Mapping the Southern Resident Orcas' Acoustic Habitat

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Abstract

I monitored the acoustic environment of the Salish Sea during October 2005. I recorded the Southern Resident Orca pods J, K & L in a variety of locations and situations in an effort to characterize the acoustic habitat in which they spend the majority of their time. Supplemental recordings were made at various times and situations involving high levels of human / biological and / or environmental sound to gain a broader perspective of the community of sounds that exist in the area.

Introduction

Marine animals are submerged in a medium that is highly sensitive to vibratory phenomena, resulting in a speed of sound in water that is five times that of air. For humans, and other animals with ears, these vibrations are perceived as acoustic energy, or sound. The vast majority of sea life has a biological dependence on sound and acoustical energy (Stocker 2003). This acoustical energy might be perceived in these organisms as dynamic changes in pressure gradients, an oscillation of particles, or a vibration of water. In the human realm, investigations into the role sound plays in forming an individual's relationship to their environment may assist us in understanding the acoustically heightened world of undersea life. Conversely, the acoustic ecosystem of marine life may also provide a magnified perspective of the role sound plays in orienting biological systems that can be extrapolated to interactions of organisms in air.

My main goal in my method of presentation of the recording data is to increase awareness of the presence and effects of anthropogenic noise in the marine ecosystem. As the physics of sound prevent us from hearing undersea sounds without electroacoustic augmentation, our interaction with the acoustic community of the sea has lacked any feedback mechanism by which to maintain a homeostatic sustainability. Without this cybernetic relationship we risk unbalancing the ecology of the earth's largest environmental region.

Methods of modeling and presenting environmental recordings through the acoustic ecology paradigm attempt to translate the soundscape of a large area (in this case the San Juan archipelago) into a form that portrays the important acoustic characteristics of the area. The most useful model is often a map, because of its familiarity and applicability to new types of superimposition of data. One drawback of this method is its primarily visual orientation. The benefit of the act of listening attentively is lost when aural information is translated into a visual medium. While the visual modeling of acoustic data is certainly useful, especially for graphing *energy* aspects of sound (such as intensity, frequency & waveform), such analysis tends to reduce the complexity of the natural ecosystem to finite details. The availability of high quality recording technology, the internet, and GPS have now made it possible to present soundscape recordings in a map format that allow the viewer access to the recordings as they were perceived at any given location.

My data is presented using the Google Maps API. This allows for the embedding of sound files at latitude / longitude markers acquired via GPS at the time of recording. The map is then posted on the Internet and viewable / listenable for the global community. The great benefit of presenting my data in this way is that it allows large numbers of people to hear what is happening under water for the first time.

Finally, it must be noted that this is a preliminary study. The presentation method is meant to encourage dialogue and my own conclusions are only starting points toward further dialogue. My brief exposition on alternative methods of scientific inquiry is included as it may assist the reader in the paradigm shift that is currently underway in some areas of the scientific arena. Unfortunately, this paper cannot fully elaborate on all of the ideas that have influenced the development of my approach to this research.

Methods

Procedure

Recordings of the Salish Sea were performed during October of 2005 while traveling aboard the 42' catamaran Gato Verde. My colleagues aboard included 5 other undergraduate researchers, 2 professors, our captain and a few guests from time to time. Each of us developed our own individual research project yet we all shared the common theme of investigating some aspect of orca whale acoustics. Specifically, our research focused on the vocalizations, environment, and habits of 'southern resident' J, K & L pods that spend the majority of their time around the San Juan Island archipelago and south Puget Sound.

We recorded at various times throughout the day in the home range of the southern resident orca population, around the San Juan archipelago. To some degree our temporal focus remained within the anthropocentric daytime routine, between the hours of 08:00 and 22:00. We attempted to venture out of this window and on some occasions were able to sample the orca habitat in the late night and pre-dawn hours.

My approach was to capture general field recordings at varying locations (both with whales and without whales in the vicinity), measuring space / time coordinates (time, latitude / longitude) with a GPS transceiver, possible sources of anthropogenic and environmental noise such as sea state, weather, and number of vessels present. Although attempts were made to accumulate recordings covering the widest area possible, our primary focus was on studying the whales themselves and hence their movement patterns during this time period influenced our recording locations. Whenever possible, attempts were made to capture recordings from those areas not yet documented. In some cases, recordings were made in a repeated location at varying dates and times.

