Indirect Effects of Invasive Species Removal Lead to Landscape-Scale Changes in an Island Ecosystem

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Supporting Information

Supporting Methods (extended methods description)

STUDY SITE AND HISTORY

Macquarie Island (54°30'S, 158°57'E) is one of the islands found in the sub-Antarctic region of the Southern Ocean (Bergstrom & Chown 1999). It was declared a World Heritage site in 1997 due to its unique geology and regional conservation significance (Parks and Wildlife Service 2006). The island is 34 km long, and narrow, with steep coastal slopes rising to an undulating plateau generally between 200 and 400 m a.s.l. The climate is cool and maritime (Pendlebury & Barnes-Keoghan 2007), and the vegetation is tundra-like, featuring tussock grasses, regional endemic megaherbs and bryophytes (Selkirk, Seppelt & Selkirk 1990). Because the island is oceanic in origin all indigenous biota has arrived via long distance dispersal or evolved in situ (Bergstrom et al. 1997).

Rabbits were introduced to the island in 1878 by sealing gangs (Cumpston 1968; Flux & Fullagar 1992; Copson & Whinam 2001) and initially reached very high numbers. They soon became the main prey of cats (Jones 1977), which had been introduced 60 years previously in 1820 (Flux & Fullagar 1992). Hyperpredation probably resulted in the extinction of two flightless bird species (an endemic Parakeet and endemic Rail, Taylor 1979). Extensive grazing by rabbits was documented at least by the early 1950s (Taylor 1955) and by 1960 the effects had been described as catastrophic, with a prediction that the, '…grassland vegetation on Macquarie Island is doomed to destruction' (Costin & Moore 1960). The management of rabbits commenced in 1968 with the introduction of the European rabbit flea (vector of the *Myxoma* virus), but it took 10 years for the flea to become widespread. The rabbit population peaked at c. 150 000 in 1978 (Copson & Whinam 2001), the year when *Myxoma* virus was finally introduced. Unfavourable environmental conditions required annual releases of the virus (Brothers & Copson 1988), but eventually rabbit numbers dropped to less than 20 000. *Myxoma* virus spreading ceased in October 2006, due to technical reasons. Vegetation on the island had recovered substantially 8-10 years after virus release (Copson & Whinam 1998), and management reviews predicted the return of several highly palatable plants given the reduction in rabbit population density (Copson & Whinam 2001).

By the mid 1980s however, it had become clear that prey switching by cats, given decreases in rabbit availability, was detrimentally affecting seabird populations (Copson & Whinam 2001). A cat eradication programme commenced in 1985 and was expanded in 1998. Between 1985 and 1995 approximately 124 cats were killed per year and it was estimated that the recruitment rate matched the kill rate (Copson 2002). Eradication rate increased to approximately 220 cats for each of the following three years, dropping to 99 cat kills in 1999, and a single cat (the last cat) shot in 2000. Rabbit numbers then increased rapidly, and in little more than five years, they have substantially altered large areas of the island (Scott & Kirkpatrick 2008), making its future conservation significance questionable in the absence of further action (Miller 2007).

CAT PREDATION AND RABBIT POPULATION ESTIMATES

Estimates of the consumption by cats of rabbits, rats and mice were made for 1997 based on estimated cat daily food intake and the proportion of food items reported for the gut content of 49 cats examined of the 157 shot in that year (consumption data reported in Copson & Whinam 2001), using the methods of Jones (1977). Weights for both rabbit kittens and adult rabbits were used in the calculations as the presence of *Myxoma* virus on the island resulted in the potential greater availability of sick adult rabbits for prey. Specifically, annual consumption by adult cats was estimated as the number of prey items needed (given their mean body mass: rabbits c. 400 – 1300 g, rats *Rattus rattus* – 140 g, mice *Mus musculus* – 20 g) per cat-day x the proportion of the item in the diet of the cats that had been shot x 365.

Estimates of annual rabbit count data were supplied by the Parks and Wildlife Service, Tasmania (PWS). Initial estimates began in 1974 with the establishment of 18 rabbit count areas (RCA) of 2 ha each across a range of vegetation types on the island. Eight RCAs became long-term monitoring sites, which were counted monthly by ranagers. As rabbits had moved onto coastal slopes, a further seven new sites were established between 2002 and 2004. A single population estimate for each year from was made available by PWS for the period 1974 to 2003.

