Supplementary Material for

Shifting elasmobranch community assemblage at Cocos Island, an isolated marine protected area

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This PDF file includes: Supplementary text, diet information, dive effort, explanatory variables, species information, distribution of counts, residual analysis, model ranking, robustness analysis, model averaged estimates

The code for these plots and those found in the manuscript is available at `https://github.com/baumlab`.

Supplementary text

Please see main text for reference information and other figures.

Cocos Island

Cocos Island (Isla del Coco; N 05°31′08″, W 87°04′18″), is located 550 km from mainland Costa Rica in the eastern tropical Pacific. The island was first named a national park in 1978 and this protection was extended to the surrounding marine area in 1984. This protection was extended in 2001 to 22.2 km around the island (Sibaja-Cordero 2008). Cocos Island is also recognized as a World Heritage site by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and listed as a wetland of international importance under the Ramsar Convention on Wetlands (Cortés 2012). The waters around Cocos Island provide habitat for a diverse suite of organisms. The island is particularly well known for its large predators. Vast schools of scalloped hammerheads (*Sphyrna lewini*) are often present, and whitetip reef (*Triaenodon obesus*), blacktip (*Carcharhinus limbatus*), Galapagos (*C. galapagensis*), silvertip (*C. albimarginatus*), and silky (*C. falciformis*) sharks are commonly observed. Pelagic fishes, including yellowfin tuna (*Thunnus albacares*), sailfish (*Istiophorus platypterus*), whale sharks (*Rhincodon typus*), and manta (*Manta birostris*) and devil (*Mobula spp.*) rays are abundant (Garrison 2005). Despite Cocos Island's protected status and enforcement efforts, illegal fishing is still known to occur (Alvarado et al. 2012; Arias et al. 2014).

Methods

Data

Divemasters with Undersea Hunter (http://underseahunter.com/), a privately owned and operated company, systematically recorded the elasmobranchs observed on each of 27,527 dives conducted between January 1993 and December 2013 (n = 21 years) at 17 major sites around Cocos Island (Figs. 1, 2). Each dive averaged approximately 60 min and was led by an experienced professional divemaster. Dive depth ranged from 10-40 m, depending on the site, but was consistent within each site. The dive sites encompassed the range of shallow-water habitats and hydrographic conditions available to marine species at Cocos Island. Upon completion of each dive, divemasters used a standardized data sheet to record the observed numbers of each of the six most common elasmobranch species, and the presence or absence of six less common shark species (Table 1). Although differentiating between certain shark species (e.g. blacktip and Galapagos sharks) is difficult, divemasters with Undersea Hunter were capable of describing even subtle differences between these species (Undersea Hunter, personal communication, November 2013) lending confidence to the identity of recorded species. Accurate counts could be made when numbers of sharks and rays were low, but only rough approximations could be made when divemasters encountered large groups (e.g. upwards of 1000 for scalloped hammerheads). We acknowledge that recounting of individual elasmobranchs also could have occurred during single dives, especially when species were seen in large schools. We attempt to account for these and other biases through mixed effects models and multiple robustness tests.

We transcribed all of the data from each of Undersea Hunter's 52 divemasters and compiled them into a single database. We then checked and cleaned the database to identify and correct transcription errors, and applied a series of filters to it: 1) We excluded records from divemasters who had conducted <100 dives total at Cocos Island, resulting in the exclusion of 1,225 records (<4.5% of the original data set). The remaining 36 divemasters averaged 731 dives (SD 512) each over an average of 4.1 years (2.3 SD) (Fig. 2b). Divemasters typically conducted dives at all dive sites around Cocos Island (Fig. 2c); 2) We excluded dives from sites visited infrequently (n<100 dives each), resulting in the exclusion of 467 additional dives (<1.69% of the original data set). Although the number of dives increased over time, the proportion of dives conducted at each site remained consistent over the study period (Figs. 2a, S1); 3) Lastly, we excluded 2,444 records with missing data for the response or explanatory variables. After all filtering steps, 23,391 individual dives (85% of the original 27,527 dives) remained for analysis. Marble rays were not recorded for 2013, so only 21,534 records were available for this species.

Model evaluation, selection, and robustness

Following our tailored modeling approach, we employed a unified approach to model diagnostics and model selection for each species. We examined the Pearson residuals plotted against model predictions and time (Fig. S6). We selected covariates for each species by first running all possible combinations of explanatory variables (N=64; excluding interaction effects) using the MuMIn package (Barto 2013), and then defined competitive models as those within 2 AIC of the best model (Table S9). If several models fell within 2 AIC of the best model, we used a model averaging approach (Zuur et al. 2009) to generate parameter estimates. The averaged model is presented for each species (Table 3).

To test the robustness of our models and specifically the estimated year effect, we conducted 2 sensitivity analyses. First, we modeled each species as described above, but using a subset of the data that included only the 5 most experienced divers, who together surveyed over the entire 21 year study period. This allowed us to test for potential observer biases. Our estimates of the year coefficient changed very little for any species (Table S10). We also examined a subset of data including only the 5 most commonly visited sites. Again, results changed little from those obtained with the complete data set (Table S10).

Appendix S1: Summary of the consumer-prey relationships among the Cocos Island study species. Since dietary literature is not always species-specific, prey are listed by class, family and then specie. Numbers are references listed below.

| *Cocos Species* **Class** **Family** Common name, *scientific name*	Hammerhead shark, *Sphyrna lewini*	Whitetip reef shark, *Triaenodon obesus*	Marbled ray, *Taeniura meyeni*	Spotted eagle ray, *Aetobatus narinari*	Giant manta ray, *Manta birostris*	Sicklefin devil ray, *Mobula tarapacana*	Silky shark, *Carcharhinus falciformis*	Silvertip shark, *C. albimarginatus*	Blacktip shark, *C. limbatus*	Galapagos shark, *C. galapagensis*	Tiger shark, *Galeocerdo cuvier*
Chondricthyes	1,4,5							1	1,6	1,7	1,2
Rays	2,5								2, 3	8	10
Myliobatidae (Mantas and eagle rays)									2		10
Aetobatus species (eagle rays)								2	2		10
Spotted eagle ray, *A. narinari*											
Mobula species (devil rays)											
Sicklefin devil ray, *M. tarpacana*											
Manta species (manta rays)											
Giant manta ray, *M. birostris*											
Dasyatidae (Stingrays)											9,10
Taeniura Species (ribbontail stingrays)											
Marbled ray, *T. meyeni*											
Sharks	2,4,5								2,3,4,11	8	10
Sphyrnidae (Hammerhead sharks)									3,4		
Sphyrna species									3,4		
Scalloped hammerhead shark*, S. lewini*									11		
Carcharhinidae (Requiem sharks)	2,4,5								2,3,4		
Triaenodon species											
Whitetip reef shark, *T. obesus*											
Carcharhinus species	2								4		
Silky shark, *C. falciformis*											
Silvertip shark, *C. albimarginnatus*											
Blacktip shark, *C. limbatus*											
Galapagos shark, *C. galapagensis*											

Table 1 Literature Cited

[1] Cortés, E. 1999. Standardized diet compositions and trophic levels of sharks. ICES Journal of Marine Science 56: 707-717.

[2] Compango, L.J.V. 1984. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Carcharhiniformes. FAO Fisheries Synopsis, Rome. No. 125, Vol. 4, Part 2. pp. 251-633.

[3] Castro, J.I. 1996. Biology of the blacktip shark, Carcharhinus limbatus, off the southeastern United States. Bulletin of Marine Science 59(3): 508-522.

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[6] Hoffmayer, E.R. and G.R. Parsons. 2003. Food habits of three shark species from the Mississippi Sound in the Northern Gulf of Mexico. Southeastern Naturalist 2(2): 271-280.