Equipment

Recordings were made using various models of hydrophone as well as various deployment methods as appropriate for each research project. My own personal project made use of recordings made from several different hydrophones and recording units combinations.

Recording Units

Sony MZ-S1 Minidisk
Sony PC100 Digital Video Camera (connected via BeachTech attenuator)
Marantz PMD660 Compact Flash Recorder
Marantz PMD101 Cassette Recorder

Hydrophones

ITC (International Transducer Cooperation) 4066 Omnidirectional
Veirs OVAL Instrumentation Preamplifier
Cetacean Research Technologies Hydrophones Omnidirectional
Brüel & Kjäer Callibrated Hydrophone / Preamplifier

Microphones

Sennheiser K6 & ME65,66
Self-fabricated parabolic dish (for in air recordings of surface blows)

Other Field Materials

Binoculars
Range-finders
Radar

Analysis Materials

Apple Powerbook G4 (OSX 10.4)
Digidesign Mbox running ProTools 6.9.2
Audacity 1.2.3
Google Maps API

Deployment Techniques

1. The B&K hydrophone / preamp was used from 10.2.05 - 10.8.05. It was deployed at a depth of 30'(?). The B&K line out was plugged into the 8" input of the Marantz PMD660.
2. A stereo array of two ITC 4066's suspended one 1.42 meters apart at a depth of 4.4 meters was used for the first half of October, then the stereo array was expanded, dropping one hydrophone off of the bow and one off of the stern resulting in a 10.05 stereo array suspended 4.08 meters underwater. The hydrophones were connected to the Veirs OVAL Preamplifier with an adjustable gain of x1 or x10 dB. The signal was then fed into the Marantz PMD660 via an 8" mini jack. The adjustable input gain on the marantz was generally set to maximum but at times was attenuated to prevent clipping.
3. A single ITC 4066 was suspended off of the stern of the boat at a depth ranging from 30-120'. It was connected to the OVAL Preamp and fed into the Marantz in the same method as technique #2.

4. The Cetacean Research Technologies hydrophone was deployed from the bow and connected to the Sony PC100 DV recorder via the BeachTech box. The camera was then used to capture surface activity of the whales while recording the underwater calls. On a few occasions the Sennheiser microphone was used to record blowhole breaths alongside the hydrophone track.
5. The Cetacean Research Technology hydrophone in the bow was, at other times, connected to the Sony MZ-S1.

Analysis

1. All recordings were imported onto the Powerbook for analysis and processing. Recorded tracks were analyzed and edited using ProTools LE, Audacity and Quicktime. In analyzing the recordings, I attempted to isolate examples of various types of acoustic phenomena occurring in the area being studied. Examples include recordings of orcas with and without vessels in the vicinity, events of large cargo containers and ferries passing by as well as times and areas without significant human or orca activity.
2. Significant samples were then mapped in an HTML web page using the Google Maps API. The web page will be an interactive way for people to experience the orca acoustic habitat. It is hoped that the presentation of the samples embedded into a map of the actual location will assist visitors to the website in relating to the underwater orca habitat as part of the global acoustic ecology.

Results

My analysis of the recordings differs from several recent investigations to the acoustic hygiene of the Salish Sea area (Gisner 1998, Simmonds, Dolman & Weilgart 2004, Mellinger & Barlow 2002**)** whose studies have tended to focus on isolating quantitive measurements such as sound level intensity (root mean square value), frequency content and observable response. The measuring of these values is, by default, performed by transferring the sounds to a computer and analyzing the sounds through visual modeling. This process, though certainly useful, has as its very nature a narrowing of focus to finite variables that veil the true complexity of reality. This reductionist approach has the side effect of denying an experience of the essential *quality* of the sound that listening can provide.[1] "Subjective qualities" such as listening have, since Locke, been considered "secondary" phenomena, as apposed to the "primary qualities" of nature, which are measurable and objective. The price of this view, widely engrained into our cultural paradigm, is to alienate us from our very lives and has been seen by some as having contributed to the moral uncertainty of our scientifically oriented society.[2] Brian Goodwin argues for the development of a *qualitive* approach to scientific investigation,

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[2] The philosopher A.N. Whitehead, speculating in the early 20th Century on the alienating tendency of the Western scientific approach pointed out a major inconsistency of Western scientific thought, that of scientific realism based on mechanism and a concurrent unwavering belief that the world of men and the higher animals are self-determining organisms (Whitehead, 1925).

“Qualities capture essential aspects of the whole expressed in behaviour that quantities cannot describe » (Goodwin 2005).

