Penguin island closure feasibility study analysis results update: random effects models applied to both Western and Eastern Cape islands

W. M. L. Robinson and D. S. Butterworth
Marine Assessment and Resource Management Group, University of Cape Town

Abstract

This Addendum updates results from previous papers using random effects instead of fixed effects models for the year factors. Results are now given for Bird and St Croix islands in addition to those for Dassen and Robben islands. The results from random effects models are qualitatively unchanged from those given earlier from the fixed effects models, except that the periods required to obtain statistically significant results are extended somewhat as a result of the removal of the negative bias in the residual variance estimates for the earlier fixed effects models.

Introduction

Several of the GLMs with fixed year effects in Robinson and Butterworth (2014) have a rather small number of degrees of freedom. This tends to give parameter estimates that (although unbiased) have high variance, and furthermore the MLE approach used resulted in negatively biased estimates of residual variance. An alternative approach is to treat the year effect as a random effect. This paper repeats the earlier fixed year effects computations in Robinson and Butterworth (2014) using this random effects approach. This has the advantage not only of increasing the number of degrees of freedom for improved estimation, but also of accounting for the bias associated with MLE estimates of residual variance for small numbers of degrees of freedom via the REML approach.

Aside from use of the random effects models, the methodology used for this paper is as detailed in Robinson and Butterworth (2014).

Results

Table 1 compares the earlier estimates of residual standard deviations under the fixed year effects approach with those under the random year effects method. Typically estimates of residual standard deviation are about 50% larger under this approach compared to the fixed year effects method used earlier, which is in the direction expected given the negative bias associated with MLE estimates of variance.

Table 2 lists estimates of the fishing effect λ (with standard errors) for all the islands (Dassen, Robben, Bird and St Croix) for the response variables (including some or all of chick condition, active nest proportion, fledging success, chick growth, foraging path length, and foraging trip duration) and catch series (sardine, anchovy and their combination within 20 nmi and 30 nmi of the islands) considered. Estimates significantly different from zero at the 15% and 5% levels are indicated. For the random effects model, the normal approximation is used in determining significance. Standard errors for λ estimates from the random effects models are generally smaller than for the fixed effects models (see Figures 1–8).

In order to give an overall impression (meta-analysis), Table 3 tallies positive and negative values of λ, both overall and at the 15% and 5% significance levels, for the different models considered. Overall, the results among the different models are similar. Under the random effects models, the proportion of estimates of λ for the Western Cape's Dassen and Robben islands that are positive increases from the 71% for the fixed effects models to 79% (though it should be noted that the 36 models considered are not fully independent). A higher proportion (by about three times) of the random effects model results are significantly different from zero at the 15% and 5% levels, though here too the great preponderance of these results reflect positive estimates of λ. For the Eastern Cape's Bird and St Croix islands, fewer data are available. Results for all four methods applied are broadly similar, giving positive estimates for λ for Bird Island, and negative estimates for St Croix Island. Under the random effects model, most of the negative estimates for λ are significant at the 15% level.

Table 4 (Dassen and Robben islands) and Table 5 (Bird and St Croix islands) provide estimates of power in terms of the number of years' additional data estimated to be required to achieve λ estimates significant at the 5% level with 95% probability.

The following points are notable with respect to results in columns (c) of Tables 4 and 5 (when effect sizes and residual variance are estimated with the random effects model – note that throughout what now follows, the word "significant" is used to mean significant at the 5% level).

- Active nest proportion already provides a significantly positive estimate for $\lambda_{\mathrm{Dassen}}$ when analysed together with the sardine and total catch series (see also Table 2a (ii)), as does chick growth with both sardine series, foraging path length with the sardine 30 nmi series, and foraging trip duration with each of the three 20 nmi series.
- Chick growth rate already provides a significantly negative estimate for $\lambda_{\mathrm{Dassen}}$ with the anchovy 30 nmi catch series. The next best result to confirm the same for Dassen Island is a further 2 years of data required for foraging path length with the anchovy 20 nmi series.
- Active nest proportion already provides a significantly positive estimate for $\lambda_{\mathrm{Robben}}$ with each of the six catch series, as does chick growth rate with both sardine catch series.
- Fledging success already provides a significantly negative estimate for $\lambda_{\mathrm{Robben}}$ for both the sardine 20 and 30 nmi series, as does foraging path length with the anchovy 20 nmi series.
- At St Croix Island, 5 years' additional foraging trip duration data with the sardine 30 nmi series are required to confirm a significantly negative estimate for λ.
- At Bird Island, obtaining an estimate for λ which is significantly different than zero is unlikely within 20 years.

Conclusions

- At this stage all the indices apart from chick condition already give some statistically significant results, though in differing, though primarily positive, directions for λ.
- Periods estimated to obtain significant results under the random effects model are somewhat lengthier than indicated for the earlier fixed effects approach.
- For Robben and Dassen islands, there is a very strong preponderance of positive estimates of λ, including under the random effects models. However for Bird and St Croix islands, the strongest indication is of negative values of λ for St Croix.

The purpose of the feasibility study has been to estimate the residual variances associated with penguin response variables with sufficient precision that experimental power can be determined

with adequate reliability. This is to be able to decide on whether an experimental closure programme could yield definitive conclusions regarding the impact of fishing close to island colonies on penguin demographics within a realistic time span (which would probably be taken to be within one or possibly two decades). The results above indicate clearly that such a determination is now possible for Dassen, Robben and St Croix islands, including under the random effects models newly considered here. It thus follows that the feasibility study can now be concluded and the island closure experiment commenced. Definitive (significant) results are already available for some combinations of response variables and prey catch series, and further significant results from this experiment can be expected for these islands with about 2–5 years' additional data. (These years include 2013 for which data are not yet available.)

Reference

Robinson, WML and Butterworth, DS. 2014. Island closure feasibility study power analysis results for Dassen and Robben islands. Document FISHERIES/2014/MAR/SWG–PEL/ICTT/05. 11pp.

Table 1: Residual standard error σ_ε and upper 95% confidence limits $\sigma_{\varepsilon,+95}$ (estimated using a likelihood profile approach) for each penguin response series available for assessing the power of the island closure experiment are listed for (i) the fixed year effect model and (ii) the random year effects model. Note that the MLE estimates for (i) are negatively biased because of the small number of degrees of freedom, but that the estimates for (ii) correct for this effect through use of REML and are consequently unbiased. The number of past data points n and the number of model parameters estimated p are indicated for the fixed year effect model. Results are given for the case of total catch within 30 nmi for the Western Cape and Sardine catch within 30 nmi for the Eastern Cape.

