LT Rommel R Pucan
17 August 2004
OC 3570

Introduction:

In 2001 an Ambient Noise (AN) survey was conducted using a an underwater Hydrophone off the coast of PT Sur, CA. Results showed that in the frequency range of 20-80Hz, there has been an increase of 10db. In the frequency range of 120 Hz and above, there was a minimum 9 dB. 2004 NPS Cruise sonobuoy data as well as Navy AN data (NAVOCENAO Warhouse) will be utilized to explore the hypothesis that AN in the low frequency band have significantly increased over several years. The low frequency band between 10-500Hz will be the focus of the experiment. Wind, biology and distant shipping dominate low frequency transmissions, and therefore may be the cause of the increase in AN.

Navy Relevance:

AN is a critical element in the Sonar Equations. Through the Sonar Equations, the Navy has continued to excel in USW sensor and weapons development. However, our understanding of underwater AN is important not only for the creation of more silent and deadly submarines and torpedoes, but also for the need to avoid injuring marine life. Our broader understanding of underwater sound has helped us to navigate safely (surface and subsurface) and has also helped us to understand the marine mammal health hazards involved with the acoustic intensity of naval systems. The significance of this research is apparent, and continues to be of high priority in the naval community.

Method:

The objective of this experiment was to extract AN data from sonobuoy measurements. Three deep-water acoustic experiments were conducted over a four-day period, 11 August 2004 to 15 August 2004 aboard the R/V POINT SUR. The cruise departed from Avalon Bay, CA and spent the majority of its research in the vicinity of San Clemente Island Undersea Range (SCIUR) OPAREA. Throughout the cruise, environmental data was collected and logged by students on an hourly basis.

Experiments involved monitoring J-9 transmissions and tracking Expendable Mobile Anti-Submarine Training Targets (EMATT) with Navy 53/57 series sonobuoys. Each sonobuoy was set for varying depths of 400m to 1000m. The ship stayed within signal range throughout the 8-hour life of the sonobuoys. Wind speed was recorded between 12-15 kts throughout the cruise, however, the students reported that sea state never went above 2.

Students monitored the sonobuoys using a shipboard receiver/amplifier. NPS technician Chris Miller, described the noise signals as “dirty,” or having excess RF interference. Only two of seven sonobuoy channels had reasonable acoustic readings. It was also noted that crewmembers picked up several “small marine mammal vocalizations”.

The two cleanest channels were used to measure AN. Data was digitized into a readable format. Matlab code was used to extract AN from the data transmissions. Data was taken at 4 different times over a period of two days. The data was averaged to reduce variability.

Cruise Data:

The raw data extracted from the sonobuoy was in Volts. Oceanographic acoustic data is usually analyzed in units of pressure, therefore a Matlab code was generated to convert dB voltage units to dB pressure units. Two methods were used for the conversion, the Laraza method, and the Navy Method. Laraza method is simple by adding 120db to the raw voltage units. Navy method adds 4.5 dB per octave (each time frequency is doubled). The two methods are yielded similar results, however in the lower frequencies, there is almost a difference of 12-15dB (Fig 1.)

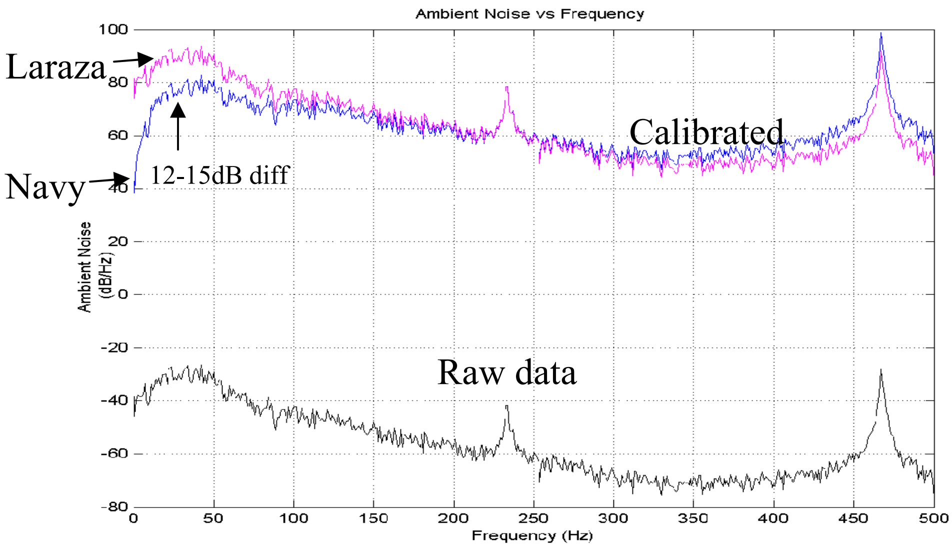


Fig1. Calibration of data

Laraza calibration method is a simple of derivation. Intensity (I) is proportional to Pressure (P) squared and:

