GLMs relating penguin demographics to pelagic catches close to islands and to pelagic abundance

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Abstract

Earlier GLM analyses of the impact of pelagic fishing in the vicinities of Robben and Dassen Islands on the dynamics of penguins breeding on those islands are extended to cover a wider set of data series, and to consider relationships involving sardine and anchovy separately as well as together. This in turn allows the estimation of the change in penguin population growth rate to be expected from suspending pelagic fishing in the vicinities of these islands. Interpretation of results is confounded by poor precision which is a consequence of the shortness of the time series. Likely the most that could be said with some confidence is that the results of the analyses do **not** support the hypothesis that suspending fishing around Robben and Dassen Islands would enhance penguin reproductive success there.

Introduction

The work presented below extends the earlier GLM models developed first in Brandão and Butterworth (2007) to address the topic of this paper to a wider set of data series, and to consider relationships involving sardine and anchovy separately, rather than only in combination as earlier.

The results from these GLMs are then used to estimate the extent to which suspending fishing near Robben Island or Dassen Island would improve penguin population increase rates.

Data

The penguin data used for these analyses are as agreed following discussions with Rob Crawford, who was assisted in their preparation by Newi Makhado.

Fledging success data are given in Table 1. There are two (non-comparable) data series for Robben Island, hence the addition of a third α parameter in GLMs (1) and (5) below to allow for an estimable multiplicative bias between these series.

Breeders per adult moulter (Table 2) are derived from the annual nest counts and moult counts. Data from after 2007 were ignored because the moult counts for those years seem unrealistically low (being well below breeder counts), probably as a result of some of the birds moulting elsewhere.

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Table 3 gives the ratio of active nests to the total number of nests counted (active plus potential nests). Table 4 lists annual survival rates calculated from tagging data. Since the proportion of nests and the survival rates fall in the range [0,1], these two data sets are transformed using a logistic transformation in models (3), (4), (7) and (8) below.

The six series of estimates for pelagic catch in the vicinity of the islands, taken from Van der Westhuizen (2010), are given in Table 5. This six pelagic survey biomass series used are given in Table 6. The choice of pelagic biomass data are as agreed following discussions with Janet Coetzee.

Models

General Linear Models are considered for fledging success $F_{y,i,s}$, breeders per adult moulter $G_{y,i}$, active nests as a proportion of total nests $P_{y,i}$, and adult survival $S_{y,i}$. The response variables are indexed by year y, island i and data series s. The four equations are:

$$\ln\left(F_{y,i,s}\right) = \alpha_s + \beta_y + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i,s} \tag{1}$$

$$\ln\left(G_{y,i}\right) = \alpha_i + \beta_y + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i} \tag{2}$$

$$\ln\left(\frac{P_{y,i}}{1-P_{y,i}}\right) = \alpha_i + \beta_y + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i} \tag{3}$$

$$\ln\left(\frac{S_{y,i}}{1-S_{y,i}}\right) = \alpha_i + \beta_y + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i} \tag{4}$$

where

α_s, α_i, β_y and λ_i are estimable parameters,

$C_{y,i,p}$ is the catch taken in year y around island i of pelagic species p, where p refers to either sardine, anchovy or the two combined, and

$\bar{C}_{i,p}$ is the average catch around island i of pelagic species p, calculated over the years for which there is penguin data available for island i for the model concerned.

An alternative form is considered where the year effect β_y is replaced by the parameter γ multiplied by the annual pelagic biomass $B_{y_q,p,q}$ where q refers to either the November adult biomass or the May recruit biomass. If this relationship with biomass accounts for much of the year effect β_y in equations (1)–(4), since this alternative form involves fewer estimable parameters it can potentially yield more precise estimates of the key λ_i parameters.

$$\ln\left(F_{y,i,s}\right) = \alpha_s + \gamma B_{y_q,p,q} + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i,s} \tag{5}$$

$$\ln\left(G_{y,i}\right) = \alpha_i + \gamma B_{y_q,p,q} + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i} \tag{6}$$

$$\ln\left(\frac{P_{y,i}}{1-P_{y,i}}\right) = \alpha_i + \gamma B_{y_q,p,q} + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i} \tag{7}$$

$$\ln\left(\frac{S_{y,i}}{1-S_{y,i}}\right) = \alpha_i + \gamma B_{y_q,p,q} + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i} \tag{8}$$

Since November is closer to the following year's breeding season, $y_q = y-1$ when q denotes the November adult biomass while $y_q = y$ when q denotes the May recruit biomass.

