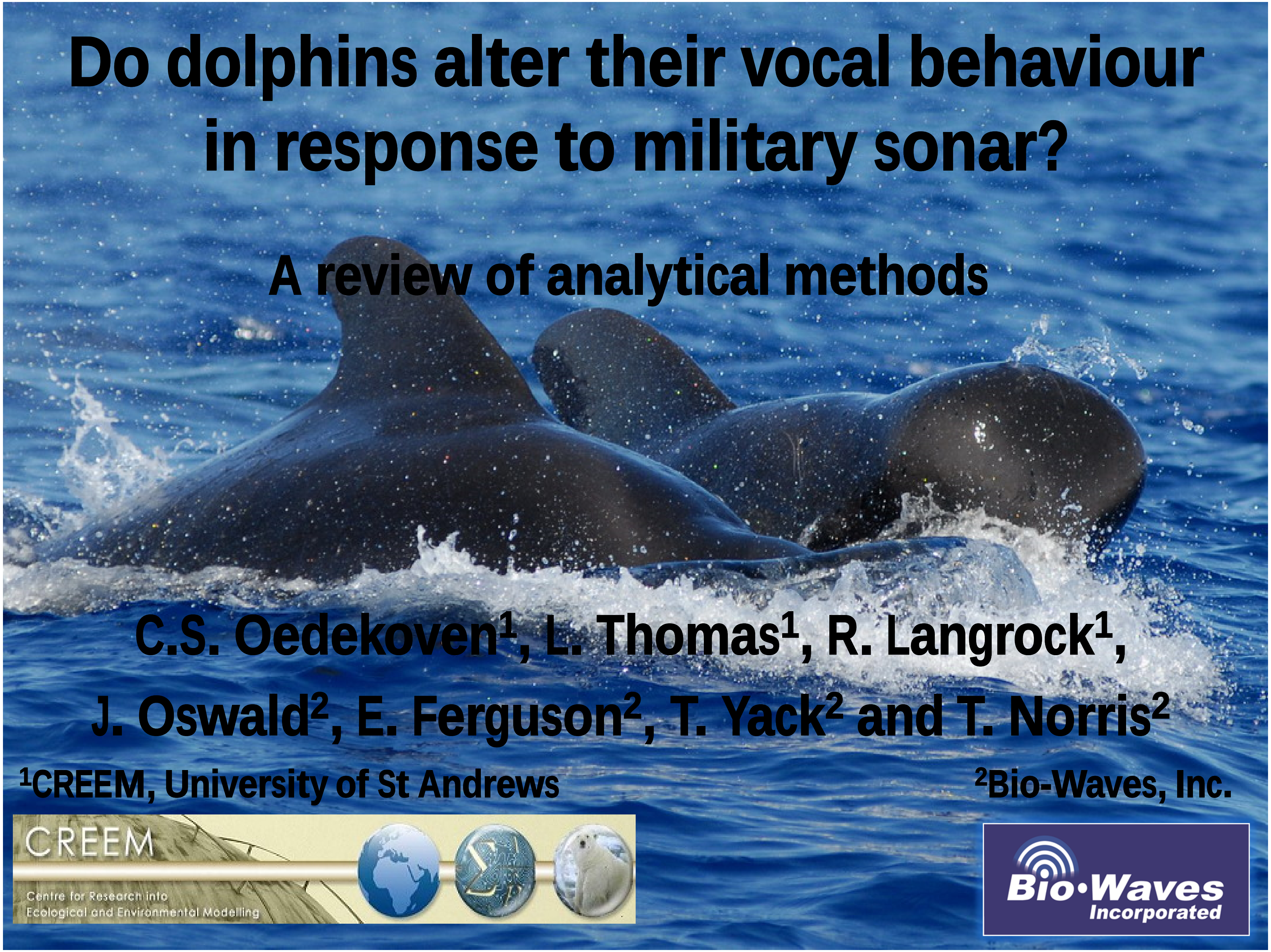


Do dolphins alter their vocal behaviour in response to military sonar?