[7] Wetherbee, B.M., G.L. Crow and C.G. Lowe. 1996. Biology of the Galapagos shark, Carcharhinus galapagensis, in Hawai'i. Environmental Biology of Fishes 45: 299-310.

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[9] Heithaus, M. R. 2001. The biology of tiger sharks, Galeocerdo cuvier, in Shark Bay, Western Australia: Sex ratio, size distribution, diet, and seasonal changes in catch rates. Environmental Biology of Fishes 61:25–36.

[10] Simpfendorfer, C. A., A. B. Goodreid, and R. B. Mcauley. 2001. Size, sex and geographic variation in the diet of the tiger shark, Galeocerdo cuvier, from Western Australian waters. Environmental Biology of Fishes 61:37–46.

[11] Clarke, T.A. 1971. The ecology of the scalloped hammerhead shark, Sphyrna lewini, in Hawaii. Pacific Science 25: 133-144.

Dive effort
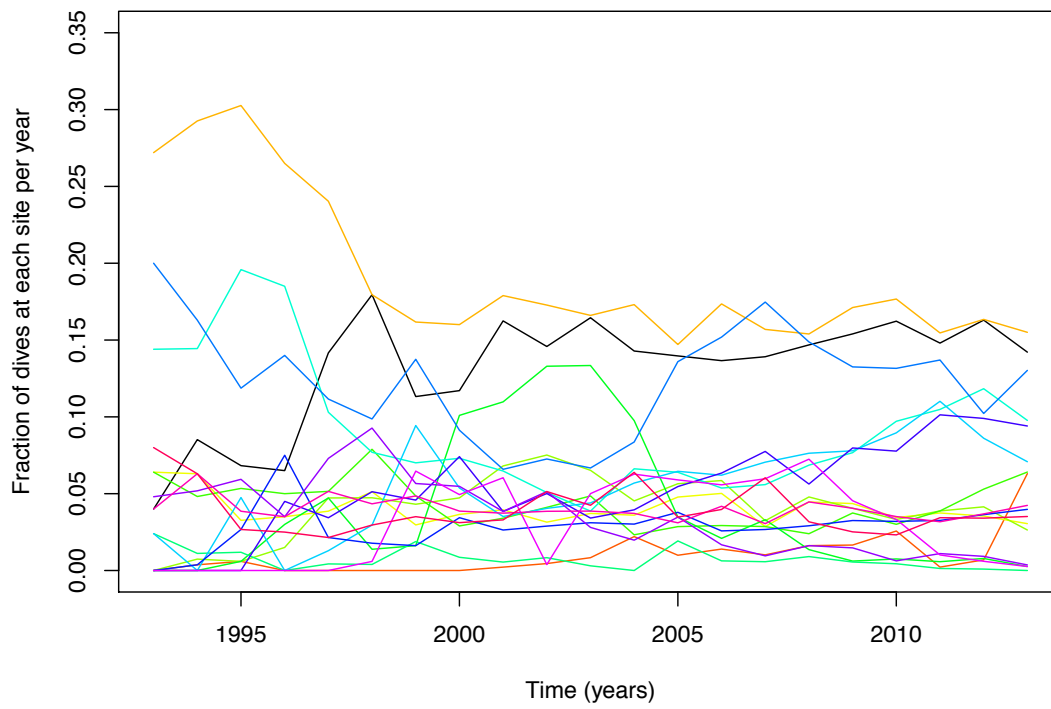
Appendix S2: Fraction of dives recorded at each site for each year. Each line represents a different site.

Explanatory variables
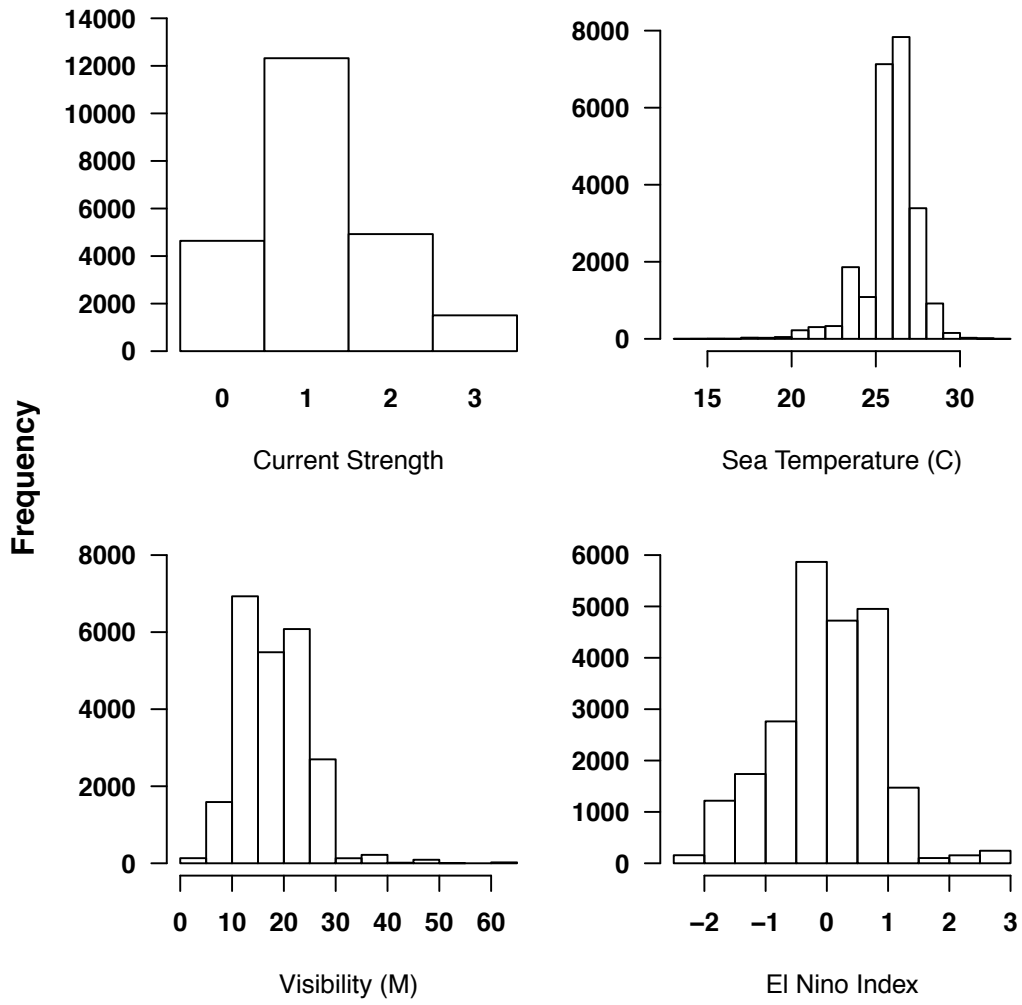
Appendix S3: Distributions of explanatory variables.

