Electronic Supplementary Materials

For the manuscript:

Title: First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active (MFA) sonar [Short Title: *Ziphius* response to MFA sonar]

Authors: Stacy L. DeRuiter, Brandon L. Southall, John Calambokidis, Walter M.X. Zimmer, Dinara Sadykova, Erin A. Falcone, Ari S. Friedlaender, John E. Joseph, David Moretti, Gregory S. Schorr, Len Thomas, and Peter L. Tyack

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Contents

Tag Data

We used data from 15 DTAGs deployed on Cuvier's beaked whales (*Ziphius cavirostris*). Two datasets, tags zc10_272a and zc11_267a, were collected as part of the Southern California Behavioral Response Study (SOCAL BRS). Those two whales underwent controlled exposure experiments, in which the whales were exposed to simulated naval mid-frequency active sonar (MFA) sounds. The second whale of the SOCAL BRS whales, zc11_267a, was also incidentally exposed to MFA sonar from a distant naval exercise. To better characterize the baseline behavior of Cuvier's beaked whales, we also used data from 13 other Cuvier's beaked whale DTAG datasets collected in the Mediterranean Sea between 2003-2012.

We also included data from 2 mk9 time-depth-recorder tags (Wildlife Computers, Redmond, WA) deployed on *Ziphius* in Hawai'i in 2004 and 2006. Almost all of these tag datasets have been described in previous publications [1, 2, 3].

Details of all the tag deployments are included in Table 1 in the main article text.

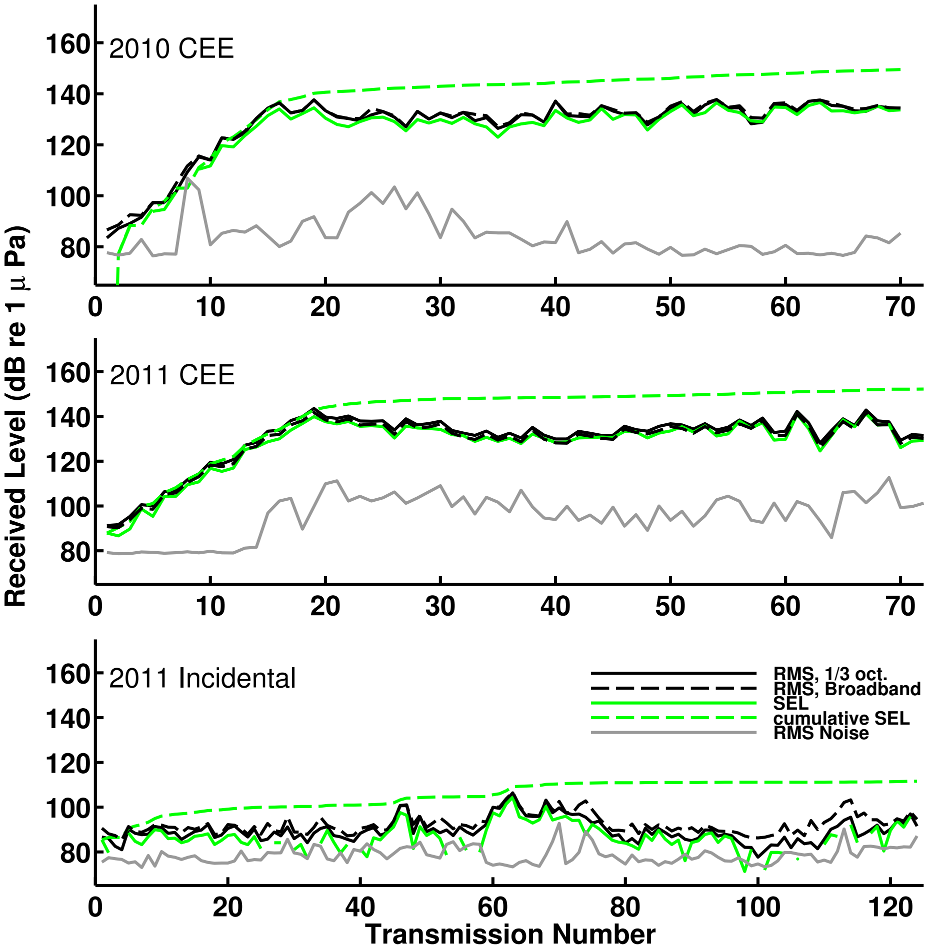
Acoustic Data Analysis

For both the controlled and incidental MFA sonar exposures, we calculated the received level on the DTAG tag recording of each MFA sonar transmission. The details of the tag electronics are published elsewhere [4]; in summary, the tag recorded 16-bit acoustic data at 192 (2010) or 480 (2011) kHz; the tag acoustic recording system was calibrated and had a peak clip level of 176 (2010) or 178 (2011) dB re 1 μPa. The main received level metric we report is the root-mean-squared (rms) level in a $\frac{1}{3}$ octave frequency band centred at the average fundamental frequency of the MFA signal. Rms levels were calculated in 200 msec windows sliding over the duration of the signal, and the reported level was the highest observed in any one 200 msec window, following the method of Tyack and colleagues [5]. We chose to use rms values in a carefully defined window corresponding approximately to the time over which a whale likely integrates received sound intensity for loudness perception [6, 7]. Similarly, we chose to use a $\frac{1}{3}$ octave frequency band for analysis because it corresponds approximately to mammalian auditory filter bandwidths [8]; this choice is also consistent with previous work [5]. The CEEs used one simulated MFA signal type, while the incidental exposure included five different MFA sonar signal types; for each signal type, we used a bandpass filter centered on the signal's mean fundamental frequency. Signal and filter characteristics are detailed in Supplemental Table 1, and the CEE signals and the CEE sound source are described in detail elsewhere [9]. We note that the signal durations are approximate for the incidental exposure signals, since reverberation and time-spreading made it difficult to pinpoint the exact start and end times of a single arrival of the signal.

