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Correlating Military Sonar Use with Beaked Whale Mass Strandings: What Do the Historical Data Show?

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Abstract

There have been several incidents in which U.S. Navy sonar operations at sea coincided in time and location with a mass stranding of marine mammals, particularly beaked whales. Although a conclusive cause-and-effect relationship has not been established, there is strong evidence and scientific concern that use of military sonar has resulted in beaked whale mass strandings. Most previous attempts to determine whether military sonar use and whale strandings are correlated have looked at mass stranding records of beaked whales and have singled out those instances in which military operations appear to coincide in time and location with a mass stranding event. In this study, historical data on beaked whale mass strandings and military exercises that were likely to include active sonar use were compiled, and statistical analyses were performed to determine the level of correlation between these events for four geographic regions. Strandings were significantly correlated with naval activity in the Mediterranean and Caribbean Seas, but not off the coasts of Japan and southern California.

Key Words: beaked whales, Ziphiidae, *Ziphius*, *Mesoplodon*, *Stenella*, *Balaenoptera*, mass strandings, military sonar, bootstrap reiterative estimation, correlation analysis

Introduction

Concern about the effects of anthropogenic noise on marine life has grown over the last decade. Early concerns about ocean noise focused on an increase in the low-frequency noise from increased shipping traffic (Payne & Webb, 1971) as well as increased speed and size of large commercial vessels impacting large whales (National Research Council [NRC], 2003). In the 1990s, the debate about ocean noise changed markedly to focus on military sonars, beginning with a mass stranding event in the Mediterranean Sea (Frantzis, 1998, 2004; D'Amico & Verboom, 1998). The NATO Undersea Research Centre (NURC), formerly known as SACLANT Undersea Research Centre, is a NATO oceanographic research center in La Spezia, Italy. NURC conducted a Shallow Water Acoustic Classification (SWAC) research trial in the Kiparissiakos Bay in western Greece in May 1996, using the Towed Vertically Directive Source (TVDS). The TVDS sound source had two individual source arrays tuned to low and mid frequencies (centered at 600 Hz and 3 kHz, maximum source levels of 228 and 226 dB re 1µPa at 1 m, respectively). Soon after one set of these trials began, a mass stranding of Cuvier's beaked whales (*Ziphius cavirostris*) occurred in the vicinity of the sonar test. Beaked whale mass strandings are relatively rare events. Simmonds & Lopez-Jurado (1991) noted a concern for a possible link between naval operations and whale mass strandings, but Frantzis (1998) was the first published paper citing specific military sonar use in relation to a beaked whale stranding, bringing concern about the possible impacts of military sonars into sharp focus for both the public and marine mammal research community.

The first major stranding event known to be associated with a U.S. Navy sonar exercise occurred in March 2000. The U.S. Navy conducted active sonar training in conjunction with a battle group exercise in a channel near the Abacos Islands, an island group of the Bahamas. The event involved several warships employing active sonar for protracted periods. Within hours of the ships' passages, 14 beaked whales (nine *Z. cavirostris*, three *Mesoplodon densirostris*, and two in which species could not be identified) were found stranded along the shores of Abaco and Grand Bahama to the north, and three single animal strandings of other species were reported nearby. Beaked whales

1950 and 2004, the period after the implementation of modern high-power MFAS. For this analysis, the listings in the D'Amico et al. data set were supplemented with additional information from records at the Navy Historical Center, Washington, DC, for the regions of interest.

Operational data for the Caribbean and southern California were primarily obtained from the U.S. Navy. Data for naval operations in the Mediterranean and off the coast of Japan included exercises led by allied navies (e.g., NATO exercises in the Mediterranean and Japanese or Korean exercises around Japan [all naval operational data were approved for release]). However, because these data were gathered from U.S. Navy records, they are skewed toward U.S. naval events and likely missed many allied exercises in which there was no U.S. involvement. Because there is no reason to assume foreign mid-frequency sonars are more or less likely to affect marine mammals than U.S. Navy sonars, the overrepresentation of U.S. operations does not introduce a bias. Only exercises in which mid-frequency sonar was likely to have been used, based on exercise descriptions and participating ships, were included. However, these exercises were not reconstructed down to the level of ship-tracks and timelines to determine exactly when and where (within the overall exercise area) sonar was used. Analyses of that type would be a useful follow-on to this study to establish definitive cause-effect relationships if the required information can be readily obtained. The goal of this paper is thus to test for significant correlations using the above data sets.

Essentially, these data comprised major (multi-ship) exercises. Correlations between beaked whale mass strandings and exercises of this type may not be applicable to all sonar use (i.e., single ship limited-use events).

Results

Mediterranean Sea

The Mediterranean Sea was divided into five regions: (1) Western, (2) Adriatic, (3) Central, (4) Aegean, and (5) Eastern (Figure 1). Figure 2 shows a timeline of periods of naval activity and times of beaked whale mass strandings in each of the five regions of the Mediterranean Sea shown in Figure 1. All of the stranding events shown in this figure involved *Z. cavirostris*, the only beaked whale that is common in the Mediterranean Sea (Notarbartolo & Demma, 1994).