The parameters of particular interest are the λ_i and γ, which respectively relate commercial fishery catches and pelagic abundance to the penguin response variables.

Results

The values of the estimated parameters γ and λ_i are given in Table 7, along with standard errors and significance levels. Note that no estimates are given for model (4) since there proved to be insufficient data for reliable estimation in this case.

Table 8 summarises the number of occurrences of parameter estimates with positive and negative signs.

Analysis

The estimates of the GLM λ_i parameters may be used to calculate estimates for the change in the penguin population growth rate to be expected from stopping fishing in the vicinity of the islands.

Assuming reproductive maturity occurs at age 4, the basic penguin population model is:

$$N_{y+1} = N_y S + H_{y-3} S^3 N_{y-3} \tag{9}$$

where S is the adult annual survival rate and H is a measure related to egg production and fledging success. In a steady situation, the population growth rate μ is thus related to S and H as follows:

$$\mu^4 = \mu^3 S + HS^3 \tag{10}$$

Differentiating implicitly and solving for $\Delta\mu$ (a change in the growth rate) gives:

$$\Delta\mu = \frac{\mu^3 + 3S^2H}{4\mu^3 - 3\mu^2 S} \cdot \Delta S + \frac{S^3}{4\mu^3 - 3\mu^2 S} \cdot \Delta H \qquad (11)$$

The growth rates μ_{ROB} and μ_{DAS} were estimated from logarithmic regressions of the moult counts for Robben Island from 2004 to 2007 and for Dassen Island from 2003 to 2007, which are the years corresponding to the recent major declines at the two colonies. The average survival rate for the years 2004–2006 at Robben Island and 2003–2006 at Dassen Island from Table 4 were used as the adult survival rates S_{ROB} and S_{DAS}. Values for H_{ROB} and H_{DAS} were then calculated using equation (10). The results were as follows:

	μ	S	H
Robben	0.712	0.604	0.178
Dassen	0.760	0.560	0.501

The parameters λ_i corresponds to the effect on the dependent variable in question of increasing the catch around the island concerned from zero to its average value. Thus if such catches are suspended, the estimated change ΔH is given by $\exp(-\lambda_i)-1$ for the fledging success and breeders per adult moulter GLMs. The active/total nests ratio does not translate readily into such a relationship, but the λ_i parameters of adult survival models of equations (4) and (8) relate similarly to ΔS after allowing through differentiation for the effect of the logistic transformation.

Table 9 and Figs 1–2 show estimates with approximate 95% CIs[2] of the change in penguin population growth occasioned by suspending fishing around colonies, as estimated from these various models. Note that the upper six plots in each figure correspond to results based on GLM analyses of reproduction-related data, while the final two plots relate to GLM 8 which considers survival.

Discussion

In terms of the λ_i parameters which estimate the impact of fishing close to islands on penguin demographic parameters, there are five cases (three positive and two negative) where the estimate is significant at the 5% level (see Table 7), but interpretation of such "significance" must be tempered by the multiplicity of the tests conducted and the incompleteness of their independence given use of partially common data. Similar problems would apply if performing non-parametric tests on the tallies of positive and negative estimates shown in Table 8. Nevertheless, the broad trends shown there are of interest and probably also not without meaning.

- When biomass is used rather than estimating a year factor separately for each year, relationships of reproduction and survival rates to pelagic biomass are nearly all positive.
- Estimates of the impact of additional fishing on penguin parameters related to reproduction are preponderantly **positive** rather than negative.

[2] Shortage of time precluded evaluating these in terms of the t-distributions involved. Instead what would be the reasonable approximation of use of +-2 standard errors was effected.

- Estimates of this impact on penguin survival rates are **near equally split** between positives and negative.

Fig. 2 probably provides the most easily interpretable summary of the estimated impacts on penguin growth rates of suspending pelagic fishing close to west coast colonies. For data series related to reproductive success the point estimates for changes in growth rate are in the main a few percent and negative, with the strongest effect related to the fledging success data for Dassen Island. The one notable positive effect is for Dassen Island when only sardine abundance is used to reflect common inter-year variability for the both islands.

