Appendix 5: The hierarchical Bayesian Generalized Linear Mixed Model (BGLMM)

Explanatory variables for the BGLMM

The information used to calculate the explanatory variables was accessed from the data collection survey with fishers in 2011. In addition to the socioeconomic aspects of fisher' households and fisher personal characteristics, we collected data on their fishing activities, including catch, fishing gear, fishing boats, fisheries, fishing crew, and time spent on a fishing trip (to and from the fishing grounds). For the Bayesian model we used fisher age, the household economic dependence on fishing (HD), and the catch per unit effort (CPUE). CPUE was estimated from the fisheries catch (in kg) and effort (days and hours) for each fisher. It was log transformed to approximate normality. The HD variable was measured based on the proportion of people who depend on fishing as an economic activity by household. Table A5.1 below shows these explanatory variables for each of the 100 fishers in the three marine protected areas.

Table A5.1: Explanatory variables of the 100 fishers in the three reserves: Reserva de Desenvolvimento Sustentável Estadual Ponta do Tubarão (RDSE Ponta do Tubarão, N=40), Reserva Extrativista Batoque (RESEX Batoque, N=30), and Reserva Extrativista Prainha do Canto Verde (RESEX Canto Verde, N=30). HD = household economic dependence on fishing; CPUE = Capture per unit of effort.

		Variables		
Fishers	MPAs	Age	HD	CPUE (-Kg/h)
1	RDSE	36	0.143	0.921
2	RDSE	56	0.333	0.398
3	RDSE	48	0.500	0.523
4	RDSE	63	0.556	0.620
5	RDSE	47	0.167	2.125
6	RDSE	32	0.400	0.620
7	RDSE	33	0.333	0.176
8	RDSE	63	0.833	0.444
9	RDSE	45	0.250	0.319
10	RDSE	49	0.500	0.620
11	RDSE	52	0.500	2.243
12	RDSE	36	0.500	1.921
13	RDSE	61	0.400	-0.079
14	RDSE	33	0.250	1.018
15	RDSE	54	0.500	-0.079
16	RDSE	50	0.333	0.699

17	RDSE	34	0.250	-0.380
18	RDSE	58	0.400	1.523
19	RDSE	29	0.333	0.444
20	RDSE	52	0.250	-1.049
21	RDSE	58	0.091	1.301
22	RDSE	27	0.400	0.143
23	RDSE	31	0.250	0.745
24	RDSE	61	0.200	0.620
25	RDSE	59	0.429	0.319
26	RDSE	44	0.400	0.824
27	RDSE	49	0.333	0.620
28	RDSE	22	0.667	0.018
29	RDSE	61	0.143	0.620
30	RDSE	67	0.333	0.620
31	RDSE	46	0.250	0.921
32	RDSE	77	0.500	0.921
33	RDSE	35	0.333	2.243
34	RDSE	67	0.500	0.921
35	RDSE	53	0.333	2.398
36	RDSE	46	0.200	2.097
37	RDSE	41	0.500	1.574
38	RDSE	51	0.200	1.222
39	RDSE	36	0.667	1.570
40	RDSE	43	0.200	0.574
41	RESEX BTQ	38	1.000	0.491
42	RESEX BTQ	43	1.000	0.745
43	RESEX BTQ	41	1.000	-0.255
44	RESEX BTQ	41	0.250	-0.255
45	RESEX BTQ	48	0.250	1.155
46	RESEX BTQ	49	0.250	0.222
47	RESEX BTQ	35	0.333	-0.079
48	RESEX BTQ	47	0.200	-0.380
49	RESEX BTQ	24	0.250	0.620
50	RESEX BTQ	54	0.500	0.456
51	RESEX BTQ	37	0.200	0.667
52	RESEX BTQ	58	0.200	0.416
53	RESEX BTQ	25	0.200	0.699
54	RESEX BTQ	48	1.000	0.143
55	RESEX BTQ	34	1.000	-0.012
56	RESEX BTQ	43	0.333	0.366
57	RESEX BTQ	24	0.333	0.097
58	RESEX BTQ	46	0.200	0.097
59	RESEX BTQ	59	0.500	0.143
60	RESEX BTQ	47	0.143	0.319

