortisol levels. The Gulf toadfish is in the same family as the plainfin midshipman, and is another "hearing specialist". The researchers demonstrated that in both laboratory and natural settings toadfish experienced an increase in noise levels between 7-9 decibels under water and a significant increase in the stress hormone cortisol during the festival (Cartolono et al. 2020). The relative elevation in cortisol (a 4-5-fold increase) that fish experienced during the Ultra Music Festival was comparable to what toadfish experience in response to another acoustic stressor, the playback of dolphin foraging vocalizations (Remage-Healey et al. 2006). While the effects of fish stress hormones are poorly understood across different species, repeated elevation of cortisol has been shown to negatively affect mitochondrial activity and the gut microbiomes in salmonid species and likely has similar effects in other species (Uren Webster et al. 2020). More research needs to be conducted to understand the effects of human music, particularly music festivals, on fish health. This type of research is essential in understanding sonic impacts on fish health in the Pacific Northwest, as many music festivals occur near freshwater fish habitats and spawning grounds.

Just as our music can harm fishes, there is some indication that some human music may reduce stress in aquarium fish species. Many recordings of music purport to calm one's aquarium fishes—and they may actually work. Auditory enrichment is regularly provided to captive mammals to limit stress, but this care has yet to be extended to fish. A study demonstrated that when laboratory zebrafish were exposed to 2 h of Vivaldi's music (65–75 dB) twice daily, for 15 days they showed a significant decrease in inflammatory markers and displayed less anxiety behavior in both light and dark tanks (Barcellos et al. 2018). This reduction in stress by merely introducing music is particularly valuable because zebra fish are often used for neurological research, and keeping them calm with low-cost methods is important to ensure that the zebrafish behave "as normal" during experimentation.

The idea that human music may be calming to certain fish species, particularly species performing well in aquarium settings, opens up exciting avenues in understanding how fishes perceive human music. Just as our music may impact fishes, fishes appear in human music across different cultures and for myriad reasons. Our reciprocal relationship with fishes is best exemplified in the music of cultures and individuals who interact with fishes near-daily.

6. Fish Impacts on Human Music

Fish (and fishing) represent important concepts in human music. Those who interact with and rely on the ocean for sustenance or a livelihood are deeply aware of changes to their environment, this reliance on fish is often exemplified in music. Fishes are physical beings, but they also exist beyond the physical form in important symbological and cultural meanings. Additionally, the act of fishing carries differing meanings across cultures. When fishing, the "catch" is not the only focus, one enters into a series of relationships with the fish, the environment, and other people to try and get a fish. Every angler is familiar with the exclamations uttered, the bonds strengthened, and the excitement about nature that is conferred in the act of fishing. These relationships between humans, fish, and the environment can be understood through song. By deeply examining how humans interact with fish and fishing, we are able to reveal truths about human/non-human interactions in the aquatic realm. Further, by examining the influence of fishes in music, we can understand the sociological impacts of fishes on humans.

7. Exploring Changing Fisheries Economies Through Music

David Taylor (1990) uses fishing songs from 19th century Maine to examine how the industrialization of the fishing industry affected fishermen, fishing culture, and the environment. At the time, a small Swedish community migrated from coastal Sweden to coastal Maine (Kanes 2008). Songs such as “Ny Fiskar Vals” (New Fisherman's Waltz) and “Lutefisk” (dried cod) served to connect recent Swedish immigrants to their old country through songs about fish and fishing. Here, we see the motif of fish as a means to remind people of a former home, evidence that fish play no small part in conceptions of nationality and identity.

Beyond expressing one's culture, fishing songs also reveal the struggles of dealing with a changing and collapsing marine life, although who is to blame depends on the song. "Penobscot Bay Fisherman" by R. Venes cautions fellow fishermen against overfishing, with the lyrics "Once there was a dollar in the lobster game[2], you'll find along the coast it's not quite the same; there's ten traps to every lobster- they're going fast from our shore; if fisherman don't mend their ways, they'll be gone forever more." (Taylor 1990). Meanwhile, "Columbia River Blues" by J.J. Jones blames politicians and infrastructure: "The statesmen count their dams and all their new creations and wonder why the valiant salmon die" (Taylor 1990). A key message that goes unspoken in these songs is that the fishermen—those who have regular contact with the marine environment and thus have a large stake in its conservation—are deeply sensitive to marine ecosystems and their changes.

