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

Review of some potential changes and the corresponding analytical methods

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1. Background

- Concerns about increasing potential disturbance of cetaceans due to human activities in the ocean have led to an increased effort to study the responses of cetaceans to such disturbances.
- A source of potential disturbance is mid-frequency active sonar (**MFAS**) used by military vessels, which involves the underwater emission of intense and repetitive sounds.
- Cetaceans produce a variety of vocalization types for social or environmental sensing which vary among species, populations and behavioural context. The range of frequencies of these sounds often overlaps with the frequencies used for MFAS increasing the potential for disturbance.
- **The goal of this study was to develop robust statistical methods that can be used to evaluate changes in the vocal behavior of cetaceans in response to MFAS.**

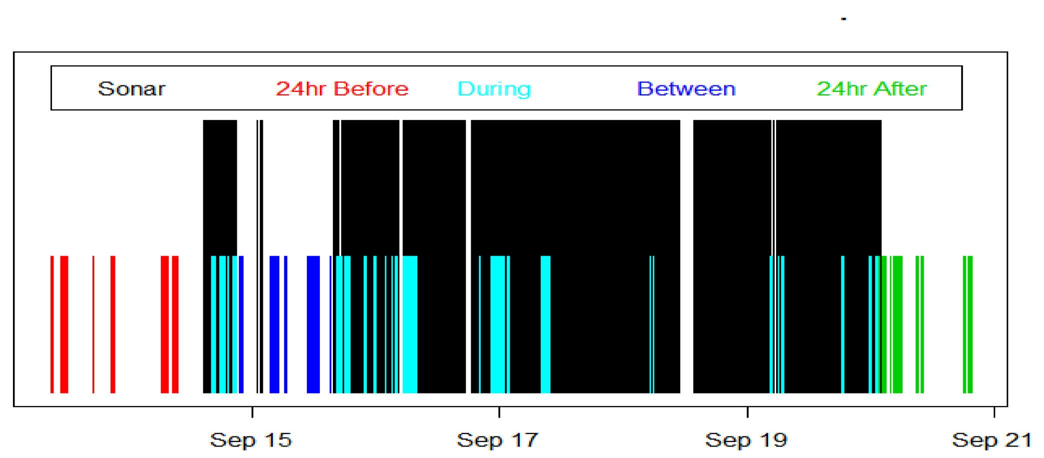


Fig. 2. Subsample of the data included: time series of detections of delphinid vocalizations (excluding pilot whales) and sonar pings at the JAX Site 2 in Sept. 2009.
- Colored lines: sub-events containing multiple vocalizations not separated by >1min. Available information was presence of vocalization type and several parameters (e.g. maximum frequency) for randomly chosen whistles
- Black lines: sonar pings with parameters