Species information

NAME	#RECORDS	MEAN	MEDIAN	VAR	ZEROS	FRAC_NOT_ZERO
scalloped hammerhead	23391	33.97	10	4663.97	5367	0.77
tiger	23391				22821	0.02
silky	23391				22570	0.04
whitetip reef	23391	25.55	20	667.82	670	0.97
blacktip	23391				22444	0.04
Galapagos	23391				21262	0.09
silvertip	23391				22777	0.03
eagle ray	23391	0.63	0	2.93	17130	0.27
marble ray	21534	8.5	5	96.49	3400	0.84
whale shark	23391				22956	0.02
mobula ray	23391	0.13	0	0.79	21779	0.07
manta ray	23391	0.05	0	0.1	22520	0.04

Appendix S4: Species specific record information. Blanks are present for species in which only presence-absence was noted.
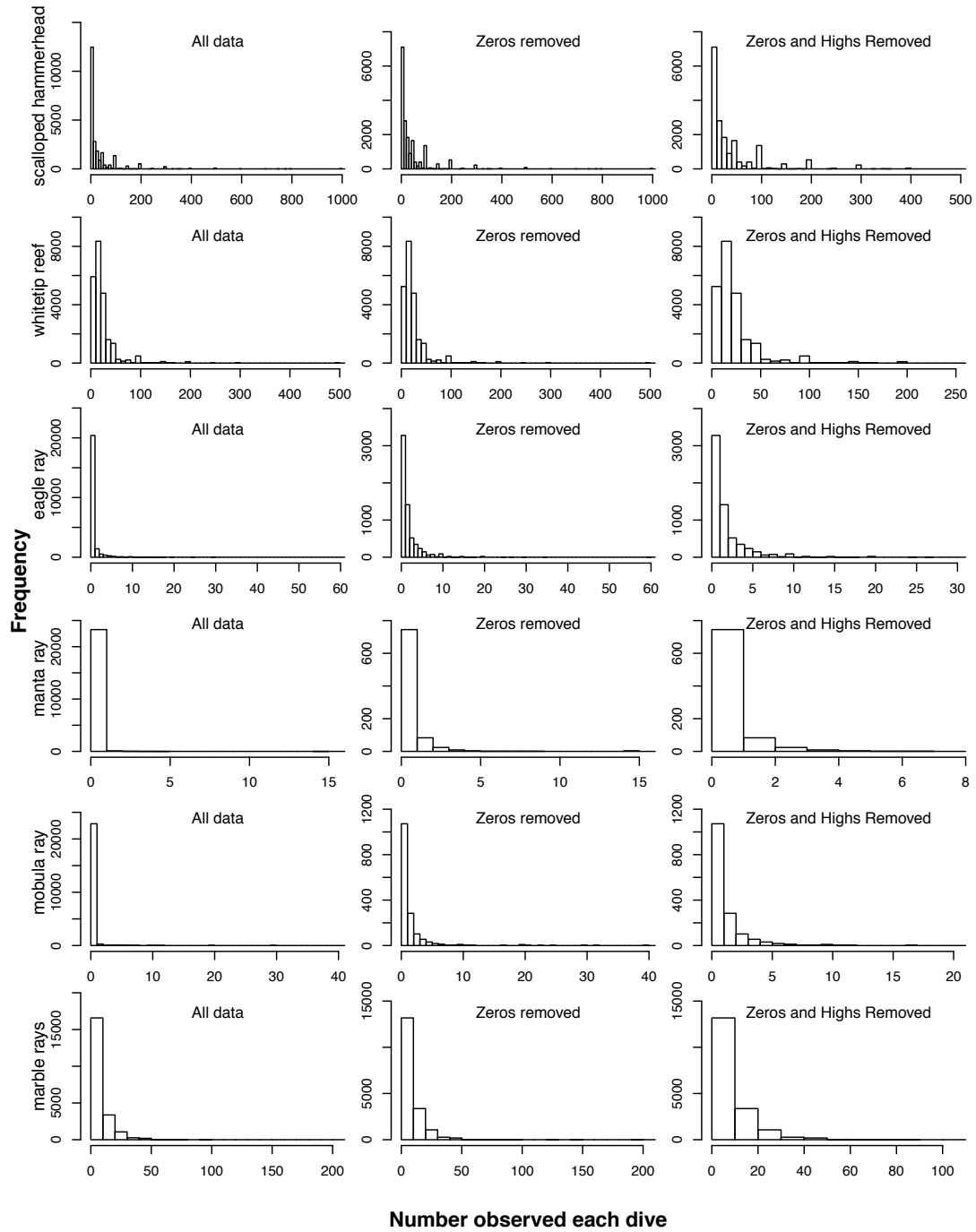
Appendix S5: Distribution of counts for each species.