For 2004 to 2006, PWS supplied three estimates for each year, based on a different model used to estimate rabbit abundance. In their first model (PWS Model 1), PWS calculated mean rabbit densities for each vegetation type and then combined this with planimetric estimates of areas of each vegetation type to calculate total rabbit population for the island. They then used the peak estimates of 1978 of the original eight sites as base line information and estimated the population as: Island population Y = Population 1978 x (Mean of annual counts year Y/Mean annual count for 1978). In their second model (PWS Model 2), PWS used the previous equation but included the new rabbit count areas in their estimates of mean annual counts. PWS Model 3 was based on the mean annual count, calculated from monthly counts for each of 15 RCAs. In this model, the counts were extrapolated to the rest of the island based on surface area measurements of similar vegetation types with the aid of a 5 m Digital Elevation Model (DEM) and a map of vegetation communities. Error estimates in Model 3 illustrate a range of best case and worst cast scenarios based on the lowest and highest rabbit counts for each vegetation type for 2005 and 2006 only.

RABBIT POPULATION CHANGE

Based on previous investigations it is clear that rabbit abundance was reduced following the introduction of the *Myxoma* virus. Moreover, variation in climate among years may have also affected abundance, and our primary hypothesis is that the eradication of cats led to an increase in rabbit abundance. To investigate the influence of *Myxoma* virus introduction and inter-annual climate variation on rabbit abundance we adopted the following approach. Monthly total precipitation and daily maximum and minimum surface air temperature data from the Macquarie Island meteorological station (station 300004) were obtained from the Australian Bureau of Meteorology. Microsoft Access database queries were used to calculate total precipitation and mean air temperatures for each season (spring, summer, autumn, winter) for each year between 1974 and 2006. Daily mean surface air temperature was calculated from daily maxima and minima rather than from 3-hourly surface air temperature observations because of missing data and variability in the sampling frequency of the 3-hourly data.

A generalized linear model (assuming a normal distribution and using an identity link function) was then constructed using the $\log_{10}$ rabbit abundance data from PWS Model 1 (and in another model from PWS Model 3) as the dependent variable, and presence/absence of *Myxoma* virus as a categorical independent variable and the seasonal temperature and precipitation data as continuous independent variables. PWS Models 1 and 3 were used as they represent the lower and upper range of abundance estimates. The Akaike Information Criterion (AIC) and Akaike weights (see Johnson & Omland 2004) were used to select the best fit model from the suite of models available. Years with missing rabbit abundance data were excluded from the analysis (1977, 1981-83). Following these analyses, the years prior to the introduction of *Myxoma* virus (1974-1977) were excluded from the analyses. The models were then applied to $\log_{10}$ rabbit abundance data, with cat presence or absence as a categorical variable and the major climatic variables identified as important in the previous models (autumn, spring and summer precipitation and autumn temperature) as the continuous variables.

VEGETATION CHANGE

Between November 2000 and March 2001 (hereafter 2001), 45, long-term ecological research sites were established to investigate long-term vegetation change and its likely causes. Sites were stratified and chosen to represent the range of vegetation types on the island, following Taylor (1955) and Selkirk, Seppelt & Selkirk (1990). Plots (5 m x 5m) were positioned within areas with the highest visual homogeneity of the vegetation. In April 2007, 18 of these sites, close to the research station were revisited during the brief, annual resupply voyage to examine their status (limited time precluded sampling of additional plots). The sites were chosen to represent a range of vegetation types and the choice was made in advance of visits to the sites (i.e. prior knowledge of the likelihood of rabbit impact played no role in site selection).

In each of the 18 plots, both in 2001 and 2007, individual plant species cover as percentage was visually calculated within five, randomly selected, 1 m^2 quadrats and mean values determined. The precision of area measurement was 1% cover, using a 10 x 10 cm template in the field to define such an area. The data matrix consisted of 18 sites, 34 taxa and temporally separated sampling intervals: 2001 and 2007. Species also included collective categories for leafy bryophytes, lichens, bare ground and dead vegetation. At each site, altitude, substrate depth, slope, aspect, a subjective estimate of the wind exposure and the degree of waterlogging were also recorded.

