Assessing the adequacy of a novel fisheries no-take zone around a major African penguin (Spheniscus demersus) colony, Dyer Island, South Africa

Auteur : Van Landuyt, Camille
Promoteur(s) : Parmentier, Eric; 28054
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SUPPLEMENTARY MATERIAL

Model	K	AIC
Gamma	4	215.9513
Lognormal	4	216.8123
Gaussian	4	217.3656

Table S1: Selection of the best model to analyse duration of long trips based on the AIC. K: number of parameters in the model. The model with the lowest AIC was selected (gamma distribution, AIC = 215.9513).

Model	K	AIC	ΔAIC
closure + Julian day + deployment year	5	586.09	0.00
closure + deployment year	4	589.73	3.64
closure	3	620.29	34.19

Table S2: Model selection for the effect of closure status on the maximum trip distance from the colony. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. Deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the best model. N = 87 trips, 9 deployment years. The model accounting for closure status, Julian day and deployment year was selected.

Model	K	AIC	ΔAIC
closure + Julian day + deployment year	5	331.47	0.00
closure + deployment year	4	331.73	0.26
closure	3	361.91	30.44

Table S3: Model selection for the effect of closure status on the maximum trip distance from the colony. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 50 trips, 6 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
closure + anchovy(60)	5	331.56	0.00
closure	4	331.73	0.17
closure + total(90)	5	333.01	1.44
closure + sardine(90)	5	333.06	1.50
closure + total(60)	5	333.21	1.65
closure + anchovy(90)	5	333.61	2.04
closure + sardine(60)	5	333.73	2.17

Table S4: Model selection for the effect of closure status on the maximum trip distance from the colony. All models use a gamma distribution with a log link function. Closure status and cumulative catches account for fixed effects. Deployment year is included in all models as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 50 trips, 6 deployment years. The model accounting for closure status and deployment year was retained.

Model	K	AIC	ΔAIC
closure + deployment year	4	368.18	0.00
closure	3	368.20	0.03
closure + Julian day + deployment year	5	369.12	0.95

Table S5: Model selection for the effect of the closure status on short trips' path length of the penguins. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 47 trips, 9 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
closure + Julian day + deployment year	5	222.15	0.00
closure + deployment year	4	223.19	1.04
closure	3	224.14	1.99

Table S6: Model selection for the effect of the closure status on short trips' path length of the penguins. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 29 trips, 5 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
closure + anchovy(90)	5	220.00	0.00
closure	4	223.19	3.20
closure + total(90)	5	223.42	3.42
closure + anchovy(60)	5	224.39	4.40
closure + sardine(90)	5	225.05	5.05
closure + sardine(60)	5	225.14	5.15
closure + total(60)	5	225.18	5.18

Table S7: Model selection for the effect of closure status on the total path length of short trips. All models use a gamma distribution with a log link function. Closure status and cumulative catches account for fixed effects. Deployment year is included in all models as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 29 trips, 5 deployment years. The model accounting for closure status, cumulated anchovy catches over the 90 days prior to deployment, and deployment year was retained.

Fixed effects	β	SE	z-value	p-value
Intercept	3.94	0.06	65.23	<2 e-16 ***
Closure	-0.22	0.11	-2.01	0.04 *
Random effects	Variance	SD		
year	0.01	0.10		

Table S8: Results of the GLMM (gamma function, log link) modelling breeding African penguins path length (km) of short foraging trips. Closure status accounts for the only fixed effect. Deployment year is included as a random effect. The pre-closure period is the reference category for the closure status variable. N = 47 trips. 8 deployment years. *p < 0.05; ***p < 0.001.

Fixed effects	β	SE	z-value	p-value
Intercept	3.85	0.05	78.25	< 2e-16 ***
Closure	0.03	0.14	0.20	0.84
Anchovy(90)	0.18	0.06	3.06	0.2 e-02 **
Random effects	Variance	SD		
year	1.36 e-10	1.18 e-05		

Table S9: Results of the GLMM (gamma function, log link) modelling breeding African penguins path length (km) of short foraging trips. Closure status and anchovy(90) account for fixed effects. Deployment year is included as a random effect. The pre-closure period is the reference category for the closure status variable. N = 29 trips. 5 deployment years. *p < 0.05; ***p < 0.001.

Fixed effects	β	SE	z-value	p-value
Intercept	3.98	0.08	51.86	< 2e-16 ***
Closure	-0.35	0.15	-2.29	0.02 *
Random effects	**Variance**	**SD**		
year	0.01	0.11		

Table S10: Results of the GLMM (gamma function, log link) modelling breeding African penguins path length (km) of short foraging trips. Closure status accounts for the only fixed effect. Deployment year is included as a random effect. The pre-closure period is the reference category for the closure status variable. N = 29 trips. 5 deployment years. *p < 0.05; ***p < 0.001.

Fixed effects	β	SE	z-value	p-value
Intercept	3.85	0.04	106.61	< 2 e-16 ***
Anchovy(90)	0.17	0.04	4.76	1.96 e-06 ***
Random effects	**Variance**	**SD**		
year	1.24 e-10	1.11 e-05		

Table S11: Results of the GLMM (gamma function, log link) modelling breeding African penguins path length (km) of short foraging trips. Anchovy(90) accounts for the only fixed effect. Deployment year is included as a random effect. N = 29 trips. 5 deployment years. ***p < 0.001.

Model	K	AIC	ΔAIC
closure + deployment year	4	324.61	0.00
closure + deployment year + Julian day	5	326.16	1.56
closure	3	332.37	7.76

Table S12: Model selection for the effect of the closure status on long trips' path length of the penguins. All models use a gamma distribution with a log link function. Closure status and Julian day account for the fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 38 trips, 9 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
closure	3	235.46	0.00
closure + deployment year	4	237.46	1.99
closure + deployment year + Julian day	5	237.47	2.01

Table S13: Model selection for the effect of the closure status on short trips' duration of the penguins. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 47 trips, 9 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
closure	3	153.20	0.00
closure + deployment year	4	155.20	1.99
closure + deployment year + Julian day	5	155.83	2.63

Table S14: Model selection for the effect of closure status on the short trips' duration. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 29 trips, 5 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
Closure	4	155.2	0.00
closure + anchovy(90)	5	155.51	0.31
closure + total(90)	5	156.25	1.05
closure + anchovy(60)	5	156.66	1.47
closure + sardine(60)	5	156.83	1.63
closure + sardine(90)	5	156.87	1.67
closure + total(60)	5	157.13	1.94

Table S15: Model selection for the effect of closure status on the short trips' duration. All models use a gamma distribution with a log link function. Closure status and cumulated catches account for fixed effects. Deployment year is included in all models as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 29 trips, 5 deployment years. The model accounting for closure status and deployment year was retained.