Distribution of counts
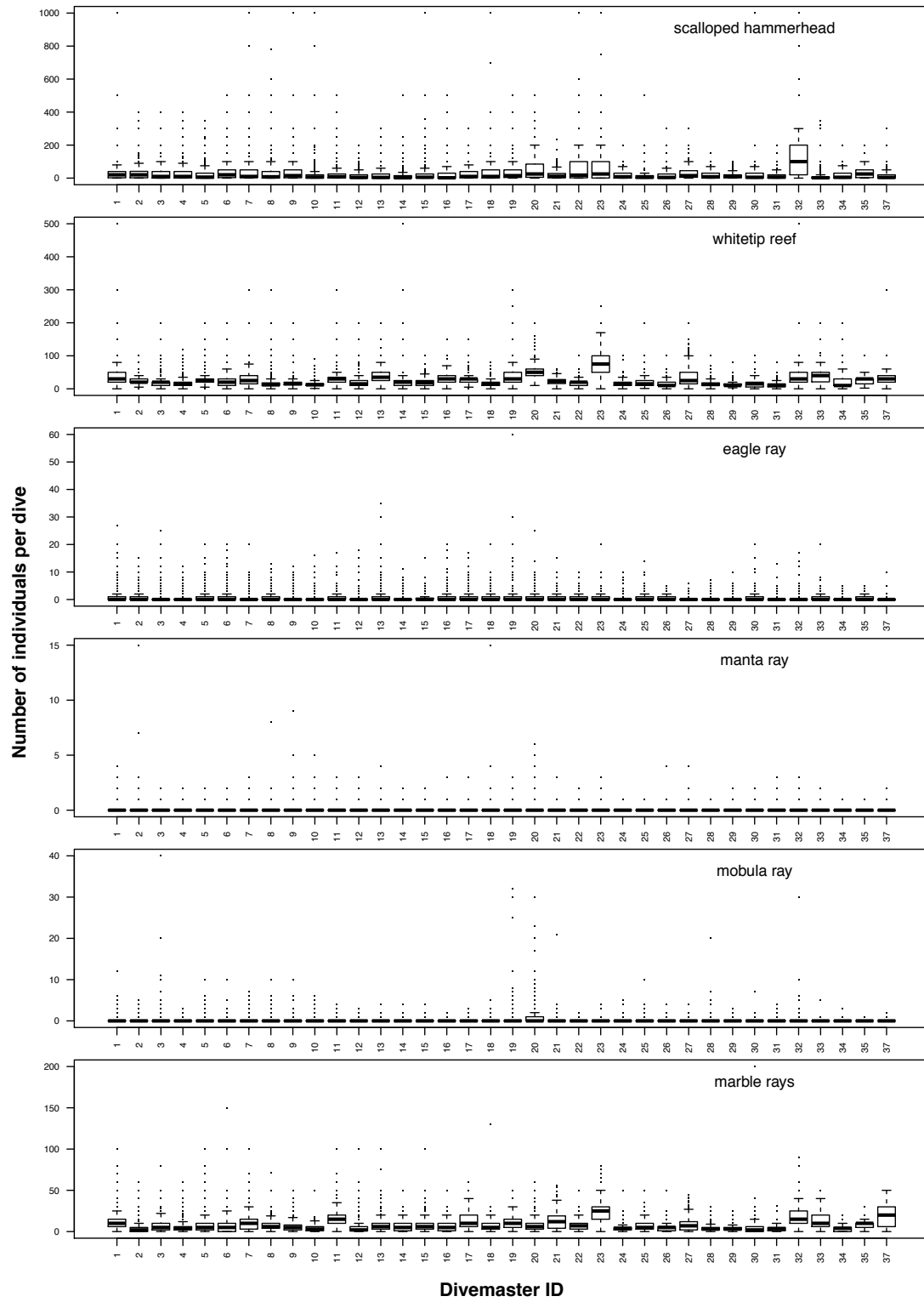
Appendix S6: Number of individuals of each species observed for each divemaster.
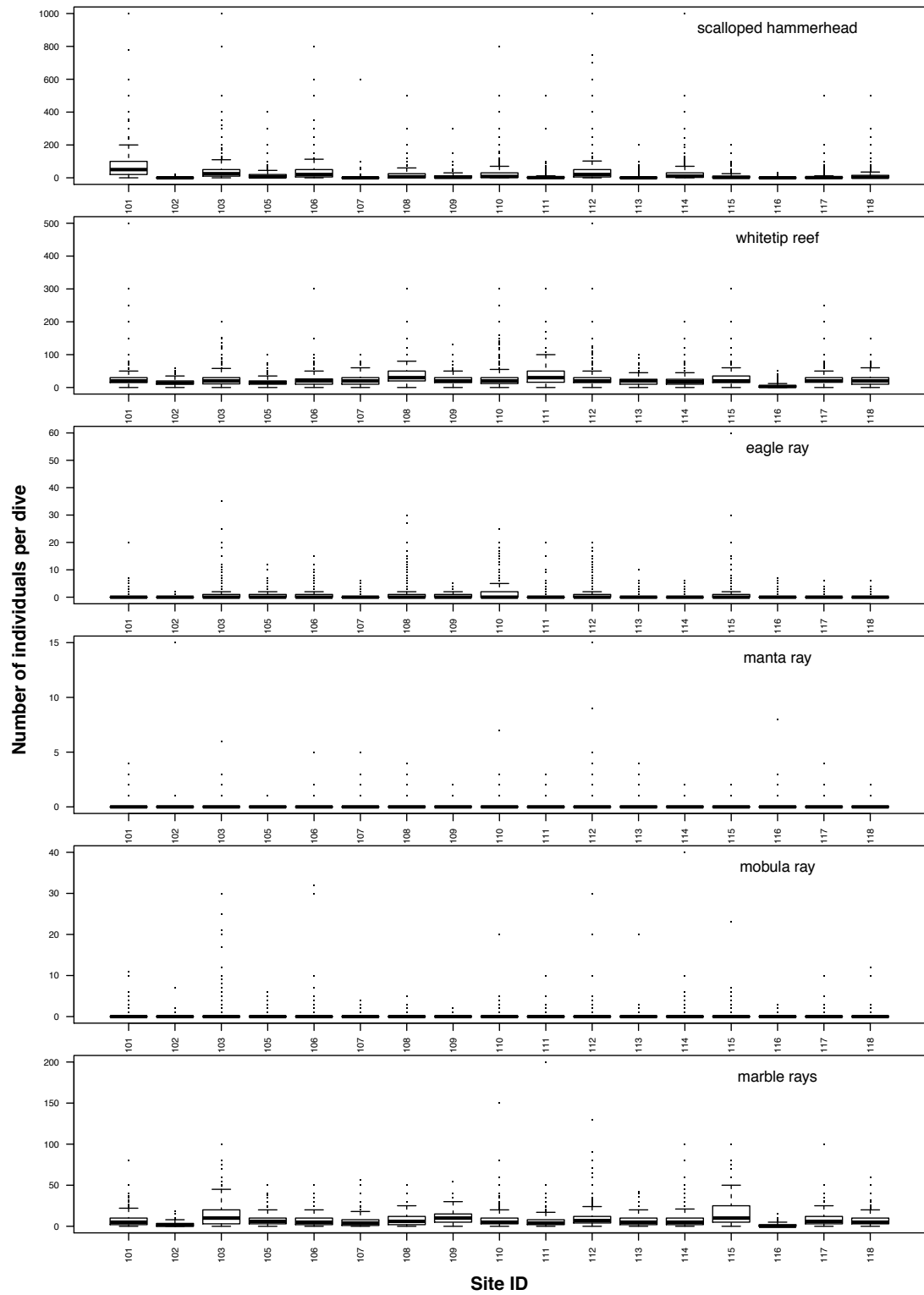
Appendix S7: Number of individuals of each species observed at each dive site.

