Supporting Information. Sex-biased survival contributes to population decline in a long-lived seabird, the Magellanic penguin. N. J. Gownaris and P. D. Boersma. *Ecological Applications.* 2018.

Appendix S2: Supplementary Tables

Table S1: Phase 1 Candidate Model Δ_{QAIC} as Compared to the Best-Supported Magellanic Penguin Mark-Recapture Model (QAIC = 41,574; Aikake weight ~ 1.0)

	p_{bst}	p_{bt}	p_{bs}	p_{b}
Φ_{sat}	**0**	452	976	931
Φ_{sa}	1351	1542	2516	2494
Φ_{at}	52	403	739	1177
Φ_{st}	1350	2958	3723	4020
Φ_{s}	3364	3807	4862	5390
Φ_{a}	1418	2045	2616	2825
Φ_{t}	2763	3417	3869	4409

	Φ (survival)	p (recapture)
sex	s	s
time	t	t
age (factor)	a	-
breeding status	-	b

For this population, the best-supported mark-recapture model from Phase 1 of model selection was the most general model tested. This model accounted for additive effects of sex, age, and time in survival and of breeding status, sex, and time in recapture and had 110 parameters (QAIC = 41,574; Aikake weight ~ 1.0). In all cases, models that accounted for sex had greater support than those that did not.

Table S2: Phase Two (Top Table) and Phase Three (Bottom Table) Magellanic Penguin Mark-Recapture Candidate Models

Phase 2	1-18 yrs	≥19 yrs	QAIC	k	$\Delta QAIC_{-s}$
General Model					
s +	t + a	t + a	41,574	110	52
Age Class Models					
s +	t + a	.	41,446	125	64
	t + a	t	41,443	137	62
	t + a	A	41,425	126	64
s +	t	.	41,495	108	65
	t	t	41,490	118	64
	t	A	41,482	107	56
s +	.	.	41,514	79	180
	.	t	41,512	90	69
	.	A	41,491	78	93

Phase 3	BS	1-18 yrs	≥19 yrs	QAIC	k	$\Delta QAIC_{-s}$
s +	BS1 +	t + a	A	41,416	127	64
	BS2 +	t + a	A	41,414*	127	64
	BS3 +	t + a	A	41,416	128	64

s - sex
t - time
a - age (factor)
A - age (linear)

BS1 – Breeders vs. Pre-Breeders and Non-Breeders
BS2 – Pre-Breeders vs. Breeders and Non-Breeders
BS3 – Pre-Breeders vs. Breeders vs. Non-Breeders
. - no additional variable

k - number of parameters
* - best supported model
$\Delta QAIC_{-s}$ - difference in AIC when sex is excluded

All models included sex as an additive variable and removing sex always led to an increase in QAIC of >50 ($\Delta QAIC_{-s}$). The best supported model resulting from Phase 2 of the model selection procedure (top table) allowed for survival of juveniles (not shown) to vary with time, of middle-aged adults (1-18 yrs old) to vary with time and age, and of elder adults (≥ 19 yrs old) to decrease linearly as a function of age. This model was used as the starting point for Phase 3 of model selection, which resulted in the most parsimonious model and showed that the survival of pre-breeders differed from that of breeders and non-breeders.

Table S3: Survival and Fecundity Parameters Used in the Time-Variant and Time-Invariant Matrices