Model	K	AIC	ΔAIC
closure + deployment year	4	215.95	0.00
closure + deployment year + Julian day	5	217.92	1.97
closure	3	220.59	4.63

Table S16: Model selection for the effect of closure status on the long trips' duration. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 38 trips. 9 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
closure + deployment year + Julian day	5	117.25	0.00
closure + deployment year	4	117.42	0.18
closure	3	124.41	7.16

Table S17: Model selection for the effect of closure status on the long trips' duration. All models use a gamma distribution with a log link function. Closure status and Julian day account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 20 trips. 6 deployment years. The model accounting for closure status and deployment year was selected.

Model	K	AIC	ΔAIC
closure + anchovy(60)	5	112.82	0.00
closure	4	117.42	4.60
closure + total(90)	5	118.64	5.82
closure + total(60)	5	118.69	5.87
closure + sardine(90)	5	118.85	6.03
closure + anchovy(90)	5	119.29	6.47
closure + sardine(60)	5	119.36	6.54

Table S18: Model selection for the effect of the closure status on long trips' path length of the penguins. All models use a gamma distribution with a log link function. Closure status and cumulated catches account for fixed effects. When mentioned in the models, deployment year is included as a random effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 20 trips, 6 deployment years. The model accounting for closure status, cumulated anchovy catches over the 60 days prior to deployment and deployment year was retained.

Fixed effects	β	SE	z-value	p-value
Intercept	2.53	0.04	64.85	<2e-16 ***
Closure	0.06	0.07	0.91	0.36

Random effects	Variance	SD
year	8.91 e-11	9.44 e-06

Table S19: Results of the GLMM (gamma function, log link) modelling breeding African penguins duration (hrs) of short foraging trips. Closure status accounts for the only fixed effect. Deployment year is included as a random effect. The pre-closure period is the reference category for the closure status variable. N = 47 trips. 8 deployment years. ***p < 0.001.

Fixed effects	β	SE	z-value	p-value
Intercept	3.54	0.06	54.89	<2e-16 ***
Closure	0.02	0.08	0.32	0.75
Random effects	Variance	SD		
year	0.01	0.10		

Table S20: Results of the GLMM (gamma function, log link) modelling breeding African penguins duration (hrs) of long foraging trips. Closure status accounts for the only fixed effect. Deployment year is included as a random effect. The pre-closure period is the reference category for the closure status variable. N = 38 trips. 9 deployment years. ***$p < 0.001$.

	df	AIC	Δ AIC
closure + month	7	6039.43	0.00
closure	5	6095.03	55.60

Table S21: Model selection for the log-normal LMM of positive anchovy haul size, within the closure perimeter (all vessels). Fixed effect includes closure status. Random effects include haul year and vessel name, accounting for inter-annual and inter-vessel variability. When mentioned in the model, seasonality (modelled via cyclic sine and cosine transformations of the month) is included as a fixed effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 1 533 hauls, 14 years, 78 vessels. The model accounting for seasonality was retained.

	df	AIC	Δ AIC
closure + month	7	5331.41	0.00
closure	5	5369.75	38.34

Table S22: Model selection for the log-normal LMM of positive sardine haul size, within the closure perimeter (all vessels). Fixed effect includes closure status. Random effects include haul year and vessel name, accounting for inter-annual and inter-vessel variability. When mentioned in the model, seasonality (modelled via cyclic sine and cosine transformations of the month) is included as a fixed effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 440 hauls, 14 years, 83 vessels. The model accounting for seasonality was retained.

	df	AIC	Δ AIC
closure + month	7	5790.46	0.00
closure	5	5809.42	18.96

Table S23: Model selection for the log-normal LMM of positive anchovy plus sardine cumulated haul size, within the closure perimeter (all vessels). Fixed effect includes closure status. Random effects include haul year and vessel name, accounting for inter-annual and inter-vessel variability. When mentioned in the model, seasonality (modelled via cyclic sine and cosine transformations of the month) is included as a fixed effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 2 104 hauls, 14 years, 85 vessels. The model accounting for seasonality was retained.

Term	β	SE	df	t-value	p-value
(Intercept)	2.16	0.57	52.43	3.82	3.56 e-04***
Closure	0.08	0.53	93.72	0.15	0.88
Month (sine)	0.38	0.08	1462.00	4.45	9.25e-06 ***
Month (cosine)	-0.51	0.08	1456.60	-6.10	1.37e-09 ***

Random effects	Variance	SD
Year	1.17	1.08
Vessel	2.13	1.46

Table S24: Results of the LMM modelling the log-transformed positive anchovy haul size within the closure perimeter (all vessels). Fixed effects include closure status and seasonality (modelled via cyclic sine and cosine transformations of the month). Random effects include haul year and vessel name, accounting for inter-annual and inter-vessels variability. The pre-closure period is the reference category for the closure status variable. The model was fitted using restricted maximum likelihood (REML). N = 1 533 hauls, 14 years, 78 vessels. ***p < 0.001.

Term	β	SE	df	t-value	p-value
(Intercept)	2.85	0.44	43.72	6.47	7.14e-08 ***
Closure	-0.82	0.43	58.19	-1.92	0.06 ·
Month (sine)	-0.13	0.06	1380.55	-2.31	0.02 *
Month (cosine)	0.40	0.08	1375.16	5.27	1.59e-07 ***

Random effects	Variance	SD
Year	0.58	0.76
Vessel	1.15	1.07

Table S25: Results of the LMM modelling the log-transformed positive sardine haul size within the closure perimeter (all vessels). Fixed effects include closure status and seasonality (modelled via cyclic sine and cosine transformations of the month). Random effects include haul year and vessel name, accounting for inter-annual and inter-vessels variability. The pre-closure period is the reference category for the closure status variable. The model was fitted using restricted maximum likelihood (REML). N = 1 440 hauls, 14 years, 83 vessels. ·p < 0.1; *p < 0.05; ***p < 0.001.