61	RESEX BTQ	35	0.333	0.097
62	RESEX BTQ	23	0.333	-0.012
63	RESEX BTQ	47	0.333	1.398
64	RESEX BTQ	37	0.500	0.796
65	RESEX BTQ	25	0.250	1.000
66	RESEX BTQ	39	0.111	-0.283
67	RESEX BTQ	54	0.500	-0.255
68	RESEX BTQ	26	0.250	1.871
69	RESEX BTQ	37	0.333	0.491
70	RESEX BTQ	61	0.333	-0.158
71	RESEX PCV	30	0.333	0.046
72	RESEX PCV	45	0.250	0.972
73	RESEX PCV	66	0.250	0.444
74	RESEX PCV	30	0.333	0.620
75	RESEX PCV	21	0.250	1.146
76	RESEX PCV	44	0.200	0.398
77	RESEX PCV	38	0.750	1.699
78	RESEX PCV	53	0.167	0.620
79	RESEX PCV	35	0.250	0.319
80	RESEX PCV	29	0.250	0.398
81	RESEX PCV	37	0.333	-0.079
82	RESEX PCV	44	0.333	0.699
83	RESEX PCV	60	0.333	1.301
84	RESEX PCV	57	0.750	1.176
85	RESEX PCV	32	0.200	-0.653
86	RESEX PCV	32	0.250	0.289
87	RESEX PCV	31	0.333	0.699
88	RESEX PCV	55	0.667	0.398
89	RESEX PCV	30	0.500	-0.234
90	RESEX PCV	27	0.571	0.491
91	RESEX PCV	23	0.500	0.491
92	RESEX PCV	58	0.500	0.667
93	RESEX PCV	58	0.333	0.871
94	RESEX PCV	43	1.000	1.699
95	RESEX PCV	53	0.125	-0.079
96	RESEX PCV	56	0.500	0.222
97	RESEX PCV	56	0.250	0.222
98	RESEX PCV	48	0.143	1.269
99	RESEX PCV	46	0.200	1.269
100	RESEX PCV	46	0.500	1.187

The beta distribution and the goodness-of-fit measures

Beta distributions have long been used in a wide range of applications involving proportions and probabilities (Gupta and Nadarajah 2004). However, only recently have they been applied to linear regression modelling (Ferrari and Cribari-Neto 2004, Smithson and Verkuilen 2006, Liu and Kong 2015, Paradinas 2016) and time-series analyses (Da-Silva and Migon 2016), to allow for bounded estimates and intervals with model parameters that are directly interpretable in terms of the response mean. For these reasons, the SERI was modeled with a beta distribution $Y_j \sim Be(\mu_j,\varphi_j)$ to avoid non-sensical predictions outside the index limits (between 0 and 1) (Paradinas et al. 2016).

In order to compare the goodness-of-fit between each model, three different measures were computed: (1) the Watanabe-Akaike information criterion (WAIC), (2) the Root Mean Square Error (RMSE), and (3) the adjusted coefficient of determination (R^2). WAIC can be viewed as an improvement to the Deviance Information Criterion (DIC) that is traditionally used in Bayesian models, and is better suited than the Akaike Information Criterion (AIC), which is usually used with frequentist modelling procedures (Spiegelhalter et al. 2002). Unlike DIC, which is conditioned on a point estimate and is not fully Bayesian, WAIC is a fully Bayesian measure and uses the entire posterior distribution to make inference about the parameters; hence, estimations are more precise (Watanabe 2010). RMSE consists in the standard deviation of the residuals and, thus, measures how much the observed values deviate from the predicted values. The R^2 expresses the percentage of variability in the response variable that was explained by the model.

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