Virtually the same comments could be made concerning the results for survival rate when the November spawner biomass surveys provide the co-variate to reflect that common inter-year variability. If the recruit survey results are used instead, all but one of the point estimates reflect positive impacts from suspending fishing, but the associated variances are much higher than for the other seven plots shown.

In summary, obtaining clear results from these analyses is frustrated by the short-ish time series available, which precludes precision estimation of the effects of interest. Likely the most that could be said with some confidence is that the results of the analyses do **not** support the hypothesis that suspending fishing around Robben and Dassen Islands would enhance penguin reproductive success there.

While further analyses of this type could be pursued (e.g. assuming different functional forms or error distributions for the models investigated), that would seem unlikely to yield results dissimilar to those above. However a case could still be made for some continued experimental closures to provide the contrast for more precise estimation of the effects of interest given further monitoring data.

References

Brandão A, Butterworth DS. 2007. An initial analysis of the power of monitoring certain Indices to determine the effect of fishing on penguin reproductive success from an experiment where pelagic fishing is prohibited in the neighbourhood of Robben Island, but continues around Dassen Island. Document MCM EAFWG/OCT2007/STG/04.

Van der Westhuizen J. 2010. Estimating anchovy and sardine catches in the region of the penguin colonies. Document MCM/2010/SWG_PEL/Island Closure Task Team/04.

Tables

Table 1: Fledging success data (GLM 1)

Year	Island	Series	F
1989	Robben	Robben1	0.415
1990	Robben	Robben1	0.319
1991	Robben	Robben1	0.592
1992	Robben	Robben1	0.590
1993	Robben	Robben1	0.535
1994	Robben	Robben1	0.446
1995	Robben	Robben1	0.383
1996	Robben	Robben1	0.654
1997	Robben	Robben1	0.968
1998	Robben	Robben1	0.748
1999	Robben	Robben1	0.600
2001	Robben	Robben2	0.756
2002	Robben	Robben2	0.516
2003	Robben	Robben2	0.449
2004	Robben	Robben2	0.487
2005	Robben	Robben2	0.811
2006	Robben	Robben2	0.627
2007	Robben	Robben2	1.142
2008	Robben	Robben2	1.031
2009	Robben	Robben2	0.937
1995	Dassen	Dassen	0.825
1996	Dassen	Dassen	1.022
1997	Dassen	Dassen	1.180
1998	Dassen	Dassen	1.343
1999	Dassen	Dassen	1.376
2009	Dassen	Dassen	1.060

Table 2: Breeders per adult moulter (GLM 2)

Year	Island	p
1989	Robben	0.478
1990	Robben	0.753
1991	Robben	0.796
1992	Robben	0.821
1993	Robben	0.665
1994	Robben	0.707
1995	Robben	0.575
1996	Robben	0.928
1997	Robben	0.914
1998	Robben	0.810
1999	Robben	0.926
2000	Robben	0.925
2001	Robben	0.998
2002	Robben	1.149
2003	Robben	0.825
2004	Robben	0.919
2005	Robben	1.150
2006	Robben	0.965
2007	Robben	1.839
1996	Dassen	1.536
1997	Dassen	1.336
1998	Dassen	1.348
1999	Dassen	1.408
2000	Dassen	1.354
2001	Dassen	1.636
2002	Dassen	1.760
2003	Dassen	1.604
2004	Dassen	2.993
2005	Dassen	2.610
2006	Dassen	2.335
2007	Dassen	3.050

Table 3: Active and potential nests (GLM 3)

Year	Island	p
2000	Robben	0.957
2001	Robben	0.951
2002	Robben	0.940
2003	Robben	0.973
2004	Robben	0.876
2005	Robben	0.789
2006	Robben	0.860
2007	Robben	0.824
2008	Robben	0.986
2009	Robben	0.826
1999	Dassen	0.953
2000	Dassen	0.915
2001	Dassen	0.850
2002	Dassen	0.804
2003	Dassen	0.658
2004	Dassen	0.543
2005	Dassen	0.489
2006	Dassen	0.403
2007	Dassen	0.432
2008	Dassen	0.613
2009	Dassen	0.482

Table 4: Adult survival (GLM 4)

year	Island	Survival
2002	Robben	0.765
2003	Robben	0.752
2004	Robben	0.644
2005	Robben	0.620
2006	Robben	0.548
2007	Robben	0.385
2002	Dassen	0.697
2003	Dassen	0.682
2004	Dassen	0.561
2005	Dassen	0.535
2006	Dassen	0.462
2007	Dassen	0.307

Table 5: Annual pelagic catch taken within 15 nautical miles of Robben Island and Dassen Island (in tonnes).