Songs in the 20th century from the same region in Maine do not discuss fishing to the same degree as they did in the previous decade (Taylor 1990). This is a subtle expression of the beyond-physical nature of fishes in American culture. The fishes in songs in the 19th century represented not only a changing marine ecosystem, but also a changing economic system for those who rely on fishes.

8. Fish and politics: a brief foray into 1980s Indonesian pop

Fishing music can be used to understand how groups and individuals felt about large-scale socioeconomic transformations, and it can also be used to examine acute political issues. During the 1980s in Indonesia, maritime events were at the forefront of political discourse (Sammy 2020). Presidential Decree number 39 of 1980 banned “tiger trawling”, a fishing practice that uses very long, wide nets with weights on the bottom (Namin 1980). This method efficiently captures fishes but results in minor habitat destruction in addition to catching and killing small and inedible fishes, leading to large-scale ecological collapse (Baum, 1978). As a result of the ban on trawling, fishermen switched to the far more destructive method of bomb fishing (Namin 1980), which caused extensive damage to reefs and biodiversity in the Indonesian archipelago. Concurrently, the explosion of the Indonesian naval ship Tampomas II in 1982 resulted in the loss of 146 lives and extensive pollution to surrounding Naya (an Indigenous group) fishing grounds (Sammy 2020). Among these events, critical voices arose in the musical scene to decry the lack of government intervention in preventing environmental destruction.

In the 1980s, there were 11 number one singles that featured songs that explicitly discussed fish or fishing. Of those, six reference the ancestral connection that Indonesian people share with fishes, their environment, and fishing (Sammy 2020). Again, we see that fish and fishing are used as symbols to explore changing marine environments and humans' negative impacts on the marine world. Just as we impact fishes, fishes are hugely impactful on human lives. It is often the anthropogenic impacts on fishes that are explored in music. By using music to understand human-fish relations, we broaden our conception of what and who produces valuable knowledge regarding marine conservation. By seeing fish not just as the subject of knowledge but knowledge producers themselves, we can center our research, work, and conservation efforts from the perspective of the fish.

9. Fish Music Beyond the Western Conception

While in many cultures, fishes exist as a motif in music, a symbolic representation of identity or ideals, fishes also exist more explicitly as spirit singers and deliver information in some Indigenous Brazilian cultures. While it may be easy for even the uninitiated to understand that the song of a bird or a frog may literally “tell” the listener something about the location or number of animals in an environment, many (including anthropologists) have neglected to understand the Indigenous

[2] I know lobsters are not fish, but it is very difficult to find fishing songs from Maine that do not mention lobsters in some capacity.

sonic relationship with creatures customarily perceived as "silent"— like fishes

Just as in Indonesia and Maine, those who spend time with the water and fishes are most sensitive to fish/human relations. The Kamayurá (Aùap) live on the Xingu River, a region extraordinarily rich in fish near the base of the Amazon. Bastos (2013) recounts an experience with Ewaka (a Kamayurá fisherman) where Ewaka stopped and put his ear to the water when paddling in a canoe. Calling for Bastos to do the same, Bastos was confused as he heard nothing. Ewaka said, "Can't you hear them? Can't you hear the fish singing?" While Bastos could not hear the fish, he argues that this exchange exemplifies how the Kamayurá understand themselves in relation to fish and nature at a larger scale. He argues that the Kamayurá do not envision the world as one divided between human and non-human, that music creation is not a strictly human activity. (Bastos 2019). Kamayurá healers learn these songs from animals to guide wayward spirits (human and animal alike) back to where they belong to maintain balance in the natural world (Tânia Stolze 1996. Here, we see a different way that fishes and humans have a reciprocal sonic relationship; the fishes quite literally sing songs, and humans listen to learn truths about our world. This diverges from commonly held Western cultural beliefs, but broadening our understanding of how fishes communicate with each other and humans lets us imagine futures where humans understand the auditory environment of fishes and are more aware of our sonic impact on the marine world.

