

**Effects of vessel traffic and underwater noise on the movement, behaviour and vocalisations of bottlenose dolphins in an urbanised estuary**

Sarah A. Marley\*, Chandra P. Salgado Kent, Christine Erbe and Iain M. Parnum

Centre for Marine Science and Technology (CMST), Curtin University, Perth, Western Australia

**\*Corresponding Author:** [sarah.marley86@gmail.com](mailto:sarah.marley86@gmail.com)

Supplementary Information

Supplementary Table S1 Definition of dolphin activity states (adapted from Shane et al. 1986 and Lusseau, 2003)

<b>Activity State</b>	<b>Definition</b>
Foraging (FO)	Dolphins involved in any effort to capture and consume prey, often involving quick, steep dives of long duration. Diving birds or jumping fish may also be observed.
Milling (MI)	Dolphins show frequent changes in heading, but stay in same location with no net movement.
Resting (RE)	Dolphins engaged in slow movements or 'logging' at the surface.
Socialising (SO)	Dolphins engaged in a diverse number of interactive behavioural events, including body contact, chasing, leaping, or hitting the water surface with body parts. Groups may split or join.
Travelling (TR)	Dolphins engaged in persistent, directional movement with short, relatively constant dive intervals.

Supplementary Table S2 Summary of the best fitting model for each whistle characteristic considering broadband noise levels, dolphin activity state, group size and calf presence. Explanatory variables with 'NA' were not included in the final model;  $\leq 0.001$  \*\*\*;  $\leq 0.01$  \*\*;  $\leq 0.05$  \*

Duration					
Smooth Term	EDF	F	p-value		
NL_BB	3.814	4.45	0.00107	**	
Parametric Terms	Parameter Estimate	Std. Error	t-value	p-value	
Intercept	-1.27040	0.13895	-9.143	3.66e-16	***
<b>Activity State</b>					
<i>Milling</i>	-0.12007	0.11740	-1.023	0.3080	
<i>Socialising</i>	-0.74158	0.15895	-4.666	6.69e-06	***
<i>Travelling</i>	0.20874	0.08920	2.340	0.0206	*
<b>Group Size</b>	0.25221	0.05753	4.384	2.16e-05	***
<b>Calf Presence</b>	NA	NA	NA	NA	
Min Frequency					
Smooth Term	EDF	F	p-value		
NL_BB	3.26	6.187	0.000102	***	
Parametric Terms	Parameter Estimate	Std. Error	t-value	p-value	
Intercept	8.30880	0.04726	175.793	< 2e-16	***
<b>Activity State</b>					
<i>Milling</i>	0.17376	0.07937	2.189	0.03010	*
<i>Socialising</i>	0.07199	0.09986	0.721	0.47205	
<i>Travelling</i>	0.17464	0.06088	2.869	0.00471	**
<b>Group Size</b>	NA	NA	NA	NA	
<b>Calf Presence</b>	-0.09619	0.05534	-1.738	0.08149	
Max Frequency					
Smooth Term	EDF	F	p-value		
NL_BB	3.14	21.46	1.08e-14	***	
Parametric Terms	Parameter Estimate	Std. Error	t-value	p-value	
Intercept	9.37662	0.02303	407.127	< 2e-16	***
<b>Activity State</b>					
<i>Milling</i>	-0.14304	0.03867	-3.699	0.000302	***
<i>Socialising</i>	-0.13646	0.04846	-2.816	0.005506	**
<i>Travelling</i>	-0.11681	0.02961	-3.944	0.000122	***

<b>Group Size</b>	NA	NA	NA	NA	
<b>Calf Presence</b>	0.20377	0.02692	7.570	3.28e-12	***

### Delta Frequency

<b>Smooth Term</b>	<b>EDF</b>	<b>F</b>	<b>p-value</b>		
<b>NL_BB</b>	3.839	20.83	3.51e-16		***

<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	8.88953	0.05168	172.010	< 2e-16	***

### Activity State

<i>Milling</i>	-0.35244	0.08673	-4.064	7.72e-05	***
----------------	----------	---------	--------	----------	-----

<i>Socialising</i>	-0.29466	0.11114	-2.651	0.00887	**
--------------------	----------	---------	--------	---------	----