Term	β	SE	df	t-value	p-value
(Intercept)	4.31	0.31	13.77	18.13	3.02e-16 ***
Closure	0.67	0.29	116.5	2.33	0.02 *
Month (sine)	0.16	0.03	2 048	4.81	1.60e-06 ***
Month (cosine)	0.02	0.04	2 035	0.55	0.58

Random effects	Variance	SD
Year	0.46	0.68
Vessel	0.37	0.60

Table 26: Results of the LMM modelling the log-transformed positive total catch haul size within the closure perimeter (all vessels). Fixed effects include closure status and seasonality (modelled via cyclic sine and cosine transformations of the month). Random effects include haul year and vessel name, accounting for inter-annual and inter-vessels variability. The pre-closure period is the reference category for the closure status variable. The model was fitted using restricted maximum likelihood (REML). N = 2 104 hauls, 14 years, 85 vessels. *p < 0.05; ***p < 0.001.

	df	AIC	Δ AIC
closure + month	7	2801.55	0.00
closure	5	2818.35	16.80

Table S27: Model selection for the log-normal LMM of positive anchovy haul size, within the closure perimeter (frequent vessels). Fixed effect includes closure status. Random effects include haul year and vessel name, accounting for inter-annual and inter-vessel variability. When mentioned in the model, seasonality (modelled via cyclic sine and cosine transformations of the month) is included as a fixed effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 770 hauls, 14 years, 14 vessels. The model accounting for seasonality was retained.

	df	AIC	Δ AIC
closure + month	7	2513.98	0.00
closure	4	2527.17	13.19

Table S28: Model selection for the log-normal LMM of positive sardine haul size, within the closure perimeter (frequent vessels). Fixed effect includes closure status. Random effects include haul year and vessel name, accounting for inter-annual and inter-vessel variability. When mentioned in the model, seasonality (modelled via cyclic sine and cosine transformations of the month) is included as a fixed effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 713 hauls, 14 years, 14 vessels. The model accounting for seasonality was retained.

	df	AIC	Δ AIC
closure + month	7	2860.50	0.00
closure	5	2863.54	3.05

Table S29: Model selection for the log-normal LMM o positive total catch haul size, within the closure perimeter (frequent vessels). Fixed effect includes closure status. Random effects include haul year and vessel name, accounting for inter-annual and inter-vessel variability. When mentioned in the model, seasonality (modelled via cyclic sine and cosine transformations of the month) is included as a fixed effect. Models are ranked by AIC. K: number of parameters in the model. ΔAIC: the difference in AIC with the lowest AIC model. N = 1 072 hauls, 14 years, 14 vessels. The model accounting for seasonality was retained.

Term	β	SE	df	t-value	p-value
(Intercept)	1.42	0.64	46.92	2.22	0.03*
Closure	0.51	0.50	85.91	1.01	0.31
Month (sine)	0.23	0.10	754.51	2.32	0.02 *
Month (cosine)	-0.37	0.10	750.17	-3.85	1.26 e-04 ***
Random effects		Variance		SD	
Year		1.08		1.04	
Vessel Name		2.08		1.44	

Table S30: Results of the LMM modelling the log-transformed positive anchovy haul size within the closure perimeter (all vessels). Fixed effects include closure status and seasonality (modelled via cyclic sine and cosine transformations of the month). Random effects include haul year and vessel name, accounting for inter-annual and inter-vessels variability. The pre-closure period is the reference category for the closure status variable. Model were fitted using restricted maximum likelihood (REML). N = 770 hauls, 14 years, 14 vessels. *p < 0.05; ***p < 0.001.

Term	β	SE	df	t-value	p-value
(Intercept)	3.20	0.45	39.81	7.17	1.12 e-08 ***
Closure	-0.76	0.38	33.25	-1.97	0.06 ·
Month (sine)	-0.18	0.08	697.24	-2.35	0.02 *
Month (cosine)	0.25	0.10	689.02	2.64	8.47 e-03 **
Random effects		Variance		SD	
Year		0.36		0.60	
Vessel Name		0.88		0.94	

Table S31: Results of the LMM modelling the log-transformed positive sardine haul size within the closure perimeter (frequent vessels). Fixed effects include closure status and seasonality (modelled via cyclic sine and cosine transformations of the month). Random effects include haul year and vessel name, accounting for inter-annual and inter-vessels variability. The pre-closure period is the reference category for the closure status variable. Model were fitted using restricted maximum likelihood (REML). N = 713 hauls, 14 years, 14 vessels. ·p < 0.1; *p < 0.05; **p < 0.01; ***p < 0.001.

Term	β	SE	df	t-value	p-value
(Intercept)	3.77	0.18	21.39	20.83	1.09e-15 ***
Closure	0.06	0.25	28.90	0.22	0.83
Month (sine)	0.11	0.04	1058	2.59	9.83 e-03**
Month (cosine)	-0.01	0.05	1056	-0.147	0.88

Random effects	Variance	SD
Vessel name	0.25	0.50
Year	0.18	0.42

Table S32: Results of the LMM modelling the log-transformed positive total catch haul size within the closure perimeter (frequent vessels). Fixed effects include closure status and seasonality (modelled via cyclic sine and cosine transformations of the month). Random effects include haul year and vessel name, accounting for inter-annual and inter-vessels variability. The pre-closure period is the reference category for the closure status variable. Model were fitted using restricted maximum likelihood (REML). N = 1 072 hauls, 14 years, 14 vessels. ***p < 0.001.