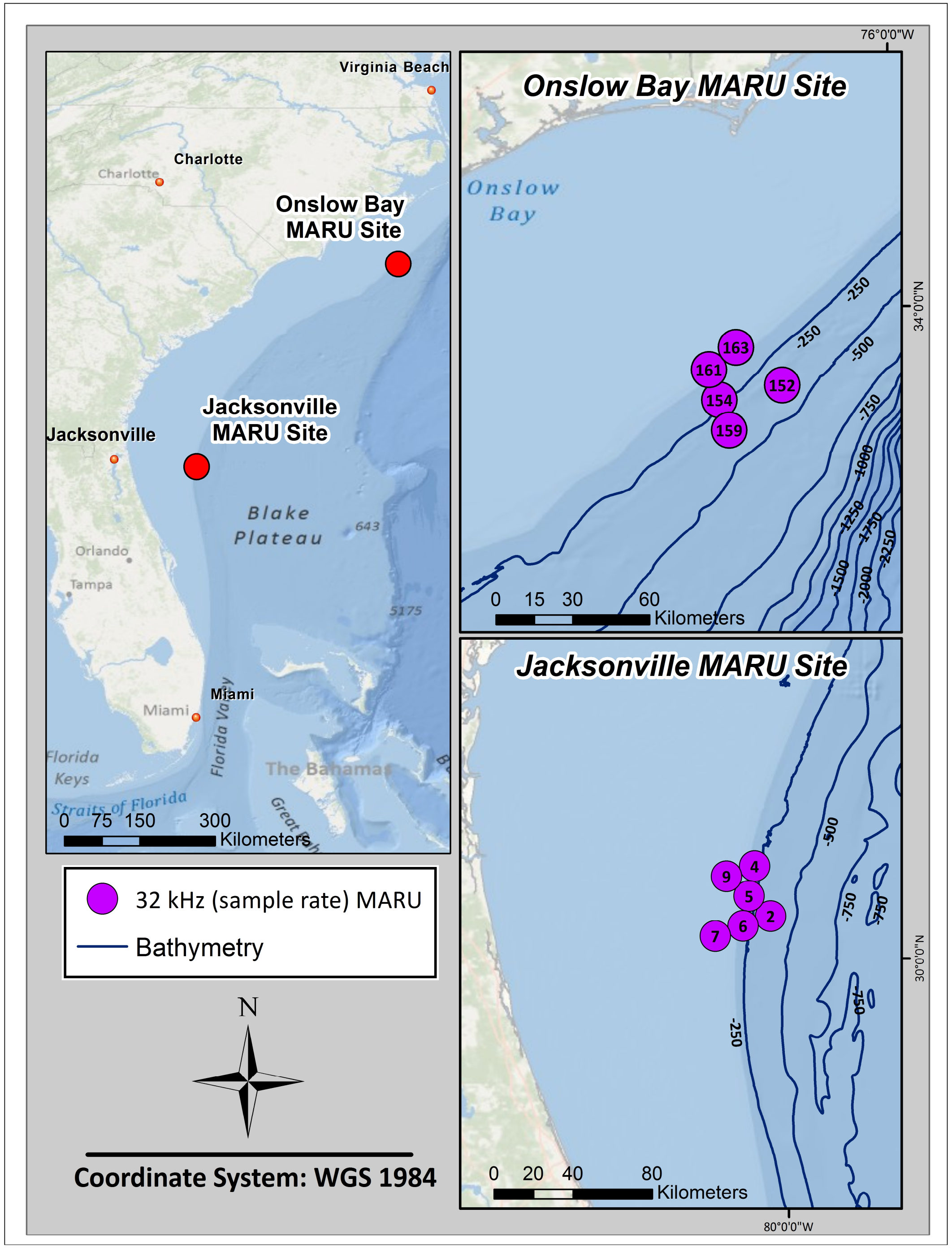
A review of analytical methods

C.S. Oedekoven[1], L. Thomas[1], R. Langrock[1],
J. Oswald[2], E. Ferguson[2], T. Yack[2] and T. Norris[2]

[1]CREEM, University of St Andrews [2]Bio-Waves, Inc.