$$10\log I/I_o = 10\log P^2/P_o^2$$

$$\text{dB in Pa} = 20\log P/P_o = 120\text{dB gain}$$

NAVOCEANO AN Warehouse database:

Naval Oceanography Office (NAVOCEANO) keeps an AN database. Theoretically the database is updated with AN data after each survey via Navy Purple messages. Navy purple messages contain sonobuoy data that can be used to analyze AN trends in Naval opareas. NAVOCEANO does have every purple message archived in files. However classification issues prevent public release of all messages. Although not all purple messages are available, the Warehouse database has been updated with useful unclassified AN information as far back as the early 1980s. Sonobuoy data was found dating back to the summer of 1984. The location of the survey data was within a few miles of the NPS exercise area. A comparison between the two data sets will provide a useful investigation of possible trends over several years.

GDEM Data:

The Generalized Digital Environmental Model (GDEM) is the Navy wide climatological model for sound speed profiles as a function of location and time. Its resolution is one month in time and 30 minutes in space. Each sound speed profile is interpolated to the nearest month from a 3-month average of all profiles found within its 30-minute grid cell.

GDEM is used in several databases including The PC-based Interactive Multi-sensor Analysis Training system (PC-IMAT), which was used to generate AN data using Wenz's formula for AN. Wenz's curve is a function of shipping noise and wind.

1994-2001 Andrew's study using a Navy hydrophone data:

Between 1994-2001 Andrews et al. AN data was gathered 40NM off the coast of Point Sur using a Navy hydrophone. 40 years prior, Wenz used the same hydrophone to conduct a similar survey. Andrews found that AN has raised as much as 10dB since Wenz conducted the survey in 1965. 1998 Navy survey data from NAVOCEANO Warehouse will be used to compare results from Andrews.

Results:

10-100Hz will be referred to as low frequencies, and 100-500Hz will be referred to as higher frequencies. The average of four 2004 Cruise samples were smoothed using a parametric 4th order interpolation on a semi log plot. 1984 data was plotted with 2004 data for comparison (fig 2a-2b). Interpolations were made in the same method as Andrews. The intensity between 1984 and 2004 at low frequency varied from 2-17dB in both the lower and higher frequencies.