<i>Travelling</i>	-0.35491	0.06701	-5.297	4.06e-07	***
-------------------	----------	---------	--------	----------	-----

<b>Group Size</b>	NA	NA	NA	NA	
-------------------	----	----	----	----	--

<b>Calf Presence</b>	0.45766	0.06094	7.510	4.7e-12	***
----------------------	---------	---------	-------	---------	-----

### Start Frequency

<b>Smooth Term</b>	<b>EDF</b>	<b>F</b>	<b>p-value</b>		
<b>NL_BB</b>	4.474	6.929	3.94e-06		***

<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	8.35023	0.04850	172.158	< 2e-16	***

### Activity State

<i>Milling</i>	0.15909	0.08120	1.959	0.05194	
----------------	---------	---------	-------	---------	--

<i>Socialising</i>	0.09588	0.10589	0.905	0.36667	
--------------------	---------	---------	-------	---------	--

<i>Travelling</i>	0.18008	0.06320	2.849	0.00499	**
-------------------	---------	---------	-------	---------	----

<b>Group Size</b>	NA	NA	NA	NA	
-------------------	----	----	----	----	--

<b>Calf Presence</b>	-0.10563	0.05756	-1.835	0.06843	
----------------------	----------	---------	--------	---------	--

### End Frequency

<b>Smooth Term</b>	<b>EDF</b>	<b>F</b>	<b>p-value</b>		
<b>NL_BB</b>	3.243	17.68	1.71e-12		***

<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	9.35074	0.03489	267.968	< 2e-16	***

### Activity State

<i>Milling</i>	-0.15346	0.05860	-2.619	0.00971	**
----------------	----------	---------	--------	---------	----

<i>Socialising</i>	-0.21389	0.07368	-2.903	0.00425	**
--------------------	----------	---------	--------	---------	----

<i>Travelling</i>	-0.21882	0.04494	-4.869	2.77e-06	***
-------------------	----------	---------	--------	----------	-----

<b>Group Size</b>	NA	NA	NA	NA	
-------------------	----	----	----	----	--

<b>Calf Presence</b>	0.23310	0.04084	5.707	5.80e-08	***
----------------------	---------	---------	-------	----------	-----

### Inflections

<b>Smooth Term</b>	<b>EDF</b>	<b>Chi-square</b>	<b>p-value</b>	
--------------------	------------	-------------------	----------------	--

<b>NL_BB</b>	4.108	14.58	0.0139	*
--------------	-------	-------	--------	---

<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
-------------------------	---------------------------	-------------------	----------------	----------------	--

<b>Intercept</b>	-0.29536	0.29108	-1.015	0.310256	
------------------	----------	---------	--------	----------	--

#### Activity State

<i>Milling</i>	-0.76595	0.24421	-3.136	0.001710	**
----------------	----------	---------	--------	----------	----

<i>Socialising</i>	-1.23611	0.36062	-3.428	0.000609	***
--------------------	----------	---------	--------	----------	-----

<i>Travelling</i>	0.04023	0.15075	0.267	0.789573	
-------------------	---------	---------	-------	----------	--

<b>Group Size</b>	0.45154	0.11981	3.769	0.000164	***
-------------------	---------	---------	-------	----------	-----

<b>Calf Presence</b>	0.61350	0.13797	4.446	8.73e-06	***
----------------------	---------	---------	-------	----------	-----

### Extrema

<b>Smooth Term</b>	<b>EDF</b>	<b>Chi-square</b>	<b>p-value</b>	
--------------------	------------	-------------------	----------------	--

<b>NL_BB</b>	3.353	26.12	3.84e-05	***
--------------	-------	-------	----------	-----

<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
-------------------------	---------------------------	-------------------	----------------	----------------	--

<b>Intercept</b>	-2.6727	0.4758	-5.618	1.94e-08	***
------------------	---------	--------	--------	----------	-----

#### Activity State

<i>Milling</i>	0.8539	0.613	1.851	0.064129	
----------------	--------	-------	-------	----------	--

<i>Socialising</i>	-1.3227	0.7810	-1.694	0.090323	
--------------------	---------	--------	--------	----------	--