For completeness and for possible comparisons with other studies, we also present several other metrics of received level here. First, we include the noise level (rms) so that the reader can assess the signal-to-noise ratio (SNR) of each recorded transmission. Noise level was determined for each individual MFA sonar transmission using a 1-second sample immediately preceding the transmission. Within this sample, the level was determined exactly as described above for the MFA sonar transmissions, using a 200 msec averaging window and taking the largest resulting level observed in any one window [5]. We also report the sound exposure level (SEL, in dB re 1 $\mu\mathrm{Pa}^2 * \mathrm{s}$), a measure of the acoustic energy in a single transmission, as well as the cumulative SEL, a measure of the total acoustic energy to which the whale has been exposed from the start of the exposure until a given point in time. SEL values were calculated over the full duration of the signal; in this case, we defined signal duration objectively as the period during which the SNR was at least 6 dB [7]. Finally, we present broadband rms levels, calculated as above but replacing the $\frac{1}{3}$ octave filter with a bandpass filter spanning 3-8 kHz (CEEs) or 2-8 kHz (incidental exposures in 2011, some of which included signals at 2-3 kHz). These broadband filters span the fundamental and the first harmonic of the MFA sonar signals, and are presented to indicate that our use of narrower filters for the bulk of our analysis did not lead to general underestimation of the received levels. (One might argue that the $\frac{1}{3}$ octave filter slightly underestimated RLs for the 5th signal type in the uncontrolled exposure, which was quite low in frequency and thus had a certain amount of energy outside the $\frac{1}{3}$ octave filter band (Supplemental Table 1); however, the whale showed no response to that exposure, so this possible bias did not affect any conclusions. In the case of a more detailed analysis of a signal clearly spanning multiple $\frac{1}{3}$ octave bands, it would be better to make and integrate measurements in several bands [5], but for the sake of simplicity we have not done so here.) All received level results are summarized in Supplemental Figure 1. We did not apply any frequency-weighting in calculation of any of these level metrics; however, the analysis bands were within the range over which the mid-frequency cetacean M-weighting function has a value of 0, so applying the M_{mf} weighting would not have changed any of the results reported here [6].

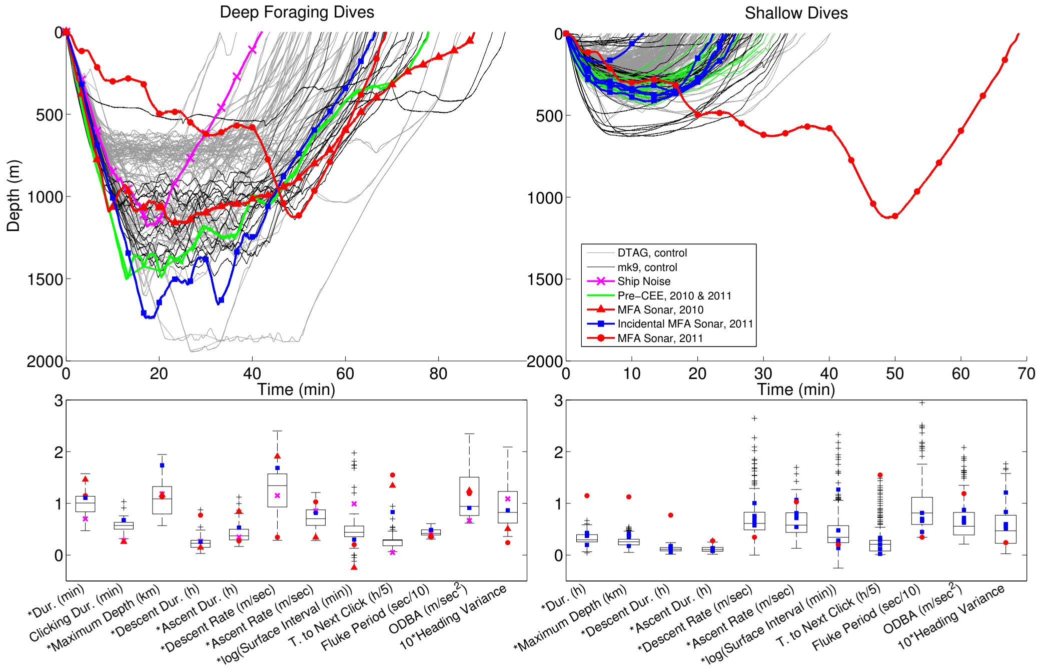
Tag Sensor Data Analysis

For all DTAG datasets, we calculated 13 dive and movement parameters (Supplemental Figure 2, Supplemental Table 2). Each parameter was measured or averaged over the period of one dive, from fluke-out to surfacing, although the original tag data were sampled much more finely (movement data at 5 Hz or greater, and acoustic data at 192 kHz or greater). If a value could not be determined (for example, surface duration after dive cannot be calculated for the last dive in a dive record), we substituted the mean value of all available control dives (dives by baseline animals that did not undergo any CEEs). These substitutions made up 2% of the data points, and making them allowed us to avoid systematically excluding from analysis the last dive and the last deep dive from each tag record.