	Robben			Dassen		
	Sardine	Achovy	Total	Sardine	Achovy	Total
1987	1577	34686	36263	5706	51526	57232
1988	2953	44734	47687	10026	33909	43935
1989	2395	30736	33131	4090	24990	29080
1990	5262	5130	10392	9961	8686	18647
1991	2880	15993	18873	4657	10433	15090
1992	4166	32012	36178	6677	42180	48857
1993	3526	7767	11293	9205	14977	24182
1994	4861	21589	26450	5674	29424	35098
1995	2777	9498	12275	10616	20223	30839
1996	5981	4243	10224	23849	7530	31379
1997	9523	7945	17468	7041	3463	10504
1998	9678	3252	12930	19455	2927	22382
1999	9275	17000	26275	25922	36286	62208
2000	2264	12908	15172	6441	30003	36444
2001	4029	12023	16052	6465	51926	58391
2002	19829	17397	37226	21152	36436	57588
2003	24511	30581	55092	16583	31338	47921
2004	2388	17925	20313	2543	25800	28343
2005	385	11046	11431	1679	56067	57746
2006	2455	21442	23897	3685	40325	44010
2007	1977	35374	37351	3912	39741	43653
2008	808	48139	48947	1977	13338	15315
2009	1409	33100	34509	330	3359	3689

Table 6: Pelagic hydroacoustic survey estimates (in millions of tonnes). The November series comprises the aggregate adult biomass west of Cape Aguhlas. The May series comprises the total recruit biomass west of Cape Infanta.

	November spawner biomass			May recruit biomass		
Year	Sardine	Anchovy	Combined	Sardine	Anchovy	Combined
1984	0.048009	1.461636	1.509645			
1985	0.025457	1.014215	1.039672	0.038265	0.368623	0.406888
1986	0.238230	1.978652	2.216883	0.050073	0.621089	0.671162
1987	0.094165	1.866430	1.960595	0.098643	0.721578	0.820220
1988	0.128043	1.289624	1.417668	0.005223	0.563107	0.568329
1989	0.198328	0.517293	0.715622	0.066081	0.173349	0.239430
1990	0.248855	0.342812	0.591667	0.031208	0.170083	0.201291
1991	0.517180	1.254359	1.771539	0.026665	0.528177	0.554842
1992	0.247756	1.036580	1.284337	0.074822	0.458455	0.533278
1993	0.480822	0.439121	0.919942	0.114956	0.481108	0.596064
1994	0.389730	0.309981	0.699711	0.072462	0.145336	0.217797
1995	0.348832	0.468678	0.817510	0.205149	0.392016	0.597164
1996	0.257763	0.029748	0.287511	0.073612	0.074842	0.148453
1997	0.964835	0.377663	1.342498	0.396718	0.404620	0.801338
1998	1.082547	0.206586	1.289132	0.134907	0.453210	0.588116
1999	0.708029	0.741961	1.449990	0.235720	0.826090	1.061810
2000	0.726230	1.960122	2.686351	0.299473	2.553502	2.852975
2001	0.669617	2.301999	2.971617	0.573427	1.998427	2.571854
2002	1.184713	2.018570	3.203283	0.616331	1.560101	2.176432
2003	1.343118	1.181111	2.524229	0.600667	1.434900	2.035567
2004	0.292522	0.736973	1.029495	0.040419	1.071419	1.111838
2005	0.075604	0.670730	0.746334	0.011236	0.560518	0.571754
2006	0.177885	1.027009	1.204894	0.050394	0.275797	0.326191
2007	0.057666	0.889676	0.947342	0.034575	1.534523	1.569099
2008	0.211871	1.421593	1.633464	0.024461	1.491847	1.516308
2009	0.262853	2.098253	2.361106	0.063468	1.317059	1.380527
2010				0.499986	1.687118	2.187104

Table 7: Values of λ_i in GLM A (top) and values of γ and λ_i in GLM B with adult biomass (middle) and recruit biomass (bottom). Estimates significant at the 5% level are in bold, and estimates significant at the 15% level are in italics.