(a) Dassen and Robben islands

Penguin response	n	p	σ_ε		$\sigma_{\varepsilon,+95}$	
			(i)	(ii)	(i)	(ii)
Chick condition	11	9	0.113	0.215	0.176	0.335
Active nest proportion	27	17	0.345	0.405	0.453	0.533
Fledging success	32	27	0.052	0.084	0.067	0.109
Chick growth	15	14	0.034	0.054	0.050	0.079
Foraging path length	11	9	0.041	0.042	0.064	0.066
Foraging trip duration	11	9	0.115	0.171	0.179	0.266

(b) St Croix and Bird islands

Penguin response	n	p	σ_ε		$\sigma_{\varepsilon,+95}$	
			(i)	(ii)	(i)	(ii)
Foraging path length	11	9	0.069	0.086	0.108	0.134
Foraging trip duration	11	9	0.071	0.099	0.111	0.154

Table 2: Fishing effect parameters λ with associated standard errors for (i) fixed year effects, (ii) random year effects, (iii) year effects given by spawner biomass, and (iv) year effects given by recruit biomass. Values significantly different than zero at the 15% and 5% levels are indicated by one and two asterisks respectively. Statistical significance is based on a normal approximation for the random effects model and a two-sided t-test for the other models.

(a) Dassen Island

Penguin response	Fish	Area	λ				s.e.			
			(i)	(ii)	(iii)	(iv)	(i)	(ii)	(iii)	(iv)
Chick condition	Sardine	20 nmi	0.23	0.07	0.01	0.04	0.26	0.18	0.20	0.22
		30 nmi	0.35	0.16	0.03	0.06	0.24	0.16	0.19	0.20
	Anchovy	20 nmi	-0.30	-0.05	0.07	0.05	0.22	0.21	0.24	0.23
		30 nmi	-1.05	0.12	0.15	0.11	1.09	0.33	0.37	0.37
	Total	20 nmi	-0.28	0.02	0.10	0.06	0.28	0.25	0.29	0.26
		30 nmi	-0.19	0.18	0.19	0.18	1.26	0.40	0.44	0.45
Active nest proportion	Sardine	20 nmi	1.16	0.69 **	0.58 **	0.64 **	0.89	0.23	0.27	0.28
		30 nmi	0.77	0.81 **	0.75 **	0.87 **	1.07	0.27	0.32	0.35
	Anchovy	20 nmi	0.03	0.17	0.72	0.70	0.38	0.37	0.68	0.59
		30 nmi	0.45	0.51	0.93	0.71	0.85	0.77	1.08	0.95
	Total	20 nmi	0.45	0.79 **	1.30 **	1.20 **	0.42	0.39	0.59	0.51
		30 nmi	1.00	1.61 **	1.99 **	1.69 **	0.87	0.64	0.78	0.71
Fledging success	Sardine	20 nmi	0.19	0.07	0.10	0.10	0.14	0.10	0.13	0.11
		30 nmi	0.39	0.03	0.15	0.13	0.37	0.12	0.17	0.14
	Anchovy	20 nmi	0.15	0.12 *	-0.01	-0.01	0.10	0.09	0.14	0.16
		30 nmi	0.43 **	0.21 *	0.02	-0.03	0.16	0.13	0.17	0.20
	Total	20 nmi	0.21	0.17 *	0.08	0.07	0.13	0.12	0.16	0.18
		30 nmi	0.50 *	0.20 *	0.16	0.13	0.24	0.19	0.24	0.26
Chick growth	Sardine	20 nmi	-0.29	0.11 **	0.08	0.11 **	0.35	0.04	0.06	0.04
		30 nmi	-0.40 **	0.14 **	0.16 **	0.13 **	0.01	0.04	0.07	0.04
	Anchovy	20 nmi	-0.04	-0.10 *	-0.10	-0.09	0.14	0.07	0.07	0.07
		30 nmi	-0.06	-0.18 **	-0.17 *	-0.16 *	0.68	0.07	0.08	0.08
	Total	20 nmi	-0.09	-0.02	0.03	-0.01	0.21	0.12	0.14	0.14
		30 nmi	-0.47	-0.19	-0.13	-0.16	0.68	0.19	0.21	0.20
Foraging path length	Sardine	20 nmi	0.16	0.14 *	-0.12	0.17	0.19	0.13	0.11	0.23
		30 nmi	0.27	0.22 **	-0.12	0.20	0.13	0.11	0.12	0.24
	Anchovy	20 nmi	-0.28	-0.20	0.72	0.71	0.19	0.19	0.47	0.48
		30 nmi	0.15	0.28	0.47	0.45	0.67	0.44	0.55	0.61
	Total	20 nmi	0.07	0.11	0.44	0.62	0.18	0.17	0.45	0.46
		30 nmi	0.48	0.45 *	0.28	0.49	0.54	0.36	0.45	0.50
Foraging trip duration	Sardine	20 nmi	0.64	0.17 **	0.09	0.17	0.78	0.10	0.11	0.14
		30 nmi	0.12	0.17 *	0.09	0.18	0.91	0.10	0.12	0.15
	Anchovy	20 nmi	-0.66	0.62 **	0.62 *	0.64 *	0.35	0.28	0.30	0.30
		30 nmi	0.40	0.14	0.19	0.22	1.32	0.36	0.39	0.43
	Total	20 nmi	0.44	0.62 **	0.60 *	0.66 **	0.44	0.22	0.26	0.25
		30 nmi	1.14	0.38 *	0.34	0.45	1.51	0.27	0.31	0.32

Table 2: Continued.

