Acoustic Assault: How Anthropogenic Noise Pollution Affects Marine Ecosystems

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Abstract: *Marine environments are essentially underwater cities; not only are they bursting with shrieks and shrills from animals, but humans have injected their own noises into the environment such as naval sonar, shipping traffic/boat noise, and blasts from oil exploration. Unlike humans, aquatic life relies on their auditory systems to navigate, communicate, forage, and reproduce. Due to the overlap of cetaceans' hearing capacity and the operating frequencies of the aforementioned sources of anthropogenic noise, marine life is subjected to a multitude of life-altering effects, ranging from hearing loss and changes in behavior to internal bleeding of organs and mass strandings. Cetaceans are biological indicators of the oceans' health and their longevity allows society to monitor the effects of other human activites and the changing conditions of the sea; without them, the balance within the ecosystem would cease to exist. An increase in awareness, education, and political involvement regarding marine disturbances could persuade legislators to hold these companies accountable and spark a movement towards quieter ocean-going technology, allowing oceans and the life within them to recover.*

In 2002 in the Bahamas, Kenneth Balcomb, senior scientist at the Center for Whale Research and former oceanographic specialist for the U.S. Navy, came across a beaked whale stuck in shallow waters. Rescuers took three attempts to push the whale back out into deeper waters because it kept coming back in, as if it wanted to sacrifice its life intentionally (*Sonic Sea*). Within twenty-four hours, sixteen whales and one dolphin had stranded themselves. After dissecting the heads of two whales and observing severe hemorrhaging in and around the ears, the Navy finally confessed to conducting warship exercises in the area at that time (Claridge). Three years later, the Navy employed sonar in an area in Washington known for porpoise and minke whale feeding grounds. The sonar signals were so "unbearably" powerful that Balcomb could hear them at his home, from his back porch. The next day, eleven porpoises washed up dead. According to Balcomb, the only comment collected from the Navy was “we can’t worry about the fish” (qtd. in *Sonic Sea*).

In 2014 in Rizal Beach, Philippines, sonar pings were so intense, divers had to abandon their dive, only to find that they could still clearly hear the screeching tones from their boat (Kuam News). In British Columbia, Canada, after only ten minutes of listening to noise generated from freighters that engulfed the killer whales’ domain, Molly Patterson, a research assistant at Orcalab, took off her headphones because of a severe headache. We, humans, can escape the ear-splitting clamor that exists underwater; we can choose to walk away from it. Marine life however, “can’t turn the volume down;” they have nowhere else to go (qtd. in Sonic Sea).

Since the 1970s, noise in the oceans has doubled every decade, whether it be pings of naval sonar, blasts from oil air-guns, or bursting of air bubbles from ship propellers. Sylvia Earle, former chief scientist at National Oceanic and Atmospheric Administration (NOAA), emphasizes, “each sound by itself is probably not a matter for much concern, but taken all together, it's creating a totally different environment than existed even fifty years ago. The high level of noise is bound to have a hard, sweeping impact on life in the sea” (qtd. in Holing). Underwater noise pollution is an environmental issue that largely goes unnoticed in society. The behavioral and physiological effects on marine life aren’t as visible to the naked eye and “many strandings will go undocumented, as will the associated noise events” (Weilgart, “The Impacts of Anthropogenic” 1096). The health of the oceans is contingent on the well-being of every marine specimen, namely cetaceans. Our actions as a society continue to push these species out of the natural balance their ecosystem relies on to thrive. As stated by Christopher Clark, senior scientist for the Bioacoustics Research Program at Cornell, “we are injecting so much noise that we are effectively acoustically bleaching the world’s oceans” and rendering them an abysmal habitat for marine life (Clark). Without proper consideration, effort, and involvement from society as a whole, the ocean will no longer be a suitable resource for us, nor home to some of the most intelligent and awe-inspiring creatures.