Supplemental Figure 1: *Received Levels of all MFA sonar transmissions recorded on the DTAGs. Reported metrics include: rms level in a $\frac{1}{3}$ octave band centered on the signal center frequency (solid black lines); broadband rms level (dotted black lines); SEL (green lines); cumulative SEL (dotted green lines); and rms level of background noise in the in $\frac{1}{3}$ octave band (solid grey lines). Data are shown for the 2010 CEE (top), 2011 CEE (middle), and 2011 incidental exposure (bottom).*

To the extent possible, we calculated the same dive and movement parameters for the mk9 datasets; however, since the mk9 tag recorded dive-depth information



Supplemental Figure 2: Ziphius *dive profiles and dive parameters for 272 dives from 15 DTAG records and 50 from 2 mk9 records. Panel A shows dive profiles of deep foraging dives. Dives without sound exposure are plotted in grey; pre-controlled-exposure, no-incidental-exposure dives by exposed whales in green; controlled exposures to simulated MFA sonar in red (triangles, 2010; circles, 2011); incidental exposures to naval MFA sonar in blue (squares, 2011); and ship noise in magenta [3]. Panel B shows dive profiles for shallower, silent dives, with color-coding as in A. The 2011 controlled exposure dive is included in all panels to facilitate comparison with both dive types. Panel C contains box-plots of dive parameters for the control foraging dives from A, with * preceding parameters that include mk9 tag data (for plots only, not statistical modelling). Black boxes span 25th-75th percentiles, black horizontal lines mark medians, error bars span 1.5 interquartile ranges, and + symbols indicate more extreme values. Exposed dive parameters were excluded from box-plot calculations but plotted individually, with symbol and color-coding as in A (except that pre-exposure dives, shown in green in the upper panels, are here included in the box-plots). Panel D shows box plots as in C, but for the dives plotted in grey (and green) in B. Abbreviations: Dur., duration; T., time; ODBA, overall dynamic body acceleration.*

only, it was not possible to calculate any of the metrics based on accelerometer or magnetometer data. The parameters calculated for the mk9 data are shown in Supplemental Figure 2 and indicated in Supplemental Table 2. The mk9 datasets were excluded from subsequent statistical analysis (since including them would have limited us to considering only the dive parameters obtainable from both DTAG and mk9 tag types). They are included only in Figure 1, to provide a more complete picture of the baseline behavior of the species in the absence of MFA sonar exposure.

Most of the parameters were calculated from the tag data in a straightforward manner, as indicated in Supplemental Table 2, with the exception of the acoustic range. This range was calculated only during the controlled exposure, as it was based on the tag recordings of the CEE sounds. The interval between MFA signal start times on the tag recordings was determined by visual inspection of spectrograms to mark each individual start time (20 second window, fast Fourier transform block size 2048, Hamming window with 50% overlap). The same procedure was applied to a recording from a monitor hydrophone less than 20 m from the sound source. The inter-transmission intervals on the tag recordings were slightly longer than those on the monitor hydrophone recording, because of the additional time required for the sound to propagate the additional distance to the tag. We calculated the relative source-whale range at the time of each transmission by subtracting the monitor hydrophone inter-transmission intervals from the corresponding tag intervals, subtracting the minimum such difference (which corresponds to the closest point of approach (CPA) between whale and source), and multiplying the resulting delay by 1500 m sec^{-1} to convert from a delay in seconds to a relative range in meters. Position data from surface visual observations were combined with the relative ranges and dead-reckoned track data from the tag to convert to absolute ranges. The range data were also used to calculate whale swim speed relative to the source during the playback, by simply dividing the range difference between sonar transmissions by the inter-transmission interval. We calculated these speed estimates for each transmission, then averaged them over the playback period to obtain a mean swim speed relative to the source during playback. The acoustic range calculations were carried out independently by both WMXZ and SDR. The resulting range values were consistent, with a mean absolute difference of only 17.1 meters, demonstrating that potential human error in marking the transmission start times did not adversely affect the results.

Supplemental Table 1: *MFA signal characteristics (duration in seconds and fundamental frequency range in kHz) and filter center frequencies (F_c, Hz)*

Signal	Frequency Range	Duration	$\frac{1}{3}$ Octave Filter $\mathrm{F_c}$
simulated MFA sonar	3.5-4.1	1.6	3729
incidental MFA sonar 1	2.5-3.5	1.5	2970
incidental MFA sonar 2	2.2-3	1.5	2610
incidental MFA sonar 3	3.2-4.5	1.9	3920
incidental MFA sonar 4	2.3-4.3	4.5	3280
incidental MFA sonar 5	2.2-3	3.5	2630

Cluster Analysis

The objective of this analysis was to collapse the multivariate time-series of dive parameters into a univariate time-series, with one value to characterize each dive. This "distance metric" (to be described in detail later on) was intended to be a measure of how different a given dive is from the "average" dive by this species. Most marine mammals perform several different types of dives. For example, beaked whales undertake at least two: deep foraging dives and shallow non-foraging dives. Since one would expect the average dive parameters to vary between dive types, it is important to classify dives by dive type before calculating the distance metric.

We chose to do this classification by applying k-means clustering analysis to data from control whales only. Each parameter was normalized prior to clustering by subtracting the mean value and then dividing by the standard deviation. The optimal number of clusters to use – in this case, two – was determined using silhouette analysis [12]. In this case, the choice to use two clusters agrees with our *a priori* assumption that beaked whales have two main dive types. Supplemental Figure 3 shows the results of the clustering analysis.