Estimate year effect directly		Sardine catch			Anchovy catch			Sardine and Anchovy catch		
		Estimate	s.e.	t pr.	Estimate	s.e.	t pr.	Estimate	s.e.	t pr.
Fledging success	λ_{Dassen}	0.254	0.25	0.417	*0.436*	*0.145*	*0.095*	0.361	0.181	0.184
	λ_{Robben}	0.221	0.277	0.509	1.142	0.586	0.191	0.335	0.505	0.575
Breeders per adult moulter	λ_{Dassen}	-0.16	0.115	0.198	0.076	0.154	0.633	-0.011	0.223	0.962
	λ_{Robben}	-0.006	0.0743	0.938	-0.051	0.152	0.745	0.002	0.147	0.992
Active and potential nests	λ_{Dassen}	*1.662*	*0.962*	*0.128*	-0.436	0.519	0.428	0.302	0.499	0.565
	λ_{Robben}	*1.006*	*0.559*	*0.115*	**1.698**	**0.491**	**0.011**	**1.299**	**0.452**	**0.024**
November adult biomass										
Fledging success	γ	-0.083	0.202	0.685	*-0.245*	*0.124*	*0.061*	*-0.1843*	*0.0954*	*0.068*
	λ_{Dassen}	0.145	0.213	0.504	-0.02	0.122	0.87	0.075	0.174	0.67
	λ_{Robben}	-0.0735	0.0783	0.359	0.11	0.119	0.364	0.066	0.151	0.667
Breeders per adult moulter	γ	0.025	0.147	0.868	0.0215	0.089	0.811	0.015	0.0748	0.843
	λ_{Dassen}	**-0.254**	**0.113**	**0.033**	*0.259*	*0.161*	*0.12*	0.143	0.251	0.573
	λ_{Robben}	0.0152	0.072	0.834	0.065	0.123	0.598	0.073	0.15	0.63
Active and potential nests	γ	0.267	0.556	0.637	0.164	0.414	0.698	0.189	0.269	0.492
	λ_{Dassen}	**0.68**	**0.31**	**0.044**	0.345	0.78	0.664	0.999	0.719	0.184
	λ_{Robben}	0.23	0.237	0.346	0.662	0.742	0.386	0.923	0.7	0.205
Adult survival	γ	*0.441*	*0.262*	*0.137*	**0.74**	**0.197**	**0.007**	**0.5**	**0.129**	**0.006**
	λ_{Dassen}	*0.366*	*0.184*	*0.087*	0.268	0.7	0.713	0.889	0.75	0.274
	λ_{Robben}	*0.287*	*0.156*	*0.108*	*-0.792*	*0.438*	*0.113*	-0.305	0.389	0.459
May recruit biomass										
Fledging success	γ	0.246	0.516	0.639	0.132	0.167	0.439	0.068	0.137	0.627
	λ_{Dassen}	0.117	0.198	0.561	0.012	0.13	0.927	0.073	0.189	0.704
	λ_{Robben}	-0.127	0.102	0.23	0.066	0.128	0.611	-0.036	0.163	0.827
Breeders per adult moulter	γ	-0.226	0.296	0.451	0.0696	0.0775	0.377	0.0459	0.0691	0.513
	λ_{Dassen}	**-0.229**	**0.111**	**0.05**	*0.234*	*0.155*	*0.144*	0.122	0.243	0.621
	λ_{Robben}	0.0541	0.0799	0.505	0.061	0.115	0.602	0.065	0.138	0.643
Active and potential nests	γ	1.18	1.19	0.336	**0.862**	**0.349**	**0.025**	**0.707**	**0.241**	**0.01**
	λ_{Dassen}	*0.565*	*0.328*	*0.105*	0.551	0.672	0.424	*1.014*	*0.582*	*0.101*
	λ_{Robben}	0.101	0.276	0.72	0.676	0.634	0.302	*0.881*	*0.567*	*0.14*
Adult survival	γ	3.39	2.81	0.267	0.38	0.44	0.417	0.385	0.328	0.279
	λ_{Dassen}	-0.53	0.833	0.545	-0.27	1.17	0.821	0.56	1.23	0.664
	λ_{Robben}	-0.42	0.683	0.558	-0.867	0.784	0.305	-0.11	0.696	0.879