In an effort to understand the relationship between animals and noise, George Prochnik, explains that "our system stress in response to noise comes from this environmental animal necessity of avoiding a threat. [Hearing] sirens on the street [leads] to some elevation in heart rate, some vascular constriction, and release of stress hormones" even if one doesn't realize it (qtd. in). Marine organisms' nervous systems react in the same way ours do. The combination of multiple sources of anthropogenic noise and the highly variable exposure time of each can have life-threatening repercussions on the animals that maintain the health and balance of our intertwined ecosystem. The need for a balance between national security, economic endeavors, and marine animal protection is vital to the health of both the oceans and the human population. This trifecta can be achieved by increased societal awareness and involvement, through the lobbying of state and national governments. An increase in interest and effort from the public to raise awareness about the implications of anthropogenic noise in the oceans on marine life could help to further educate the general public on this issue. Moreover, a more educated society could generate a movement towards quieter technological solutions, such as improved ship hull and propeller design, a new approach to sonar technology, and advanced oil exploration methods. Additionally, if society takes on a more active role in the politics that surround this issue, governmental agencies might be persuaded into intensifying legislative oversight, regarding global companies' abuse of power concerning cetaceans' well-being. New technology and a more directed focus on the issue will minimize the reverberation of man-made noise through essential marine animal habitats, preserving their population statuses and preventing further decline, while also maintaining our ability to gauge the health of the oceans.

Background

The ocean is not silent. It is a biological orchestra of high winds, precipitation, grunting fish, and bellowing whales. Sound intensity or the amplitude of a sound wave is measured in decibels, whereas the frequency of a sound wave in a period of time is measured in Hertz (Nieukirk). Noise propagates differently through water than through air because of the difference between the densities of the media. Because water molecules are more tightly packed together than molecules of air, sound travels about four times faster in water (National Ocean Service). Sound also travels thousands of meters farther through water than through air. Temperature decreases and pressure increases with depth, causing the speed of sound to slow and the sound waves to refract downwards. Below a certain depth, called the thermocline, "temperature remains constant, but pressure continues to increase, [causing the speed of sound to quicken] and the sound waves to refract upwards" (National Ocean Service). This bending of sound waves through the sound channel allows the waves to retain energy for longer distances. These properties of water allow marine animals to survive in an environment that would be void of communication otherwise. Not only do these properties facilitate communication, but they amplify underwater sources of anthropogenic noises, such as naval sonar operations, shipping traffic, and seismic surveys, when compared to the same sounds resonating through air.

Because cetaceans are vocal animals, they are the focus of most of the research that has been conducted on underwater noise pollution. Toothed whales (Odontocetes) and dolphins rely on echolocation to find food, contact family, and navigate the ocean basins. When cetaceans transitioned from land mammals to marine mammals, their nostrils evolved into what are called phonic lips, which lie right beneath the blowhole. By sending air over these phonic lips at a high pressure, vibrations are made that travel to the forehead of the mammal called the melon. The melon is comprised of acoustic fats that emit the vibrations outward into the surrounding environment. Once the sound waves hit an object or an organism, echoes bounce off and return to the marine mammal. The vibrations are transmitted through the lower jaw, comprised of the same acoustic fat found in the melon, and into the middle ear where the mammal can then form a detailed image of the object that the sound waves encountered (Hoelzel 152).

Mysticetes, commonly referred to as baleen whales, communicate through series of clicks that form "songs" up to 190 decibels in intensity and 2000 Hertz in frequency. Odontocetes, known as toothed whales, produce high-pitched sounds that don't travel as far through the water as their lower-frequency counterparts (Weilgart, "The Impacts of Anthropogenic" 1094). Human-generated noises such as naval sonar operations, shipping traffic, and seismic surveys, range between 190 and 255 decibels. For comparison, human hearing damage can ensue after hours of exposure to noises at an intensity of 85 decibels, while our pain threshold rests at 130 decibels (Pike and Sherman).