<i>Travelling</i>	1.6834	0.3735	4.508	6.56e-06	***
-------------------	--------	--------	-------	----------	-----

<b>Group Size</b>	0.5887	0.1655	3.558	0.000374	***
-------------------	--------	--------	-------	----------	-----

<b>Calf Presence</b>	NA	NA	NA	NA	
----------------------	----	----	----	----	--

### Harmonics

<b>Smooth Term</b>	<b>EDF</b>	<b>Chi-square</b>	<b>p-value</b>	
--------------------	------------	-------------------	----------------	--

<b>NL_BB</b>	7.306	16.04	0.0455	*
--------------	-------	-------	--------	---

<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
-------------------------	---------------------------	-------------------	----------------	----------------	--

<b>Intercept</b>	-2.7016	0.6562	-4.117	3.83e-05	***
------------------	---------	--------	--------	----------	-----

#### Activity State

<i>Milling</i>	3.0940	0.8174	3.785	0.000154	***
----------------	--------	--------	-------	----------	-----

<i>Socialising</i>	0.8052	1.0343	0.778	0.436307	
--------------------	--------	--------	-------	----------	--

<i>Travelling</i>	2.5907	0.7374	3.513	0.000442	***
-------------------	--------	--------	-------	----------	-----

<b>Group Size</b>	NA	NA	NA	NA	
-------------------	----	----	----	----	--

<b>Calf Presence</b>	NA	NA	NA	NA	
----------------------	----	----	----	----	--

Supplementary Table S3 Summary of the best fitting model for each whistle characteristic, considering octave-band levels (OBLs) centred around 1 kHz (NL\_1000), 16 kHz (NL\_16000), and 32 kHz (NL\_32000). Explanatory variables with 'NA' were not included in the final model;  $\leq 0.001$  \*\*\*,  $\leq 0.01$  \*\*,  $\leq 0.05$  \*

Duration					
Parametric Terms	Parameter Estimate	Std. Error	t-value	p-value	
Intercept	-0.65978	0.03453	-19.11	< 2e-16	***
Smooth Terms	EDF	F	p-value		
NL_1000	8.423	7.810	9.84e-10		
NL_16000	1.000	3.820	0.052602		
NL_32000	8.000	3.532	0.000665		
					***
Min Frequency					
Parametric Terms	Parameter Estimate	Std. Error	t-value	p-value	
Intercept	8.3862	0.0213	393.8	< 2e-16	***
Smooth Terms	EDF	F	p-value		
NL_1000	8.103	10.024	5.02e-12		
NL_16000	4.765	1.675	0.114		
NL_32000	NA	NA	NA		
Max Frequency					
Parametric Terms	Parameter Estimate	Std. Error	t-value	p-value	
Intercept	9.37007	0.01236	758.0	< 2e-16	***
Smooth Terms	EDF	F	p-value		
NL_1000	3.808	25.40	< 2e-16		
NL_16000	1.000	20.17	1.34e-05		
NL_32000	NA	NA	NA		
Delta Frequency					
Parametric Terms	Parameter Estimate	Std. Error	t-value	p-value	
Intercept	8.84362	0.02947	300.1	< 2e-16	***
Smooth Terms	EDF	F	p-value		
NL_1000	3.868	19.24	5.20e-05		
NL_16000	NA	NA	NA		
NL_32000	1.000	17.28	5.23e-05		
					***
Start Frequency					