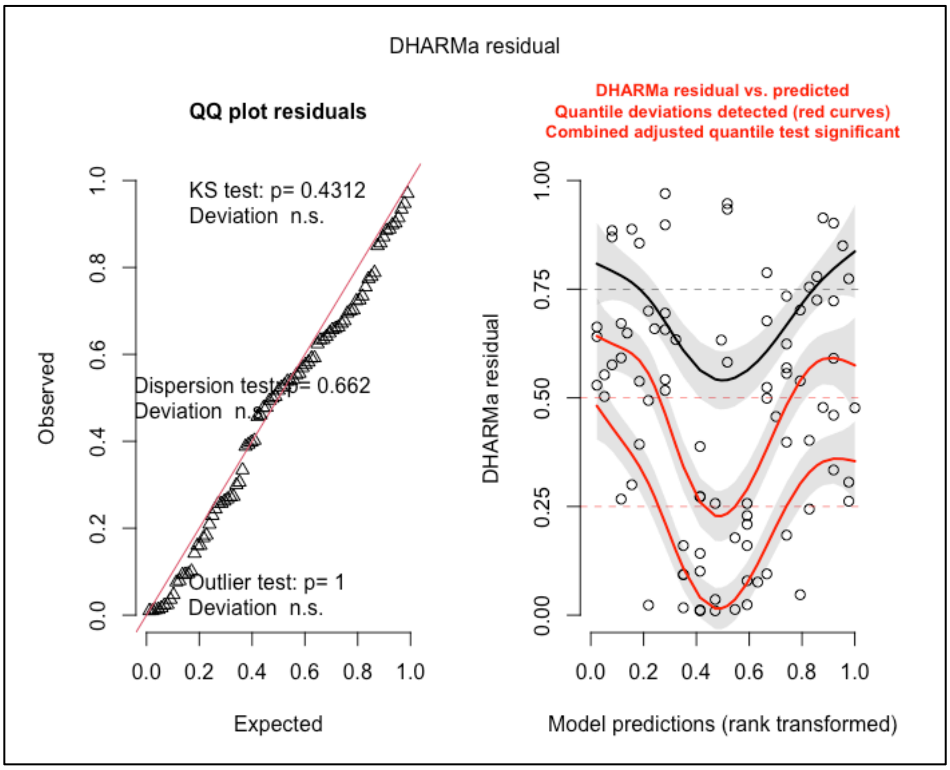

Figure S1: DHARMa residual diagnostic for the selected GLMM (closure + Julian day + deployment year) assessing maximum trip distance from the colony. The QQ-plot (left) showed no significant violation of model assumption (KS: p = 0.43; dispersion test: p = 0.66; outliers test: p = 1). Residual vs. predicted values plot (right) showed a significant deviation in the lower quantile and the median of the distribution from the expected distribution. The model was considered acceptable.

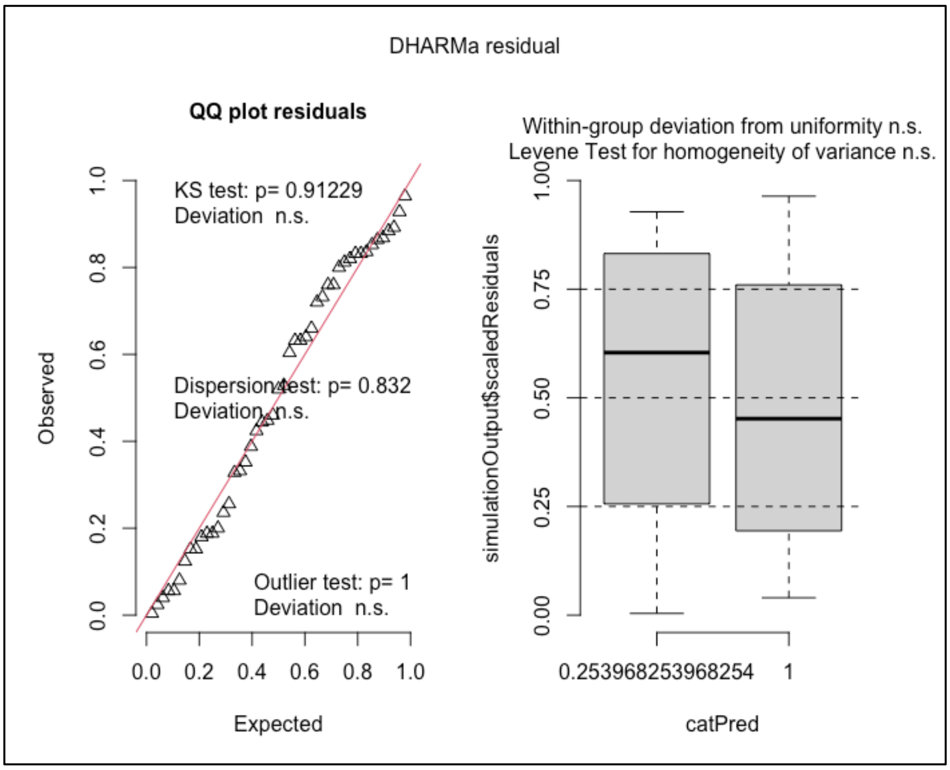

Figure S2: DHARMa residual diagnostic for the selected GLMM (closure + deployment year) assessing short trips' path length. No significant violation of model assumptions was detected. The model was considered acceptable.

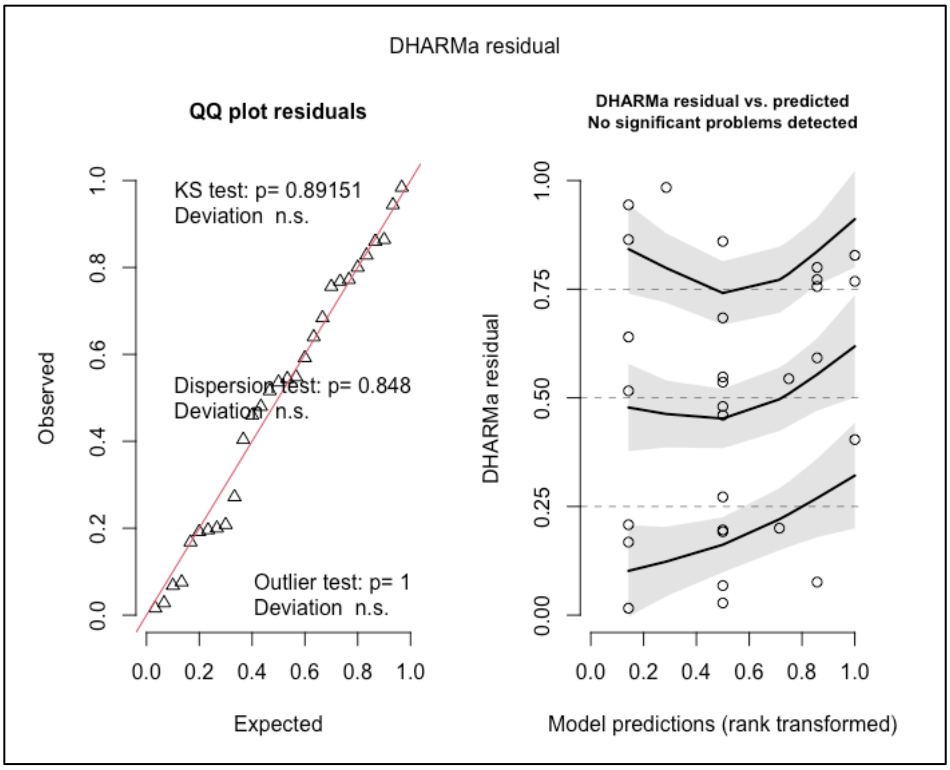

Figure S3: DHARMa residual diagnostic for the selected GLMM (closure + anchovy(90) + deployment year) assessing short trips' path length. No significant violation of model assumptions was detected. The model was considered acceptable.