When anthropogenic noise is involved in the "interference of natural sounds", these highly complex abilities to communicate become limited (Weilgart, "The Impacts of Anthropogenic" 1092). Human-generated noise essentially tears apart the social framework that most marine life relies on to survive. In addition, the potential of "increased stress levels, permanent hearing loss, abandonment of important habitats," cerebral hemorrhages, and mass strandings scattered across coastlines all over the world are dangerously high (Weilgart, "The Impacts of Anthropogenic" 1092).

A common misunderstanding amongst the general public is that because cetaceans are able to withstand natural sounds exceeding the human pain threshold, a few anthropogenic noises wouldn't make a drastic difference in the survival and well-being of marine life; cetaceans would simply adjust. However, human-derived sources of noise invading the oceans is a relatively recent phenomenon. Aquatic mammals are "highly unlikely to be able to genetically adapt at a pace similar to that of habitat change" and to develop coping mechanisms for anthropogenic sources (Weilgart, "The Impacts of Anthropogenic" 1095). Even if they did adapt, there are "biological constraints" limiting the extent of adaptation to noise, due to the laws of physics concerning the relationship between pressure, depth, and the propagation of sound waves (Weilgart, "The Impacts of Anthropogenic" 1095).

Beginning in the 1960s, or the post-World War II era, mass strandings of species of beaked whales began to occur. Naval maneuvers in the area triggered the strandings, as this time period marked the transition between passive and active sonar (Weilgart, "The Impacts of Anthropogenic" 1092). Passive sonar consists of simply listening for unnatural noises in the underwater soundscape. However, active sonar emits a signal of 230 decibels, twice as loud as a jet engine, at a frequency range of 75-1,000 Hertz to create echoes off of submarines (Preston). Although anthropogenic noise started wreaking havoc in the environment, it did not receive attention from the public until 30 years later when a controversy broke through the surface. In 1994, Scripps Institute of Oceanography launched a project called "Acoustic Thermometry of Ocean Climate" (ATOC). This project required transmitters off of Big Sur, California and Kauai, Hawaii that operated for twenty minutes, every four hours, for over ten years, at 195 decibels through the deep sound channel (Holing). The scientists at Scripps placed hydrophones in the Pacific Rim and the Aleutian Islands to determine the travel time and intensity level of the signals. Because sound travels farther through warmer water, predictions could be made regarding the changing ocean temperatures associated with global warming. Two scientists living in Hawaii complained of the malignant effects the 1991 pilot test had on sperm whale and blue whale vocalizations. Dr. Linda Weilgart and Hal Whitehead both complained of alterations in communication and diving patterns of these species (Holing). Their complaints sparked the beginning of the debate over how much is too much noise in the ocean.

Sources of Anthropogenic Noise

For over twenty years, there has been an ongoing battle between preserving our national security and protecting the safety of the gentle giants of the oceans. In the 1990s, a lawsuit was filed against the Navy, pertaining to its negligence to report details regarding their warfare training and its effects on marine mammals (NRDC, "Protect Marine"). In 2003, the National Marine Fisheries Service (NMFS) granted the Navy a permit to exercise a new, low-frequency sonar system called SURTASS LFA, or "Surveillance Towed Array Sensor System Low Frequency Active Sonar," projected to emit tones of 230 decibels or greater, affecting upwards of 75% of the world's oceans (*NRDC v. Donald Evans*). In the words of Jean-Michel Cousteau, son of pioneering oceanographer, Jacque Cousteau, "the LFA permit is nothing less than a license to kill" (NRDC, "Federal Court"). Despite efforts to prevent the activation of this new sonar system, it was eventually implemented. In 2005, a lawsuit was filed against the Navy for their refusal to implement mitigation measures, "obtain take permits for the animals its activities will necessarily harass, harm or kill", and the violation of the Marine Mammal Protection Act, the National Environmental Policy Act, and the Endangered Species Act (NRDC, "Navy Sued"). In 2014, "the federal government granted the U.S. Navy permission to [harass] marine mammals nearly ten million times in Southern California and Hawaii" over the 2013-2018 period, an increase of approximately 1,100% from the previous five-year period (NRDC, "Groups Sue"). In the words of Joel Reynolds, senior attorney at the National Resource Defense Council (NRDC), when active sonar was put into use, the Navy had "no permits, no environmental reviews, and no safeguards built [into the] program to protect the environment;" they acted without ethics for years (qtd. in *Sonic Sea*). William Parker, retired naval captain, argued that "if you know there's a whale in the area, unless you're at war, you're trying to avoid using those sonars" (qtd. in Sonic Sea). However, the history of court cases involving the Navy's lack of proactivity towards this issue proves otherwise.