Residual analysis
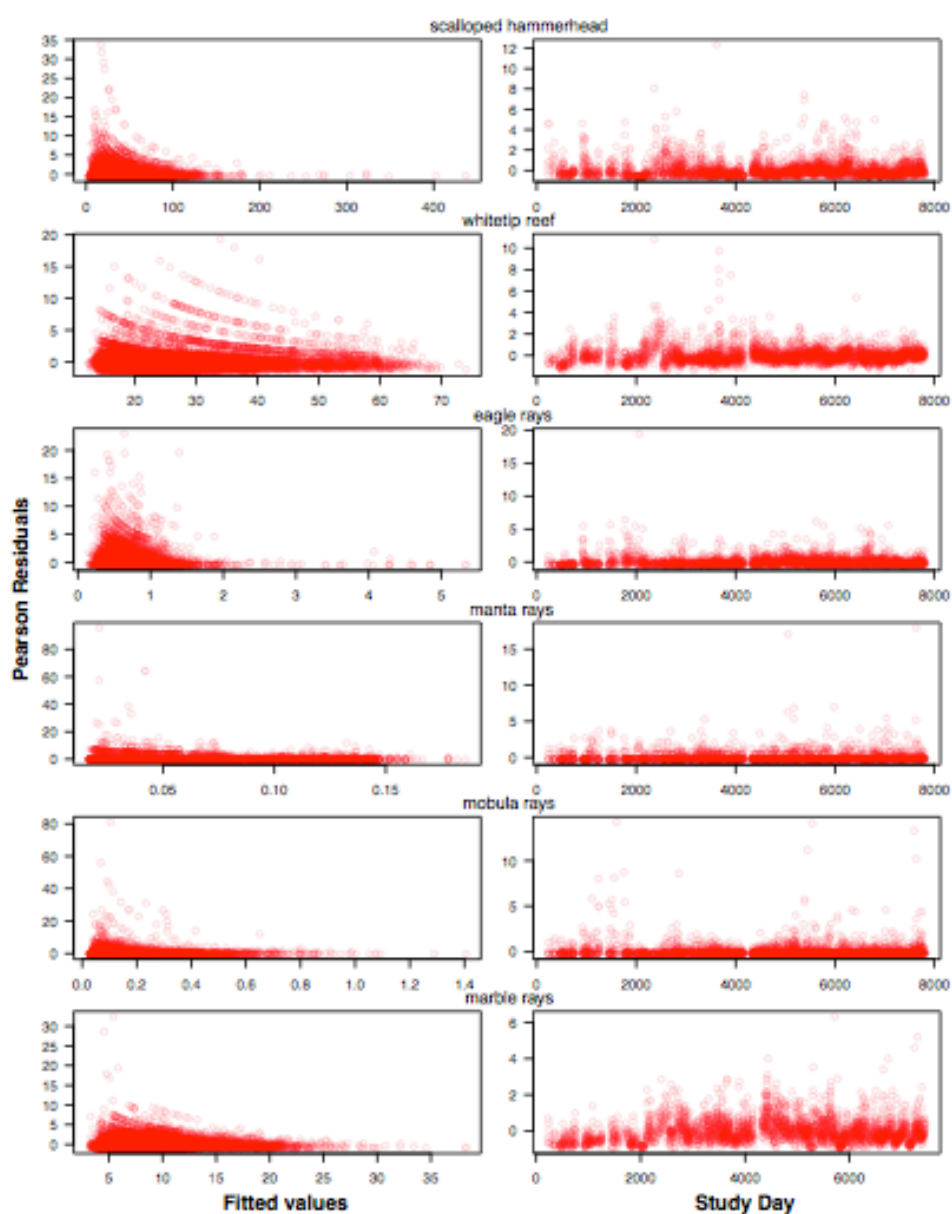
Appendix S8.1: Residual plots for species with count data.
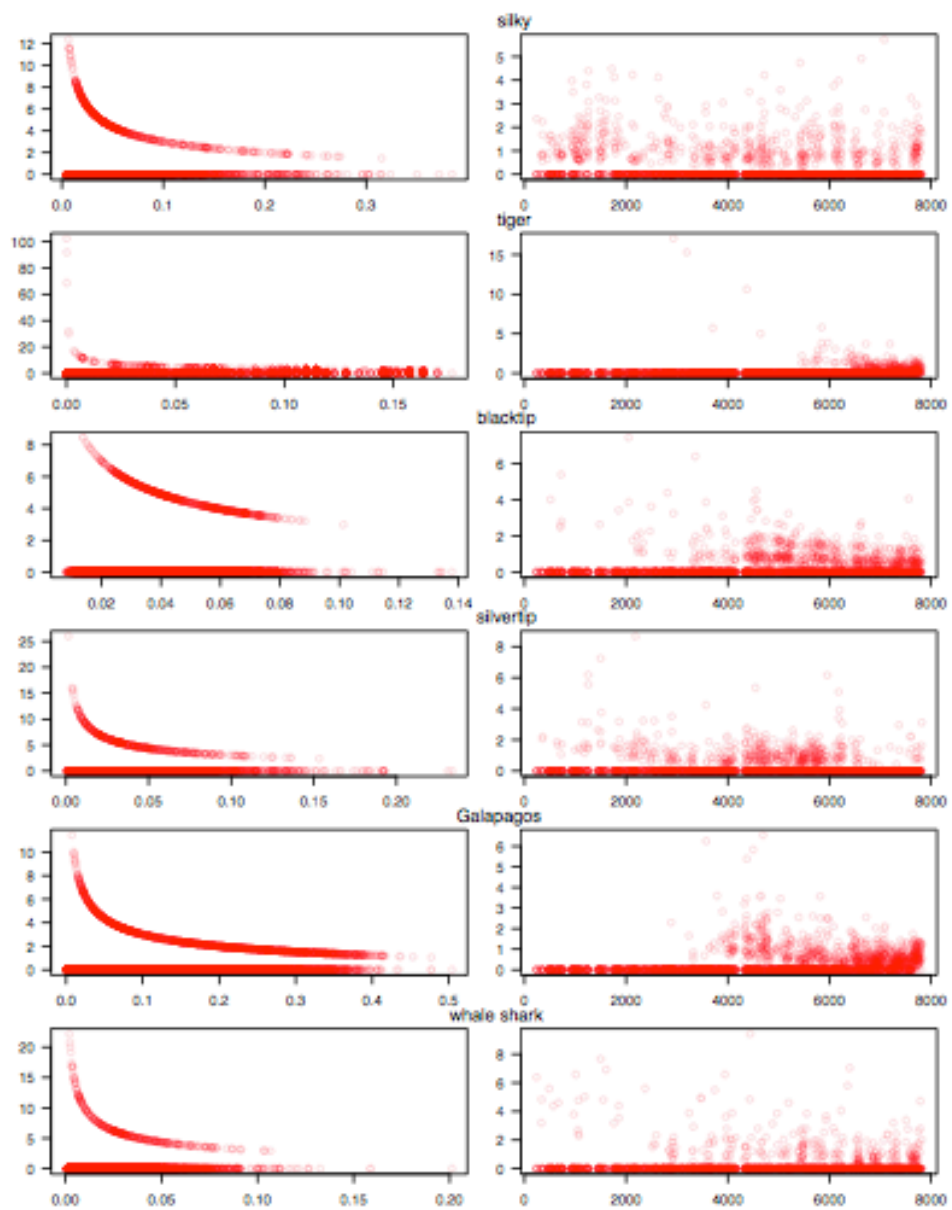
Appendix S8.2: Residual plots for species with only presence-absence data.

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
5.204	0.598	+	-0.333	-0.111	-0.096	-0.028	0.038	11.000	-94893.900	189809.800	0.000	1.000

Appendix S9.1: Top models for scalloped hammerheads

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-16.052		+			0.047	0.583		6.000	-2122.680	4257.360	0.000	0.330
-14.674		+				0.577		5.000	-2124.140	4258.280	0.920	0.208
-16.129		+	-0.059		0.047	0.586		7.000	-2122.260	4258.520	1.160	0.185
-16.120	-0.070	+		0.072	0.050	0.583		8.000	-2121.450	4258.900	1.540	0.153
-16.088		+			0.046	0.584	0.002	7.000	-2122.650	4259.300	1.940	0.125

Appendix S9.2: Top models for tiger sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
1.957	0.525	+		-0.200	-0.158	-0.114		8.000	-3307.600	6631.200	0.000	0.315
1.857	0.530	+		-0.199	-0.161	-0.111	0.007	9.000	-3306.850	6631.700	0.500	0.245
1.837	0.536	+	-0.058	-0.207	-0.152	-0.116		9.000	-3306.880	6631.760	0.560	0.238
1.724	0.542	+	-0.061	-0.207	-0.155	-0.113	0.007	10.000	-3306.040	6632.080	0.880	0.203

Appendix S9.3: Top models for silky sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
5.036	0.049	+	-0.031	0.028	-0.025	-0.070	-0.006	11.000	-95765.900	191553.800	0.000	1.000

Appendix S9.4: Top models for whitetip reef sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.226	0.020	+		0.100		0.087	0.025	8.000	-3883.410	7782.820	0.000	0.239
-4.350		+			-0.032	0.086	0.026	7.000	-3884.530	7783.060	0.240	0.212
-4.532	0.017	+		0.091	-0.026	0.086	0.026	9.000	-3882.680	7783.360	0.540	0.182
-5.213		+				0.087	0.024	6.000	-3885.710	7783.420	0.600	0.177
-5.235	0.017	+	0.021	0.102		0.088	0.025	9.000	-3883.290	7784.580	1.760	0.099
-4.318		+	0.023		-0.034	0.087	0.025	8.000	-3884.370	7784.740	1.920	0.091

Appendix S9.5: Top models for blacktip sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-7.147	0.347	+		0.463	-0.039	0.278	0.032	9.000	-6036.590	12091.180	0.000	1.000

Appendix S9.6: Top models for Galapagos sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-0.155	0.107	+		-0.170		-0.096	-0.085	8.000	-2685.110	5386.220	0.000	0.500
0.495	0.107	+		-0.180	-0.025	-0.096	-0.084	9.000	-2684.690	5387.380	1.160	0.280
-0.143	0.113	+	-0.032	-0.175		-0.097	-0.085	9.000	-2684.930	5387.860	1.640	0.220

Appendix S9.7: Top models for silvertip sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-3.001	0.165	+	-0.062	-0.056	0.068	-0.020	0.039	12.000	-23052.100	46128.200	0.000	1.000

Appendix S9.8: Top models for eagle rays

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
4.338	0.110	+	-0.057	0.018	-0.063	-0.066	0.011	11.000	-67707.100	135436.200	0.000	1.000

Appendix S9.9: Top models for marble rays

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.990	1.133	+		-0.556		0.044	0.034	9.000	-2021.990	4061.980	0.000	0.727
-5.819	1.132	+	-0.380	-0.559	-0.006	0.044	0.034	10.000	-2021.970	4063.940	1.960	0.273

Appendix S9.10: Top models for whale sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
1.205	-0.263	+	-0.130	-0.279	-0.113	-0.073	0.023	12.000	-7695.320	15414.640	0.000	1.000

