INTRODUCTION

One way to quantify the effects of underwater sound on marine animals is through the use of a noise budget. A noise budget is a listing of the various sources of noise at a receiver and their associated ranking by importance. A number of different types of budgets can be conceived using various acoustic measures such as intensity, energy, or duration of maximum amplitude level. These budgets are typically parameterized by frequency and are usually computed over bands such as third octave.

Noise budgets are useful for marine mammal masking studies, habitat characterization, and environmental studies and may be useful for studies of the evolution of animal hearing. Noise from shipping may be affecting the communication and behaviour of marine mammals (Tyack & Clark 2000). The use of the budget allows the computation of the acoustic environment prior to man’s introduction of sound into the oceans. The Wenz curves (Wenz 1962), a common way to display the contributions of the myriad of oceanic sound sources, can be used as a basis for averaged noise budgets. With the assumption that the curves correctly represent the acoustic environment of marine life, noise budgets will provide marine mammal hearing evolution studies with the baseline data for establishing mammal hearing response. More importantly, if that budget is changing with time, it provides details of the change and can be used to predict impact.

METHODS

In 2003, a panel convened by the National Research Council of the U.S. to study the effect of sound on marine animals wrote a report recommending the use of noise budgets (Frisk et al. 2003). Although explicit budgets were not included in the report, a conceptual framework was developed by the committee members using average intensity (AI) budget in third-octave bands. The intensity of sound
has been considered to be appropriate for marine mammal hearing and masking studies (Ketten 2000).

In an ocean with constant sound speed and density, the instantaneous intensity of a wave far from a small source labelled $n$ is given by

$$I_n(f,t) = \text{Re}[p_n(f,t)u_n^*(f,t)] = \frac{|p_n(f,t)|^2}{\rho c}$$

where $p_n(f,t)$ is the acoustic pressure in a band of frequencies centred at frequency ($f$) and time ($t$) and $u_n(r,t)$ is the radial component of acoustic particle velocity. The average intensity in the frequency band is

$$\langle I_n(f) \rangle = \frac{1}{T \rho c} \int_0^T |p_n(f,t)|^2 \, dt$$

where $T$ is the averaging time. If one is able to classify the source ($n$) of sound for all times between 0 and $T$, a noise budget can be calculated using the average intensity in the frequency band for each source.

Since the publication of the NRC report, Nystuen has collected a large amount of noise data in various ocean sites using passive acoustic listener (PAL) systems to measure rainfall at sea (Ma et al. 2005). He has also computed sound budgets based on temporal detections and classifications (Nystuen & Howe 2005). These temporal detection (TD) noise budgets are closely related to the AI budget model but use the duration of maximum received level in frequency bands. Unique spectral characteristics of different sound sources are used to identify the sound source. Typical sources include breaking waves from wind (to measure wind speed), raindrop splashes (to measure rain), drizzle, shipping (both distant and local), and marine mammals (especially whales).

RESULTS

We describe an algorithm to convert the intensity data collected by the PAL systems into the AI formulation. Average intensity budgets are shown for a number of geographical locations including the intertropical convergence zone in the eastern Pacific, northeast Pacific, Ionian Sea, Cape Flattery off the Washington Coast, and the Bering Sea.

For example, Figure 1 shows a noise budget calculated for the Ionian Sea during the period from January 10, 2004 to April 17, 2004. The third-octave band of frequencies centred at 500 Hz is dominated
by wind, with an average intensity of 298 \( \mu \text{W/m}^2 \) (86 dB re 1 \( \mu \text{Pa} \)), followed by shipping with 160 \( \mu \text{W/m}^2 \) (84 dB re 1 \( \mu \text{Pa} \)) and rain with 39 \( \mu \text{W/m}^2 \) (78 dB re 1 \( \mu \text{Pa} \)).

CONCLUSIONS

Two different styles of ambient noise budgets are presented: average intensity and temporal detection. Each of these presentations can be used to quantify the underwater ambient sound field of the marine environment. Data from the PAL systems are shown in both formats from various locations around the world. These data provide information about the physical environment (wind, rain), biological animal populations (especially whales), and human activities.

REFERENCES


UNDERSTANDING SONAR AS A PRECURSOR TO UNDERSTANDING ITS ENVIRONMENTAL RISKS

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INTRODUCTION

“Sonar” is a broad, generic term commonly used without a complete understanding of what is being referred to, and, by extension, its environmental risks. In reality, “sonar” covers an expansive and diverse array of systems, active and passive, that rely on underwater acoustics to extract information from the marine environment. It is, therefore, axiomatic that an understanding of the different types of sonar is critical to effective understanding of the potential effects of these systems on sensitive aquatic fauna and the management of those risks.

DISCUSSION

The likelihood of a sonar system causing some form of disturbance or, in extreme cases, physical effects on aquatic fauna is a function and interplay of a range of factors related to the source, the water medium, and the receptor (URS 2004). Fundamentally, for an aquatic organism to be affected by a sonar, it needs to be able to “hear” the sonar (or, in severe cases, be close enough to be physiologically affected), be within the sonar’s zone of influence or the space within the water column where the sonar is detectable above background, and be at a received level where some form of response is elicited. These, in turn, are factors of the intensity, frequency, shape, and direction of the sonar signal, the “transparency” of the conducting water medium, and the hearing sensitivity of the receptor.

The role, function, and method of employment of an active sonar dictate its signal characteristics, including aspects such as frequency,