

Supplemental Materials for: Diving Behavior and
Fine-Scale Kinematics of Free-Ranging Risso's Dolphins
Foraging in Shallow and Deep-Water Habitats (doi:
[10.3389/fevo.2019.00053](https://doi.org/10.3389/fevo.2019.00053))

Patricia Arranz, Kelly J. Benoit-Bird, Ari S. Friedlaender, Elliott L. Hazen, Jeremy A. Goldbogen, Alison K. Stimpert, Stacy L. DeRuiter, John Calambokidis, Brandon L. Southall, Andreas Fahlman, and Peter L. Tyack

Contents

Description	1
Models	2
Buzz rate	2
Bottom Phase Duration	3
Inter-buzz Interval (IBI)	4
Buzz Duration	5
Roll variance	6
Stroke Rate	7
V02 (by dive phase)	8

Description

The tables below provide additional detail on the generalized linear mixed-effects models presented in the paper. Each table shows the fitted model parameter estimates with their standard errors, as well as random effect and residual variances. Finally, for each model, an ANOVA table comparing models with and without the predictor of interest is shown.

Models

Buzz rate

Table 1: Parameter estimates for Buzz rate model

Term	Estimate	Standard Error
(Intercept)	-3.8548215	0.3328188
typeMidwater	0.1257752	0.2170591
typeIntermediate	0.1716542	0.1904960
typeShallow	-0.2484355	0.1993626
ageclassJuvenile	-0.6336680	0.6110725
habitatDeep	-0.4666140	0.3362192

Table 2: Random effect variances for Buzz rate model

Group	Variance Estimate
tag	0.3607697

Table 3: ANOVA table for Buzz rate model, testing for differences between shallow and deep-water habitats.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	7	1363.375	1388.743	-674.6873	1349.375	NA	NA	NA
Habitat	8	1363.650	1392.642	-673.8248	1347.650	1.725154	1	0.1890309

Table 4: ANOVA table for Buzz rate model, testing for differences between dive types.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	5	1367.486	1385.606	-678.7429	1357.486	NA	NA	NA
Dive Type	8	1363.650	1392.642	-673.8248	1347.650	9.83618	3	0.0200112

Table 5: Pairwise comparisons between dive types (averaging over other predictors, and using Tukey's method to adjust for multiple comparisons).

Type 1	Type 2	Estimate	SE	Z-ratio	p-value
Deep	Midwater	-0.1257752	0.2170591	-0.5794514	0.9382818
Deep	Intermediate	-0.1716542	0.1904960	-0.9010905	0.8042518
Deep	Shallow	0.2484355	0.1993626	1.2461495	0.5973798
Midwater	Intermediate	-0.0458790	0.1598439	-0.2870238	0.9917646
Midwater	Shallow	0.3742107	0.1840495	2.0332068	0.1757648
Intermediate	Shallow	0.4200897	0.1374484	3.0563457	0.0120139

Bottom Phase Duration

Table 6: Parameter estimates for bottom phase duration model.

Term	Estimate	Standard Error
(Intercept)	244.13111	20.78543
typeMidwater	-62.01063	17.99284
typeIntermediate	-113.84178	16.01622
typeShallow	-151.62401	15.27112
habitatDeep	-22.43864	17.96068
ageclassJuvenile	35.67553	22.38341

Table 7: Random effect variance estimate for bottom phase duration model.

Group	Variance Estimate
tag	988.4902
Residual	2972.2557

Table 8: ANOVA table for bottom phase duration model, testing for differences between dive types.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	5	3317.585	3335.968	-1653.792	3307.585	NA	NA	NA
Dive Type	8	3213.571	3242.985	-1598.785	3197.571	110.0139	3	0

Table 9: ANOVA table for bottom phase duration model, testing for differences between shallow and deep-water habitats.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	7	3213.121	3238.858	-1599.560	3199.121	NA	NA	NA
Habitat	8	3213.571	3242.985	-1598.785	3197.571	1.550065	1	0.2131258

Table 10: Pairwise comparisons between dive types (averaging over other predictors, and using Tukey's method to adjust for multiple comparisons).