CREEM
Centre for Research into Ecological and Environmental Modelling

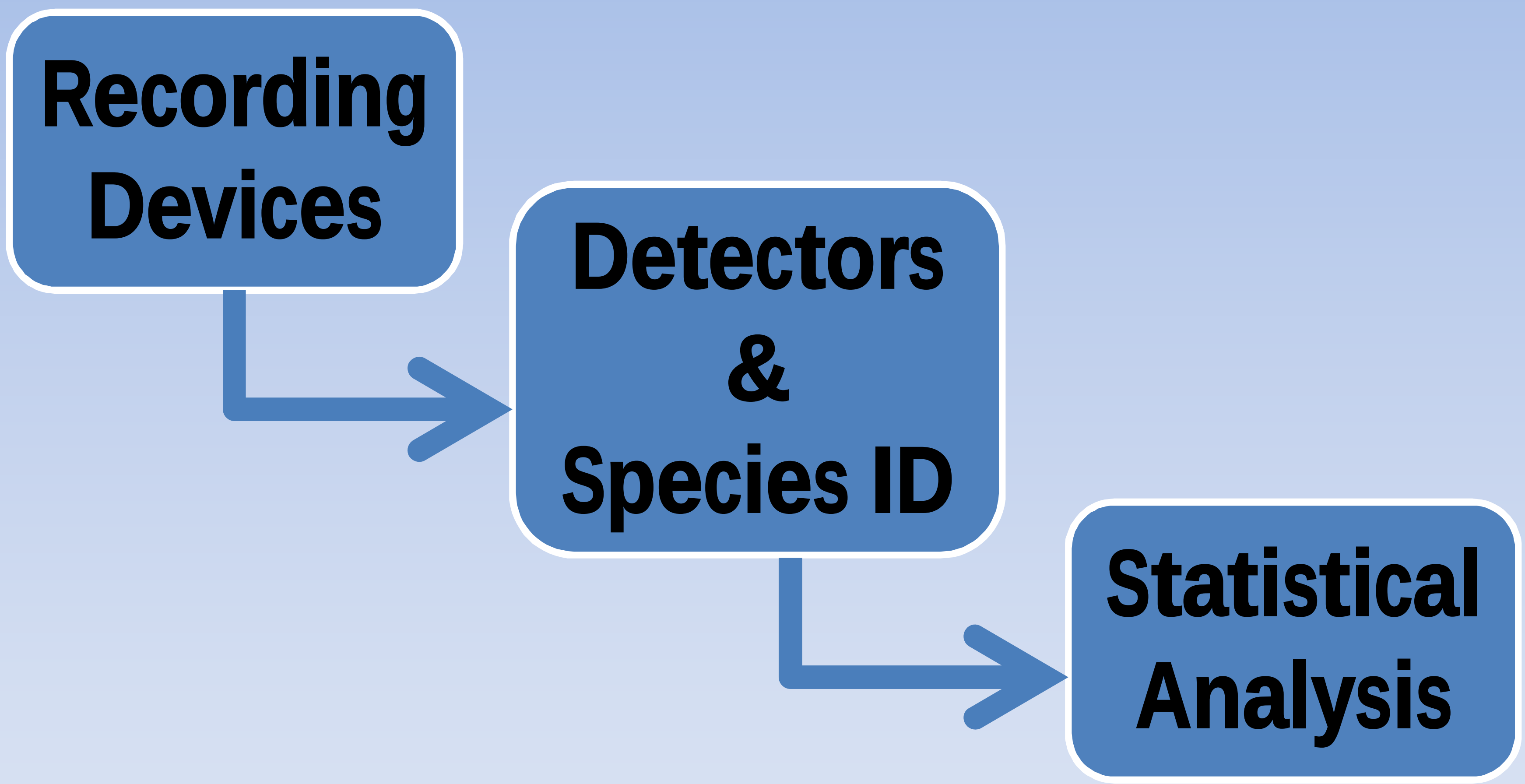
Bio·Waves Incorporated