PATN, a software package for identifying and displaying patterns in multivariate data (Belbin 1993), was used to discover and explore the patterns in the dataset. Examination of the cover values suggested that a cubed root transformation was needed to reduce the influence of species with high cover values. A Bray-Curtis (Bray & Curtis 1957) association matrix was generated between all pairs of the 18 sites. This matrix was then used for hierarchical classification (flexible UPGMA, beta = -0.1) to produce a set of vegetation groups. The matrix was also used for ordination using semi-strong hybrid multidimensional scaling (Belbin 1991). Ordination attempts to display the sites in a few dimensions (usually 3) with little loss of information. The classification and ordination were repeated by iteratively removing those species that contributed least to group discrimination. The structure of the 18 sites in the classification dendrogram and their distribution in the 3-dimensional ordination plot were both used to select eight vegetation groups. These groups summarized the variations between the sites.

Analysis of similarity (ANOSIM) was used to test for significance difference between the a priori groups defined by sample time (2001 and 2007). ANOSIM (Clark & Green 1988) is a multivariate statistical technique used for testing the discrimination between a set of groups of objects. ANOSIM is similar to ANOVA but uses pair-wise association values between objects within and between groups. The difference between the mean ranks of between and within pair-wise association is calculated as a reference. This statistic is therefore similar to an F-ratio. All objects are then randomly re-allocated between groups and the statistic recalculated. This randomization procedure produces a distribution against which the realized statistic is tested.

ANOSIM was also run on the dataset without three sites that showed no loss or gain of species between 2001 and 2007. The probability that the 2001 and 2007 time groups for the complete dataset could have been formed at random was 12%. This declined to <0.01% with removal of the three sites that had not changed (two fellfield sites and a *Stilbocarpa polaris* (Hombr. et Jacquinot ex Hook. F. A. Gray) monospecific herbfield). Additional information of species richness and turnover between 2001 and 2007 was calculated for each site and evidence of rabbit activity in 2007 recorded (See Table S1 below).

USE OF REMOTE SENSING IMAGERY

Information on changes in vegetation communities was examined at a whole-island level using satellite imagery. Good quality, cloud-free imagery of the island is limited due to its remote location in an area that is commonly covered by cloud. We used Landsat ETM+ imagery acquired on 12 December 2000 and Quickbird imagery acquired on 15 March 2007 to detect changes in vegetation cover on Macquarie Island. These images were the only cloud-free satellite images available for the Island at a sufficiently large time interval for change detection. Due to improvement in technology, the Quickbird image had a greater resolution than the Landsat image. In consequence, the pixel values in the Quickbird image were scaled from 11-bit to 8-bit to match the radiometric resolution of the Landsat image. The blue (450 – 520 nm), green (520 – 600 nm), red (630 – 690 nm), and near-infrared (760 - 900 nm) bands of the Landsat image were extracted to match the spectral resolution of the Quickbird image. The Quickbird image with its 2.4 m pixel size was resampled (by pixel averaging) to the 25 m Landsat pixel size to compare the images at the same resolution. The images were orthorectified to correct terrain and geometric distortions. Radiometric, illumination, and atmospheric differences were also corrected. These corrections are crucial for change detection algorithms as false changes are often introduced by geometric offsets and shadowing effects (Coppin, Bauer & Marvin 2004).

Two methods of change detection were used. Change Vector Analysis (CVA) (Lambin & Strahler 1994) quantifies the difference in pixel intensity (spectral reflectance) of all multispectral bands between two images. The change image in this study (Fig. 1) shows the magnitude (amount) of change for each pixel. This change value is based on the length of the change vector, representing the movement of a pixel in a multidimensional space of image bands between two images taken at different time periods. The change magnitude values range between 0 – 100%, where a value of 100% indicates a spectral change from complete absorption to complete reflection (or the opposite) in all image bands. The change magnitude values were classified into five classes. The threshold for the no-change class was set at 17%, which included the change magnitude values that were observed in geo-referenced field sites for gravel (no change), water (no change), and vegetation which was known to show seasonal change. This approach ensured that the changes depicted by the change classes highlighted significant changes in vegetation as opposed to sensor differences or seasonal spectral variation. Sensor differences and seasonal effects were not responsible for the major differences between the two images. Geo-referenced sites such as lakes and barren areas, and sites dominated by vegetation exhibiting seasonal colour signals have substantially smaller pixel intensity changes between sample years than plot sites impacted by rabbits (Change Vector Analysis using stratified random sampling of 231 pixels within field sample sites, and a non-parametric Wilcoxon signed-rank test, $S = 11175.5$, $Z = 10.34$, $P < 0.0001$).