Table 8: Tallies of positive and negative estimated GLM parameters.

a) Reproduction GLMs

	Sardine	Anchovy	Combined	Overall
All γ	4 : 2	5 : 1	5 : 1	14 : 4
All λ_i	12 : 6	15 : 3	16 : 2	43 : 11
λ_i significant at 15%	4 : 2	4 : 0	3 : 0	11 : 2
λ_i significant at 5%	1 : 2	1 : 0	1 : 0	3 : 2

b) Survival GLMs

	Sardine	Anchovy	Combined	Overall
All γ	2 : 0	2 : 0	2 : 0	6 : 0
All λ_i	2 : 2	1 : 3	2 : 2	5 : 7
λ_i significant at 15%	2 : 0	0 : 1	0 : 0	2 : 1
λ_i significant at 5%	0 : 0	0 : 0	0 : 0	0 : 0

c) All GLMs

	Sardine	Anchovy	Combined	Overall
All γ	6 : 2	7 : 1	7 : 1	20 : 4
All λ_i	14 : 8	16 : 6	18 : 4	48 : 18
λ_i significant at 15%	6 : 2	4 : 1	3 : 0	13 : 3
λ_i significant at 5%	1 : 2	1 : 0	1 : 0	3 : 2

Table 9: Point estimates and approximate 95% confidence intervals for the changes in penguin population growth attributable to stopping fishing, as estimated by various GLMs.

Estimate year effect directly		Sardine			Anchovy			Sardine and Anchovy		
		$\Delta\mu$	-95%	+95%	$\Delta\mu$	-95%	+95%	$\Delta\mu$	-95%	+95%
Fledging success	Dassen	-5.0%	-14.7%	4.7%	-7.9%	-13.8%	-2.0%	-6.8%	-14.0%	0.5%
	Robben	-6.6%	-26.4%	13.2%	-22.7%	-59.0%	13.7%	-9.5%	-42.0%	23.0%
Breeders per moulter	Dassen	3.9%	-0.9%	8.6%	-1.6%	-7.9%	4.6%	0.2%	-8.5%	9.0%
	Robben	0.2%	-5.7%	6.1%	1.7%	-9.8%	13.3%	-0.1%	-11.3%	11.1%

November adult biomass		Sardine			Anchovy			Sardine and Anchovy		
		$\Delta\mu$	-95%	+95%	$\Delta\mu$	-95%	+95%	$\Delta\mu$	-95%	+95%
Fledging success	Dassen	-3.0%	-11.4%	5.4%	0.5%	-4.6%	5.5%	-1.6%	-8.6%	5.4%
	Robben	2.5%	-3.6%	8.7%	-3.5%	-12.7%	5.7%	-2.1%	-13.6%	9.4%
Breeders per moulter	Dassen	6.5%	1.8%	11.1%	-5.1%	-11.6%	1.4%	-3.0%	-12.7%	6.7%
	Robben	-0.5%	-6.2%	5.2%	-2.1%	-11.6%	7.4%	-2.3%	-13.8%	9.1%
Adult survival	Dassen	-8.7%	-18.1%	0.7%	-6.7%	-34.9%	21.4%	-16.8%	-46.3%	12.7%
	Robben	-6.3%	-13.5%	0.8%	30.5%	13.0%	48.1%	9.0%	-6.9%	25.0%

May recruit biomass		Sardine			Anchovy			Sardine and Anchovy		
		$\Delta\mu$	-95%	+95%	$\Delta\mu$	-95%	+95%	$\Delta\mu$	-95%	+95%
Fledging success	Dassen	-2.5%	-10.3%	5.4%	-0.3%	-5.6%	5.1%	-1.6%	-9.1%	6.0%
	Robben	4.5%	-3.4%	12.5%	-2.1%	-12.0%	7.7%	1.2%	-11.1%	13.6%
Breeders per moulter	Dassen	5.7%	1.1%	10.3%	-4.7%	-10.9%	1.6%	-2.6%	-12.0%	6.9%
	Robben	-1.8%	-8.0%	4.5%	-2.0%	-10.9%	6.9%	-2.1%	-12.7%	8.5%
Adult survival	Dassen	19.9%	-11.7%	51.6%	8.8%	-29.7%	47.4%	-12.2%	-51.8%	27.3%
	Robben	13.2%	-11.3%	37.7%	34.9%	7.9%	61.8%	2.9%	-21.9%	27.8%