Overall, five of the 14 *Z. cavirostris* mass strandings observed in the Mediterranean Sea from 1992 to 2004 coincided with the following naval operations:

- 25 February 1996 in the Gulf of Valencia, Spain
- 12 May 1996 on the west coast of Greece
- 2 and 3 October 1997 on the west coast of Greece
- 7 February 2001 on the coast of Algeria

Note that two of the mass strandings occurred within 1 d and 96.5 km of each other. These were counted as two separate events to be consistent with the definitions in D'Amico et al. (this issue). Counting this as a single event does not change the conclusions of the statistical analyses. Of the five events that coincided with naval operations, only the 7 February 2001 event is not reported in D'Amico et al. The inclusion of an additional spatial-temporal correlation between naval activities and a beaked whale mass stranding off the coast

Figure 1. Geographic boundaries of the five study regions, Mediterranean Sea

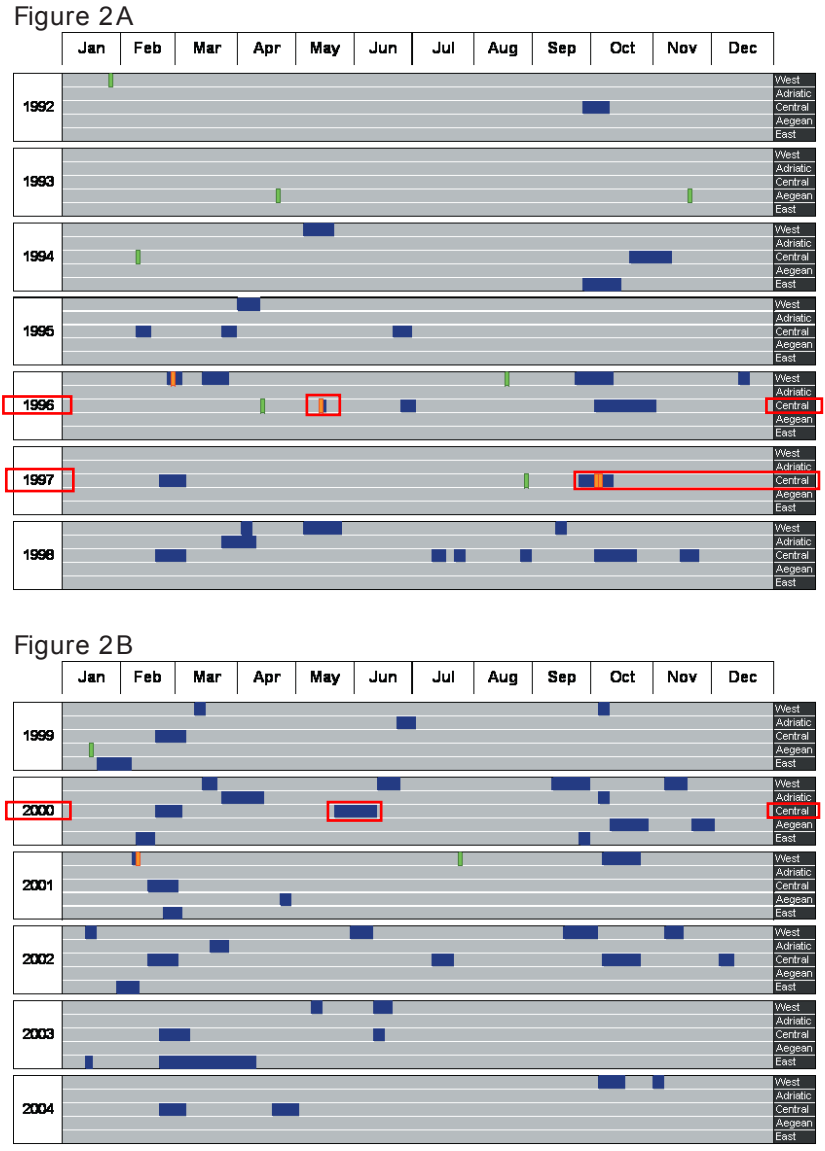

Figure 2. Timeline of naval operations and beaked whale mass strandings, Mediterranean Sea; bars indicate periods of major naval activity, and vertical tick marks indicate beaked whale mass strandings. A: 1992 to 1998; B: 1999 to 2004.

of Algeria is due to the availability of the detailed operational data used for this study.

What are the implications of five of the 14 beaked whale mass stranding events coinciding with naval operations? To address this question, a bootstrap resampling technique was used (Efron & Tibshirani,1993). The bootstrap uses the stranding data distribution to estimate the number of strandings likely to have occurred during periods of naval activity if stranding occurrences during periods of naval activity followed the same underlying distribution as the strandings during times of no naval activity. This procedure resulted in an estimate for the number of strandings expected during times of naval activity in the absence of a correlation between strandings and sonar. This process was then repeated many times to develop a distribution of such estimates. This distribution can then be compared to the number of strandings actually observed. The expected value of this distribution reflects the stranding rate during the entire time period. The bootstrap is nonparametric, assumes no analytic distribution of data, and is based only upon the empirical distribution of the strandings