In addition to sonar, "60,000 ships traverse the oceans at any given point", the majority of them shipping products overseas for human consumption or for commercial fishing purposes (*Sonic Sea*). These ships consist of supertankers that produce noise in the range of 187-232 decibels, freighters that operate from 185-200 decibels, and smaller vessels that generate 150-160 decibels of noise (Holing). For comparison, a rocket launch produces noise at an intensity of 180 decibels (Fox). 60,000 ships in motion all day, every day that produce sound equivalent to a rocket launch, add up to an environment with an unchecked growth of noise. To make matters worse, ships are now being built at a length equivalent to the height of the Empire State Building (*Sonic Sea*). Because the propeller is mechanically linked to a metal frame, the rotation of the propeller blades reverberates through this metal. A larger ship design could possibly generate an even greater amount of noise through the water column (*Sonic Sea*).

The third major source of anthropogenic noise comes from the utilization of oil-air guns. Oil-air guns are used in seismic surveys and the exploration of oil reserves. Air guns are a "modern form of dynamite;" once activated, the array that is positioned perpendicular to the ocean bottom, explodes all at once at high intensities, averaging about 175 decibels (*Sonic Sea*). A barrage of noise emitted from an air gun off Northern Brazil can be heard off the coast of Virginia, approximately 3600 miles away (Clark). During one of these surveys, the technology is fired every twelve seconds to create a geological map of the ocean floor with great detail (NRDC, "Protect Marine"). About thirty to forty of these surveys are set to erupt simultaneously and can last for weeks to months at a time. They are known to alter the migration speed and routes of humpback whales (Dunlop). The combination of these three sources of human-generated noise alone is filling up the oceans and drowning out essential biological processes vital to the survival of marine life.

Behavioral Effects on Marine Life

Anthropogenic noise is growing increasingly pervasive in the ocean ecosystem, such that physical behaviors of cetaceans like communication, diving and surfacing patterns, migration routes, and foraging habits are altered. Because man-made noise overlaps with the same frequency and intensity level as some species of whales and dolphins, they attempt to cope with this growing presence of noise in their environment. Cetaceans will sometimes increase their communication frequencies to a higher tone; this way, the low-frequency noises such as sonar and shipping traffic do not interfere with these vital communication pathways. However, higher frequency sound does not travel as far through the water, causing communication to be limited by the distance it can be carried (Tyack). Dr. Susan Parks, a biology professor at Syracuse University, highlights the difference in North Atlantic right whale vocalization between 1956 and the early 2000s (Vox). In the 1950s, they communicated at as low of a frequency as 70 Hertz, while in the early 2000s, that measurement jumped to as high as 195 Hertz, as illustrated in Figure 1.