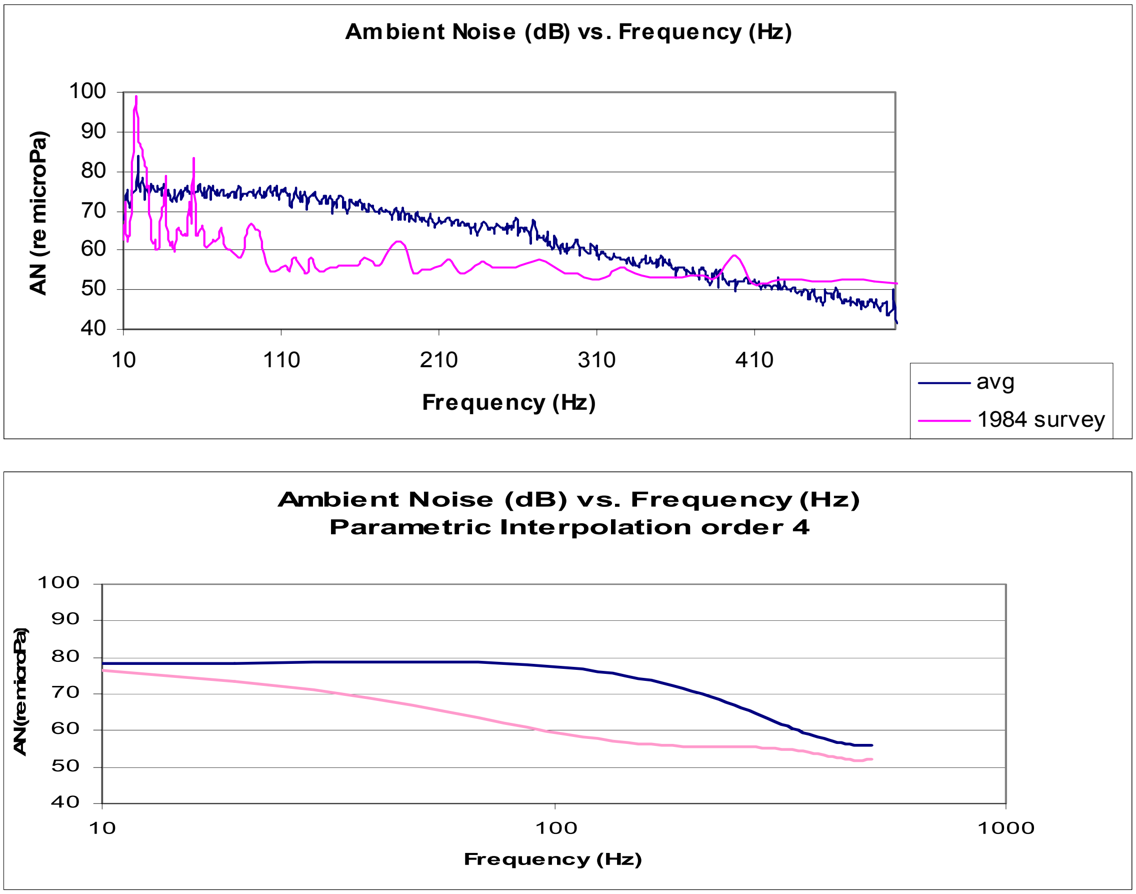


Fig 2a-2b.

GDEM Wenz Curve Model utilizing PCIMAT calculated intensities of 80-85dB at 10-100Hz, a difference of about 6dB higher in comparison to 2004 data, and 7.5dB higher than 1984 data. Shipping densities of 6 and sea state of 2 were the input parameters used for the calculation.

The 1998 Navy data and Andrews data were found to be much higher than the 1984 data and 2004 data. The PT Sur study and score range are more than 200 hundred miles away from each other so oceanographic conditions for sound propagation differ. The 1998 Navy data and the Andrews data will be compared to each other independently.

The 1998 Navy data fit the Andrews data from 20 to 100Hz, however from 10-20Hz there is up to a 10dB difference. GDEM Wenz Curve Model utilizing PCIMAT calculated intensities of 82-86dB at 10-100Hz, which was1-8dB lower in comparison to 1998 data. Andrews's data matched GDEM with (+/-) 4dB difference.

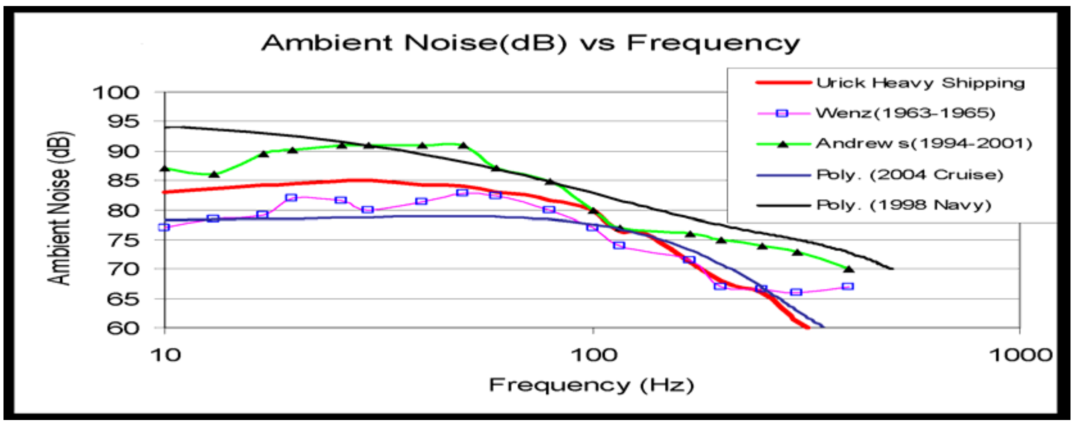


Fig 3.