(b) Robben Island

Penguin response	Fish	Area	λ				s.e.			
			(i)	(ii)	(iii)	(iv)	(i)	(ii)	(iii)	(iv)
Chick condition	Sardine	20 nmi	0.09	0.18	0.17	0.24	0.39	0.23	0.35	0.29
		30 nmi	0.42	0.30 *	0.34	0.31	0.51	0.20	0.26	0.22
	Anchovy	20 nmi	-0.05	-0.07	-0.09	-0.13	0.18	0.17	0.23	0.21
		30 nmi	-0.61	0.14	0.18	0.12	0.85	0.25	0.29	0.30
	Total	20 nmi	-0.04	-0.06	-0.10	-0.09	0.22	0.19	0.25	0.22
		30 nmi	0.07	0.25	0.28	0.25	0.91	0.29	0.33	0.33
Active nest proportion	Sardine	20 nmi	0.70	0.38 **	0.22	0.24	0.48	0.16	0.19	0.22
		30 nmi	0.59	0.51 **	0.34	0.44	0.74	0.22	0.26	0.30
	Anchovy	20 nmi	1.33 **	1.27 **	1.01 *	0.86 *	0.30	0.29	0.54	0.48
		30 nmi	1.46 **	1.29 **	0.74	0.63	0.61	0.55	0.78	0.69
	Total	20 nmi	1.26 **	1.27 **	1.14 **	1.03 **	0.31	0.31	0.49	0.42
		30 nmi	1.84 **	1.90 **	1.34 *	1.16 *	0.72	0.57	0.72	0.64
Fledging success	Sardine	20 nmi	0.25	-0.16 **	-0.16 **	-0.20 **	0.19	0.05	0.06	0.07
		30 nmi	0.29	-0.15 **	-0.14 *	-0.17 *	0.31	0.07	0.09	0.09
	Anchovy	20 nmi	0.03	0.01	0.03	-0.02	0.11	0.09	0.11	0.12
		30 nmi	0.38 *	0.14 *	0.08	0.07	0.20	0.13	0.13	0.15
	Total	20 nmi	0.04	-0.10	-0.08	-0.18	0.14	0.10	0.12	0.14
		30 nmi	0.36	-0.07	-0.04	-0.18	0.26	0.16	0.17	0.19
Chick growth	Sardine	20 nmi	-0.47	0.23 **	0.05	0.23 *	0.40	0.13	0.26	0.11
		30 nmi	-1.81 **	0.55 **	0.72	0.56 **	0.04	0.24	0.62	0.23
	Anchovy	20 nmi	0.08	0.05	0.03	0.07	0.15	0.09	0.11	0.12
		30 nmi	0.03	-0.02	0.00	0.03	0.40	0.07	0.08	0.09
	Total	20 nmi	0.09	0.05	0.01	0.06	0.15	0.10	0.13	0.14
		30 nmi	-0.15	0.01	0.04	0.10	0.39	0.14	0.17	0.17
Foraging path length	Sardine	20 nmi	0.05	0.03	-0.13	0.14	0.13	0.09	0.09	0.16
		30 nmi	0.14	0.10 *	-0.16	0.18	0.11	0.09	0.11	0.20
	Anchovy	20 nmi	-0.18	-0.15 **	0.16	0.18	0.09	0.09	0.23	0.22
		30 nmi	0.11	0.21	0.33	0.33	0.53	0.35	0.43	0.51
	Total	20 nmi	-0.09	-0.06	0.11	0.23	0.11	0.11	0.28	0.30
		30 nmi	0.27	0.25	0.29	0.48	0.47	0.31	0.41	0.46
Foraging trip duration	Sardine	20 nmi	0.38	0.06	0.00	0.08	0.56	0.07	0.09	0.10
		30 nmi	0.00	0.07	-0.01	0.09	0.76	0.09	0.11	0.13
	Anchovy	20 nmi	-0.45 *	0.13	0.11	0.14	0.15	0.12	0.15	0.14
		30 nmi	0.61	0.35 *	0.30	0.34	1.04	0.29	0.31	0.36
	Total	20 nmi	0.23	0.16 *	0.16	0.21	0.27	0.13	0.16	0.16
		30 nmi	1.02	0.36 *	0.31	0.42	1.33	0.24	0.28	0.29

Table 2: Continued.

(c) Bird Island

Penguin response	Fish	Area	λ				s.e.			
			(i)	(ii)	(iii)	(iv)	(i)	(ii)	(iii)	(iv)
Foraging path length	Sardine	20 nmi	0.21	0.08	0.06	0.08	0.19	0.09	0.08	0.10
		30 nmi	0.09	0.07	0.07	0.10	0.16	0.10	0.09	0.13
Foraging trip duration	Sardine	20 nmi	0.24	0.04	0.04	0.03	0.20	0.07	0.08	0.07
		30 nmi	0.04	0.04	0.05	0.04	0.17	0.08	0.09	0.08

(d) St Croix Island

Penguin response	Fish	Area	λ				s.e.			
			(i)	(ii)	(iii)	(iv)	(i)	(ii)	(iii)	(iv)
Foraging path length	Sardine	20 nmi	-0.09	-0.13 $*$	-0.04	-0.16	0.12	0.09	0.11	0.10
		30 nmi	-0.22	-0.26	0.04	-0.28	0.44	0.34	0.36	0.48
Foraging trip duration	Sardine	20 nmi	-0.16	-0.09 $*$	-0.11	-0.08	0.13	0.07	0.10	0.07
		30 nmi	-0.51	-0.39 $*$	-0.33	-0.26	0.45	0.28	0.34	0.29

Table 3: Tallies of positive and negative values of λ, those significantly different from zero at the 15% level, and those significantly different from zero at the 5% level.

(a) Western Cape

		Fixed year effects			Random year effects			Spawner Biomass			Recruit Biomass		
		all	15%	5%	all	15%	5%	all	15%	5%	all	15%	5%
Chick condition	Dassen	2:4	0:0	0:0	5:1	0:0	0:0	6:0	0:0	0:0	6:0	0:0	0:0
	Robben	3:3	0:0	0:0	4:2	1:0	0:0	4:2	0:0	0:0	4:2	0:0	0:0
Active nest proportion	Dassen	6:0	0:0	0:0	6:0	4:0	4:0	6:0	4:0	4:0	6:0	4:0	4:0
	Robben	6:0	4:0	4:0	6:0	6:0	6:0	6:0	3:0	1:0	6:0	3:0	1:0
Fledging success	Dassen	6:0	2:0	1:0	6:0	4:0	0:0	5:1	0:0	0:0	4:2	0:0	0:0
	Robben	6:0	1:0	0:0	2:4	1:2	0:2	2:4	0:2	0:1	1:5	0:2	0:1
Chick growth	Dassen	0:6	0:1	0:1	2:4	2:2	2:1	3:3	1:1	1:0	2:4	2:1	2:0
	Robben	3:3	0:1	0:1	5:1	2:0	2:0	6:0	0:0	0:0	6:0	2:0	1:0
Foraging path length	Dassen	5:1	0:0	0:0	5:1	3:0	1:0	4:2	0:0	0:0	6:0	0:0	0:0
	Robben	4:2	0:0	0:0	4:2	1:1	0:1	4:2	0:0	0:0	6:0	0:0	0:0
Foraging trip duration	Dassen	5:1	0:0	0:0	6:0	5:0	3:0	6:0	2:0	0:0	6:0	2:0	1:0
	Robben	5:1	0:1	0:0	6:0	3:0	0:0	5:1	0:0	0:0	6:0	0:0	0:0
Total	Dassen	24:12	2:1	1:1	30:6	18:2	10:1	30:6	7:1	5:0	30:6	8:1	7:0
	Robben	27:9	5:2	4:1	27:9	14:3	8:3	27:9	3:2	1:1	29:7	5:2	2:1
	Both	51:21	7:3	5:2	57:15	32:5	18:4	57:15	10:3	6:1	59:13	13:3	9:1