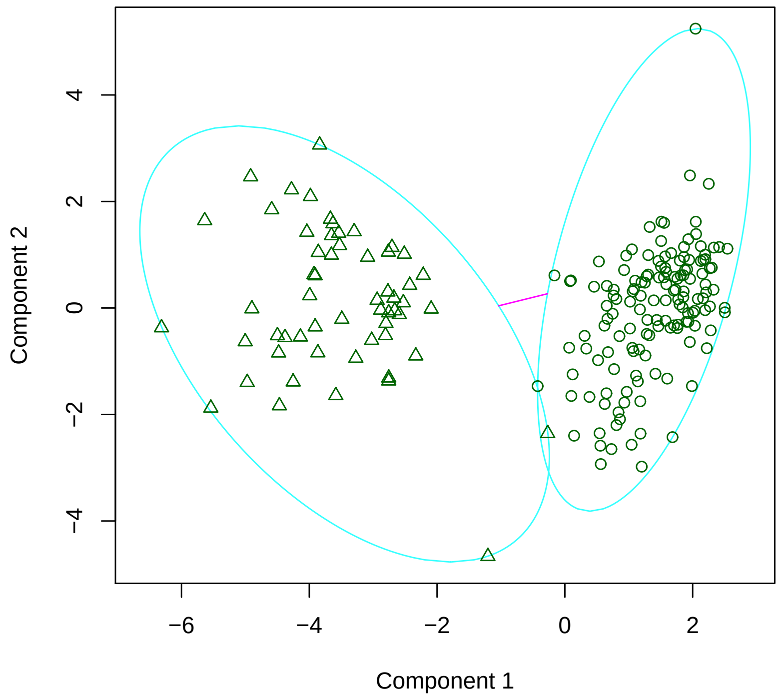
Mahalanobis Distance Calculation

We then calculated the Mahalanobis distance [13] of each point (that is, each dive) from the center of the cluster to which it belonged, assigning dives by exposed whales to clusters such that the resulting distance was minimized. The Mahalanobis distance is a measure of distance in multi-dimensional space. It is scale-invariant and takes into account correlations between dimensions. Mahalanobis distance is calculated according to:

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

Supplemental Table 2: *Variables Measured for Each Dive*

Description	Details	Which Tags
Descent Duration (minutes)	Time from last surfacing to first depth exceeding 90% of the maximum depth of the current dive	DTAG, mk9
Ascent Duration (minutes)	Time from the last time the animal was at or below 90% of the maximum depth until surfacing	DTAG, mk9
Descent Rate (m $\sec^{-1}$)	Mean descent rate during the whole descent (as defined above)	DTAG, mk9
Ascent Rate (m $\sec^{-1}$)	Mean ascent rate during the whole ascent (as defined above)	DTAG, mk9
Dive Duration (hours)		DTAG, mk9
Maximum Dive Depth (m)		DTAG, mk9
Surface Interval (minutes)	Time from surfacing at the end of the current dive until the start of the next dive exceeding 50 m	DTAG, mk9
Time to Next Click (hours)	Time from surfacing at end of current dive until next start of echolocation clicking	DTAG
Clicking Duration (hours)	Time from first to last echolocation click produced during the current dive	DTAG
Average Fluke Rate (Hz)	Fluke-stroke rate was determined as in [1], using a pitch threshold of 3 degrees and a period of 0.3-4 s	DTAG
Average Overall Dynamic Body Acceleration (odba, m $\sec^{-2}$)	Calculated as in [10], using an averaging period of 5 s	DTAG
Average Variance of Heading	Calculated (for circular variable) as in [11], using a 1-minute window sliding forward at sensor sampling rate	DTAG
Acoustic Range	Range from CEE sound source to whale	DTAG



Supplemental Figure 3: *Results of k-means cluster analysis to produce 2 clusters based on mean-normalized beaked whale dive data. The clustering results are indicated by the symbols (triangles and circles), with each cluster enclosed by an ellipse. The results are plotted in 2-dimensional component space using the first two components from a Principal Components Analysis (PCA), although the PCA output was not used by the clustering algorithm.*

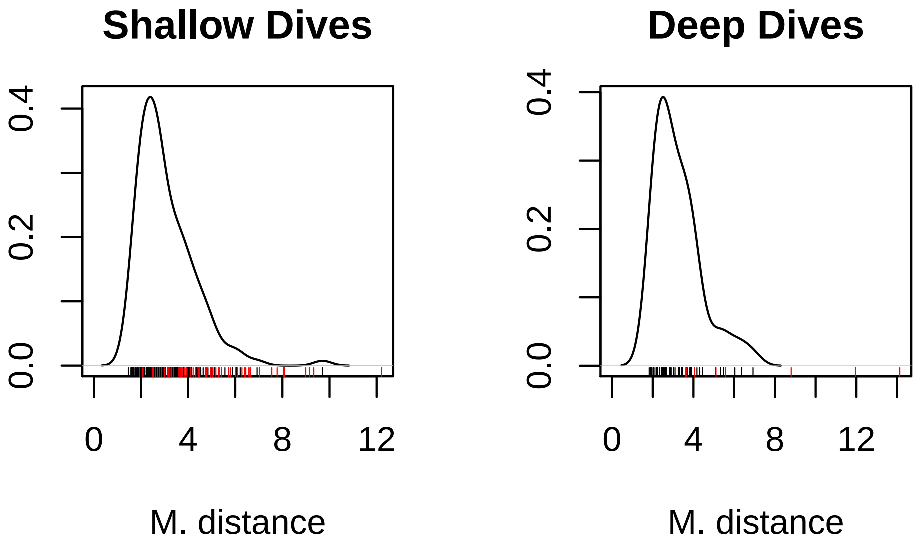
where x is a vector of dive parameters $1 - N$ for an individual dive,

$$x = (x_1, x_2, x_3, ..., x_N)^T,$$

μ is the vector of coordinates of the center point of the cluster of dives from control whales, in other words, a vector of mean values for each parameter for all control dives in a cluster,

$$\mu = (\mu_1, \mu_2, \mu_3, ..., \mu_N),$$

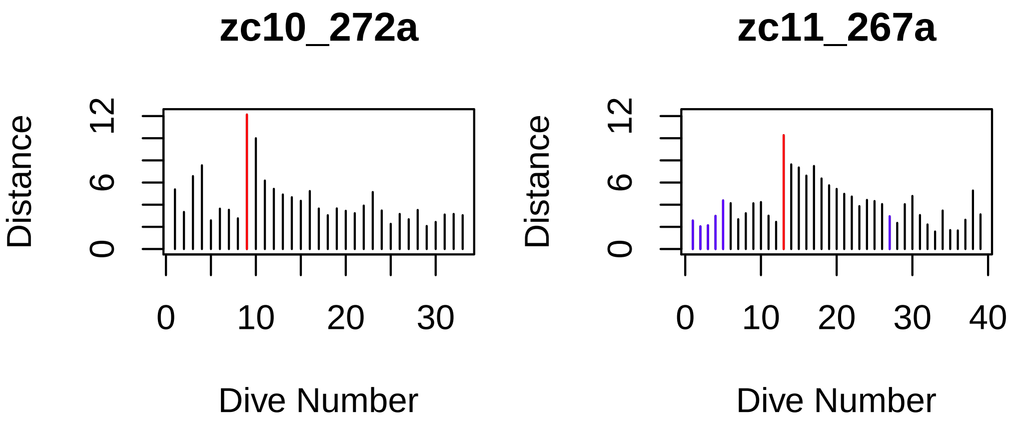
and S is the covariance matrix for all control dives in the cluster. The distance values were normalized by dividing by the standard deviation of the distance for control whales in each cluster. This adjustment was intended to correct for possible different shapes or spatial extents of the two clusters. Supplemental Figure 4 shows the results of the Mahalanobis distance calculations for beaked whale dives.