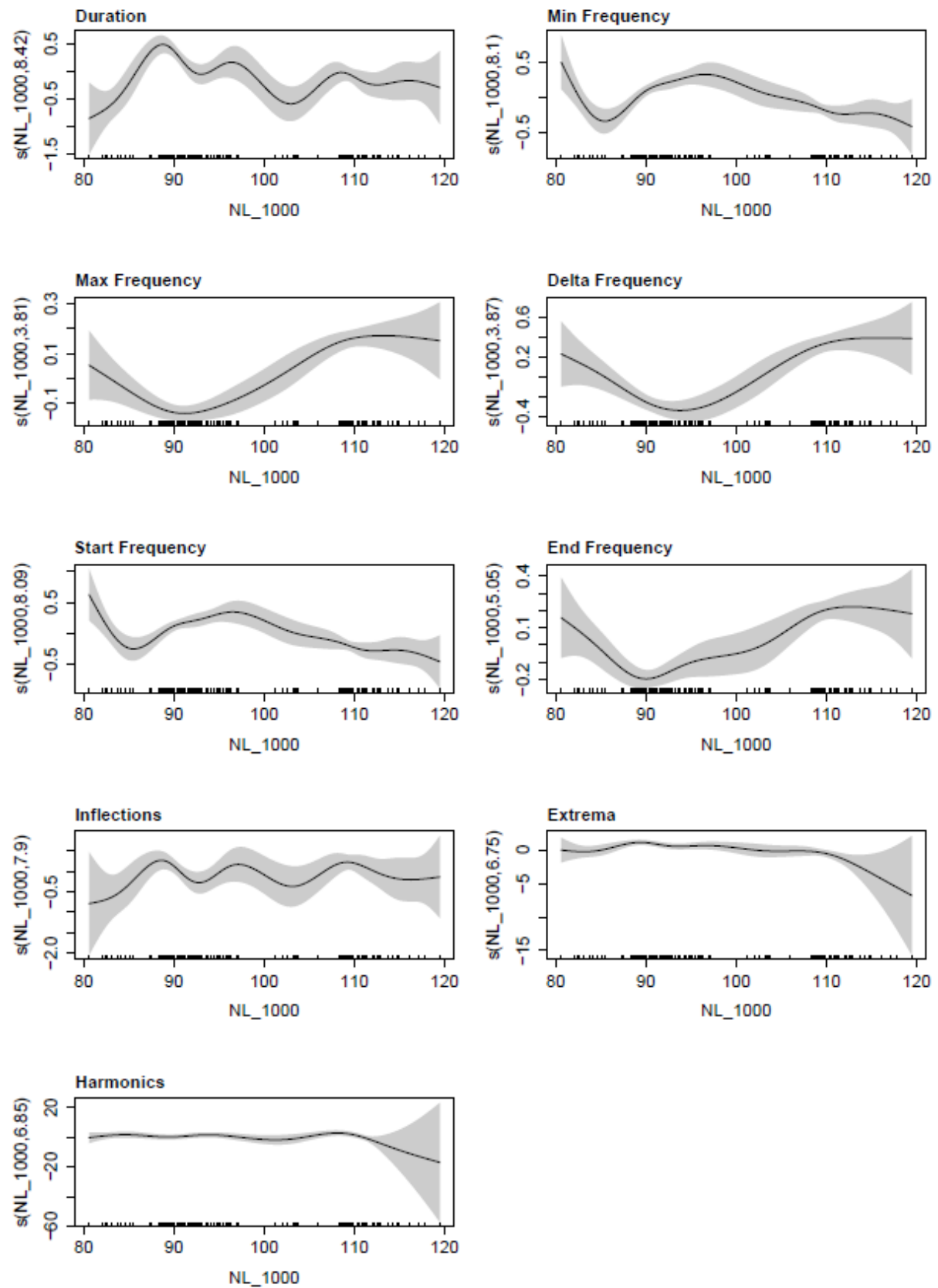
<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	8.4294	0.0228	369.7	< 2e-16	***
<b>Smooth Terms</b>	<b>EDF</b>	<b>F</b>	<b>p-value</b>		
<b>NL_1000</b>	8.092	10.11	3.62e-12		***
<b>NL_16000</b>	3.528	1.58	0.188		
<b>NL_32000</b>	NA	NA	NA		
<b>End Frequency</b>					
<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	9.29580	0.01806	514.6	< 2e-16	***
<b>Smooth Terms</b>	<b>EDF</b>	<b>F</b>	<b>p-value</b>		
<b>NL_1000</b>	5.045	14.148	1.29e-13		***
<b>NL_16000</b>	NA	NA	NA		
<b>NL_32000</b>	1.428	9.049	0.000271		***
<b>Inflections</b>					
<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	0.89326	0.05163	17.3	< 2e-16	***
<b>Smooth Terms</b>	<b>EDF</b>	<b>Chi-square</b>	<b>p-value</b>		
<b>NL_1000</b>	7.902	19.253	0.0169		*
<b>NL_16000</b>	2.824	9.063	0.0599		
<b>NL_32000</b>	8.483	18.271	0.0267		*
<b>Extrema</b>					
<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	-0.3372	0.1702	-1.981	0.0476	*
<b>Smooth Terms</b>	<b>EDF</b>	<b>Chi-square</b>	<b>p-value</b>		
<b>NL_1000</b>	6.753	49.354	2.49e-08		***
<b>NL_16000</b>	2.108	3.846	0.19614		
<b>NL_32000</b>	1.000	10.734	0.00105		**
<b>Harmonics</b>					
<b>Parametric Terms</b>	<b>Parameter Estimate</b>	<b>Std. Error</b>	<b>t-value</b>	<b>p-value</b>	
<b>Intercept</b>	-1.5032	0.7219	-2.082	0.0373	*
<b>Smooth Terms</b>	<b>EDF</b>	<b>Chi-square</b>	<b>p-value</b>		