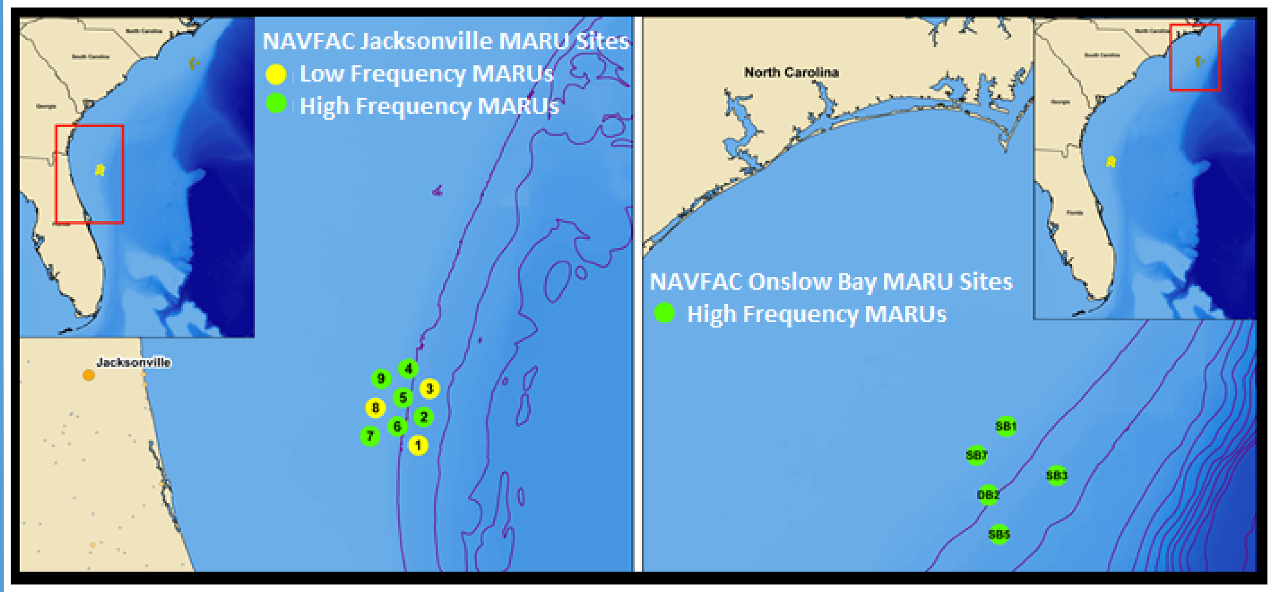


Fig. 1. Marine Acoustic Recording Units (MARUs) off Jacksonville, FL (JAX) and Onslow Bay, NC (OB) off the US east coast during July 2008 and Sept.-Oct. 2009.

2. Methods

- We compared the detected vocalizations from periods before (24hr), during and after (24hr) sonar exercises using acoustic data collected in the presence of vocalizing cetaceans (Minke whales, sperm whales and delphinids) and MFAS using Marine Acoustic Recording Units (**MARUs**).
- Using Real-time Odontocete Call Classification Algorithm (ROCCA, Oswald 2007), delphinid detections were classified to the lowest taxonomic group possible: short-finned pilot whale, striped dolphin, short-beaked common dolphin or unidentified dolphins.
- Separate statistical models that describe potential changes in vocal behaviour were built for minke, sperm and pilot whales and remaining delphinids combined (**hereafter dolphins**) due to relatively high uncertainty in species id.
- **We describe the methods using dolphin detections.**

3. Analytical and data challenges

- Time discretization:
  - 1-min segments (presence of acoustic encounters models)
- Categories for covariate Sonar:
  - 24hr before or after sonar = before or after
  - Sonar on = during
  - <48hr gap in sonar = between
- Correlated and overdispersed data:
  - Model fitting tool: **Generalized estimating equations** (**GEEs**, Gisletta & Spini 2004)
- **Alternatively: Hidden Markov Models: ASK ME!!!!**

Fig. 3. Autocorrelation of Pearson's residuals from presence models for delphinids including 95% CIs around zero autocorrelation (blue lines).

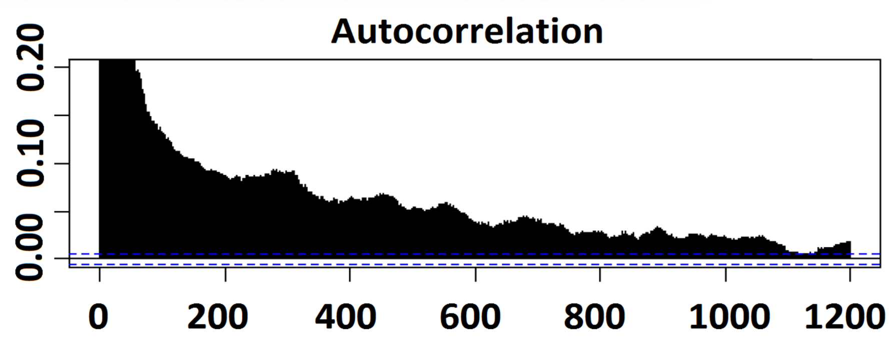


Table 1. Explanatory covariates for GEE analysis (excluding collinear covariates)