Supplemental Figure 4: *Empirical distribution of Mahalanobis distances for beaked whale shallow dives (cluster 1) and deep dives (cluster 2). The black curves show the proportion of control observations at each distance (specifically, they are kernel density estimates with Gaussian kernels and bandwidths satisfying Silverman's 'rule of thumb' [14]). At the bottom of the plot, along the x-axis, the black tick marks indicate observed distances for individual dives by control whales, and red ticks the same for exposed whales.*

Mahalanobis Distance as a Measure of Response Intensity

Supplemental Figure 5 shows the Mahalanobis distances for the two whales that were exposed to MFA sounds, plotted as time series, with sonar exposure dives indicated in colour. In both cases, there was a large peak in the distance metric at the time of the exposure. The distance also remained elevated for a time after the exposure, slowly decaying back to baseline values after a number of dives. Similar patterns were not prominent in the data from control whales (Supplemental Figure 6).

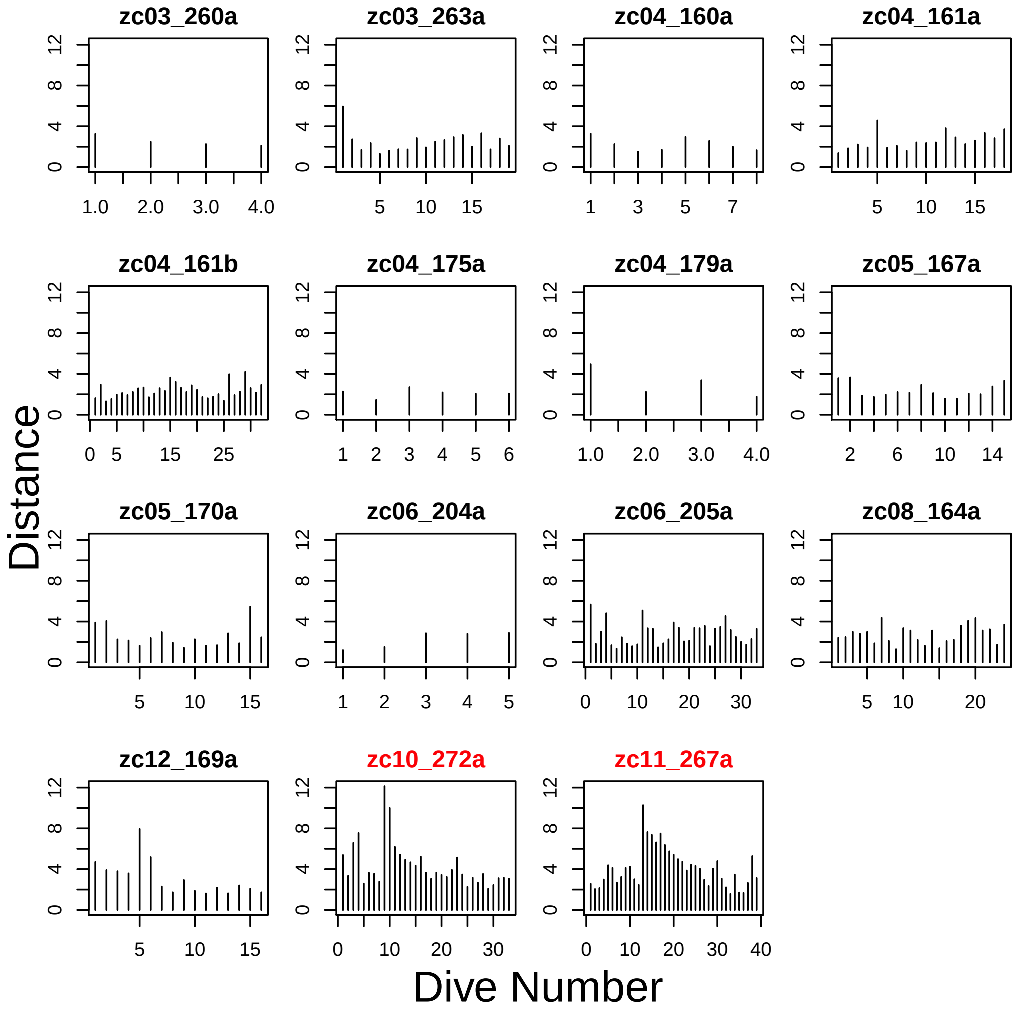


Supplemental Figure 5: *Time series of Mahalanobis distances for MFA-exposed beaked whales. Dives during which experimental MFA exposures occurred are shown in red. Dive during which the whale was incidentally exposed to distant, incidental Naval MFA sonar are shown in blue.*

To check for temporal autocorrelation in the time-series of Mahalanobis distances for control whales, we plotted the Mahalanobis distance results (Supplemental Figure 6). We also calculated the autocorrelation function for these control datasets, and we did not find strong evidence of autocorrelation in the data.

