Do dolphins alter their vocal behaviour in response to military sonar?

A review of analytical methods

C.S. Oedekoven¹, L. Thomas¹, R. Langrock¹, J. Oswald², E. Ferguson², T. Yack² and T. Norris²

¹CREEM, University of St Andrews ²Bio-Waves, Inc.
Study Sites

Marine Acoustic Recording Units (MARU): with 32 kHz sampling rate
Working with Acoustic Data

- Recording Devices
- Detectors & Species ID
- Statistical Analysis
Types of dolphin vocalizations

- Whistle
- Click
- Buzz
ROCCA:
Real-time identification of whistles

Types of dolphin vocalizations
Start times of vocalisation events
Start times of sonar pings

Whistles

Duration
Presence of vocalization type
Species ID

Various parameters e.g. Sound pressure level
Peak frequency
Etc.

Sep 13  
Sep 18  
Sep 23  
Sep 28  
Oct 03

Sonar exercise

Data included: 24 hours before - 24 hours after each sonar exercise
How do we quantify a potential effect of sonar?

1. Is the probability of detecting vocalisations different in the presence of sonar?

Data: 1 minute segments

Response: presence of vocalisations
How do we quantify a potential effect of sonar?

2. Does the probability of detecting whistles, clicks or buzzes within a given vocalization event change in the presence of sonar?

Data: Vocalisation events

Response: presence of whistles, clicks or buzzes (separate models)
How do we quantify a potential effect of sonar?

3. Given that a dolphin school produces whistles, do whistle characteristics change in the presence of sonar?

Data: Individual whistles

Response: Response intensity using Mahalanobis distances\(^1\): 9 whistle characteristics

Problems encountered

- Correlation
- Overdispersion
- Collinearity of covariates
- Model selection for GEEs

Generalised estimating equations (GEEs)¹
Variance inflation factors²
Marginal p-values³


³Scott-Hayward LAS, CS Oedekoven, ML Mackenzie and E Rexstad. 2013. MRSea package (version 0.0.1). Tech report. CREEM. University of St Andrews.
1-minute presence of vocalisations

Final model

- Factor covariate Site and polynomial spline for Time of day

Partial fit plots for delphinids excluding pilot whales

Partial fit is on the logit-link scale
Presence of whistles given vocalisations

Final model

- Factor covariates: Site, Presence of clicks, Sonar

Partial fit plots for delphinids excluding pilot whales

Partial fit is on the logit-link scale
Response intensity: Mahalanobis distances using 9 whistle characteristics

Preliminary model

- Factor covariates: Site and Sonar

Partial fit plots for delphinids excluding pilot whales

Partial fit is on the identity link scale
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Calculating Mahalanobis Distances

\[ D_M(x) = \sqrt{(x - \mu)^T S^{-1} (x - \mu)} \]

- $x$ is a vector of whistle parameters
- $\mu$ is a vector of mean values for each parameter for all control whistles
- $S$ is the covariance matrix for all control whistles