(b) Eastern Cape

		Fixed year effects			Random year effects			Spawner Biomass			Recruit Biomass		
		all	15%	5%	all	15%	5%	all	15%	5%	all	15%	5%
Foraging path length	Bird	2:0	0:0	0:0	2:0	0:0	0:0	2:0	0:0	0:0	2:0	0:0	0:0
	St Croix	0:2	0:0	0:0	0:2	0:1	0:0	1:1	0:0	0:0	0:2	0:0	0:0
Foraging trip duration	Bird	2:0	0:0	0:0	2:0	0:0	0:0	2:0	0:0	0:0	2:0	0:0	0:0
	St Croix	0:2	0:0	0:0	0:2	0:2	0:0	0:2	0:0	0:0	0:2	0:0	0:0
Total	Bird	4:0	0:0	0:0	4:0	0:0	0:0	4:0	0:0	0:0	4:0	0:0	0:0
	St Croix	0:4	0:0	0:0	0:4	0:3	0:0	1:3	0:0	0:0	0:4	0:0	0:0
	Both	4:4	0:0	0:0	4:4	0:3	0:0	5:3	0:0	0:0	4:4	0:0	0:0

Table 4: The number of additional years' data required to detect a fishing effect with 95% probability is given for each of Dassen and Robben islands for three cases: (a) effect sizes λ and residual variances σ_ε estimated with the fixed year effect model, (b) effect sizes estimated with the fixed effects model, residual variances estimated with the random effects model, and (c) effect sizes and residual variances estimated with the random effects model.

			Dassen Island			Robben Island		
Response	Fish	Area	(a)	(b)	(c)	(a)	(b)	(c)
Chick condition	Sardine	20 nmi	10	> 20	> 20	> 20	> 20	> 20
		30 nmi	3	4	11	5	7	19
	Anchovy	20 nmi	5	16	> 20	> 20	> 20	> 20
		30 nmi	2	3	> 20	4	6	> 20
	Total	20 nmi	8	> 20	> 20	> 20	> 20	> 20
		30 nmi	> 20	> 20	> 20	> 20	> 20	> 20
Active nest proportion	Sardine	20 nmi	9	9	0	8	9	0
		30 nmi	14	16	0	13	15	0
	Anchovy	20 nmi	> 20	> 20	> 20	0	0	0
		30 nmi	> 20	> 20	> 20	0	0	0
	Total	20 nmi	> 20	> 20	0	0	0	0
		30 nmi	8	8	0	0	0	0
Fledging success	Sardine	20 nmi	10	18	> 20	8	15	0
		30 nmi	5	6	> 20	6	8	0
	Anchovy	20 nmi	7	10	15	> 20	> 20	> 20
		30 nmi	0	0	3	3	3	11
	Total	20 nmi	6	9	> 20	> 20	> 20	> 20
		30 nmi	2	2	> 20	4	4	> 20
Chick growth	Sardine	20 nmi	6	17	0	4	10	0
		30 nmi	0	0	0	0	0	0
	Anchovy	20 nmi	> 20	> 20	> 20	14	> 20	> 20
		30 nmi	> 20	> 20	0	> 20	> 20	> 20
	Total	20 nmi	19	> 20	> 20	12	> 20	> 20
		30 nmi	3	3	6	5	7	> 20
Foraging path length	Sardine	20 nmi	4	4	5	11	11	17
		30 nmi	2	2	0	3	3	3
	Anchovy	20 nmi	2	2	2	2	2	0
		30 nmi	11	13	5	20	> 20	6
	Total	20 nmi	> 20	> 20	13	10	12	> 20
		30 nmi	2	2	2	4	4	4
Foraging trip duration	Sardine	20 nmi	5	6	0	6	8	> 20
		30 nmi	> 20	> 20	> 20	> 20	> 20	> 20
	Anchovy	20 nmi	2	3	0	1	4	> 20
		30 nmi	7	8	> 20	4	4	10
	Total	20 nmi	5	8	0	10	> 20	18
		30 nmi	2	2	8	3	4	19

Table 5: The number of additional years' data required to detect a fishing effect with 95% probability is given for each of Bird and St Croix islands for three cases: (a) effect sizes λ and residual variances σ_ε estimated with the fixed year effect model, (b) effect sizes estimated with the fixed effects model, residual variances estimated with the random effects model, and (c) effect sizes and residual variances estimated with the random effects model.

			Bird			St Croix		
Response	Fish	Area	(a)	(b)	(c)	(a)	(b)	(c)
Foraging path length	Sardine	20 nmi	7	19	> 20	20	> 20	> 20
		30 nmi	> 20	> 20	> 20	11	13	11
Foraging trip duration	Sardine	20 nmi	6	14	> 20	7	16	> 20
		30 nmi	> 20	> 20	> 20	4	5	5