Model for Response Intensity as a Function of Sonar Dose

We took Mahalanobis distance (as calculated earlier) as a proxy for behavioural Response Intensity (RI). In modelling this response intensity as a function of sonar exposure intensity, we considered two possible metrics for exposure intensity or "dose": sound level and distance between the whale and the sound source.



Supplemental Figure 6: *Time series of Mahalanobis distances for all beaked whales. Sub-plot titles indicate whale ID, with the IDs for whales that were exposed to MFA sonar printed in red.*

Sound exposure levels were determined from the DTAG acoustic recordings according to the method described in [5]. Briefly, after filtering with a $\frac{1}{3}$ octave filter spanning the CEE sound frequencies (512-point FIR filter, 3300-4158 Hz) and processing to remove loud transients such as animal clicks or other impulsive noise, the root-mean-squared sound pressure level (in dB re 1 μPa) was calculated in 200 msec windows spanning the duration of the signal. Signal duration was defined as the time when the signal to noise ratio was at least 6 dB. The reported level for an individual MFA transmission was the highest level measured in any one 200 msec window. The level used for response intensity modelling was the highest observed for any transmission that occurred during the dive in question. It is important to note that expert inspection of the controlled exposure data indicated that the animals began to react to the sound near the start of the exposure, when the received sound level was much lower than the maximum level during the same dive.

The distance from the sound source to the whale is more difficult to estimate with currently available data, since the exact positions of the beaked whales during the sound exposures are unknown. For the controlled, experimental MFA exposures, source-whale range at the start of the MFA playback was determined by combining data from the DTAG movement record, animal sighting positions from before the exposure, and acoustically-based estimates of relative source-whale range during the exposure (described earlier). For the incidental exposure of whale zc11_267a to U.S. Navy MFA sonar from a distant naval exercise, an approximate position and range of the sound sources relative to the tagged whale was obtained from the U.S. Navy (by D. Moretti). Supplemental Table 3 shows current range and level estimates for dives during which beaked whales were exposed to MFA.

Using these data on range and level for each dive, we proceeded to model response intensity (expected value of Mahalanobis distance, $RI = E(D)$) as

$$RI = E(D) = \beta_0 + \sum_{i=1}^{n} x_i(t) \tag{1}$$

$$x_i(t) = \begin{cases} \frac{\beta_1 L_{\tau_i} e^{\beta_2(\tau_i - t))}}{(1+\beta_3 R_i)} & \text{if } t \geq \tau_i \\ \\ 0 & \text{otherwise} \end{cases}, \tag{2}$$

where RI is the expected value of the Mahalanobis distance, $t = 1, 2, 3...T$ is the dive number, n is the number of exposures, L_{τ_i} is the received sound level during exposure dive τ_i, R_i is the source-whale range at the start of exposure i, τ_i is the dive number of exposure dive i, and $\vec{\beta} = [\beta_0, \beta_1, \beta_2, \beta_3]$ are parameters to be estimated. β_0 is the expected distance when there is no exposure, β_1 scales the initial response intensity as a function of received sound level, L, β_2 is the decay rate of the response, and β_3 scales the response intensity as a function of range, R. We modelled the observed Mahalanobis distance using a Gamma distribution.

The Gamma distribution for a random variable x with shape parameter k and scale parameter θ has probability density function

$$\Gamma(x,k,\theta) = \frac{1}{\theta^k}\frac{1}{\Gamma(k)}x^{k-1}e^{-\frac{x}{\theta}}, \tag{3}$$

expectation $\frac{k}{\theta}$, and variance $k\theta^2$. To fit the model, we expressed the parameters of the gamma distribution in terms of the RI (that is, the expected value of Mahalanobis distance ($E(D(\vec{\beta}))$)) and the new parameter ω defined as

$$\omega = \frac{(E(D(\vec{\beta})))^2}{k} = E(D(\vec{\beta}))\theta \tag{4}$$

or

$$k = \frac{(E(D(\vec{\beta})))^2}{\omega}; \theta = \frac{\omega}{(E(D(\vec{\beta})))} \tag{5}$$

Assuming that each observed Mahalanobis distance is independently distributed, given the above model, the log-likelihood $\mathcal{L}$ is given by

$$\log\mathcal{L} = \sum_{t=1}^{T}\log\mathcal{L}_t = \sum_{t=1}^{T} -k\log\theta - \log(\Gamma(k)) + (k-1)\log(D_t) - \frac{D_t}{\theta} \tag{6}$$

We estimated the parameters ω and $\vec{\beta}$ by maximizing this likelihood in the statistical software R (http://www.r-project.org/).

We fit the model to each whale individually. The parameters ω, β_0, β_1 and β_3 can only take positive values, so they were log-transformed for the maximization only, to allow fitting over all real values. Results are presented in the original (untransformed) parameter space; we calculated standard errors on the parameters using the Hessian matrix, obtaining standard error estimates for the transformed parameters in the original parameter space using the delta method [15]. For whale zc10_272a, there was only one exposure at a single range and level, so it was not possible to extract information about the effects of both range and level on response; we thus excluded the range term β_3 for the 2010 whale. We also fit a set of models with fewer parameters (see Supplemental Table 4). For each fitted model, we calculated Akaike's Information Criterion (AIC), and selected for inference the model with lowest AIC. Supplemental Table 4 shows the AIC values; the ΔAIC values between the full models and the next-best reduced models were $\geq$ 28.5, giving very strong support for the full models in both years. The resulting parameter estimates $(\omega, \vec{\beta})$ (and their standard errors), for the full models only,