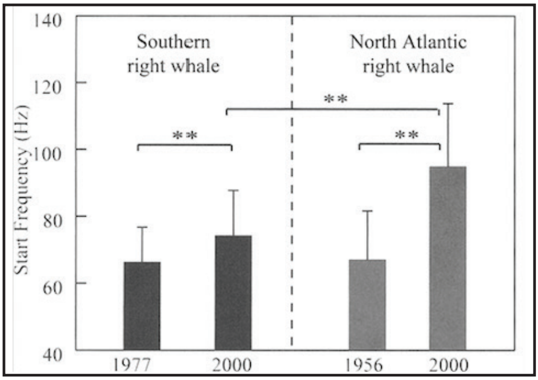

Figure 1: Difference in Vocalization of Right Whales Between 1956 and 2000 (Modified from P.L. Tyack 2008, *Journal of Mammalogy* 89: 549-558)

Alternatively, some marine mammals fall silent until the disturbance has passed. Natacha Soto, a researcher at the University of St. Andrews, calculated that "the maximum communication range at frequencies used by Cuvier's beaked whales would be reduced by 82%...when exposed to a fifteen decibel increase in ambient noise" and was projected to reach 97% by 2050 (qtd. in Wright 280). Communication is a driving force in mating rituals; with a limited ability to contact other individuals, the window for breeding may be restricted. In cases where unnatural and natural noises do not interfere, the former source can mimic a predator signal, in turn triggering a dolphin or whale to strand itself. This anti-predatory behavior is commonly seen in Cuvier's beaked whales (Tyack).

Whether frequencies are changed or not employed at all, the effects range beyond just the inability to send signals out. In a highly active environment, rampant with persistent noise, hearing one's surroundings, including oncoming ships, can be a challenge. Many times, marine mammals get so disorientated due to the overlapping frequencies of their own calls with man-made noise that they can't accurately measure the distance separating them from an approaching ship, often leading to a collision. Point Blue Conservation Science estimates that approximately 80 whales are struck and killed by ships every year on the west coast of the United States. Cotton Rockwood, senior scientist for the organization, even admits that their estimates were "conservative" because once whales are fatally hit, most sink and never wash ashore. Therefore, the actual death toll is most likely higher than this statistic (Rockwood).

In addition to not being able to assess their surroundings, marine mammals are also subjected to involuntary changes in behavior. The activation of a fire alarm is sure to frighten a human and trigger the release of adrenaline. Similarly, loud and abrasive noises send marine mammals into a panic. These animals exhibit typical avoidance behavior, characteristic of a rapid ascent to the surface or a quickened pace away from the source of noise. For example, when sea lion pups are born, they communicate with their mothers for about 15 minutes in order "to establish a sound imprint if they ever become separated" (Holing). Ranging in weight from 220 pounds (females) to 770 pounds (males), these adult sea lions become startled as aircraft fly over pupping beaches. These heavy mammals are known to rush back into the water during this time period, trampling their babies in the process and leaving them vulnerable on the beach.

An incident in 2008 in Madagascar illustrates just how detrimental this avoidance behavior can be for the well-being of cetaceans. 100-200 melon-headed whales were trapped in an estuary, 65 kilometers away from the open ocean in Madagascar. They had sunburns, bruises and cuts from the mangroves, and blood pouring out of their mouths. Katie Moore, director of International Fund for Animal Welfare's (IFAW) Rescue Program, and her team spent hours trying to guide these whales back out into the ocean, only managing to save a few. IFAW confronted Exxon Mobil, a well-known oil and gas company, because the documented use of a multi-beam echo-sounder system used to map the ocean floor for oil, coincided with the stranding event. The company claimed the whales were stranding themselves long before they had started exploring for oil. Exxon Mobil sent photos to validate their alibi. However, the figures in the photos were not stranded whales, but fishing canoes that had been pulled ashore (*Sonic Sea*). Unfortunately, the company denied having any part in killing these whales. Again, this testimony demonstrates that powerful companies' misuse of power can lead to devastating consequences for life in the ocean.