Although the field of acoustic ecology is still not well connected with academic inquiry, recent developments in the field of psychoacoustics[3], have begun acknowledge the usefulness of studying environmental sound (Epstein, 2003). R. Murray Shafer coined the term *acoustic ecology* to describe the study of the effects of the acoustic environment, or *soundscape*, on the biological organisms living within it, with special attention paid to imbalances that might be the result of some acoustic disturbance (Truax 1984). Schafer proposed that there was a vocal “give and take” between species (see figure) in the naturally occurring soundscape.

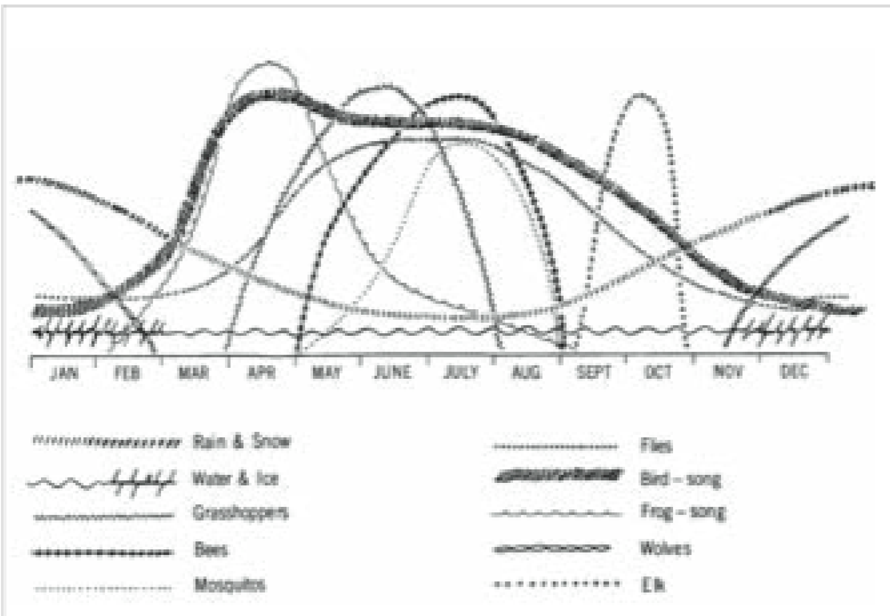

Figure 1: The cycles of the natural soundscape of the west coast of British Columbia showing the relative level of sounds (from Truax 1984: 142).

This figure appears to show that the presence / absence of environmental sound may influence when a species vocalizes. Krause argued that this “niche theory” was also present across the frequency spectrum, when he noticed that the vocalizations of different species seemed to occupy small frequency bands, leaving open other “spectral niches” for other animals, birds and insects to fit in (Krause 1993).

The continuous rise in anthropogenic noise over the past 100 years has increased the awareness of how the anthropogenic noise may be disrupting human culture as well as interfering with the network of communication among the other species on planet earth. The 1998 publication *Workshop on the effects of anthropogenic noise in the marine environment* clearly points to the biggest culprit in marine noise pollution, “The sound radiated by the enormous number of ships plying the world’s seas is the single largest contributor to the total acoustic budget of the ocean” (Gisner 1998). Furthermore, the effects of this noise are both local, as discrete sources of sound, and global, where they comprise the dominant component of oceanic ambient noise within the frequencies

[3] A branch of cognitive psychology having to do with the processing and interpretation of auditory phenomena by the human brain.

below 500 Hz. In air the monotonous din of industrial culture has weakened our ability to detect subtle alterations in our environmental soundscape but in the acoustically enhanced realm of the earth's waters evidence suggests that human created acoustic disturbances are impacting other species (Stocker 2003, Hastings & Popper 2005). It has been recognized that any sounds that interfere with natural communication or perception of relevant sounds could potentially compromise the survival of an animal (Gisner 1998). Included in many of the recent studies on oceanic noise and its effects on marine life is the recommendation is the monitoring of ambient noise levels (Mellinger & Barlow 2002, Gisner 1998).

My *Puget Soundscape Map* presents recordings made during October 2005 at various locations, times and situations that should give some idea of the state of the acoustic ambience of the southern resident orca populations' habitat.