Covariates for analyses	Description
Sonar	Before / During / Between / After
Time	Time of day
Site	Site numbers
Sonarlag	Time lag since last sonar
Peak frequency	--
Length of sonar event	--
Mean ping interval	--
SDEV ping interval	--
Mean repetition rate	--
SDEV repetition rate	--
Mean peak frequency	--
SDEV minimum frequency	--
SDEV maximum frequency	--
Presence of sonar ping type	3 sonar ping types x 3 lengths
Presence of signal type	Whistles / Clicks / Buzzes

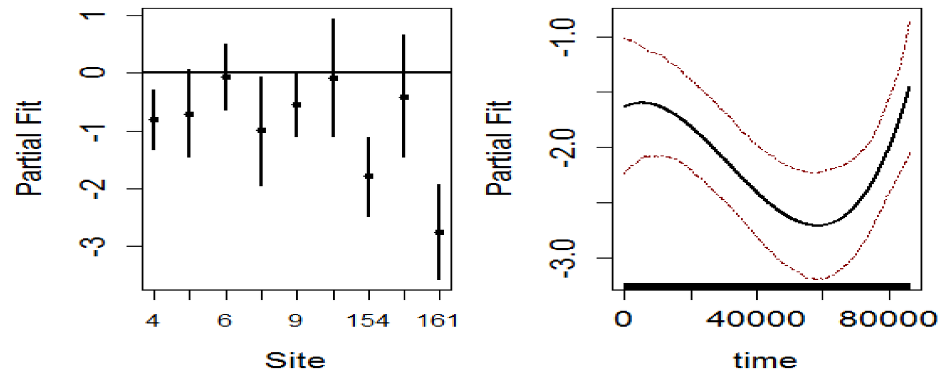
4. How do we quantify a potential effect of sonar? GEE models for dolphins

(Research question, response variable for analysis, number of observations)

4.1 Is the probability of detecting vocalizations different in the presence of sonar?

Presence / absence of acoustic encounters in 1-min segments: 148,359 1-min segments (only 6% presences)

Fig. 4. Partial fit (on the scale of the logit-link function) for final presence model including covariates *Site* and *Time*.