Appendix S9.11: Top models for mobula rays

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-0.418			-0.167		-0.046	-0.104		6.000	-4160.170	8332.340	0.000	0.330
-0.600	0.054		-0.169	0.078	-0.039	-0.104		8.000	-4158.570	8333.140	0.800	0.221
-1.640	0.057		-0.187	0.091		-0.104		7.000	-4159.880	8333.760	1.420	0.162
-0.463			-0.169		-0.047	-0.103	0.004	7.000	-4159.990	8333.980	1.640	0.145
-1.630			-0.189			-0.104		5.000	-4162.020	8334.040	1.700	0.141

Appendix S9.12: Top models for manta rays

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
5.204	0.598	+	-0.333	-0.111	-0.096	-0.028	0.038	11.000	-94893.900	189809.800	0.000	1.000

Appendix S10.1: Top models for scalloped hammerheads

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
4.817	0.530	+	-0.304	0.003	-0.071	-0.029	0.025	11.000	-21256.300	42534.600	0.000	1.000

Appendix S10.2: Top models for scalloped hammerheads for subset of divemasters

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
5.916	0.492	+	-0.260	-0.117	-0.096	-0.033	0.027	11.000	-63042.800	126107.600	0.000	1.000

Appendix S10.3: Top models for scalloped hammerheads for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-16.052		+			0.047	0.583		6.000	-2122.680	4257.360	0.000	0.330
-14.674		+				0.577		5.000	-2124.140	4258.280	0.920	0.208
-16.129		+	-0.059		0.047	0.586		7.000	-2122.260	4258.520	1.160	0.185
-16.120	-0.070	+		0.072	0.050	0.583		8.000	-2121.450	4258.900	1.540	0.153
-16.088		+			0.046	0.584	0.002	7.000	-2122.650	4259.300	1.940	0.125

Appendix S10.4: Top models for tiger sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-14.925	-0.540			0.321		0.590		4.000	-179.594	367.188	0.000	0.309
-15.945	-0.566			0.368	0.040	0.602		5.000	-178.941	367.882	0.694	0.219
-15.198	-0.473		-0.246	0.277		0.599		5.000	-179.010	368.020	0.832	0.204
-16.206	-0.504		-0.247	0.325		0.609	0.042	6.000	-178.330	368.660	1.472	0.148
-15.760	-0.541			0.347	0.029	0.596		5.000	-179.540	369.080	1.892	0.120

Appendix S10.5: Top models for tiger sharks for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-16.008	-0.193	+		0.084		0.631	0.028	8.000	-1537.400	3090.800	0.000	0.346
-17.265	-0.185	+		0.102	0.044	0.636	0.027	9.000	-1536.460	3090.920	0.120	0.326
-16.119	-0.182	+	-0.056	0.077		0.635	0.029	9.000	-1537.120	3092.240	1.440	0.168
-17.380	-0.175	+	-0.057	0.095	0.044	0.640	0.027	10.000	-1536.170	3092.340	1.540	0.160

Appendix S10.6: Top models for tiger sharks for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
1.957	0.525	+		-0.200	-0.158	-0.114		8.000	-3307.600	6631.200	0.000	0.315
1.857	0.530	+		-0.199	-0.161	-0.111	0.007	9.000	-3306.850	6631.700	0.500	0.245
1.837	0.536	+	-0.058	-0.207	-0.152	-0.116		9.000	-3306.880	6631.760	0.560	0.238
1.724	0.542	+	-0.061	-0.207	-0.155	-0.113	0.007	10.000	-3306.040	6632.080	0.880	0.203

Appendix S10.7: Top models for silky sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
1.548	0.450	+	-0.379	-0.220	-0.094	-0.168		9.000	-1092.850	2203.700	0.000	0.715
1.450	0.456	+	-0.383	-0.222	-0.094	-0.167	0.004	10.000	-1092.770	2205.540	1.840	0.285

Appendix S10.8: Top models for silky sharks for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
2.268	0.535	+	-0.084	-0.176	-0.156	-0.120		9.000	-2213.940	4445.880	0.000	0.358
2.426	0.519	+		-0.164	-0.163	-0.116		8.000	-2215.010	4446.020	0.140	0.334
2.334	0.532	+	-0.083	-0.176	-0.155	-0.121	-0.004	10.000	-2213.770	4447.540	1.660	0.156
2.497	0.516	+		-0.164	-0.162	-0.118	-0.004	9.000	-2214.800	4447.600	1.720	0.152

Appendix S10.9: Top models for silky sharks for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
5.036	0.049	+	-0.031	0.028	-0.025	-0.070	-0.006	11.000	-95765.900	191553.800	0.000	1.000

Appendix S10.10: Top models for whitetip reef sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
5.060	0.102	+	-0.105	0.055	-0.038	-0.059	-0.005	11.000	-20743.800	41509.600	0.000	1.000

Appendix S10.11: Top models for whitetip sharks for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
5.158	0.039	+	-0.038	0.029	-0.019	-0.074	-0.009	11.000	-56149.100	112320.200	0.000	1.000

Appendix S10.12: Top models for whitetip sharks for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.226	0.020	+		0.100		0.087	0.025	8.000	-3883.410	7782.820	0.000	0.239
-4.350		+			-0.032	0.086	0.026	7.000	-3884.530	7783.060	0.240	0.212
-4.532	0.017	+		0.091	-0.026	0.086	0.026	9.000	-3882.680	7783.360	0.540	0.182
-5.213		+				0.087	0.024	6.000	-3885.710	7783.420	0.600	0.177
-5.235	0.017	+	0.021	0.102		0.088	0.025	9.000	-3883.290	7784.580	1.760	0.099
-4.318		+	0.023		-0.034	0.087	0.025	8.000	-3884.370	7784.740	1.920	0.091

Appendix S10.13: Top models for blacktip sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.980		+				0.133	0.053	6.000	-756.426	1524.852	0.000	0.469
-6.028		+	0.115			0.138	0.052	7.000	-755.697	1525.394	0.542	0.358
-6.056		+			0.003	0.133	0.053	7.000	-756.424	1526.848	1.996	0.173

Appendix S10.14: Top models for blacktip sharks for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-4.282	-0.084	+		0.163		0.060	0.017	8.000	-2640.570	5297.140	0.000	0.347
-3.347	-0.087	+		0.151	-0.035	0.059	0.019	9.000	-2639.600	5297.200	0.060	0.337
-4.271	-0.078	+	-0.037	0.159		0.058	0.018	9.000	-2640.280	5298.560	1.420	0.171
-3.394	-0.082	+	-0.028	0.148	-0.033	0.058	0.019	10.000	-2639.440	5298.880	1.740	0.145

Appendix S10.15: Top models for blacktip sharks for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-7.147	0.347	+		0.463	-0.039	0.278	0.032	9.000	-6036.590	12091.180	0.000	1.000

Appendix S10.16: Top models for Galapagos sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-6.071	0.571			0.484	-0.111	0.318	0.061	6.000	-873.881	1759.762	0.000	0.728
-6.079	0.567		0.015	0.487	-0.111	0.319	0.061	7.000	-873.864	1761.728	1.966	0.272

Appendix S10.17: Top models for Galapagos sharks for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.721	0.364	+		0.546	-0.068	0.271		8.000	-3491.840	6999.680	0.000	0.368
-5.839	0.365	+		0.549	-0.070	0.274	0.007	9.000	-3491.030	7000.060	0.380	0.305
-5.734	0.369	+	-0.029	0.542	-0.067	0.270		9.000	-3491.580	7001.160	1.480	0.176
-5.856	0.369	+	-0.031	0.544	-0.070	0.273	0.008	10.000	-3490.730	7001.460	1.780	0.151

Appendix S10.18: Top models for Galapagos sharks for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-0.155	0.107	+		-0.170		-0.096	-0.085	8.000	-2685.110	5386.220	0.000	0.500
0.495	0.107	+		-0.180	-0.025	-0.096	-0.084	9.000	-2684.690	5387.380	1.160	0.280
-0.143	0.113	+	-0.032	-0.175		-0.097	-0.085	9.000	-2684.930	5387.860	1.640	0.220