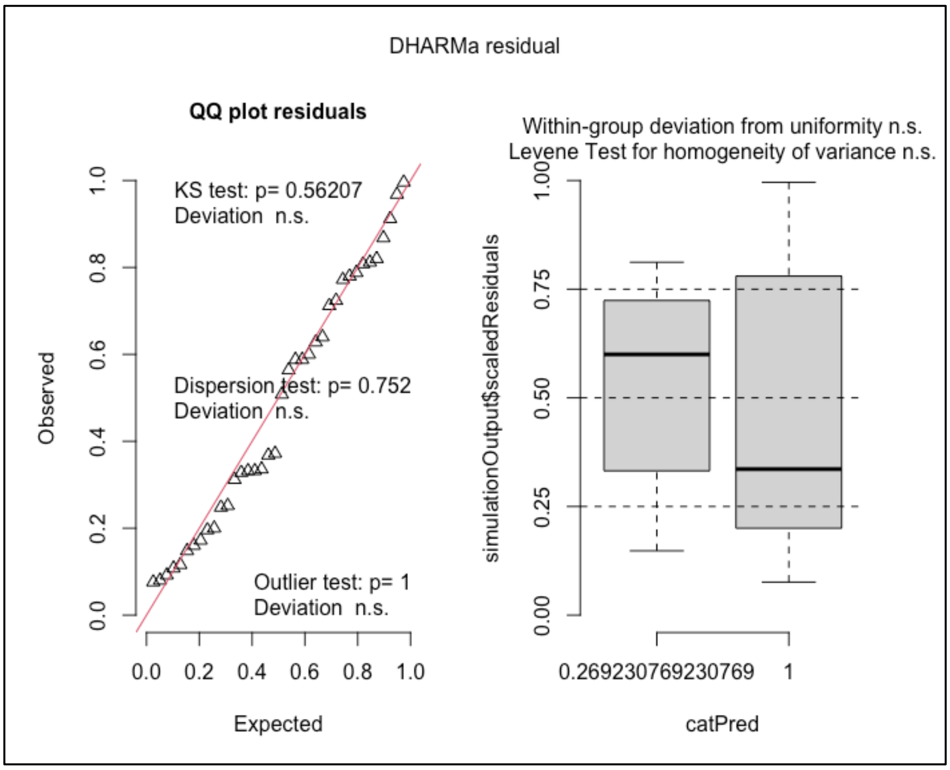

Figure S4: DHARMa residual diagnostic for the selected GLMM (closure + deployment year) assessing long trips' path length. No significant violation of model assumptions was detected. The model was considered acceptable.

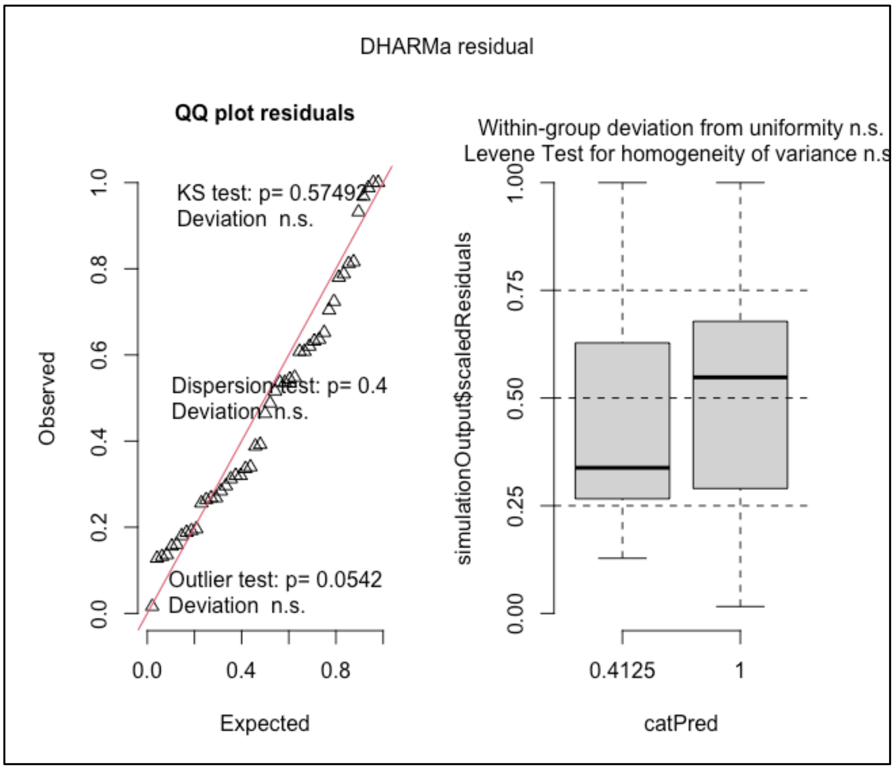

Figure S5: DHARMa residual diagnostic for the selected GLMM (closure + deployment year) assessing short trips' duration. No significant violation of model assumptions was detected. The model was considered acceptable.