Type 1	Type 2	Estimate	SE	Z-ratio	p-value
Deep	Midwater	62.01063	17.992843	3.446405	0.0031866
Deep	Intermediate	113.84178	16.016216	7.107908	0.0000000
Deep	Shallow	151.62401	15.271120	9.928808	0.0000000
Midwater	Intermediate	51.83115	12.709299	4.078207	0.0002651
Midwater	Shallow	89.61339	12.343251	7.260112	0.0000000
Intermediate	Shallow	37.78223	8.319609	4.541347	0.0000331

Inter-buzz Interval (IBI)

Table 11: Parameter estimates for IBI model

Term	Estimate	Standard Error
(Intercept)	3.2857667	0.2516268
typeMidwater	-0.2796209	0.2426046
typeIntermediate	-0.2684605	0.2241720
typeShallow	-0.3623129	0.2264479
habitatDeep	0.1634048	0.1932415
ageclassJuvenile	0.8467172	0.3758653

Table 12: Random effect variances for IBI model

Group	Variance Estimate
tag	0.0399924

Table 13: ANOVA table for IBI model, testing for differences between shallow and deep-water habitats.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	7	1338.687	1360.30	-662.3433	1324.687	NA	NA	NA
Habitat	8	1340.029	1364.73	-662.0145	1324.029	0.6574832	1	0.4174499

Table 14: ANOVA table for IBI model, testing for differences between dive types.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	5	1336.723	1352.161	-663.3616	1326.723	NA	NA	NA
Dive Type	8	1340.029	1364.730	-662.0145	1324.029	2.694199	3	0.4412141

Buzz Duration

Table 15: Parameter estimates for buzz duration model

Term	Estimate	Standard Error
(Intercept)	0.4843471	0.1796554
typeMidwater	-0.3238668	0.1868892
typeIntermediate	-0.0546439	0.1730282
typeShallow	-0.1064921	0.1708456
habitatDeep	-0.0946926	0.0999092
ageclassJuvenile	0.3200324	0.2434574

Table 16: Random effect variances for buzz duration model

Group	Variance Estimate
tag	0

Table 17: ANOVA table for buzz duration model, testing for differences between shallow and deep-water habitats.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	7	477.2204	500.5155	-231.6102	463.2204	NA	NA	NA
Habitat	8	478.3234	504.9464	-231.1617	462.3234	0.8969691	1	0.3435957

Table 18: ANOVA table for buzz duration model, testing for differences between dive types.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	5	476.6080	493.2474	-233.3040	466.6080	NA	NA	NA
Dive Type	8	478.3234	504.9464	-231.1617	462.3234	4.284652	3	0.2323221

Roll variance

Note that for this variable, the random effect did not seem to be required and its estimated variance was approximately zero. It was included for consistency with all the other models.

Table 19: Parameter estimates for roll variance model

Term	Estimate	Standard Error
(Intercept)	0.5987093	0.0543128
typeMidwater	-0.0126979	0.0565356
typeIntermediate	-0.0559271	0.0519896
typeShallow	-0.1127780	0.0518833
ageclassJuvenile	-0.0282443	0.0736455
habitatDeep	-0.0591239	0.0301613

Table 20: Random effect variances for roll variance model

Group	Variance Estimate
tag	0.000000
Residual	0.034683

Table 21: ANOVA table for roll variance model, testing for differences between shallow and deep-water habitats.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	7	-90.58379	-67.25476	52.29189	-104.5838	NA	NA	NA
Habitat	8	-92.39117	-65.72942	54.19559	-108.3912	3.807383	1	0.0510271

Table 22: ANOVA table for roll variance model, testing for differences between dive types.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	5	-89.83019	-73.16659	49.91509	-99.83019	NA	NA	NA
Dive Type	8	-92.39117	-65.72942	54.19559	-108.39117	8.560984	3	0.0357348

Table 23: Pairwise comparisons between dive types (averaging over other predictors, and using Tukey's method to adjust for multiple comparisons).