Appendix S10.19: Top models for silvertip sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-0.025		+				-0.035	-0.103	6.000	-662.750	1337.500	0.000	0.560
-0.010		+	-0.052			-0.038	-0.102	7.000	-662.629	1339.258	1.758	0.233
0.136		+			-0.006	-0.036	-0.103	7.000	-662.744	1339.488	1.988	0.207

Appendix S10.20: Top models for silvertip sharks for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-0.688					-0.106	-0.163	0.024	4.000	-442.938	893.876	0.000	0.133
-3.398			-0.207			-0.170	0.024	4.000	-442.986	893.972	0.096	0.127
-0.257					-0.098	-0.175		3.000	-444.040	894.080	0.204	0.120
-2.878						-0.172		2.000	-445.055	894.110	0.234	0.119
-2.760			-0.188			-0.181	0.021	3.000	-444.102	894.204	0.328	0.113
-3.463						-0.162	0.025	3.000	-444.132	894.264	0.388	0.110
-1.244			-0.158		-0.083	-0.168		5.000	-442.337	894.674	0.798	0.089
-0.752			-0.142		-0.077	-0.181		4.000	-443.559	895.118	1.242	0.072
-0.855		+			-0.105	-0.148	0.028	7.000	-440.682	895.364	1.488	0.063
-3.643		+				-0.147	0.026	6.000	-441.843	895.686	1.810	0.054

Appendix S10.21: Top models for silvertip sharks for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-3.001	0.165	+	-0.062	-0.056	0.068	-0.020	0.039	12.000	-23052.100	46128.200	0.000	1.000

Appendix S10.22: Top models for eagle rays

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-7.646	0.238	+	-0.060	0.009	0.242	0.032	0.021	12.000	-5408.230	10840.460	0.000	0.530
-7.406	0.218	+		0.018	0.232	0.034	0.020	11.000	-5409.350	10840.700	0.240	0.470

Appendix S10.23: Top models for eagle rays for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-3.536	0.180	+	-0.073	-0.020	0.095	-0.014	0.036	12.000	-14812.600	29649.200	0.000	1.000

Appendix S10.24: Top models for eagle rays for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
4.338	0.110	+	-0.057	0.018	-0.063	-0.066	0.011	11.000	-67707.100	135436.200	0.000	1.000

Appendix S10.25: Top models for marble rays

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
3.264	0.086	+		-0.068	-0.037	-0.049		9.000	-14791.900	29601.800	0.000	0.363
3.188	0.094	+	-0.028	-0.071	-0.034	-0.049		10.000	-14791.200	29602.400	0.600	0.269
3.303	0.083	+		-0.069	-0.036	-0.050	-0.003	10.000	-14791.400	29602.800	1.000	0.220
3.228	0.091	+	-0.026	-0.072	-0.033	-0.050	-0.003	11.000	-14790.800	29603.600	1.800	0.148

Appendix S10.26: Top models for marble rays for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
4.621	0.100	+	-0.019	0.025	-0.058	-0.071	0.004	11.000	-40593.700	81209.400	0.000	0.574
4.660	0.095	+		0.028	-0.060	-0.070	0.004	10.000	-40595.000	81210.000	0.600	0.426

Appendix S10.27: Top models for marble rays for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.990	1.133	+	-0.380	-0.556		0.044	0.034	9.000	-2021.990	4061.980	0.000	0.727
-5.819	1.132	+	-0.380	-0.559	-0.006	0.044	0.034	10.000	-2021.970	4063.940	1.960	0.273

Appendix S10.28: Top models for whale sharks

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.045	0.874		-0.255	-0.382			0.033	5.000	-388.670	787.340	0.000	0.161
-7.859	0.883		-0.302	-0.354	0.110		0.030	6.000	-387.907	787.814	0.474	0.127
-7.593	0.859		-0.278	-0.361	0.124			5.000	-389.063	788.126	0.786	0.109
-4.349	0.849		-0.218	-0.398				4.000	-390.079	788.158	0.818	0.107
-4.946	0.798			-0.331			0.028	4.000	-390.095	788.190	0.850	0.105
-4.353	0.781			-0.352				3.000	-391.131	788.262	0.922	0.102
-5.154	0.859	+	-0.259	-0.396			0.034	8.000	-386.332	788.664	1.324	0.083
-8.951	0.877		-0.263	-0.356	0.139	0.023	0.033	7.000	-387.466	788.932	1.592	0.073
-5.228	0.869		-0.229	-0.387		0.012	0.035	6.000	-388.539	789.078	1.738	0.068
-5.313	0.803			-0.351		0.022	0.033	5.000	-389.579	789.158	1.818	0.065

Appendix S10.29: Top models for whale sharks for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-5.085	1.179		-0.409	-0.583		0.028	0.020	6.000	-1490.900	2993.800	0.000	0.648
-4.215	1.177		-0.409	-0.595	-0.033	0.027	0.021	7.000	-1490.510	2995.020	1.220	0.352

Appendix S10.30: Top models for whale sharks for subset of dive sites

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
1.205	-0.263	+	-0.130	-0.279	-0.113	-0.073	0.023	12.000	-7695.320	15414.640	0.000	1.000

Appendix S10.31: Top models for mobula rays. Top models for other data subsets are not available because of function maximzer failure in glmmADMB()

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-0.418			-0.167		-0.046	-0.104		6.000	-4160.170	8332.340	0.000	0.330
-0.600	0.054		-0.169	0.078	-0.039	-0.104		8.000	-4158.570	8333.140	0.800	0.221
-1.640	0.057		-0.187	0.091		-0.104		7.000	-4159.880	8333.760	1.420	0.162
-0.463			-0.169		-0.047	-0.103	0.004	7.000	-4159.990	8333.980	1.640	0.145
-1.630			-0.189			-0.104		5.000	-4162.020	8334.040	1.700	0.141

Appendix S10.32: Top models for manta rays

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-1.144	0.207	+	-0.298	0.273		-0.114		10.000	-1160.260	2340.520	0.000	0.372
-1.528	0.205		-0.289	0.279		-0.111		7.000	-1163.470	2340.940	0.420	0.301
-0.902	0.194	+	-0.288	0.274		-0.118	-0.009	11.000	-1159.940	2341.880	1.360	0.188
-0.955	0.207	+	-0.295	0.270	-0.007	-0.115		11.000	-1160.250	2342.500	1.980	0.138

Appendix S10.33: Top models for manta rays for subset of divemaster

(Intercept)	COS_TIME	CurrentCode	ElNinoIndex	SIN_TIME	SeaTempCelsius	StudyYear	VisibilityMeters	df	logLik	AIC	delta	weight
-1.599			-0.212			-0.105		5.000	-2439.320	4888.640	0.000	0.466
-1.831			-0.220			-0.102	0.009	6.000	-2438.600	4889.200	0.560	0.352
-1.291			-0.207		-0.012	-0.105		6.000	-2439.260	4890.520	1.880	0.182

Appendix S10.34: Top models for manta rays for subset of dive sites

Model averaged estimates

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	5.204	0.211	24.664	2.58E-134
COS_TIME	0.598	0.016	36.945	8.73E-299
CurrentCode1	0.304	0.030	10.143	3.56E-24
CurrentCode2	0.632	0.035	18.217	3.79E-74
CurrentCode3	0.644	0.051	12.731	3.98E-37
ElNinoIndex	-0.333	0.014	-23.455	1.18E-121
SIN_TIME	-0.111	0.016	-6.897	5.31E-12
SeaTempCelsius	-0.096	0.008	-12.664	9.35E-37
StudyYear	-0.028	0.002	-11.438	2.7E-30
VisibilityMeters	0.038	0.002	19.090	3.06E-81