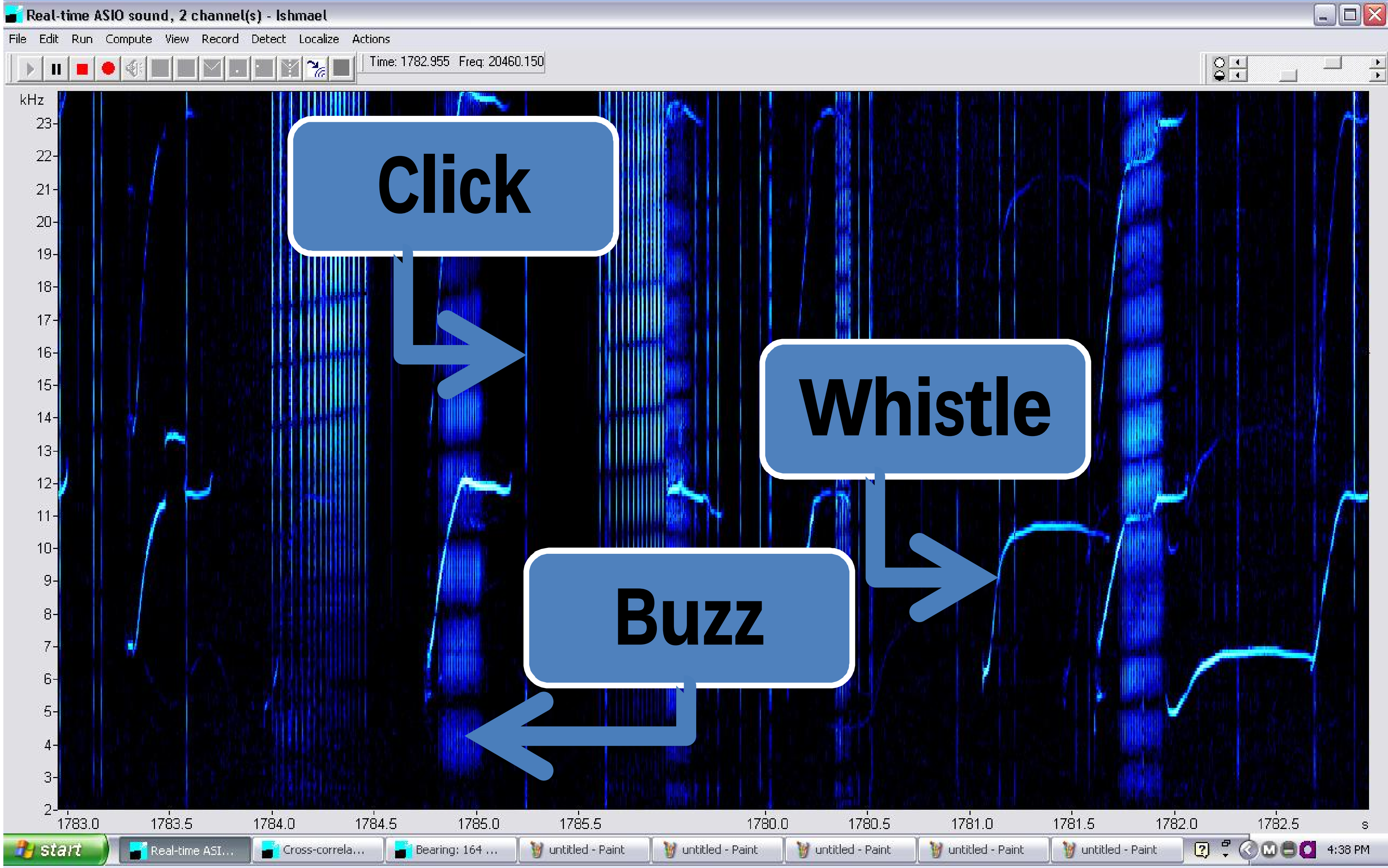
Study Sites

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

Working with Acoustic Data