Conclusions:

A comparison of the 1984 Navy Survey and 2004 NPS Cruise Sonobuoy data showed an increase of up to 17dB in the 1-500Hz frequency band. The difference can be attributed to temporal and spatial variability. Locations were in the same general location, but still not in the same exact location. The 1984 data was taken in July and 2004 data was taken in August; temporal variability may have caused an increase. Within the four insitu samples taken in 2004, AN levels differed in some cases by 15 dB in just a few hours. The variability of the 4 insitu samples are represented in fig. 4.

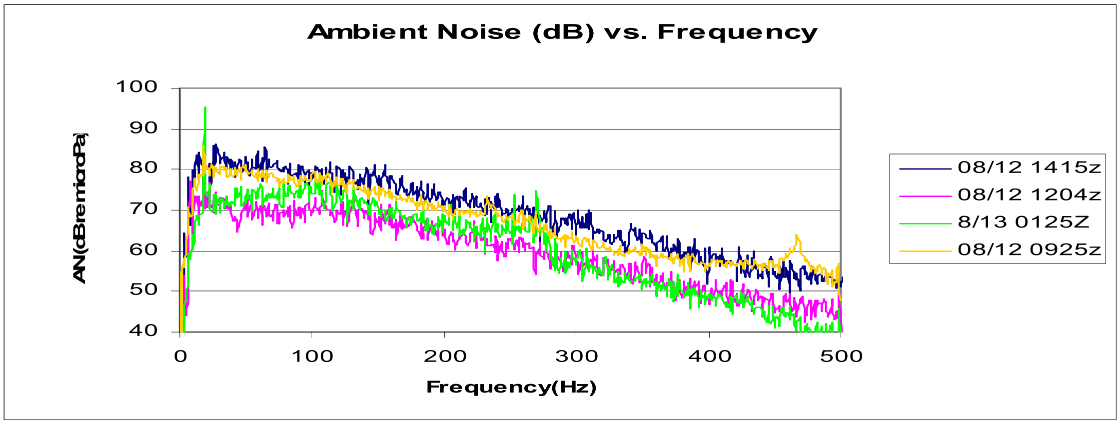
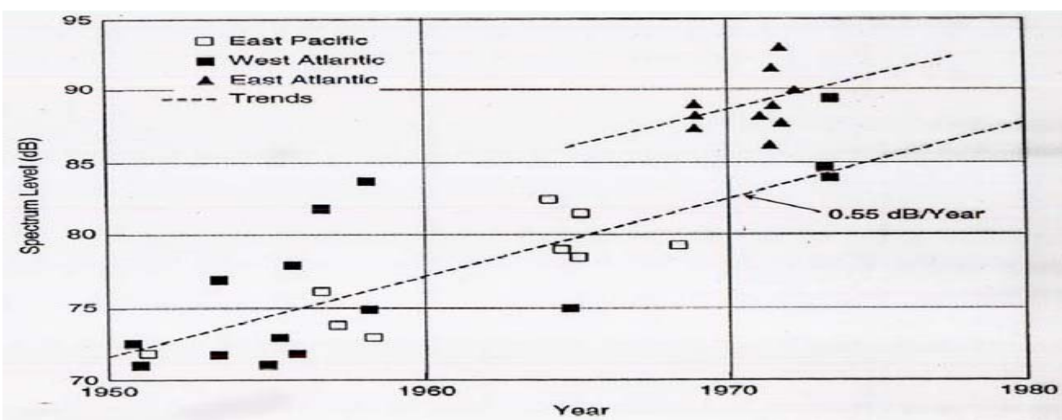


Fig 4.

Increase in shipping from 87k gross tons to 543 million gross tons over 27 years is an obvious correlation to an increase at frequencies 20-80Hz (Mazzuca, 2001). A study from Ross shows an average increase in .55dB per year (Fig 5a) or 5.5 dB per decade due to shipping. Ross has not given frequency range in his report, however shipping is dominant in between 10-100Hz (Urick, 1993), so we can assume he was referring low frequencies. Although AN has not gone up as much as Ross predicted, data collected from 1984-2004, fig 3. clearly showed a steady increase in AN (Ross, 1993).