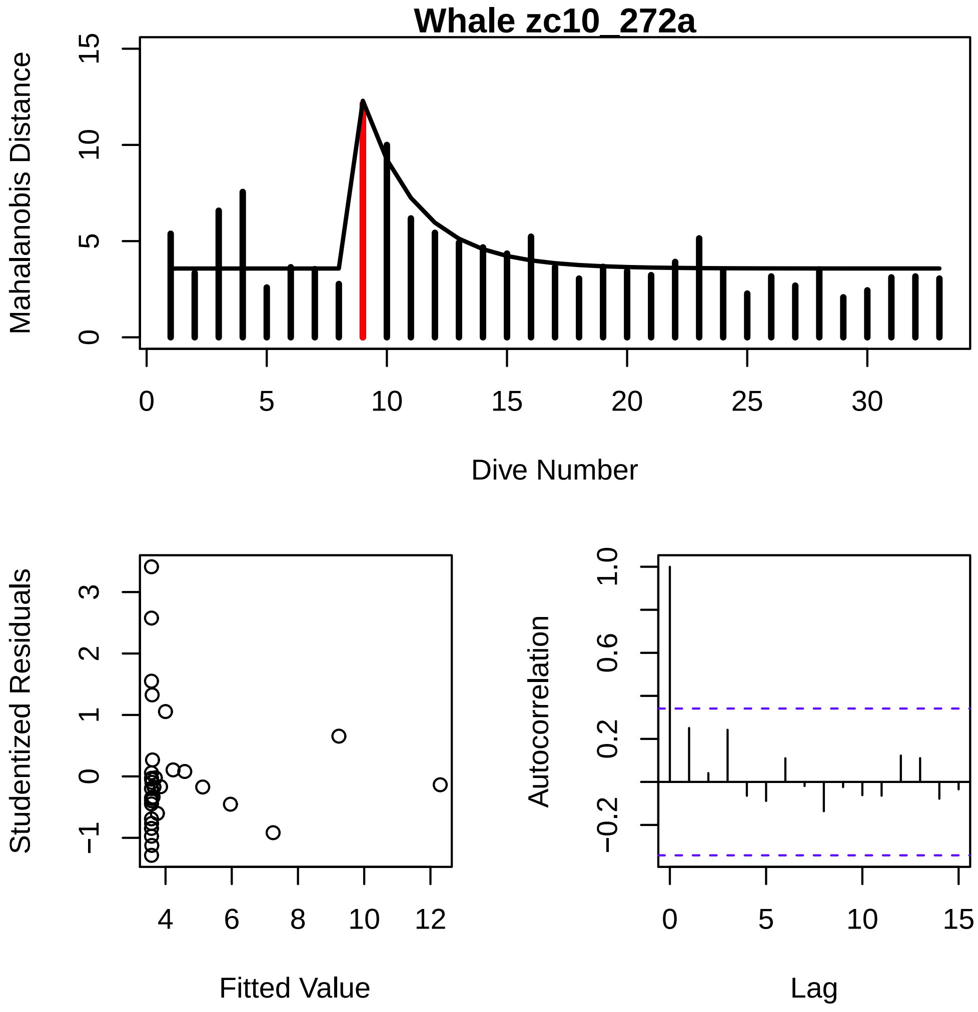
Supplemental Table 3: *Received Levels and Ranges for Beaked Whale MFA Exposures*

Whale ID	Dive Number	Maximum Received Level (dB re 1 μPa rms)	Source-Whale Range (start of playback, km)
zc10_272a	9	138	4.0
zc11_267a	1	106	118
zc11_267a	2	94	118
zc11_267a	3	91	118
zc11_267a	4	94	118
zc11_267a	5	96	118
zc11_267a	13	144	4.9
zc11_267a	27	97	118

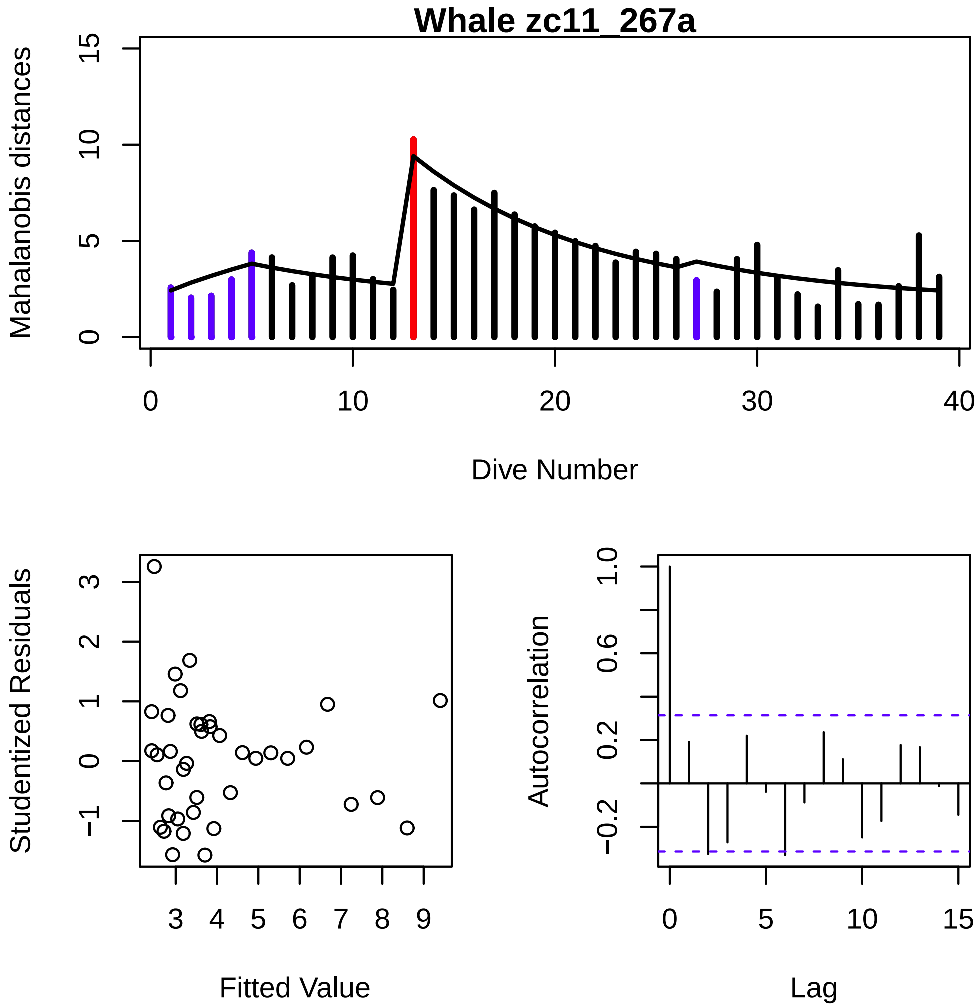
Supplemental Table 4: *Akaike's Information Criterion for all fitted models*