Types of dolphin vocalizations



ROCCA:
Real-time identification of whistles

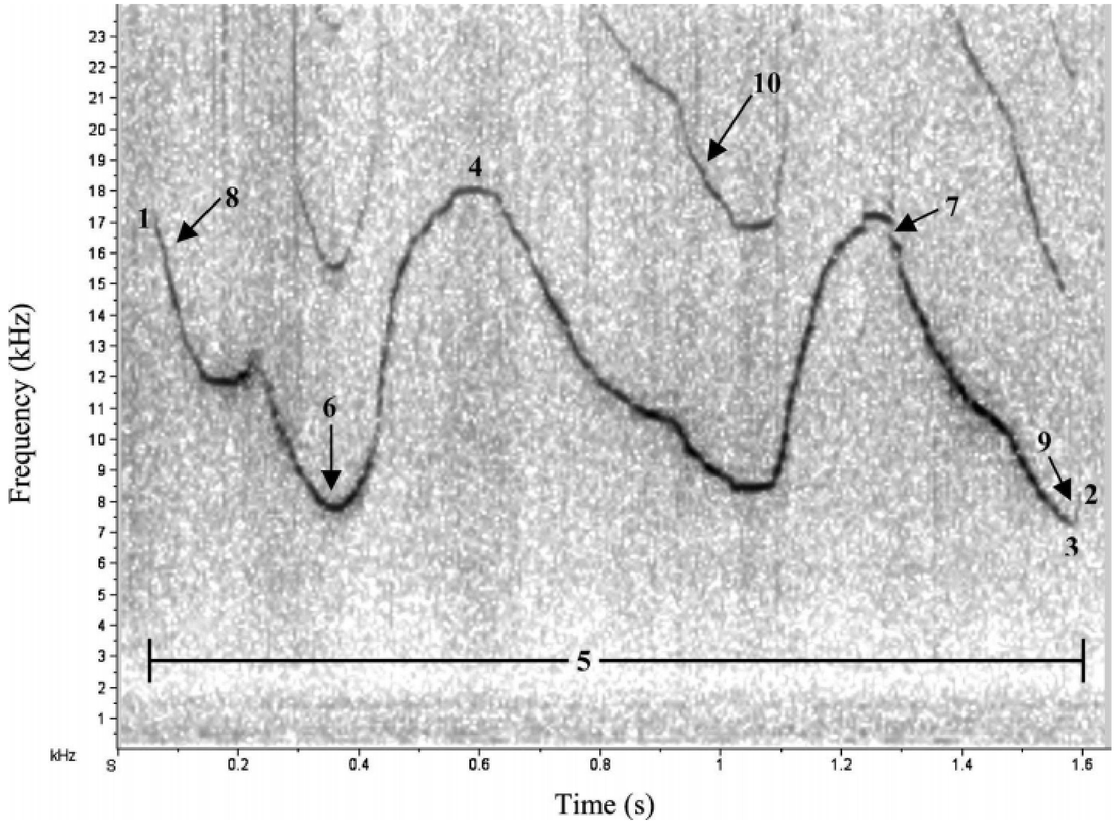
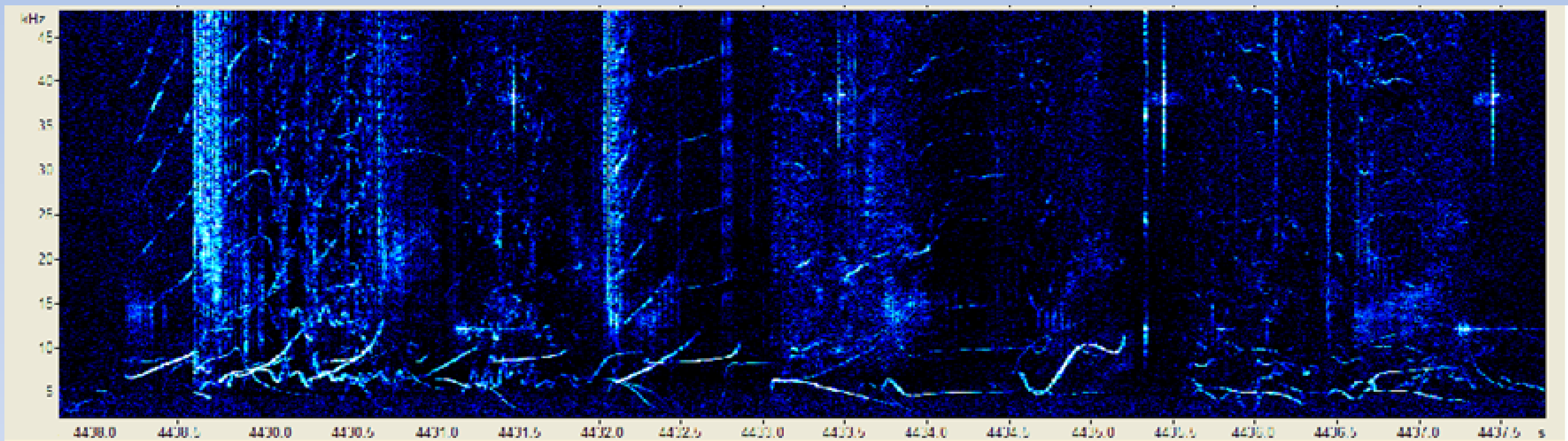