<b>NL_1000</b>	6.847	21.969	0.01558	*
<b>NL_16000</b>	1.000	5.974	0.01452	*
<b>NL_32000</b>	4.089	16.820	0.00514	**

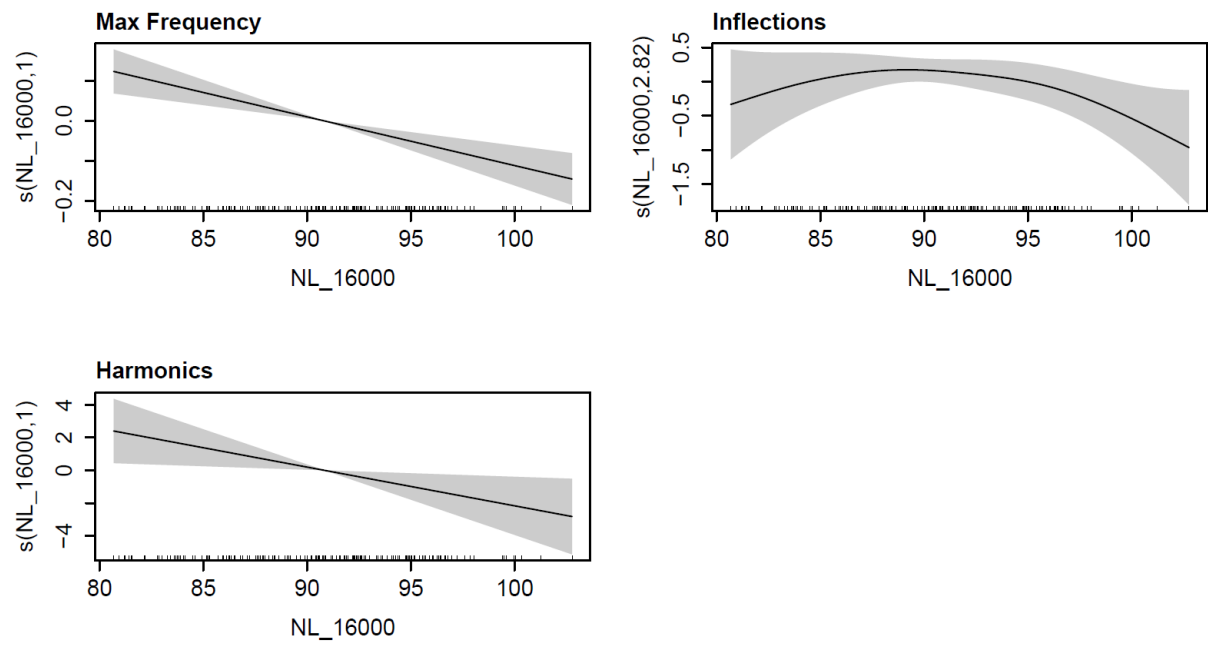
---



Supplementary Figure S4 Results of the nine whistle GAMs which selected the 1 kHz octave-band level (NL\_1000) as a significant explanatory variable.



Supplementary Figure S5 Results of the three whistle GAMs which selected the 16 kHz octave-band level (NL\_16000) as a significant explanatory variable.



Supplementary Figure S6 Results of the six whistle GAMs which selected the 32 kHz octave-band level (NL\_32000) as a significant explanatory variable.