Year	Parameters	Number of Parameters	Model Description	AIC	ΔAIC
2010	ω, β_0, β_1, β_2	4	Full Model	101.9	0
2010	ω, β_0, β_2	3	Intercept, Time Decay	130.4	28.5
2010	ω, β_0, β_1	3	Intercept, RL	135	33.1
2010	ω, β_0	2	Intercept Only	136.4	34.5
2011	ω,β_0, β_1, β_2, β_3	5	Full Model	104.5	0
2011	ω, β_0, β_2, β_3	4	Intercept, Time Decay, Range	149.8	45.3
2011	ω, β_0, β_1, β_3	4	Intercept, RL, Range	158.3	53.8
2011	ω, β_0, β_1, β_2	4	Intercept, RL, Time Decay	159.7	55.2
2011	ω, β_0, β_3	3	Intercept, Range	156.5	52
2011	ω, β_0, β_2	3	Intercept, Time Decay	150.6	46.1
2011	ω, β_0, β_1	3	Intercept, RL	157.3	52.8
2011	ω, β_0	2	Intercept Only	188.9	84.4

were [1.05 (0.27), 3.6 (0.21), 0.063 (0.0068), 0.43 (0.088)] for 2010, and [0.68 (0.16), 1.9 (0.6), 0.074 (0.024), 0.11 (0.023), 0.12 (0.093)] for 2011. Supplemental Figures 7-8 show the data, the fitted models, the residuals, and the residual autocorrelation functions.



Supplemental Figure 7: *Model results for whale zc10_272a. Upper panel: data with fitted model (black line); lower left panel: internally Studentized residuals; and lower right panel: residual autocorrelation function.*



Supplemental Figure 8: *Model results for whale zc10_267a. Upper panel: data with fitted model (black line); lower left panel: internally Studentized residuals; and lower right panel: residual autocorrelation function.*

References

[1] Peter L. Tyack, Mark P Johnson, Natacha Aguilar Soto, A Sturlese, and P T Madsen. Extreme diving of beaked whales. *Journal of Experimental Biology*, 209(21):4238–4253, 2006.

[2] Robin W Baird, Daniel L Webster, Gregory S Schorr, Daniel J McSweeney, and Jay Barlow. Diel variation in beaked whale diving behavior. *Marine Mammal Science*, 24(3):630–642, July 2008.

[3] Natacha Aguilar Soto, Mark P Johnson, Peter T Madsen, Peter L Tyack, A Bocconcelli, and J F Borsani. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (<i>Ziphius cavirostris</i>)? *Marine Mammal Science*, 22(3):690–699, 2006.

[4] Mark P Johnson and Peter L Tyack. A digital acoustic recording tag for measuring the response of wild marine mammals to sound. *IEEE Journal of Oceanic Engineering*, 28(1):3–12, 2003.

[5] Peter L. Tyack, Walter M X Zimmer, David Moretti, Brandon L Southall, Diane E Claridge, John W Durban, Christopher W Clark, Angela D'Amico, Nancy Dimarzio, Susan Jarvis, Elena McCarthy, Ronald Morrissey, Jessica Ward, and Ian L Boyd. Beaked whales respond to simulated and actual navy sonar. *PloS one*, 6(3):e17009, January 2011.

[6] Brandon L Southall, Ann E Bowles, William T Ellison, James J Finneran, Roger L Gentry, Charles R Greene, David Kastak, Darlene R Ketten, James H Miller, Paul E Nachtigall, W John Richardson, Jeanette A Thomas, and Peter L Tyack. Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals*, 33(4):411–521, 2007.

[7] P T Madsen. Marine mammals and noise: Problems with root mean square sound pressure levels for transients. *Journal of the Acoustical Society of America*, 117(6):3952–3957, 2005.

[8] Stacy L DeRuiter. Marine Animal Acoustics. In Xavier Lurton, editor, *An Introduction to Underwater Acoustics*, pages 425–474. Praxis Publishing Limited, Chichester, UK, 2010.

[9] Brandon L. Southall, David Moretti, Bruce Abraham, John Calambokidis, Stacy L DeRuiter, and Peter L Tyack. Marine mammal behavioral response

studies in southern California: Advances in technology and experimental methods. *Marine Technology Society Journal*, 46(4):48–59, 2012.

[10] Lama Qasem, Antonia Cardew, Alexis Wilson, Iwan Griffiths, Lewis G Halsey, Emily L C Shepard, Adrian C Gleiss, and Rory Wilson. Tri-axial dynamic acceleration as a proxy for animal energy expenditure; should we be summing values or calculating the vector? *PloS one*, 7(2):e31187, January 2012.

[11] Jerrold H Zar. *Biostatistical Analysis*. Pearson Prentice-Hall, Upper Saddle River, NJ, 5th ed edition, 2010.

[12] Peter J Rousseeuw. Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20(null):53–65, November 1987.

[13] P. C. Mahalanobis. On the generalized distance in statistics. *Proceedings of the National Institute of Sciences of India*, 2:49–55, 1936.

[14] B W Silverman. *Density Estimation for Statistics and Data Analysis*. Chapman & Hall, London, U.K., 1986.

[15] Gary W. Oehlert. A note on the delta method. *The American Statistician*, 46(1):27–29, February 1992.