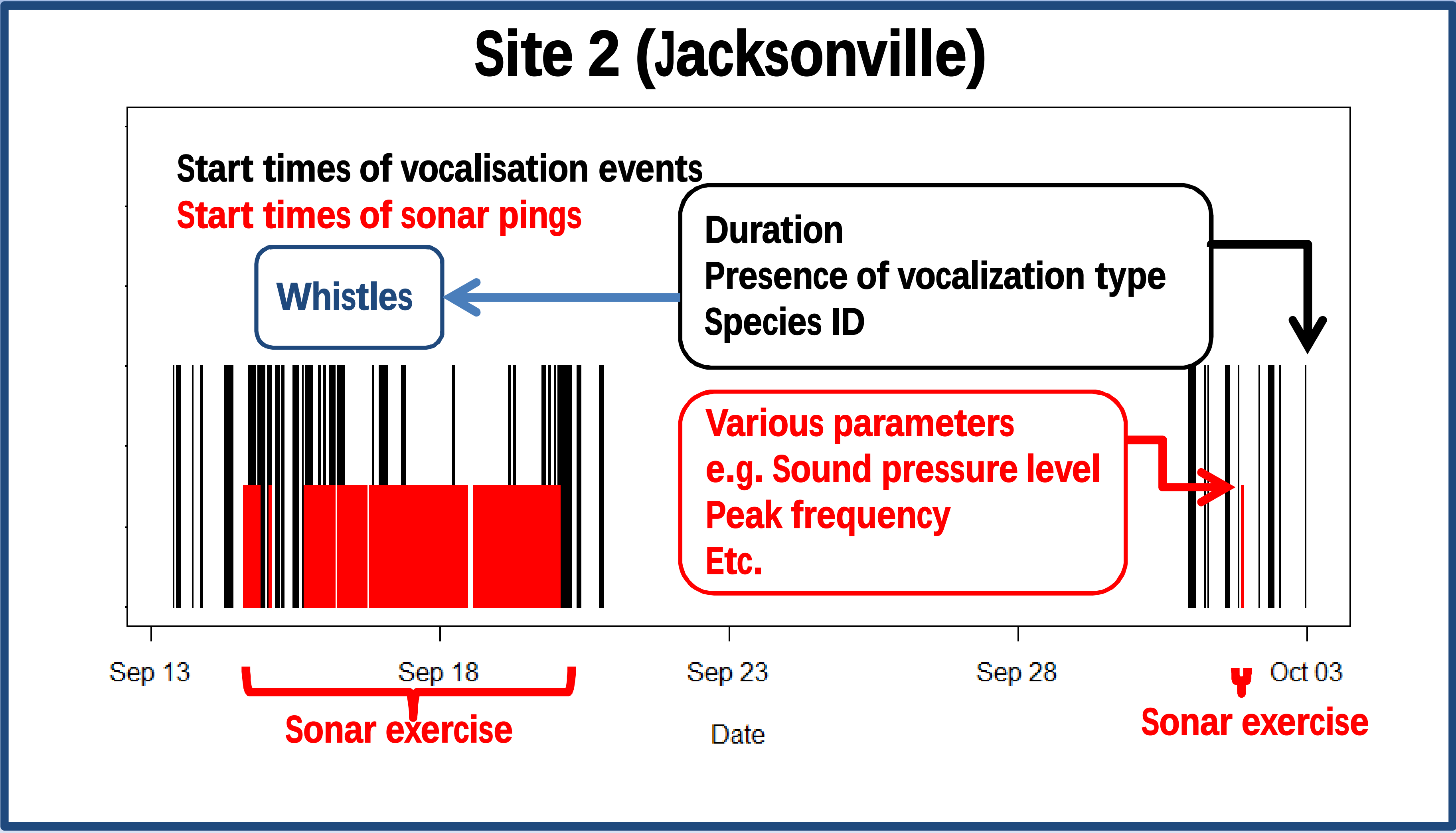
FIG. 2. Spectrogram of a bottlenose dolphin whistle (512-point FFT, Hanning window), showing the ten variables that were measured from each whistle. (1) Beginning frequency (kHz), (2) end frequency (kHz), (3) minimum frequency (kHz), (4) maximum frequency (kHz), (5) duration (s), (6) number of inflection points (defined as a change from positive to negative or negative to positive slope), (7) number of steps (defined as a 10% or greater increase or decrease in frequency over two contour points), (8) slope of the beginning sweep (positive, negative, or zero), (9) slope of the end sweep (positive, negative, or zero), and (10) presence/absence of harmonics (a binary variable).

Oswald et al. 2007: A tool for real-time acoustic species identification of delphinid whistles. J. Acousti. Soc. Am. 122(1) 587-595

Types of dolphin vocalizations



Time series



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

[1]DeRuiter et al. 2013. First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. Biol Lett 9: 20130223.

Problems encountered

- Correlation
- Overdispersion

→ Generalised estimating equations (GEEs)[1]

- Collinearity of covariates → Variance inflation factors[2]
- Model selection for GEEs → Marginal p-values[3]

[1]Ghisletta , P and D Spini. 2004. An Introduction to Generalized Estimating Equations and an Application to Assess Selectivity Effects in a Longitudinal Study on Very Old Individuals. J.of Edu.and Beh. Statistics.29(4) 421–437