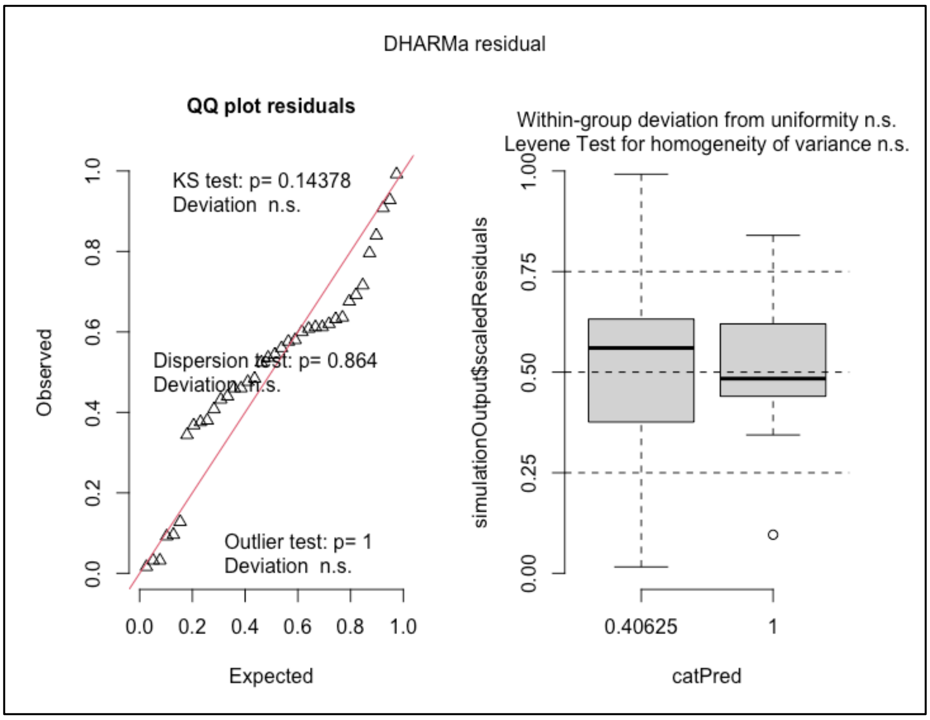

Figure S6: DHARMa residual diagnostic for the selected GLMM (closure + deployment year) assessing long trips' path duration. No significant violation of model assumptions was detected. The model was considered acceptable.

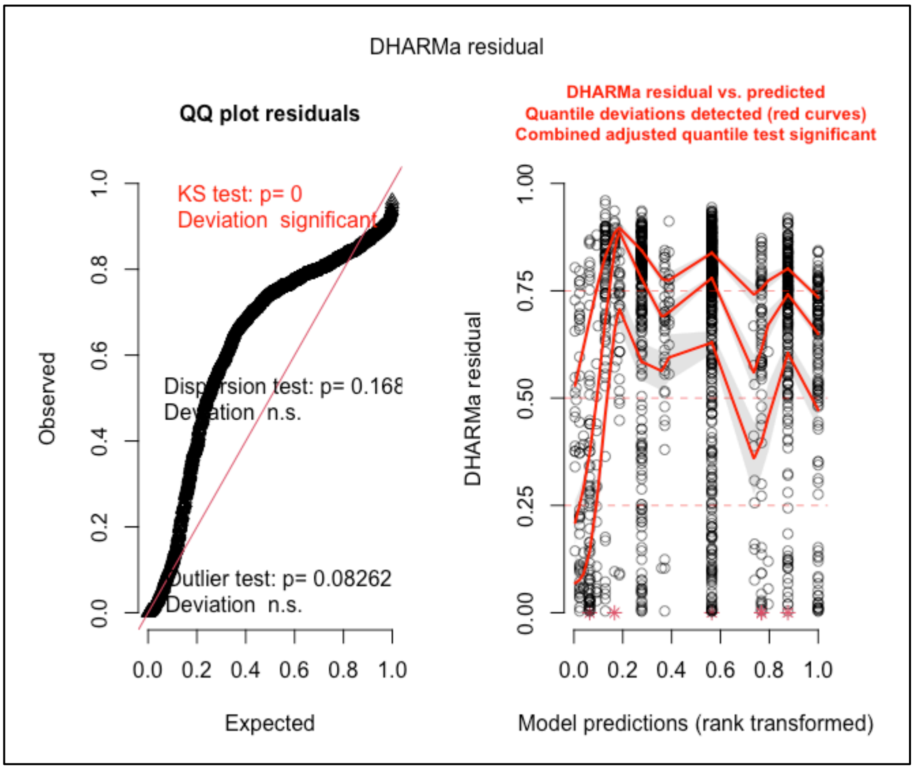

Figure S7: DHARMa residual diagnostic for the LMM model on log-transformed anchovy haul size within the closure perimeter (all vessels, positive catches only). The QQ-plot (left) showed a significant KS test ($p < 0.001$), attributable to the large sample size ($n = 1\ 533$ hauls). Dispersion test: $p = 0.168$. Outliers test: $p = 0.08$. Residual vs. predicted values plot (right) showed quantile deviation. The model was considered acceptable.

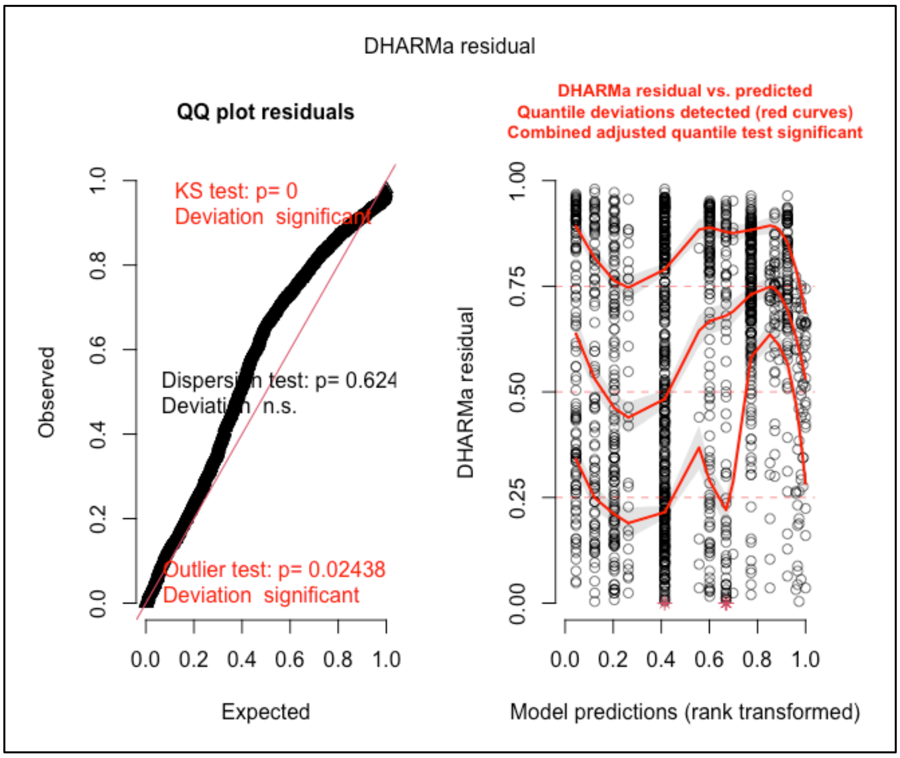

Figure S8: DHARMa residual diagnostic for the LMM model on log-transformed sardine haul size within the closure perimeter (all vessels, positive catches only). The QQ-plot (left) showed a significant KS test ($p < 0.001$), attributable to the large sample size ($n = 440$ hauls). Dispersion test: $p = 0.62$. Outliers test: $p = 0.02$ (significant). Inspection of the 4 flagged observations revealed legitimate haul sizes. Residual vs. predicted values plot (right) showed quantile deviation. Results should be interpreted with caution.