Parameters	Description	Average Survival (±SD across ages/years)	Average Survival 1990-2009 (±SD across ages/years)
$\Phi_{♀J}$	Survival Female Juveniles (Age 0)	0.12 (±0.10)[B]	0.16 (±0.11)[C]
$\Phi_{♂J}$	Survival Male Juveniles (Age 0)	0.17 (±0.14)[B]	0.19 (±0.14)[C]
$\Phi_{♀P}$	Survival Female Prebreeders (Age 1-5)[A]	0.92 (±0.11)[B]	0.94 (±0.04)[C]
$\Phi_{♂P}$	Survival Male Prebreeders (Age 1-6)[A]	0.95 (±0.10)[B]	0.91 (±0.06)[C]
$\Phi_{♀BA}$	Survival Female Breeders (Age 6-18)	0.88 (±0.07)[B]	0.87 (±0.07)[C]
$\Phi_{♂BA}$	Survival Male Breeders (Age 7-18)	0.92 (±0.05)[B]	0.92 (±0.05)[C]
$\Phi_{♀BE}$	Survival Female Breeders (Age ≥19)	0.70 (±0.16)[B]	0.80 (±0)[C]
$\Phi_{♂BE}$	Survival Male Breeders (Age ≥19)	0.78 (±0.14)[B]	0.92 (±0)[C]
HSR	Hatching Sex Ratio	0.50[D]	0.50[D]
Φ_{C}	Reproductive Success	0.50 ± 0.26[E]	0.55±0.27[F]

[A] 50% of females breed by age six and 50% of males breed by age seven (Boersma et al., 2013)
[B] Year- and age-averaged values for 1983-2014 as estimated from the mark-recapture model in this study
[C] Year-specific, age-averaged values for 1990-2009 as estimated from the mark-recapture model in this study
[D] Based on the proportion of males: Koehn et al., 2016; Ciancio et al., 2017
[E] Based on two egg clutch: Boersma, unpublished data
[F] Based on two egg clutch: Rebstock & Boersma 2017

Table S4: Predicted Magellanic Penguin Population Change 1990-2009 Based on a Juvenile Survival Fitness Landscape Analysis

→ Increase Male Survival	0.0	0.1	0.2	0.3	0.4	0.5
↓ Increase Female Survival	*No. Females; Sex-Specific Survival*					
0	-85%	-85%	-85%	-85%	-85%	-85%
0.1	-73%	-73%	-73%	-73%	-73%	-73%
0.2	-62%	-59%	-59%	-59%	-59%	-59%
0.3	-52%	-46%	-43%	-43%	-43%	-43%
0.4	-42%	-35%	-27%	-24%	-24%	-24%
0.5	-33%	-23%	-14%	-6%	-4%	-4%
↓ Increase Female Survival	*No. Females; Sex-Averaged Survival*					
0	-78%	-77%	-77%	-77%	-77%	-77%
0.1	-66%	-62%	-60%	-60%	-60%	-60%
0.2	-55%	-49%	-44%	-41%	-41%	-41%
0.3	-43%	-37%	-30%	-23%	-19%	-19%
0.4	-32%	-24%	-16%	-8%	0%	6%
0.5	-20%	-11%	-2%	7%	16%	25%

→ Increase Male Survival	0.0	0.1	0.2	0.3	0.4	0.5
↓ Increase Female Survival	*No. Males; Sex-Specific Survival*					
0	-73%	-59%	-45%	-32%	-18%	-4%
0.1	-70%	-55%	-40%	-24%	-9%	6%
0.2	-69%	-50%	-34%	-17%	0%	16%
0.3	-69%	-49%	-29%	-11%	7%	25%
0.4	-69%	-49%	-26%	-5%	14%	33%
0.5	-69%	-49%	-26%	-1%	21%	42%
↓ Increase Female Survival	*No. Males Sex-Averaged Survival*					
0	-79%	-66%	-54%	-42%	-31%	-19%
0.1	-79%	-64%	-50%	-36%	-23%	-10%
0.2	-79%	-64%	-47%	-31%	-16%	-2%
0.3	-79%	-64%	-47%	-28%	-9%	7%
0.4	-79%	-64%	-47%	-28%	-7%	14%
0.5	-79%	-64%	-47%	-28%	-7%	16%

Baseline apparent survival estimates used to develop the population matrix models for the analysis were either sex-specific (top half of table) or sex-averaged (bottom half of table). Annual surveys may underestimate population decline if nests with a single male present are counted as active nests. Therefore, rates of change for the male population (breeders and non-breeders; right half of table) are shown for comparison to rates of change for the effective population, which is constrained by the number of females (left half of the table).