Puget Soundscape
Http://homepage.mac.com/brettbecker/soundscape/pugetsoundscape

Discussion

The fact that sound attenuates drastically when passing between the medium of water and air has left the oceanic realm outside the domain of human noise ordinance laws. These same laws, in recent decades reflect a consensual dissatisfaction with increase in noise levels in human society (Truax 6). Furthermore, recent studies of acoustic pollution have shown an association with negative reactions in marine mammals and other sea fauna (Bressan 2004, Simmonds, Dolman & Weilgart 2004, Stocker 2003). Still, these correlations are based upon short-term response and the long-term impact of continued exposure to unnatural noise is as yet unknown. If these studies are just recently releasing data that suggests the negative impact of short-term exposure to noise, what does this say about the extended impact of anthropogenic noise as it has intensified over the past 100 years? It is hoped that the Puget Soundscape Map will stimulate further research exploring marine acoustic ecology and encourage the dissemination of recordings into public awareness.

Problems

Though my hope is to reflect the acoustic ecology of the southern resident habitat in an unbiased, all-inclusive way, in actuality my data is biased in many respects. The fact that my recordings are from only the month of October is itself a significant drawback in that by this time of year the number of boats has dropped considerably. Another drawback to my methods was that my recordings were performed with a variety of hydrophones, depths, amplifiers and recording units, restricting my data to mostly uncalibrated recordings. This will, unfortunately, limit the usefulness of many of my recordings to future researchers. Other biasing factors are the time of day my research was preformed, almost always between the hours of 8:00am and 8:00pm, with the exception of a few night observations. Still, even with these problems, the Puget Soundscape map is successful in offering a wide audience the opportunity to listen to a realm of acoustic interaction that is normally inaccessible.

Future Research

My hope for future research is to create a more interactive research method by using underwater playback in addition to recording. My hypothesis is that this technique would achieve assist in opening up lines of communication with orca whales. As attempting to manage or limit vessel traffic may be extremely difficult because of the number of vessels and the economic factors involved it may be beneficial to encourage active attempts at interspecies communication with a creature whose brain size suggests high level of intelligence (Lilly 1978). Furthermore, the objectification of a species recognized to be highly intelligent debases and restricts the possibility of achieving communication.

Possibilities include the association of a ‘signature sound’ for the vessel used in the study, or a time delayed reiterative feedback chorus similar to the one described by David Dunn in his lecture at the Sante Fe Institute (Dunn 2001). In his example, he played a simple sine wave at a field location in a wooded area. Initially, the nearby birds seemed to be disturbed and aggravated by the noise. While playing this he recorded both the sign and the response of the birds. This sound was then played back and the process repeated again. Eventually, he found, the birds began to flock around the speaker and no longer seemed disturbed, rather that the complexity of the reiterated recording seemed to be a strange attractor for the emergence of an interactive web of sound within the nearby acoustic environment (Dunn 1999). In theorizing what causes such phenomenon Dunn references the “cybernetic epistemology” of Gregory Bateson as the groundwork for understanding what amounts to an emergent mind within the larger environment. Bateson, interestingly, first proposed the idea that cetaceans might actually function as a sort of ‘group mind’. (Bateson 1972). This idea, scientifically unpalatable at the time, has in recent years achieved acceptance in the scientific community researching cetaceans (Baine, personal communication).

To grasp the idea of a mind beyond the individual it is helpful to be familiar with Maturana’s definition of consciousness as an *epiphenomenon* of self-reflexive feedback loops. These loops, creating homeostasis, or equilibrium, between the outside and inner worlds, blur the boundary between self and community. With an obvious nod to Bateson, Dunn states, “human consciousness does not rule out the potential for other complex forms of self-referential consciousness to exist on higher levels of organization within the interaction of either members of a species or an ecosystem. Furthermore, Dunn sees sound “as a prime-integrating factor in the understanding of our place within the biosphere's fabric of mind” (Dunn 1984). This seems to point to a growing awareness of Schafer’s acoustic ecology, as the relationship of the listener to the environment. We are a part of the environment in which we live and thereby a part of the soundscape. Our presumed isolation in “objectivity” is burdened by the reality of our integration within our ecology. In the words of Brian Goodwin, “We are experiencing global crises in health, in community relations, in agriculture, in habitat, species and cultural destruction, and in climate change, all as a result of the way we have chosen to see these aspects of culture and nature from a scientific and technological perspective (Goodwin 2005). Opening up a line of communication with the most probable form of intelligent life on the planet might help us reconnect to global ecology, or as Dunn says, the « eco-systemic mental structure » in which we live. (Dunn 1984).

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