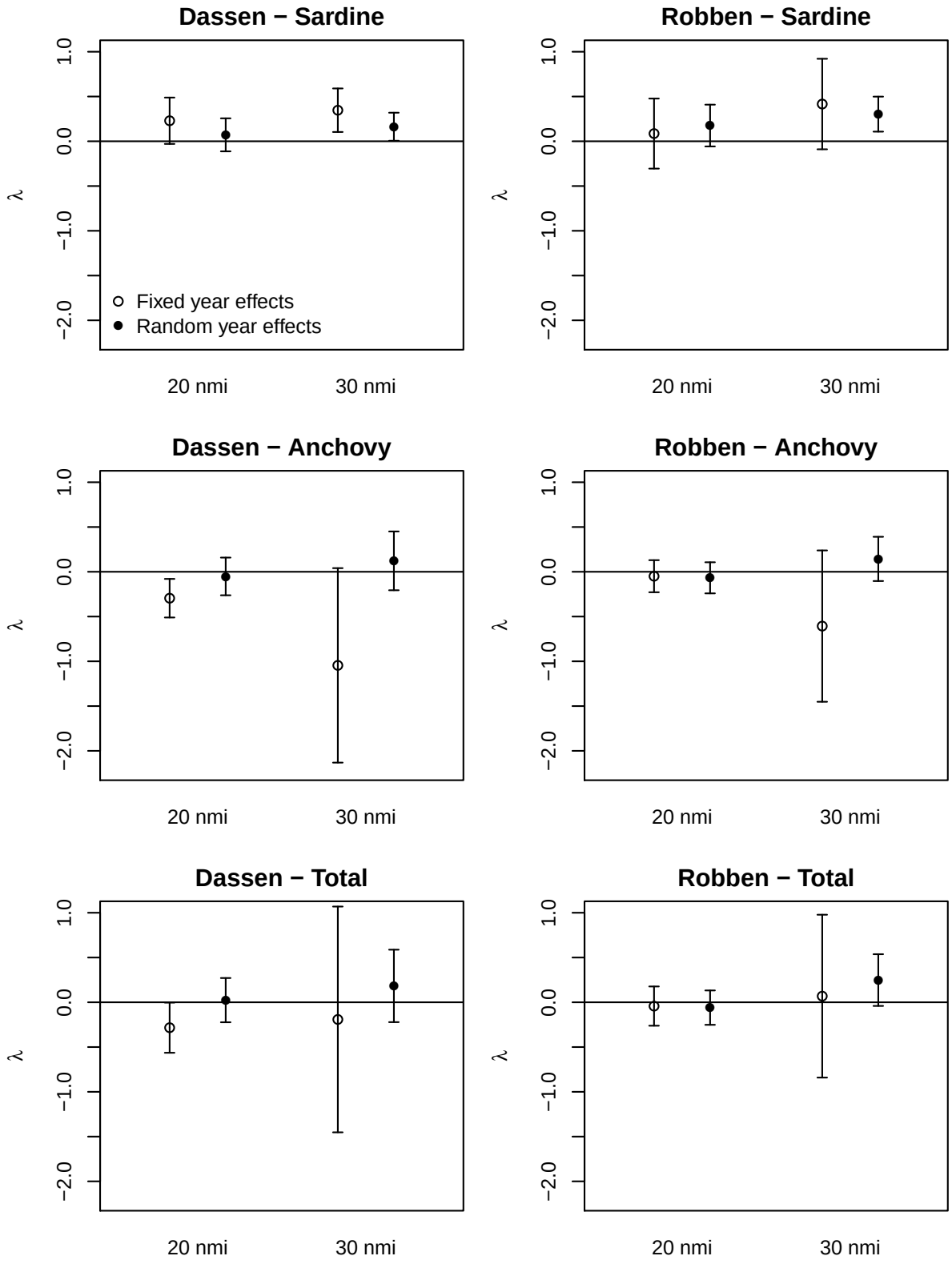

Figure 1: Dassen and Robben islands fishing effect estimates: chick condition. Bars indicate one standard error.

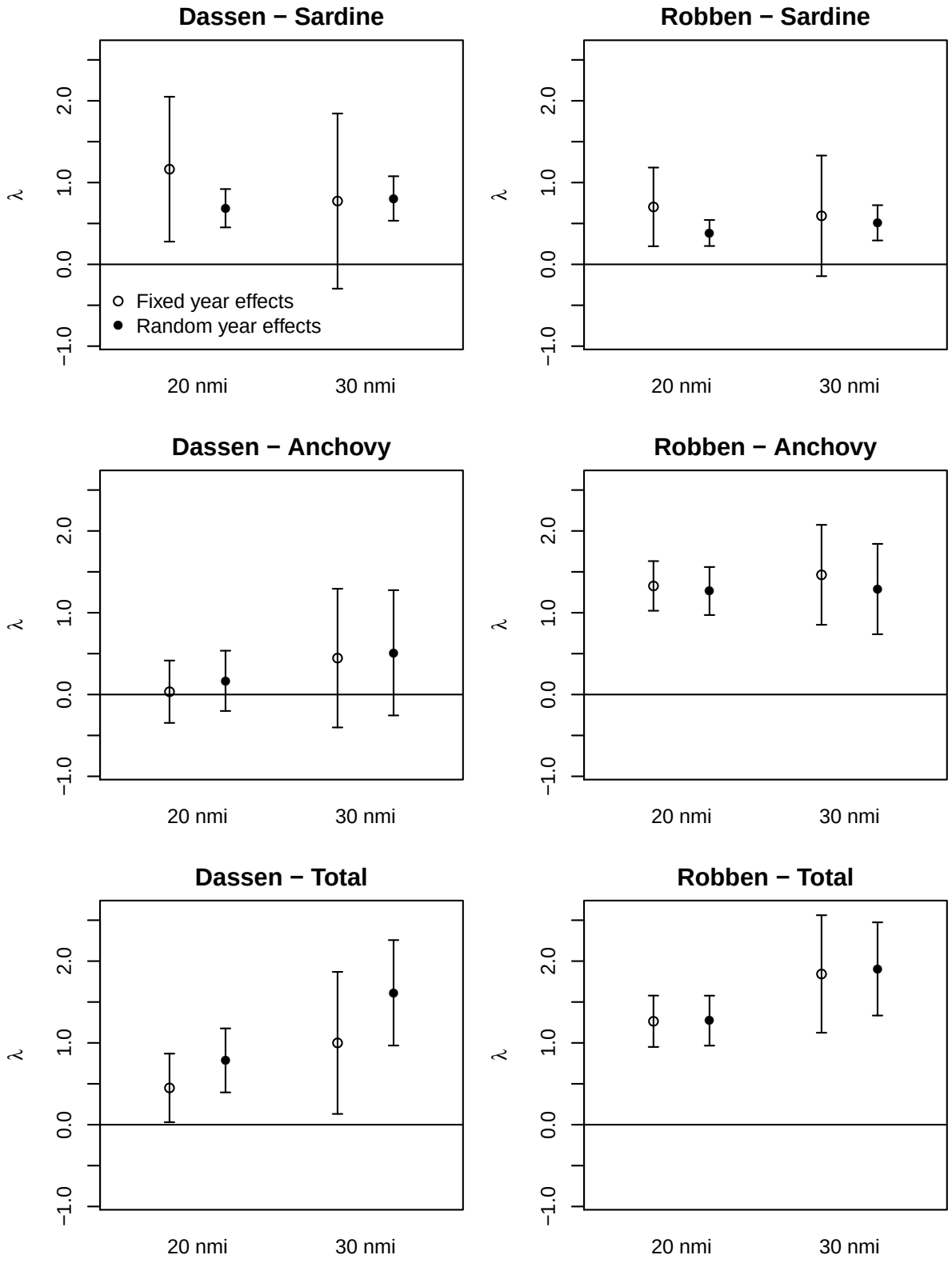

Figure 2: Dassen and Robben islands fishing effect estimates: active nest proportion. Bars indicate one standard error.