Abandonment of an essential habitat can also affect population health and size. The need to escape a threatening sound outweighs the need for other important activities such as foraging for prey. A reduction in food intake can in turn result in a loss of energy. In order to maintain homeostasis, this decrease in energy level has to be accounted for in other areas of survival, like reproductive success. In Doubtful Sound, New Zealand, where the presence of dolphin-watching boats is rapidly increasing, the population of dolphins is in decline and the number of "perinatal deaths" is increasing. In order for the female dolphins to offset the losses in energy from the disturbing nature of the boats, very little energy is put into the reproduction process (Wright).

Aside from habitat displacement, an alteration in diving patterns can also be damaging to the anatomy of deep-diving whales. Just as humans can get "the bends", marine life can experience decompression sickness as well in certain circumstances. Marine mammals' respiratory system works differently from humans'; when diving to deep depths, a marine mammals' heart rate slows, one lung collapses, and blood flow is directed to essential organs. Dr. Párraga and the scientists at Woods Hole Oceanographic Institution believe that blood flows through the one collapsed lung, minimizing the amount of nitrogen exchange into the bloodstream, thereby potentially avoiding decompression sickness (Párraga). However, an anthropogenic trigger, such as naval sonar signals, can induce stress in these mammals, leading to the failure of these adaptive mechanisms and the saturation of tissues with nitrogen. If these mammals rise to the surface at accelerated speeds in response to the trigger, nitrogen bubbles form in internal organs and the brain (Weilgart, "The Impacts of Anthropogenic" 1098).

Cetaceans are sometimes unaffected by these gas bubbles because the mammals take the necessary decompression dives to allow the nitrogen to be diffused back into the lungs and exhaled. However, if decompression dives are not taken due to the dire need to escape the threat, these bubbles can become very serious. In shallower water, the bubbles expand and can result in lesions and severe hemorrhaging that can block blood vessels (Weilgart, “The Impacts of Anthropogenic” 1098). This fatal effect precipitated the 2002 mass stranding event in the Canary Islands. After naval sonar exercises, fourteen beached whales were necropsied and gas bubbles were found in their body tissues, indicating signs of decompression sickness (Woods Hole).

Physiological Effects on Marine Life

Not only are interactions within and between species significantly impacted, but the physical anatomy and biological systems can be altered as well. Depending on the frequency, duration, and directionality of the noise, the structure of the inner ear can be damaged, leading to chronic hearing loss. There are two categories of hearing loss: temporary threshold shift (TTS) or permanent threshold shift (PTS). TTS typically occurs if the source of noise has a short duration. However, TTS can last from only seconds to days at a time. The longer the hearing loss persists, the greater the chances are for missing a critical sign of an approaching hazardous situation such as predators or boats. Killer whales experience temporary threshold shift after less than an hour of cavitation noise generated from the formation and collapse of air bubbles on propeller blades from whale watching boats that are 450 kilometers away. After only twenty minutes of noise generated from an ice breaker ship, belugas experience TTS (Weilgart, “The Impacts of Anthropogenic” 1099). Repeated cases of TTS can also lead to permanent threshold shift, characterized by the loss of sensory hairs in the inner ear.

Just as excessive, loud noises can cause stress and atrocious headaches in humans, the continuous chaotic buzzing present in the underwater environment results in elevated stress levels in cetaceans. The level of glucocorticoids, a steroid hormone found in whales around 9/11 is a testament to how strong of a correlation exists between noise and stress in the ocean. Rosalind Rolland, a senior scientist at the New England Aquarium, explains that "concentrations of [fecal glucocorticoids] reflect adrenal activation and relative physiological stress levels" (Rolland). In 2001, after the twin towers fell, human activity in the ocean such as "vessel traffic" nearly ceased, resulting in a decrease of about 6 decibels in the Bay of Fundy in Canada (Rolland). As shown in Figure 2, in 2001 and the beginning of 2002, glucocorticoid levels in North Atlantic right whales were significantly low until a few years later. In 2003 as shipping traffic resumed, the hormone levels sky-rocketed. The reduced levels of steroid hormones in right whales immediately after 9/11 has never again been documented (Rolland).