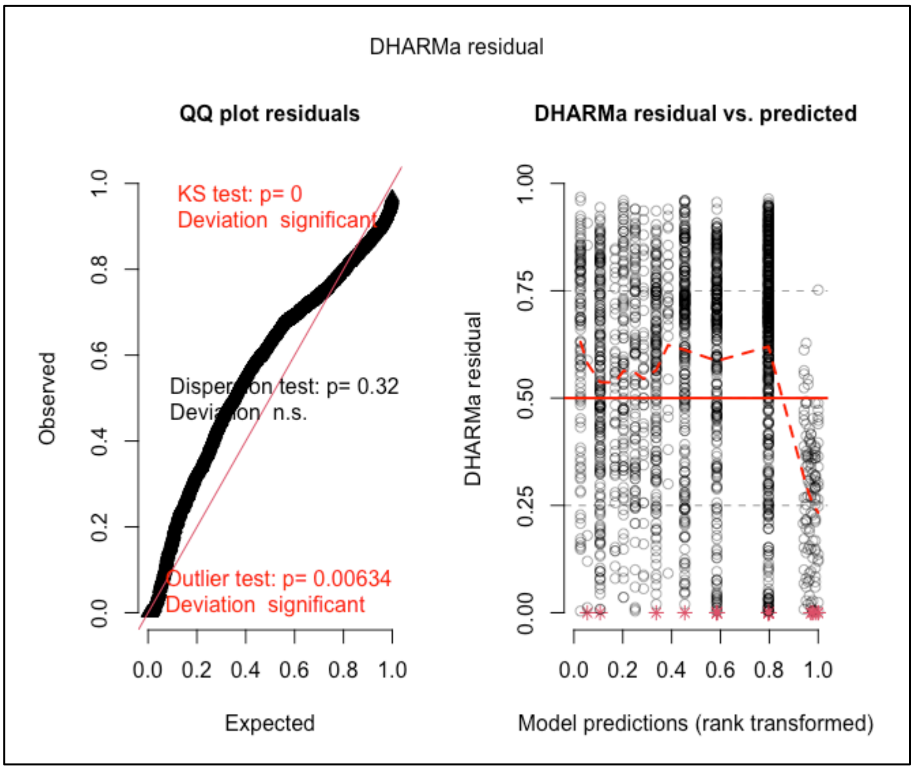

Figure S9: DHARMa residual diagnostic for the LMM model on log-transformed total catch haul size within the closure perimeter (all vessels, positive catches only). The QQ-plot (left) showed a significant KS test ($p < 0.001$), attributable to the large sample size (n = 2 104 hauls). Dispersion test: $p = 0.32$. Outliers test: $p = 0.006$ (significant). Inspection of the 29 flagged observations revealed legitimate haul sizes. Residual vs. predicted values plot (right) showed slight quantile deviation. Results should be interpreted with caution.

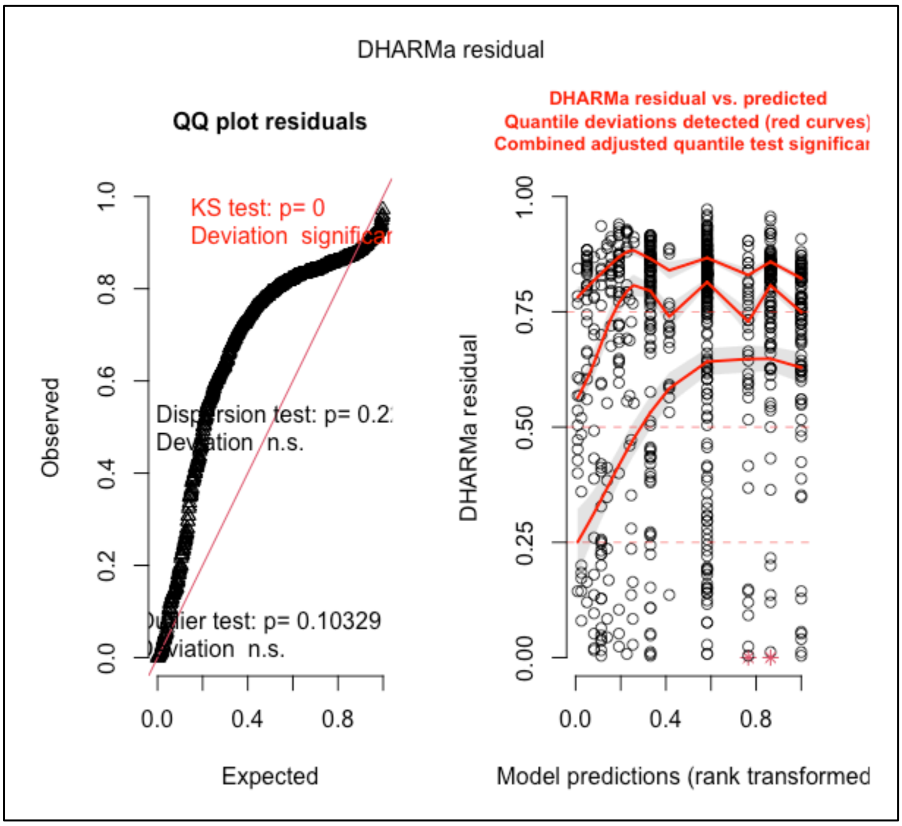

Figure S10: DHARMa residual diagnostic for the LMM model on log-transformed anchovy haul size within the closure perimeter (frequent vessels, positive catches only). The QQ-plot (left) showed a significant KS test ($p < 0.001$), attributable to the large sample size (n = 770 hauls). Dispersion test: $p = 0.22$. Outliers test: $p = 0.10$. Residual vs. predicted values plot (right) showed quantile deviation. The model was considered acceptable.