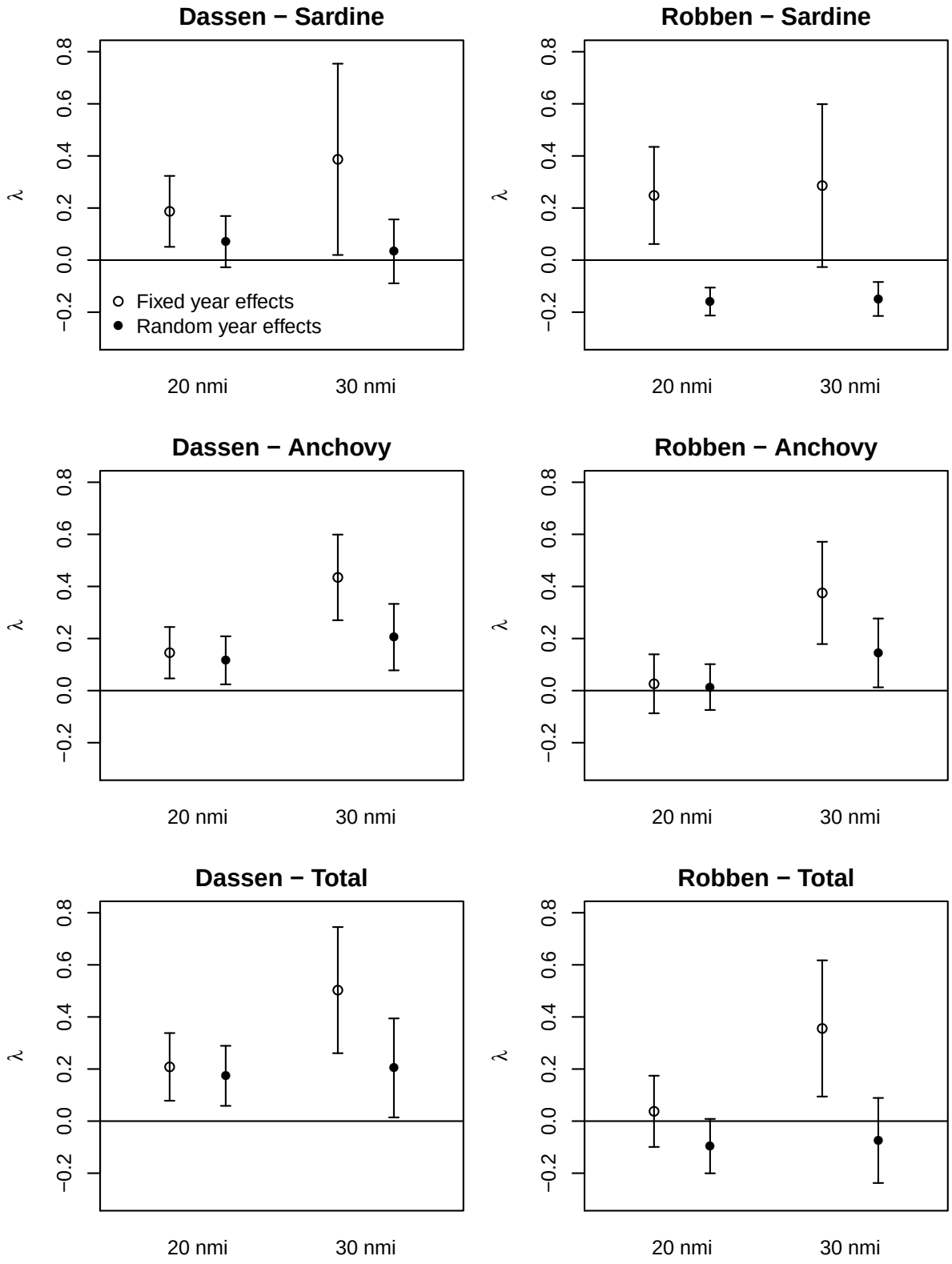

Figure 3: Dassen and Robben islands fishing effect estimates: fledging success. Bars indicate one standard error.