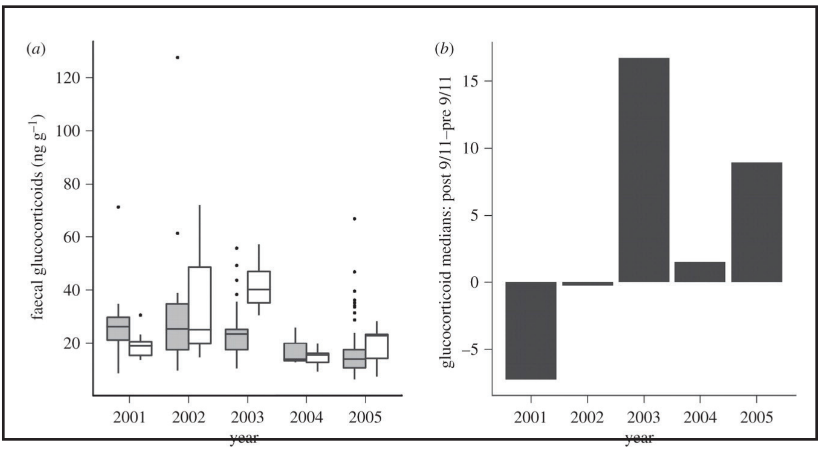

Figure 2: Average Fecal Glucocorticoid Levels in North Atlantic Right Whales Before and After 9/11 (Rolland)

Whether anthropogenic sound in the ocean causes differences in behavior or physiological changes in marine life, both can adversely affect population size and health. The different population distributions of the Atlantic right whales in the Northern and Southern hemispheres could possibly be explained in part by the variability of human population and activity. Because there are more humans living and interacting in the Northern hemisphere, their abundant activities create an underwater chaos that caps the North Atlantic right whale population size at around 450 whales, while the Southern population grows to about 14,000 individuals (Edds). Even though some effects of human-generated noise are temporary and can be recovered from, many effects are irreversible and can cause a chain of tragic events to follow.

The Importance of Life in the Oceans

Enric Sala, a marine biologist, comments on how vital a role the oceans play within our world: "[they] give us more than half of the oxygen we breathe, regulate the climate, [provide] us [with] seafood and recreational opportunities," and absorb most of the atmospheric carbon dioxide (National Geographic Society). They provide us with valuable minerals and fossil fuels that we extract and synthesize into everyday products. The ocean sediments serve as tools in learning about Earth's climate, continental features, and evolutionary relationships from the past that we can then use to predict future circumstances. The abundance and richness of species in the oceans are what make the oceans healthy. Each individual is a piece of the puzzle in helping to maintain the biodiversity of such an under-researched environment.

Although most research has been conducted on marine mammals, underwater noise affects almost every species, from the largest apex predators to the smallest primary producers. Starting from the very bottom of the food chain are phytoplankton, who make up the vast majority of primary production and oxygen levels in the ocean. Zooplankton feed on phytoplankton and serve as "not only an essential food source for whales but also upon which the whole ocean ecosystem, from fish to larger invertebrates (oysters, clams, crabs, shrimp) to seabirds, depends" (Weilgart, "The Impact of Ocean Noise"). However, because the increase in noise is causing die-offs of zooplankton, those food sources are becoming increasingly depleted. Mortality rates of sea hares, a "slug-like marine invertebrate" that "keep corals, algae, [and toxic bacteria] in balance" are increasing (Weilgart, "The Impact of Ocean Noise"). Catches off of Norway are reduced by 60%. Sea turtles are dying and sea horses are malnourished (Peng). Cephalopods' sensory systems are being mutilated (Peng). The inner ear hairs and sensitive tissue in lateral lines that sharks and other fish use to detect changes in water pressure are being destroyed (UWA Oceans Institute). Marine mammals, especially those that are critically endangered are severely impacted physiologically and behaviorally (*Sonic Sea*). The loss of any one of these species throws the marine ecosystem out of balance, in so far as each has a purpose vital to the maintenance of the oceans' health. For example, whales, dolphins, and sharks are biological-indicators of the health of our oceans and help to stabilize the food-chain. Because of their longevity, we can monitor the effects of overfishing, accumulation of toxins released into our oceans, and the changing populations of other important keystone species. Without these stewards of the sea, society would no longer be able to gather data in order to implement policies to further protect not only life in the oceans, but ensure that life for us continues as well.