Type 1	Type 2	Estimate	SE	Z-ratio	p-value
Deep	Midwater	0.0126979	0.0565356	0.2246001	0.9960067
Deep	Intermediate	0.0559271	0.0519896	1.0757363	0.7043786
Deep	Shallow	0.1127780	0.0518833	2.1736878	0.1305749
Midwater	Intermediate	0.0432292	0.0426479	1.0136305	0.7414559
Midwater	Shallow	0.1000801	0.0425182	2.3538186	0.0862242
Intermediate	Shallow	0.0568509	0.0295405	1.9245086	0.2176720

Stroke Rate

Table 24: Parameter estimates for stroke rate model

Term	Estimate	Standard Error
(Intercept)	0.7208860	0.0543588
typeMidwater	-0.1243218	0.0488346
typeIntermediate	-0.0710582	0.0435184
typeShallow	-0.1890178	0.0419092
ageclassJuvenile	-0.1102560	0.0547861
habitatDeep	0.0120141	0.0428556

Table 25: Random effect variances for stroke rate model

Group	Variance Estimate
tag	0.0049705
Residual	0.0219096

Table 26: ANOVA table for stroke rate model, testing for differences between shallow and deep-water habitats.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	7	-237.9278	-212.3850	125.9639	-251.9278	NA	NA	NA
Habitat	8	-236.0071	-206.8153	126.0035	-252.0071	0.0793244	1	0.778215

Table 27: ANOVA table for stroke rate model, testing for differences between dive types.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Full Model	5	-204.5175	-186.2726	107.2588	-214.5175	NA	NA	NA
Dive Type	8	-236.0071	-206.8153	126.0035	-252.0071	37.48958	3	0

Table 28: Pairwise comparisons between dive types (averaging over other predictors, and using Tukey's method to adjust for multiple comparisons).

Type 1	Type 2	Estimate	SE	Z-ratio	p-value
Deep	Midwater	0.1243218	0.0488346	2.545772	0.0531683
Deep	Intermediate	0.0710582	0.0435184	1.632829	0.3600560
Deep	Shallow	0.1890178	0.0419092	4.510169	0.0000383
Midwater	Intermediate	-0.0532636	0.0343495	-1.550637	0.4071989
Midwater	Shallow	0.0646960	0.0333943	1.937336	0.2124042
Intermediate	Shallow	0.1179596	0.0225595	5.228820	0.0000010

VO2 (by dive phase)

Table 29: Parameter estimates for VO2 model

Term	Estimate	Standard Error
(Intercept)	3.1253745	0.2534692
phaseDescent	-0.1085906	0.0478394
phaseBottom	0.2677432	0.0478394
phaseAscent	0.3357710	0.0478394
typeMidwater	0.1142862	0.1650970
typeIntermediate	0.2936717	0.1469955
typeShallow	0.1690041	0.1398179
habitatDeep	0.0675165	0.2628763
ageclassJuvenile	-1.0385031	0.3159293

Table 30: Random effect variances for VO2 model

Group	Variance Estimate
divenumber:tag	0.1704118
tag	0.2635599
Residual	0.2966185

Table 31: ANOVA table for VO2 model, testing for differences between shallow and deep-water habitats.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Without Habitat	11	2233.011	2288.234	-1105.506	2211.011	NA	NA	NA
Full Model	12	2234.946	2295.188	-1105.473	2210.946	0.0658067	1	0.797543

Table 32: ANOVA table for VO2 model, testing for effect of dive phase.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Without Dive Phase	9	2349.869	2395.051	-1165.935	2331.869	NA	NA	NA
Full Model	12	2234.946	2295.188	-1105.473	2210.946	120.9237	3	0

Table 33: ANOVA table for VO2 model, testing for effect of dive type.

term	df	AIC	BIC	logLik	deviance	statistic	Chi.Df	p.value
Without Dive Type	9	2234.527	2279.708	-1108.263	2216.527	NA	NA	NA
Full Model	12	2234.946	2295.188	-1105.473	2210.946	5.580991	3	0.1338739

Table 34: Pairwise comparisons between dive phases (averaging over other predictors, and using Tukey's method to adjust for multiple comparisons.

Phase 1	Phase 2	Estimate	SE	Z-ratio	p-value
Full Dive	Descent	0.1085906	0.0478394	2.269902	0.1051081
Full Dive	Bottom	-0.2677432	0.0478394	-5.596715	0.0000001
Full Dive	Ascent	-0.3357710	0.0478394	-7.018719	0.0000000
Descent	Bottom	-0.3763339	0.0450736	-8.349310	0.0000000
Descent	Ascent	-0.4443616	0.0450736	-9.858567	0.0000000
Bottom	Ascent	-0.0680277	0.0450736	-1.509258	0.4318597