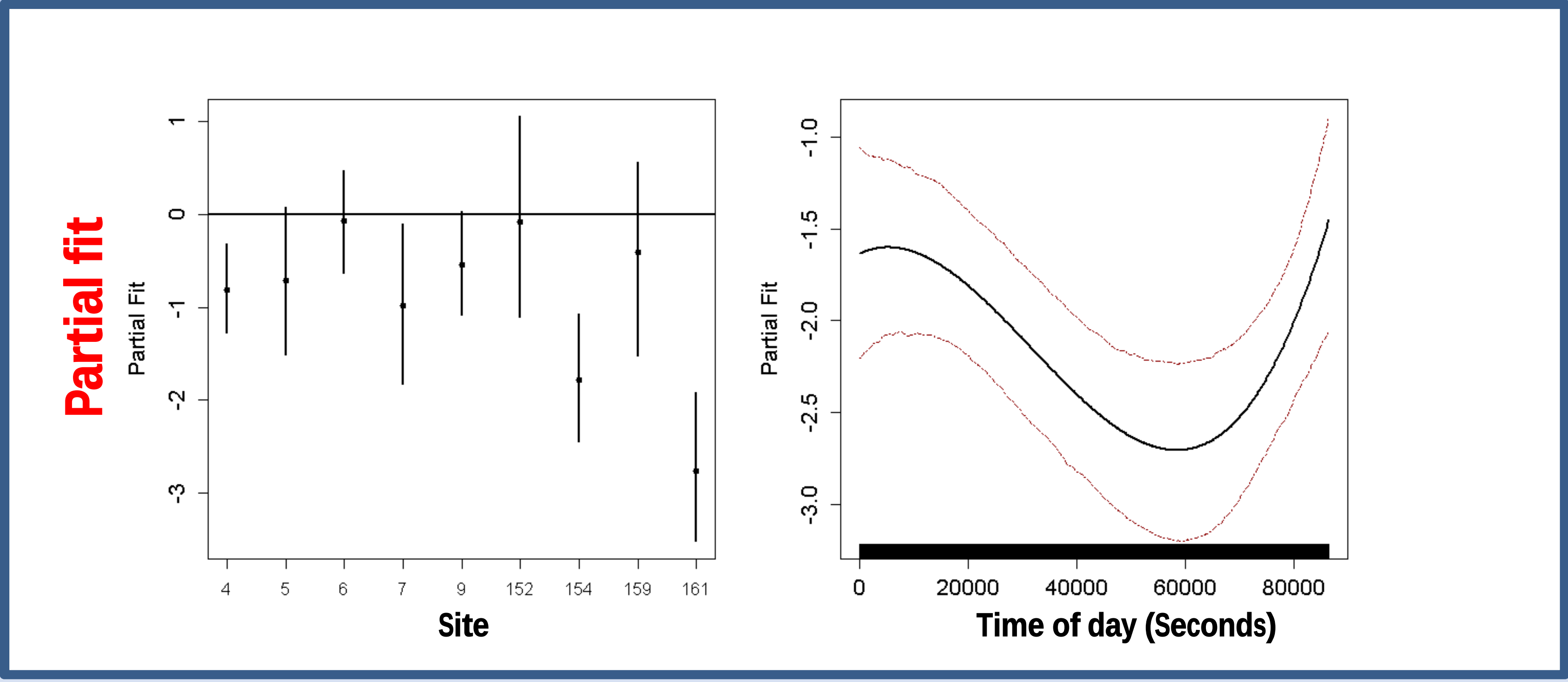
[2]Fox, J. 2008. Applied Regression Analysis and Generalized Linear Models, Second Edition.

[3]Scott-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



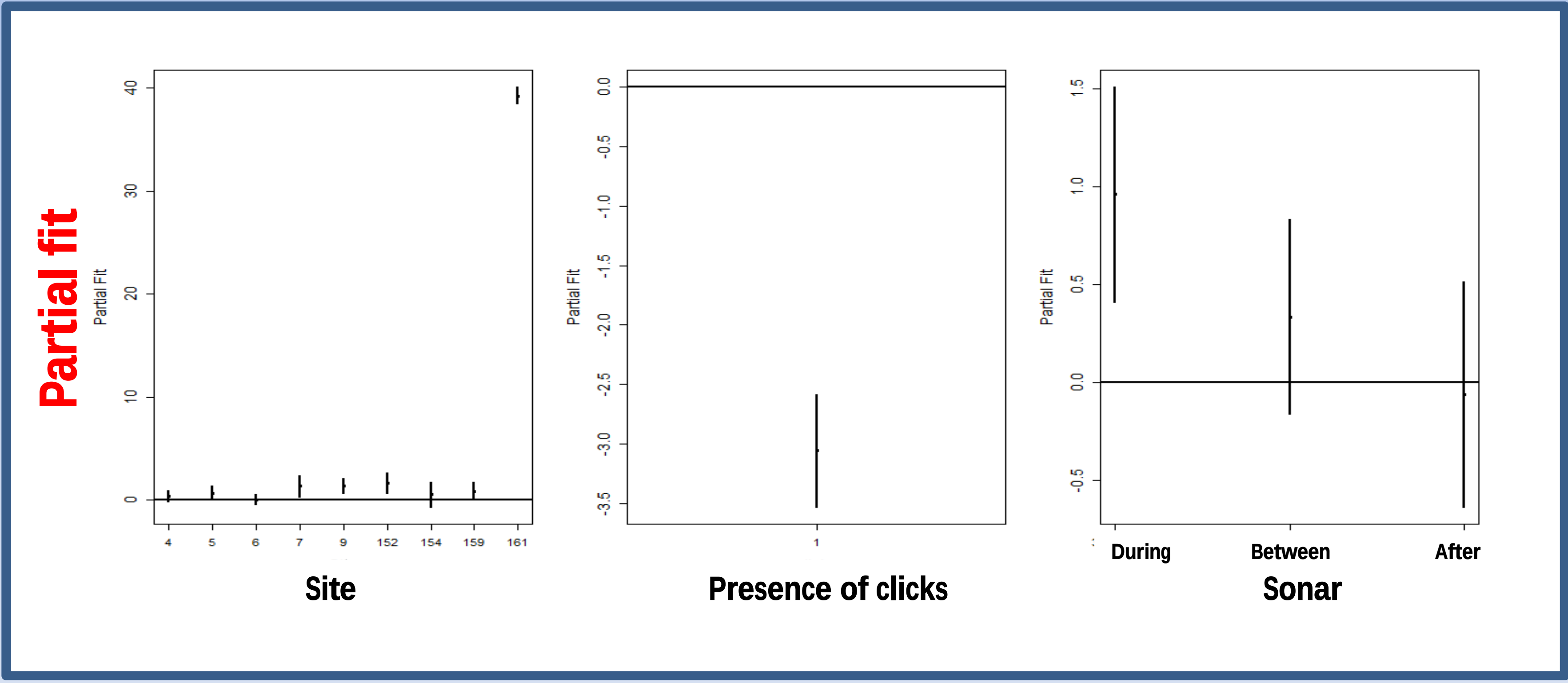
Partial fit plots for delphinids excluding pilot whales