Long-term trend for low-frequency ambient levels for period 1958–1975. SOURCE: Ross, 1993, courtesy of Acoustics Bulletin.

Fig 5a.

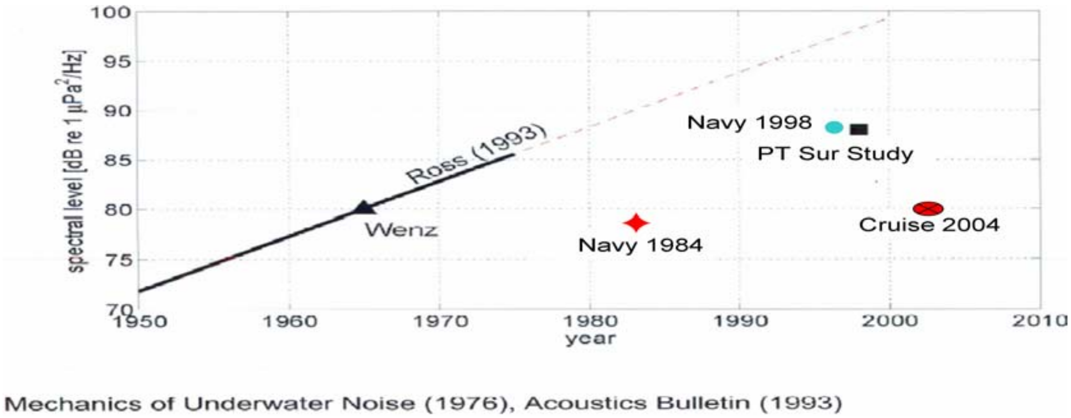


Fig 5b.

An increase in North Pacific whale stock may also be a contributing factor to the increase of AN. When the last study was conducted in the sixties, whale population was more than likely at an all-time low because of whaling. The blue whale and fin whale populations are slightly increasing since the International Whaling Commission declared a moratorium on commercial whaling at the turn of the century (IWC, 2004). Having frequencies around 20 Hz, blue whales have increased the noise spectrum below 30 Hz (Andrews, 2002).

The increase in AN levels at higher frequencies (100-250 Hz) is still a mystery. A possible cause could be a long-term increase in wind speed, however, Wenz's "law of fives" states that a doubling in surface wind speed produces an increase in AN of approximately 5 db; a 10 db increase would require a quadrupling of average wind speeds which is not the case. Raw data from Wenz's original report has never been found (Andrews, 2002). Until the original data is found, the general question will be "Is his Wenz's analysis correct?" In this project, calibrating raw data from voltage to pressure units using 2 different methods yielded a variance of 12-15dB (Fig 1). Andrews' method of calibration may have been completely different from Wenz's method.

In order to further eliminate temporal and spatial variability, more samples need to be analyzed and averaged. Historical sonobuoy data exists in the form of Naval Messages dating as far back as the late sixties to early seventies. Once this data is released, it will be the key to validating Wenz' and Andrews' studies.

Recommendations for further studies:

Continue to gather sonobuoy data at each cruise. Do not limit sonobuoy drops to the SCIUR range. Conduct a sonobuoy survey proximal to PT Sur in order to cross correlate Andrew's data. Compare historical AN data to NAVOCEANO Dynamic AN Model. Pursue the search for Wenz' missing data.

Bibliography

Mazucca, L.L., “Potential Effects of Low Frequency Sound (LFS) from Commercial Vessels on Large Whales,” Master’s Thesis, School of Marine Affairs, University of Washington, Seattle, WA (2001).

Ross, D., “On Ocean Water Ambient Noise”*,* Acoust. Bull. 18, 5-8,1993.

Ross, D. *Mechanics of Underwater Noise,* Pergamon Press, New York, 1976.

Urick, R.J., *Principals of Underwater Sound*, McGraw Hill, New York, 1983.

V.O. Knudsen (UCLA), R.S. Alford and J.W. Emling (both of Bell Telephone Laboratories, New York), “Underwater Ambient Noise”, The Sears foundation for Marine Research, Yale University Journal of Marine Research, V.3, 410-429, 1948.

Wenz,G.M., “Low-frequency deep-water ambient noise along the Pacific Coast of the United States,” U.S. Navy J. Underwater Acoust. 19, 423-444, recently declassified, 1969.

International Whaling Commission (IWC), www.iwcoffice.org