The second change detection method used the direction of change to determine locations of vegetation loss. The direction of change was quantified by differencing the Normalized Difference Vegetation Index (NDVI) for both images (Lyon et al. 1998).

The NDVI images highlight vegetation density by applying a normalized difference ratio of the highest absorption and reflectance wavelengths of chlorophyll (red and NIR respectively). Subtraction of the 2000 NDVI image from the 2007 NDVI image resulted in negative and positive change values for each image pixel. Positive change is generally an indication of increased levels of chlorophyll in a pixel and negative change is a decrease, most often associated with dead vegetation or bare ground (see Fig. S1-2).

Quantification of change in pixel intensity in CVA and chlorophyll loss and gain for NDVI were calculated and expressed as percentages of total pixels for each of the change categories. The locations of the chlorophyll gain areas however, on the NDVI difference image revealed that strong chlorophyll gain was observed in the shadow areas on the west coast of the island, thus a component of the positive NDVI difference values was an artefact of the difference in illumination angle and shadows at the time of satellite image acquisitions. Accordingly, we present only chlorophyll loss data.

Change in vegetation, detected using the above methods could be a consequence not only of rabbit influences, but also changing climates that are typical of the island (Pendlebury & Barnes-Keoghan 2007) and the region as a whole (Bergstrom & Chown 1999). To determine whether annual and seasonal (as above) temperature and precipitation have changed over the period since cats have been eradicated (2000-2006), linear regressions were used to examine the relationship between year and annual mean temperature and precipitation, and year and each of the seasonal temperature and precipitation parameters (see Table S4).

ADDITIONAL REFERENCES

Bergstrom, D.M., Selkirk P.M., Keenan H.M. & Wilson, M.E. (1997) Reproductive behaviour of ten flowering plant species on subantarctic Macquarie Island. Opera Botanica 30, 1-12.

Johnson, J. B. & Omland, K. S. (2004) Model selection in ecology and evolution. Trends in Ecology and Evolution 19, 101-108.

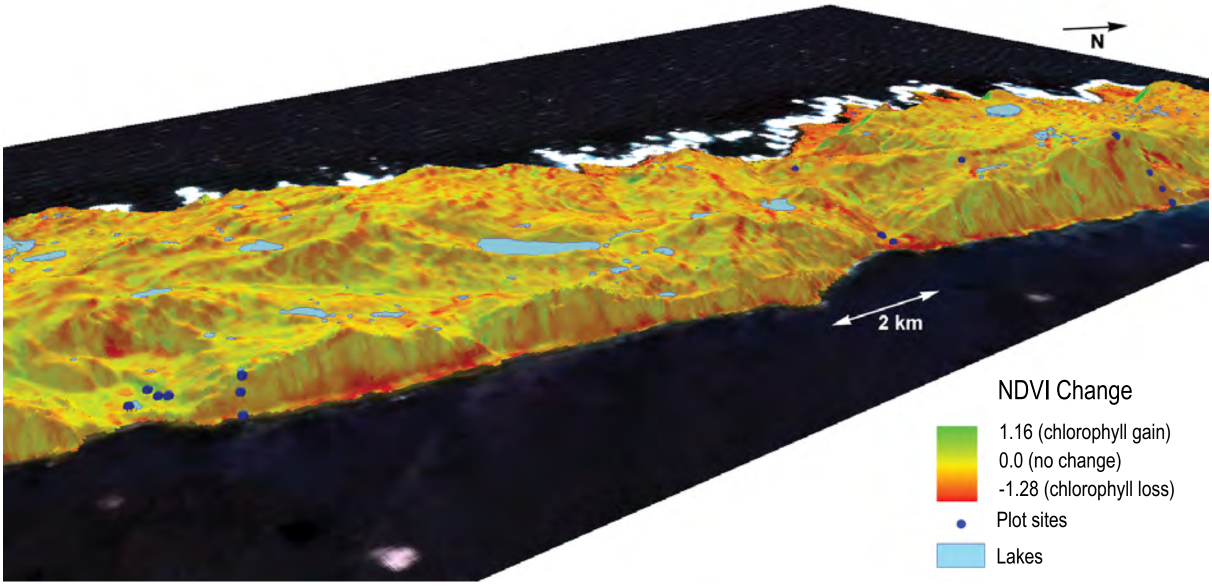


Figure S1. Normalized Difference Vegetation Index (NDVI) difference image for approximately two thirds of Macquarie Island based on pixel comparisons between 2000 and 2007. The image is draped over the digital elevation model. The image shows substantial loss of chlorophyll and hence vegetation on both coastal and valley slopes. In other ecosystems an increase on chlorophyll could be interpreted as an improvement. Most areas of NDVI increase are also areas of impact but at a later stage in grazing succession reflecting regime shift from the previous vegetation to grazing lawns.