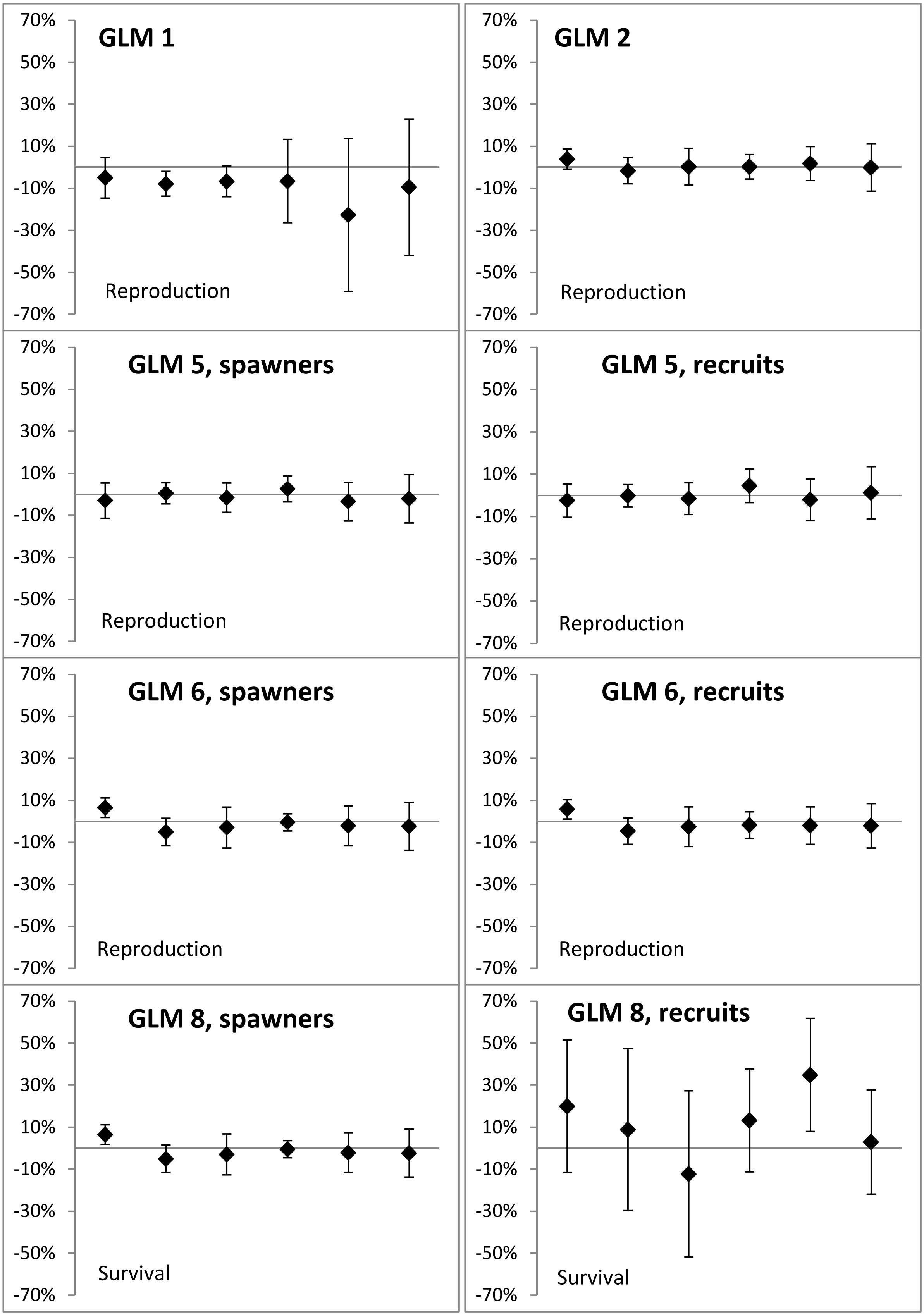

Figure 1: Plots of growth rate change projected for suspending fishing, with 95% confidence intervals, corresponding to the horizontal blocks in Table 9. In each case the points are, from left to right, Dassen Island (sardine, anchovy, combined) then Robben Island (sardine, anchovy, combined).