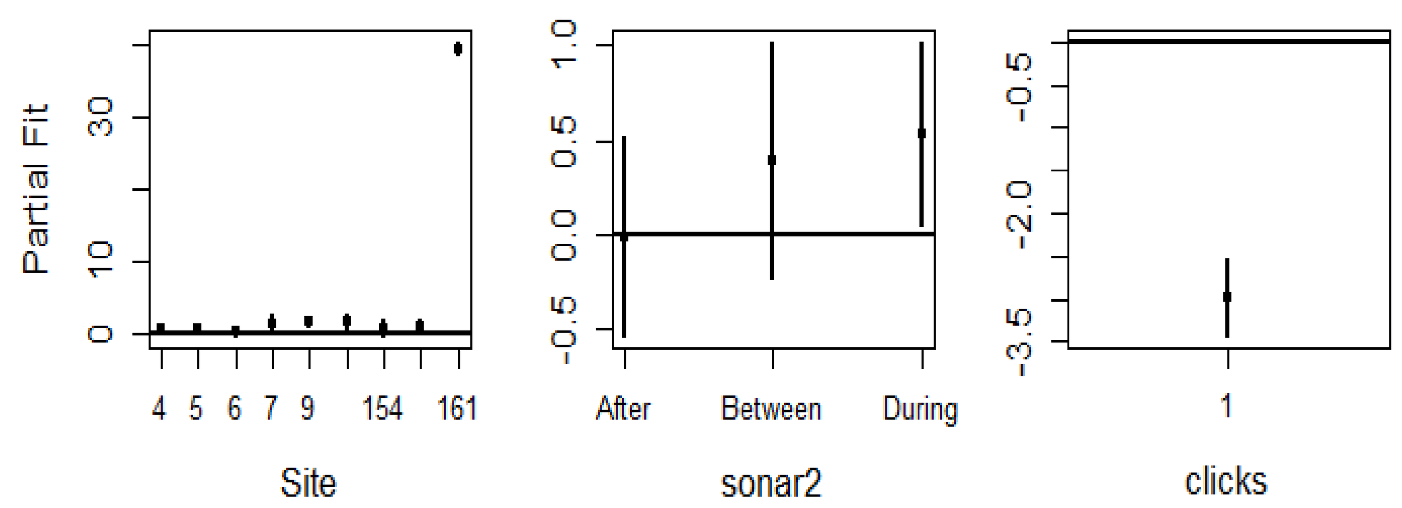


We found no evidence in our data that the probability of detecting dolphin vocalizations changed in the presence of sonar. The final model only contained covariates that were not related to sonar.

4.2 Does the signal type (whistle, click or buzz) change in the presence of sonar? Example: whistles

Presence / absence of whistles within a vocalization sub-event (no gaps > 1 minute): 2401 vocalization sub-events

Fig. 5. Partial fit (on the scale of the logit-link function) for final presence of whistles within acoustic sub-event model including covariates *Site*, *Sonar* and *Presence of clicks*.

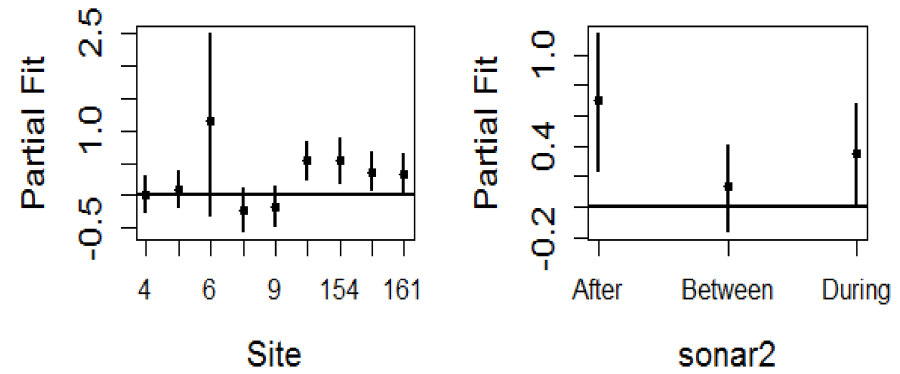


We found some evidence in our data for an increased presence of whistles during sonar emissions. The final model contained the covariate *Sonar* for which the coefficient 'during' was significantly positive.

4.3 Do the characteristics of vocalizations change in the presence of sonar? 2234 whistles classified as common or striped

Response intensity (constructed by combining multiple whistle characteristics into Mahalanobis distances; DeRuiter et al. 2013)

Fig. 6. Partial fit for response intensity models including covariates *Site* and *Sonar*.



We found some evidence in our data for an increased response intensity after sonar emissions. The final model contained the covariate *Sonar* for which the coefficients 'during' and 'after' were significantly positive. An increased response intensity corresponds to more extreme measured values for one or more whistle characteristics.

5. Conclusions

- Using passive acoustic monitoring devices has the advantage of providing large amounts of data at a relatively low cost. However:
- Inclusion of covariates representing a cumulative effect of sonar is necessary to make these analyses more robust.
- Predictive power for presence models relatively low; hence, a larger number of both independent sonar events and delphinid acoustic encounters should be analyzed to improve statistical power.
- Potential confounding issues when combining multiple delphinid species as species may have opposing reactions to sonar.
- Responses in delphinid acoustic behaviors to sonar are very likely influenced by behavioural context, an animal's previous experience with sonar, and the animal's motivation and habituation.
- Visual observation, tagging and localization capabilities would be valuable additions to our methods. Currently it is unknown, whether increases in the probability of detection of vocalizations in the presence of sonar are due to increases in the number of animals present, due to increases in the acoustic activity of the animals in the area or due to some combination of these.

References

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