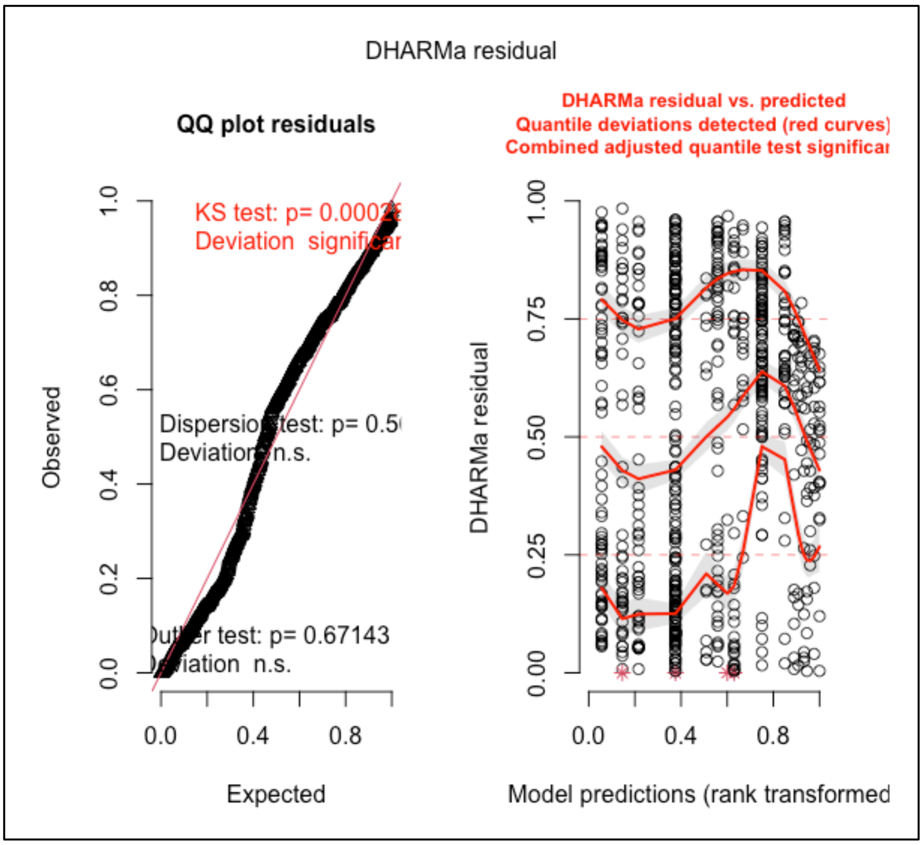

Figure S11: DHARMa residual diagnostic for the LMM model on log-transformed sardine haul size within the closure perimeter (frequent vessels, positive catches only). The QQ-plot (left) showed a significant KS test ($p < 0.001$), attributable to the large sample size ($n = 713$ hauls). Dispersion test: $p = 0.57$. Outliers test: $p = 0.67$. Residual vs. predicted values plot (right) showed quantile deviation. The model was considered acceptable.

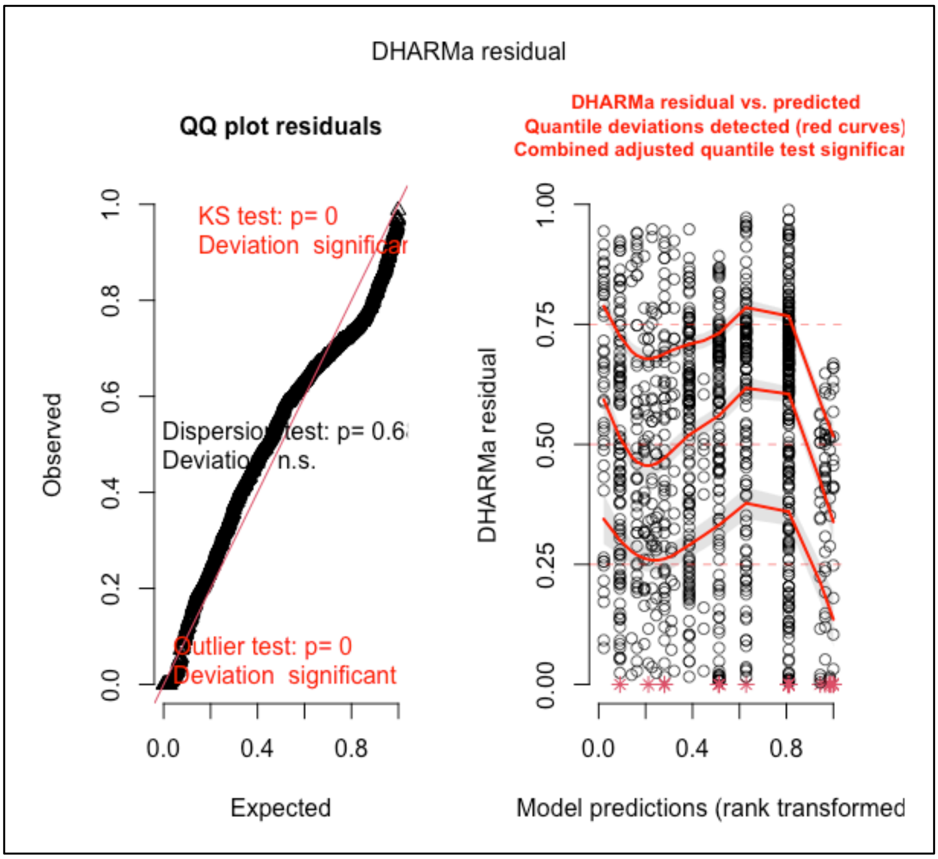

Figure S12: DHARMa residual diagnostic for the LMM model on log-transformed total catch haul size within the closure perimeter (frequent vessels, positive catches only). The QQ-plot (left) showed a significant KS test ($p < 0.001$), attributable to the large sample size ($n = 2\ 104$ hauls). Dispersion test: $p = 0.69$. Outliers test: $p < 0.001$ (significant). Inspection of the 28 flagged observations revealed legitimate haul sizes. Residual vs. predicted values plot (right) showed quantile deviation. Results should be interpreted with caution.