The Influence of Marine Biological Noise on Sonar Detection

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Introduction
It has long been noted that many marine animals make sound. After World War II, vocalization and acoustic characteristics of marine animals began to be extensively studied.
Sonar makes use of sound waves for detection in the ocean, so the sound emitted by marine animals affects sonar detection performance, just like other ocean ambient noise.
It is of great significance to study the effect of marine biological noise on sonar performance. Current research mainly focus on the effect of sonar systems on marine animals, especially marine mammals like whales and dolphins. Conversely, in this paper, we will investigate the influence of marine biological sound on sonar detection performance.

Properties of Marine Biological Noise
Marine animals including invertebrates, fish and marine mammals all make sounds. They use sound for predation, reproduction and communication. Crabs, shrimps and other crustaceans are among those marine invertebrates that make sounds. They make cracking sound, clicks or a rasping sound during eating or exercise – either by friction or hitting of their clamps and antennae. The frequency spectrum of the noise made by these invertebrates covers from 20 Hz to 20 kHz. Some mollusks also make sounds, which are relatively weaker and discretively distributed, and contribute little to the ocean ambient noise.

Fig. 1. Time-frequency representations of some typical marine biological noise: (a) blue whale song; (b) dolphin sound; (c) sperm whale sound.

Fig. 2. Sound speed profile.

Fig. 3. Transmission loss versus range.

Influence of Marine Biological Noise on Sonar Detection
Marine biological noise is a key component of ocean ambient noise, which even dominates in certain sea regions. Research finds that a variety of toothed whales can emit chirps or whistles between 1000 Hz and 10 kHz and are used for long range communication. The frequency of the sound emitted by large size baleen whales are generally lower than 400 Hz - some even lower than 20 Hz - and this is appropriate for remote communication. Sperm whale sounds have a detection range greater than 10 km. Blue whales and fin whales emit low frequency grunts at 10 Hz ~ 25 Hz, which can be detected by a large aperture sonar array at 600 km distance. As a result, the impact of marine mammal noise in raising ocean ambient noise would directly lead to a performance degradation of sonar systems.
Assume the depth of the sea area is 200 m. A broadband signal with the frequency from 500 Hz to 1 kHz is used for simulation because this resembles humpback whale noise. The source depth is 8 m and the receiving towed array is set at 150 m. A popular parabolic equation model, RAM, is used to predict the sound field in a range dependent waveguide. The environment was represented in this work by a three-layer model consisting of the water column; an underlying sedimentary layer; and, an absorbing substrate or basement. The sound speed profile is shown in Fig. 2. The properties of the silty sand are given by Hamilton.

Conclusion
Marine biological noise increases the ocean ambient noise notably in certain sea regions and this would influence passive sonar detection. Simulation results off the Hawaii sea regions where humpback whales are active reveal that the detection range of a towed sonar array drops dramatically from 25 km to 2~10 km due to the humpback whale sound.
The parameters of active sonar resemble those of marine mammal sound. Hence, active sonar detection will also be affected, with a higher false alarm rate due to marine mammal noise.