Conclusion

Events and issues that societies around the world collectively deem as important, usually become the focus of conversation and are given the attention and resources they need to be resolved. An increase in societal awareness and the active participation of the public in matters concerning marine disturbances is a recipe for the change that our ocean environment needs. A strong public interest in anthropogenic noise pollution and its effects on marine ecosystems could eventually spark a movement towards quieter technology, including improvements in sonar, ship and propeller design, and oil exploration techniques.

Additionally, an increase in societal involvement with differing levels of government could lead to the support needed to strengthen the legislative oversight of global companies' activities concerning marine disturbances. In the 1980s, countries around the world agreed to put an end to the whaling of species that were on the brink of extinction (*Sonic Sea*). If societies around the world gain the same political will to make underwater noise pollution and the transparency of companies' motives and activities a priority, this too can be regulated. Shedding light on the destructive role companies play in the colonization of the ocean environment can help in recruiting public involvement and pressuring these agencies to adhere to the federal laws put in place for the protection of the environment. Noise pollution differs from other forms of pollution in that, once it is recognized and prioritized as a problem, the noise will disappear, unlike the plastics and chemicals that remain in the system for centuries.

In retrospect, the United States has made progress in moving shipping lanes and decreasing speed limits for boats in marine animal protected areas. However, a battle is ongoing between environmental organizations and agencies that find their motives to be more important than the health of our oceans. The human population depends on oil exploration, transoceanic shipping, and the national security with which each country provides their citizens. However, every system, whether ecological or economical, functions efficiently and effectively because constituent forces balance each other. Currently, that balance has been shifted into the hands of powerful organizations like federal agencies such as the Navy or companies that provide us with our resources. The ability of these companies "to take resources from the global commons…and exploit those and damage the ocean ecosystem without cost … is intolerable" and unacceptable, according to Christopher Clark, Cornell University's bioacoustics expert (qtd. in Sonic Sea). Even though more research is needed on specific species, enough information has been collected on marine life as a whole to conclude that anthropogenic noise has the potential to have life-changing impacts. No one, no matter their status, is above the law. Encouraging the public to lobby for the enactment of increased legislative measures, for example, when and where certain technologies can be used and consequences for those who break those regulations would hopefully start to hold these agencies accountable for the damage they create. Continual oversight might eventually pressure and ultimately force them to comply with federal environmental laws.

Everything, in an ecological sense, is connected. The oceans lay the foundation for life to thrive in a world that would be inhospitable otherwise; the demise of the oceans would create a domino effect that would result in the destruction of every other system we have come to know. As Enric Sala points out, even though oceans cover 72% of the Earth's surface, "less than 2% is protected" (National Geographic Society). Sala's statistic further emphasizes how essential it is to protect the species that not only provide recreational and economic opportunities for the public like ecotourism, but also can give us a glimpse into what our oceans and ultimately our entire ecosystem are heading towards in the future. Like Sylvia Earle, world-renowned oceanographer, asserts, "oceans, throughout all of human history, have made it possible for us to survive; [now], we need to return the favor" (qtd. in *Sonic Sea*). By not paying attention to the deterioration of the oceans and the flora and fauna inhabiting it, we are putting our own livelihoods at stake. Protecting our oceans is man-kind's most important job.

Note: This essay was composed in Dr. Daniel Wollenberg's AWR 201 class.

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