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Program book page 37-38:  
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## **The Soundscape of the Southern Ocean – How Quiet and how Loud can Nature be?**

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The Southern Ocean around the Antarctic continent provides some of the most extreme environmental conditions on earth which shape also the unique underwater soundscape. The area probably contains the most quiet locations within the world's oceans but is also stage for some of the loudest natural events. It is still relatively void of anthropogenic noise and is one of the most important feeding grounds for great whales. However, comparatively little acoustic data exists from this region so far because the collection of acoustic recordings is hindered by logistic constraints associated with this remote region.

### **Very Quiet**

The large cavities below the giant floating ice shelves of Antarctica are amongst the most isolated areas in the world - but with a window to the open sea. Neither local surface noise nor biological sources are present within hundreds of kilometers radius. Sound levels here should reflect unbiased readings of the long-range acoustic energy field - and yield a lower boundary of how quiet the ocean can get. During much of the year large parts of the polar oceans are covered by sea ice, which has a significant impact on the underwater acoustics. Sea ice isolates the water from the air, impeding the generation of waves, while the snow layer absorbs acoustic energy efficiently, creating an "anechoic chamber" which may serve as a natural lab to test and verify sound propagation models.

### **Very Loud**

But ice is also a major source of noise. Table icebergs, calved from the shelf, are the largest moving objects on earth, spanning areas of 1000 square kilometers with a thickness of several hundred meters. Driven by the ocean currents, billions of tons of ice can gain terajoules of kinetic energy, equaling that of a nuclear bomb. This energy can be released within a brief period of time when the iceberg touches ground or collides with other bergs or the ice shelf. These events produce some of the loudest natural broadband sounds in the ocean, rivaled only by earthquakes and can be recorded in distances as far as other continents. They would probably make perfect test signals to measure long range broadband sound propagation. However, their occurrence is relatively sparse, we detect about one or two such events in the vicinity of our Antarctic observatory per year. Additionally, smaller but frequent iceberg calving events, reaming of ice floes, exploding little bubbles of high pressure gas occlusions in melting glacier ice combine to a most diverse abiotic soundscape.

## **Relevant Biology**

However, it is the biology that produces the major contribution to the overall sound budget here. Despite the reduction of the blue whale population to a small fraction of their pre whaling size, the chorus of blue whales is the predominant acoustic source in the Southern Ocean, present on 365 days per year. Together with about ten other marine mammal species occupying this ocean area, they fill the whole audible frequency range with relatively little spatio-temporal overlap, suggesting that acoustic bandwidth is an important natural resource that different species compete for. Here we have the unique chance to study the acoustic ecology of a large ecosystem which is not yet significantly influenced by anthropogenic sound and resides in an extremely rich natural soundscape. And as many of its acoustic ingredients compare to anthropogenic emissions in other areas of the world, one could derive reference models of the interaction of sound and biology from here.

## **Data Acquisition**

All this is based on long term, wide area and high quality passive acoustic data. Our current effort builds on an established network of oceanographic moorings in the Weddell sea, which is fitted with long term acoustic recorders capable of recording broad band audio continuously for several years. Along with the permanent acoustic observatory on the ice shelf, PALAOA, which features a hydrophone array protected under a 100 m thick ice shield, this covers a significant part of the Weddell basin from the shore to the deep sea. Sea ice coverage and ice berg movement is captured by high resolution satellite images and local ship traffic is monitored by AIS receivers. Our acoustic record spans 6 years by now will be continued to be able to characterize typical annual fluctuations and long term trends in both the acoustic background and animal behavior and set them in relation to abiotic factors. We believe that this dataset will serve as a valuable reference for many ocean noise related questions and encourage to set up a similar networks in other polar seas.