Do dolphins alter their vocal behaviour in response to military sonar? A review of analytical methods

C.S. Oedekoven[a,*], **L. Thomas**[a], **R. Langrock**[a], **J. Oswald**[b], **E. Ferguson**[b], **T. Yack**[b] and **T. Norris**[b]

[a]Centre for Research into Ecological and Environmental Modelling
School of Mathematics and Statistics
University of St Andrews
St Andrews, Scotland
*cso2@st-andrews.ac.uk

[b]Bio-Waves, Inc.
364 2nd Street, Suite 3
Encinitas, CA

Keywords: Cox point process; generalised estimating equations; Mahalanobis distances; presence-absence; state-space models

Abstract: The vocal repertoire of dolphins encompasses three categories of vocalisations – whistles, clicks and buzzes – which are used in different contexts, e.g. for socialising, under water echolocation or homing in on prey during foraging. Mid-frequency active sonar (MFAS) is used by military vessels for detecting objects. It involves the underwater emission of intense sound pulses that are often repeated. As the range of sound frequencies used for MFAS often overlaps that of dolphin vocalisations, we were interested in identifying any potential changes in the vocal behaviour that dolphins may exhibit in response to military sonar exercises. To identify such changes, we compare the vocal behaviour of dolphins from periods before the sonar exercises to the behaviour of dolphins from periods during or after the exercise at the same locations. We review some of the potential changes in vocal behaviour in response to military sonar using acoustic data collected with passive acoustic monitoring devices and the corresponding analytical methods: 1. do dolphins vocalise more or less in the presence of sonar? 2. given vocalisation, does the probability of using any of the vocalisation categories change in the presence of sonar? 3. do parameters describing the individual vocalisations, e.g. maximum frequency, change in the presence of sonar? For each question, we define a response variable which is modelled using factor, linear and smooth terms. Regardless of approach, we expect model errors to be correlated and potentially overdispersed. These issues may be addressed using generalised estimating equations or, alternatively, using stochastic processes such as state-space models or Cox point processes. We illustrate the approaches with acoustic data collected in the presence of vocalising dolphins and MFAS using Marine Acoustic Recording Units off the coast of Jacksonville, FL and in Onslow Bay, NC.