Appendix S11.1: Model averaged estimates for scalloped hammerhead sharks

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-15.794	1.091	14.471	0
CurrentCode1	-0.085	0.149	0.575	0.565
CurrentCode2	0.324	0.166	1.953	0.0508
CurrentCode3	0.253	0.248	1.020	0.308
SeaTempCelsius	0.037	0.031	1.194	0.232
StudyYear	0.582	0.028	20.690	0
ElNinoIndex	-0.011	0.036	0.304	0.761
COS_TIME	-0.011	0.035	0.301	0.763
SIN_TIME	0.011	0.036	0.307	0.759
VisibilityMeters	0.000	0.003	0.079	0.937

Appendix S11.2: Model averaged estimates for tiger sharks

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.857	0.594	3.127	0.00177
COS_TIME	0.532	0.056	9.442	0
CurrentCode1	0.303	0.109	2.793	0.00522
CurrentCode2	0.410	0.118	3.482	0.000497
CurrentCode3	0.953	0.133	7.144	0
SIN_TIME	-0.203	0.055	3.706	0.00021
SeaTempCelsius	-0.157	0.022	7.271	0
StudyYear	-0.113	0.007	15.206	0
VisibilityMeters	0.003	0.005	0.615	0.539
ElNinoIndex	-0.026	0.043	0.600	0.548

Appendix S11.3: Model averaged estimates for silky sharks

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	5.036	0.088	57.547	0
COS_TIME	0.049	0.007	7.142	9.18E-13
CurrentCode1	-0.041	0.013	-3.271	0.00107
CurrentCode2	0.019	0.015	1.253	0.21
CurrentCode3	0.094	0.021	4.364	1.27E-05
ElNinoIndex	-0.031	0.006	-4.990	6.04E-07
SIN_TIME	0.028	0.007	4.124	3.72E-05
SeaTempCelsius	-0.025	0.003	-7.932	2.15E-15
StudyYear	-0.070	0.001	-64.793	0
VisibilityMeters	-0.006	0.001	-7.635	2.27E-14

Appendix S11.4: Model averaged estimates for whitetip reef sharks

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-4.830	0.603	8.014	0
COS_TIME	0.010	0.036	0.269	0.788
CurrentCode1	0.232	0.096	2.408	0.016
CurrentCode2	0.115	0.114	1.011	0.312
CurrentCode3	-0.078	0.184	0.426	0.67
SIN_TIME	0.050	0.060	0.846	0.398
StudyYear	0.087	0.008	10.335	0
VisibilityMeters	0.025	0.005	4.719	2.4E-06
SeaTempCelsius	-0.015	0.021	0.693	0.489
ElNinoIndex	0.004	0.020	0.208	0.835

Appendix S11.5: Model averaged estimates for blacktip sharks

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-7.147	0.456	-15.677	2.17E-55
COS_TIME	0.347	0.037	9.500	2.1E-21
CurrentCode1	0.289	0.077	3.758	0.000171
CurrentCode2	0.460	0.088	5.242	1.59E-07
CurrentCode3	0.466	0.131	3.551	0.000384
SIN_TIME	0.463	0.036	12.970	1.82E-38
SeaTempCelsius	-0.039	0.015	-2.560	0.0105
StudyYear	0.278	0.008	33.396	1.57E-244
VisibilityMeters	0.032	0.004	7.573	3.66E-14

Appendix S11.6: Model averaged estimates for Galapagos sharks

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.029	0.517	0.057	0.955
COS_TIME	0.108	0.061	1.787	0.074
CurrentCode1	-0.640	0.094	6.782	0
CurrentCode2	-1.004	0.128	7.840	0
CurrentCode3	-1.107	0.200	5.539	0
SIN_TIME	-0.174	0.060	2.891	0.00384
StudyYear	-0.096	0.009	10.745	0
VisibilityMeters	-0.085	0.007	11.354	0
SeaTempCelsius	-0.007	0.018	0.384	0.701
ElNinoIndex	-0.007	0.028	0.248	0.804

Appendix S11.7: Model averaged estimates for silvertip sharks

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-3.001	0.295	-10.164	2.86E-24
COS_TIME	0.165	0.023	7.281	3.3E-13
CurrentCode1	0.212	0.043	4.975	6.51E-07
CurrentCode2	0.416	0.049	8.491	2.05E-17
CurrentCode3	0.227	0.071	3.212	0.00132
ElNinoIndex	-0.062	0.019	-3.334	0.000856
SIN_TIME	-0.056	0.023	-2.484	0.013
SeaTempCelsius	0.068	0.011	6.429	1.28E-10
StudyYear	-0.020	0.004	-5.251	1.52E-07
VisibilityMeters	0.039	0.003	14.602	2.73E-48

Appendix S11.8: Model averaged estimates for eagle rays

	Estimate	Std. Error	z value	Pr($>$|z|)
(Intercept)	4.338	0.135	32.196	2.03E-227
COS_TIME	0.110	0.011	10.171	2.67E-24
CurrentCode1	0.136	0.019	6.995	2.65E-12
CurrentCode2	0.271	0.023	11.917	9.61E-33
CurrentCode3	0.194	0.033	5.925	3.12E-09
ElNinoIndex	-0.057	0.010	-5.965	2.44E-09
SIN_TIME	0.018	0.011	1.643	0.1
SeaTempCelsius	-0.063	0.005	-12.705	5.58E-37
StudyYear	-0.066	0.002	-35.657	1.83E-278
VisibilityMeters	0.011	0.001	9.447	3.5E-21

Appendix S11.9: Model averaged estimates for marble rays

	Estimate	Std. Error	z value	Pr($>$|z|)
(Intercept)	-5.943	0.552	10.770	0
COS_TIME	1.133	0.093	12.242	0
CurrentCode1	0.113	0.141	0.800	0.424
CurrentCode2	0.430	0.154	2.788	0.00531
CurrentCode3	0.051	0.253	0.202	0.84
ElNinoIndex	-0.380	0.066	5.732	0
SIN_TIME	-0.557	0.082	6.781	0
StudyYear	0.044	0.012	3.759	0.000171
VisibilityMeters	0.034	0.008	4.477	7.6E-06
SeaTempCelsius	-0.002	0.018	0.099	0.921

Appendix S11.10: Model averaged estimates for whale sharks

	Estimate	Std. Error	z value	Pr($>$|z|)
(Intercept)	1.205	0.548	2.199	0.0278
COS_TIME	-0.263	0.048	-5.534	3.13E-08
CurrentCode1	0.239	0.087	2.735	0.00623
CurrentCode2	0.435	0.098	4.424	9.69E-06
CurrentCode3	0.867	0.129	6.700	2.08E-11
ElNinoIndex	-0.130	0.041	-3.155	0.00161
SIN_TIME	-0.279	0.044	-6.276	3.48E-10
SeaTempCelsius	-0.113	0.020	-5.580	2.4E-08
StudyYear	-0.073	0.007	-11.071	1.73E-28
VisibilityMeters	0.023	0.005	4.450	8.57E-06

Appendix S11.11: Model averaged estimates for mobula rays

	Estimate	Std. Error	z value	Pr($>$|z|)
(Intercept)	-0.834	0.757	1.102	0.271
ElNinoIndex	-0.174	0.047	3.716	0.000203
SeaTempCelsius	-0.031	0.029	1.076	0.282
StudyYear	-0.104	0.007	14.288	0
COS_TIME	0.021	0.042	0.504	0.614
SIN_TIME	0.032	0.052	0.609	0.543
VisibilityMeters	0.001	0.003	0.201	0.841

Appendix S11.12: Model averaged estimates for manta rays