10. In Cod-clusion

The underwater acoustic environment has been woefully understudied, as have fish-human relations beyond conservation concerns. There is too little funding and too few studies on fish audio reception and the positive or negative impacts of anthropogenic noise on fishes and marine conservation. This perhaps means there is some systemic misunderstanding in ichthyology and marine conservation that the impacts of noise on fish are not meaningful because they hear differently then we do. This conception that human ways of being are the most important ways of being is rooted in a Western scientific understanding that there is a division between human and environment. Paradoxically, the studies that do exist highlight that there is growing concern about the possible impacts of noise on fish. There must be a renewed focus on understanding how and what fishes hear.

Fishes are deeply important to human civilization, this is reflected in our music, culture, and spiritual. Humans have the power to impact fish with our noise and music; recognizing this reciprocal relationship is integral for preserving the health of our waters. As fishes continue to face challenges in changing oceans, we must create legislation that respects and understands the ancestral, reciprocal relationship that many peoples around the globe continue to have with fishes.

References

Barcellos, Heloísa H. A., Gessi Koakoski, Fabiele Chaulet, Karina S. Kirsten, Luiz C. Kreutz, Allan V. Kalueff, and Leonardo J. G. Barcellos. 2018. "The Effects of Auditory Enrichment on Zebrafish Behavior and Physiology." *PeerJ* 6 (July): e5162. https://doi.org/10.7717/peerj.5162.

Cartolano, Maria C., Igal Berenshtein, Rachael M. Heuer, Christina Pasparakis, Mitchell Rider, Neil Hammerschlag, Claire B. Paris, Martin Grosell, and M. Danielle McDonald. 2020. "Impacts of a Local Music Festival on Fish Stress Hormone Levels and the Adjacent Underwater Soundscape." *Environmental Pollution* 265 (October): 114925. https://doi.org/10.1016/j.envpol.2020.114925.

Dijkgraaf, S., Arie Schuijf, and A. D. Hawkins, eds. 1976. *Sound Reception in Fish: Proceedings of a Symposium Held in Honour of Professor Dr. Sven Dijkgraaf, Utrecht, the Netherlands, April 16-18, 1975.* Developments in Aquaculture and

Fisheries Science, v. 5. Amsterdam ; New York : New York: Elsevier Scientific Pub. Co. ; distributors for the United States and Canada, Elsevier/North-Holland.

Enger, P. S. 1963. *Single Unit Activity in the Peripheral Auditory System of Teleost Fish*. https://books.google.ca/books?id=dVTVzwEACAAJ.

Forbes, Jeffrey G., H. Douglas Morris, and Kuan Wang. 2006. "Multimodal Imaging of the Sonic Organ of Porichthys Notatus, the Singing Midshipman Fish." *Magnetic Resonance Imaging* 24 (3): 321–31. https://doi.org/10.1016/j.mri.2005.10.036.

Fritzsch, Bernd. 1992. "The Water-to-Land Transition: Evolution of the Tetrapod Basilar Papilla, Middle Ear, and Auditory Nuclei." In *The Evolutionary Biology of Hearing*, edited by Douglas B. Webster, Arthur N. Popper, and Richard R. Fay, 351–75. New York, NY: Springer New York. https://doi.org/10.1007/978-1-4612-2784-7_22.

Lima, Tânia Stolze. 1996. "O Dois e Seu Múltiplo: Reflexões Sobre o Perspectivismo Em Uma Cosmologia Tupi." *Mana* 2 (2): 21–47. https://doi.org/10.1590/S0104-93131996000200002.

Mann, D.A. 2006. "Fish Communication." In *Encyclopedia of Language & Linguistics*, 489–93. Elsevier. https://doi.org/10.1016/B0-08-044854-2/00832-4.