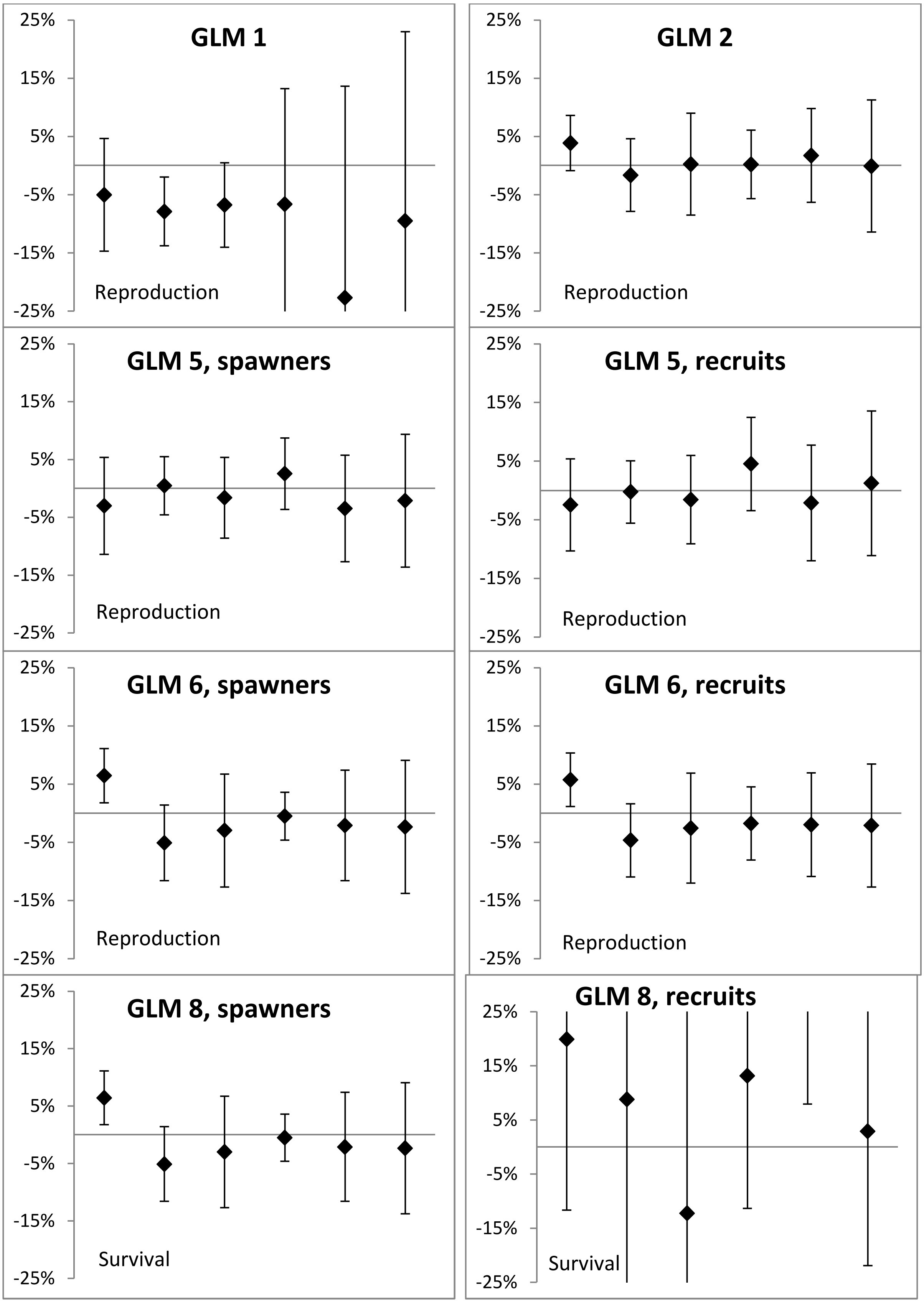

Figure 2: A repeat of the plots in Fig. 1, but at a larger scale.