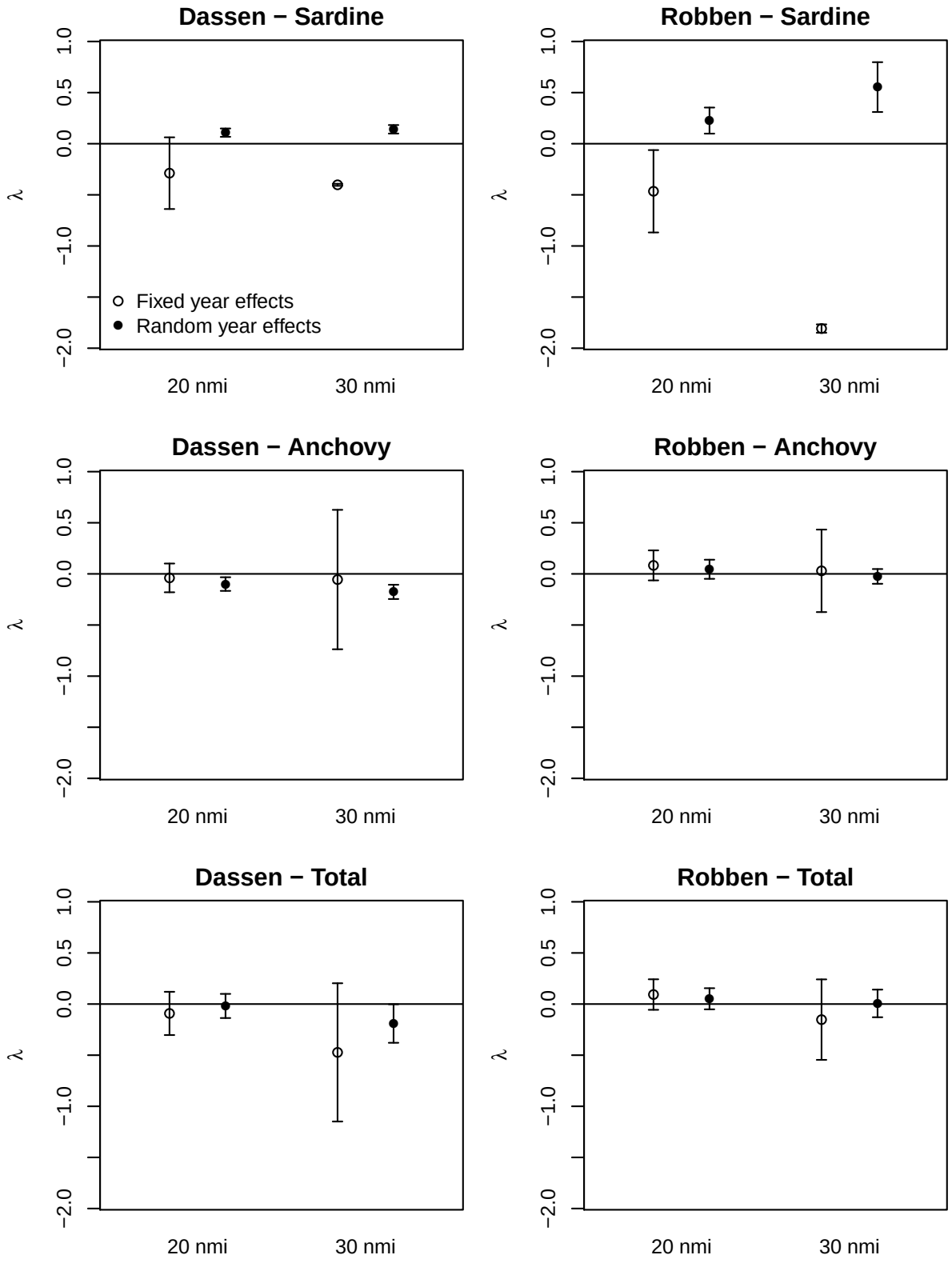

Figure 4: Dassen and Robben islands fishing effect estimates: chick growth rate. Bars indicate one standard error.

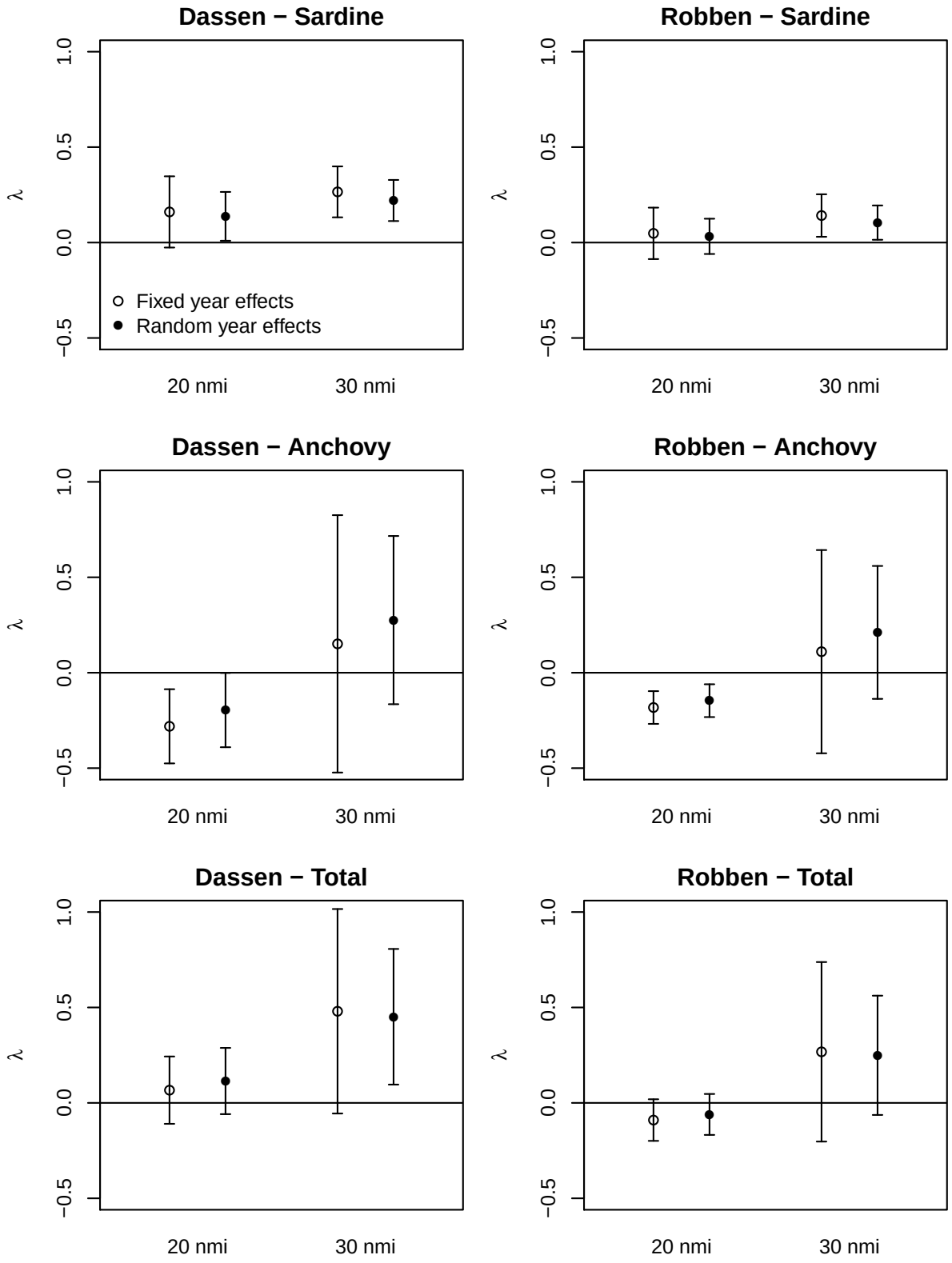

Figure 5: Dassen and Robben islands fishing effect estimates: foraging path length. Bars indicate one standard error.