Maruf, and Warwick Gullett. 2022. "Tackling Anthropogenic Underwater Noise through the Convention on Biological Diversity: Progress and Future Development." *Marine Policy* 146 (December): 105293. https://doi.org/10.1016/j.marpol.2022.105293.

Montgomery, John C., Andrew Jeffs, Stephen D. Simpson, Mark Meekan, and Chris Tindle. 2006. "Sound as an Orientation Cue for the Pelagic Larvae of Reef Fishes and Decapod Crustaceans." In *Advances in Marine Biology*, 51:143–96. Elsevier. https://doi.org/10.1016/S0065-2881(06)51003-X.

Nedelec, Sophie L., James Campbell, Andrew N. Radford, Stephen D. Simpson, and Nathan D. Merchant. 2016. "Particle Motion: The Missing Link in Underwater Acoustic Ecology." Edited by Diana Fisher. *Methods in Ecology and Evolution* 7 (7): 836–42. https://doi.org/10.1111/2041-210X.12544.

Peng, Chao, Xinguo Zhao, and Guangxu Liu. 2015. "Noise in the Sea and Its Impacts on Marine Organisms." *International Journal of Environmental Research and Public Health* 12 (10): 12304–23. https://doi.org/10.3390/ijerph121012304.

Plack, Christopher J., Andrew J. Oxenham, and Richard R. Fay, eds. 2005. *Pitch: Neural Coding and Perception*. Springer Handbook of Auditory Research, v. 24. New York: Springer.

Popper, Arthur N., and Anthony D. Hawkins. 2019. "An Overview of Fish Bioacoustics and the Impacts of Anthropogenic Sounds on Fishes." *Journal of Fish Biology* 94 (5): 692–713. https://doi.org/10.1111/jfb.13948.

Remage-Healey, Luke, Douglas P. Nowacek, and Andrew H. Bass. 2006. "Dolphin Foraging Sounds Suppress Calling and Elevate Stress Hormone Levels in a Prey Species, the Gulf Toadfish." *Journal of Experimental Biology* 209 (22): 4444–51. https://doi.org/10.1242/jeb.02525.

Rountree, Rodney A., and Jeanette Bowers-Altman. 2002. "SONIFEROUS BEHAVIOUR OF THE STRIPED CUSK-EEL *OPHIDION MARGINATUM*." *Bioacoustics* 12 (2–3): 240–42. https://doi.org/10.1080/09524622.2002.9753709.

Sammy, Abdullah. 2020. "Song From the Sea: Maritime Influence on Indonesian Popular Songs in the 1980s." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3671299.

Shafiei Sabet, Saeed, Kees Wesdorp, James Campbell, Peter Snelderwaard, and Hans Slabbekoorn. 2016. "Behavioural Responses to Sound Exposure in Captivity by Two Fish Species with Different Hearing Ability." *Animal Behaviour* 116 (June): 1–11. https://doi.org/10.1016/j.anbehav.2016.03.027.

Sisneros, Joseph A. 2007. "Saccular Potentials of the Vocal Plainfin Midshipman Fish, Porichthys Notatus." *Journal of Comparative Physiology A* 193 (4): 413–24. https://doi.org/10.1007/s00359-006-0195-5.

Todd, Zoe. 2015. "Fish Pluralities: Human-Animal Relations and Sites of Engagement in Paulatuuq, Arctic Canada." *Études/Inuit/Studies* 38 (1–2): 217–38. https://doi.org/10.7202/1028861ar.

Uren Webster, Tamsyn M., Deiene Rodriguez-Barreto, Sofia Consuegra, and Carlos Garcia De Leaniz. 2020. "Cortisol-Related Signatures of Stress in the Fish Microbiome." *Frontiers in Microbiology* 11 (July): 1621. https://doi.org/10.3389/fmicb.2020.01621.

Wilson, Ben, Robert S. Batty, and Lawrence M. Dill. 2004. "Pacific and Atlantic Herring Produce Burst Pulse Sounds." *Proceedings of the Royal Society of London*.