Partial fit is on the logit-link scale

Presence of whistles given vocalisations

Final model

- Factor covariates: Site, Presence of clicks, Sonar



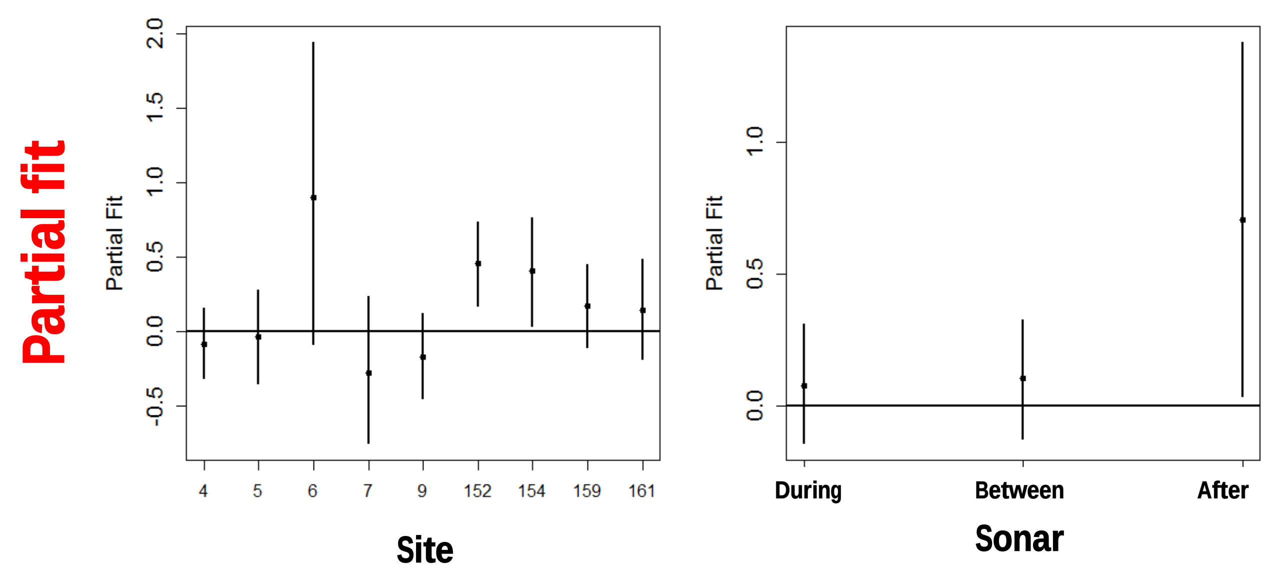
Partial fit plots for delphinids excluding pilot whales

Partial fit is on the logit-link scale

Response intensity: Mahalanobis ditances 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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Lindesay Scott-Hayward and Ben Stevenson (all CREEM)
Logistical support: Joel Bell and Anurag Kumar (NAVFAC LANT) and Daniel Engelhaupt (HDR)

Calculating Mahalanobis Distances

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

x is a vector of whistle parameters

μ is a vector of mean values for each parameter for all control whistles

S is the covariance matrix for all control whistles