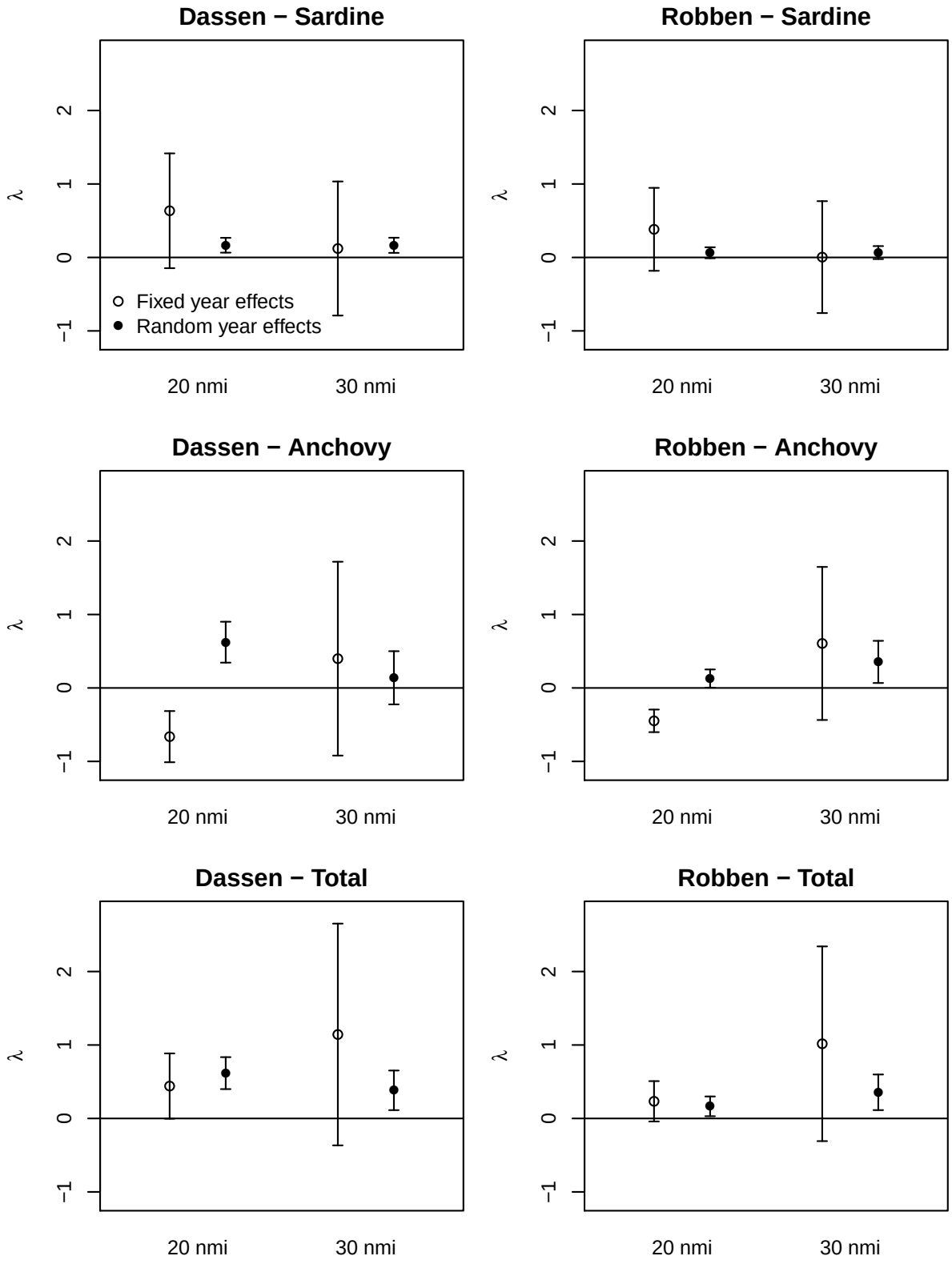

Figure 6: Dassen and Robben islands fishing effect estimates: foraging trip duration. Bars indicate one standard error.

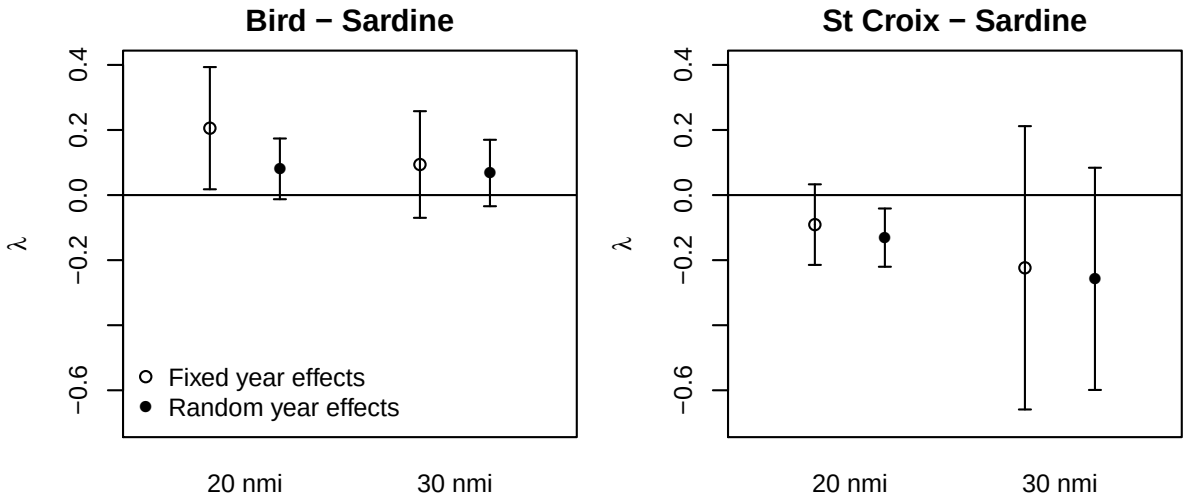

Figure 7: Bird and St Croix islands fishing effect estimates: foraging path length. Bars indicate one standard error.

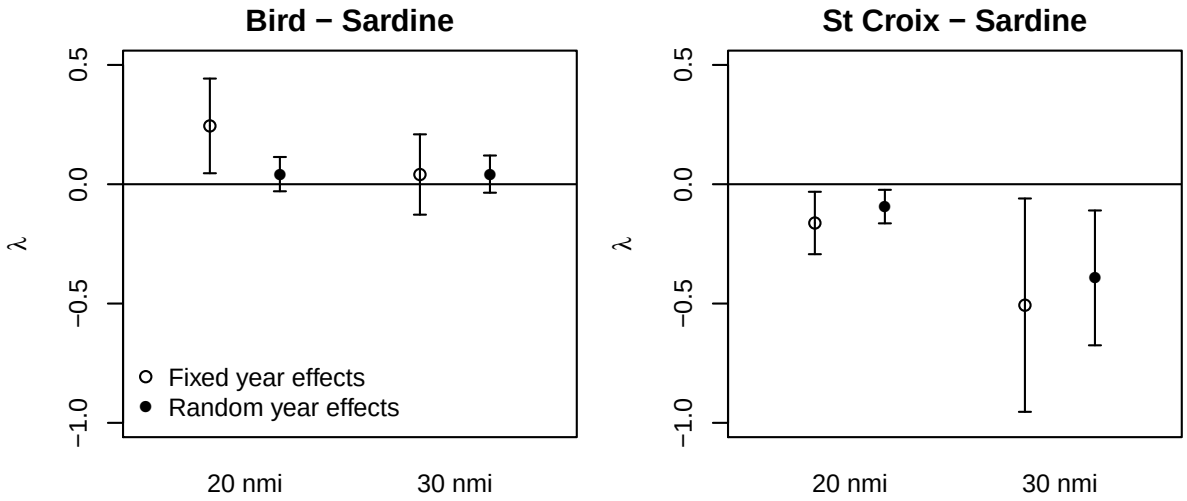

Figure 8: Bird and St Croix islands fishing effect estimates: foraging trip duration. Bars indicate one standard error.