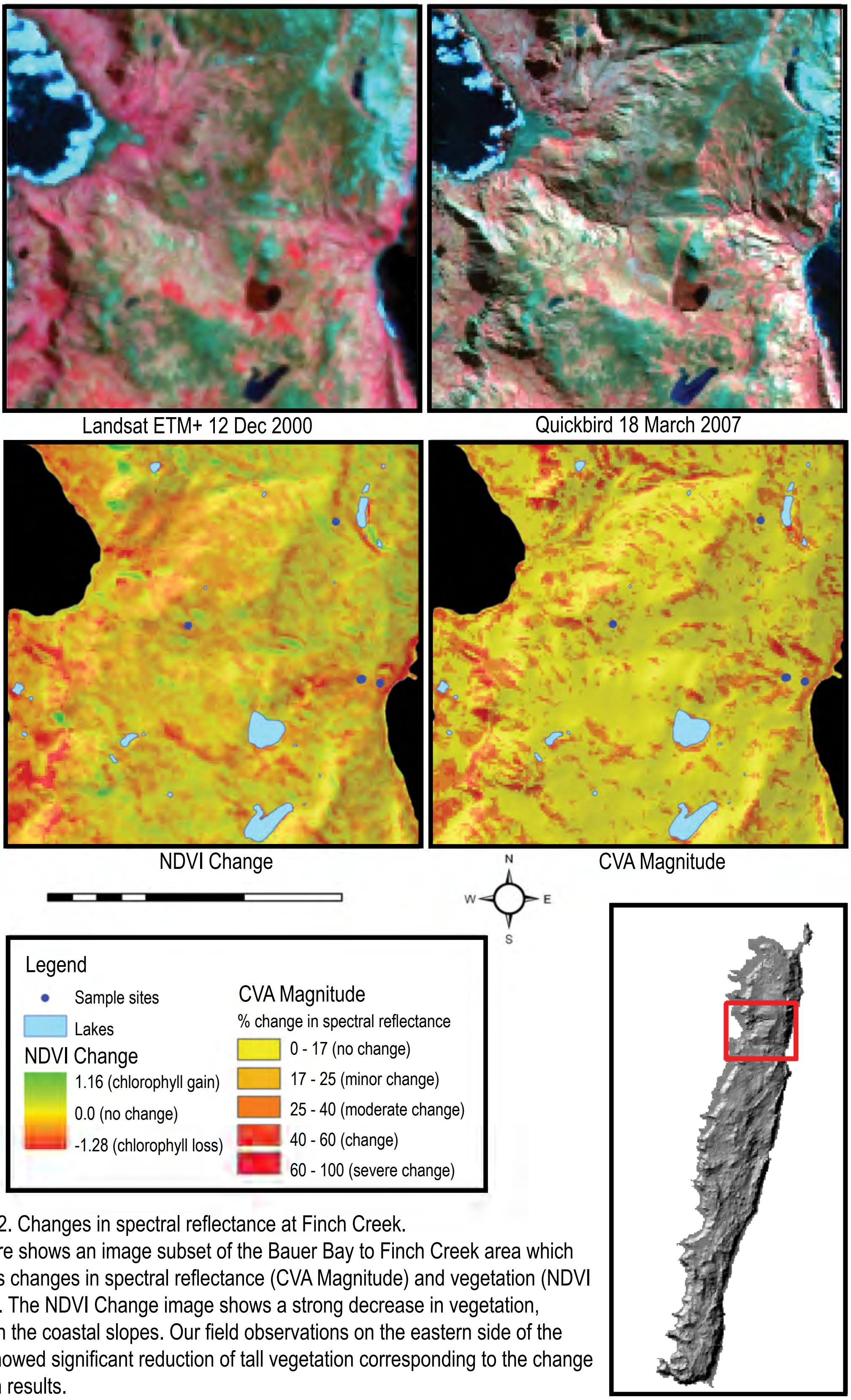
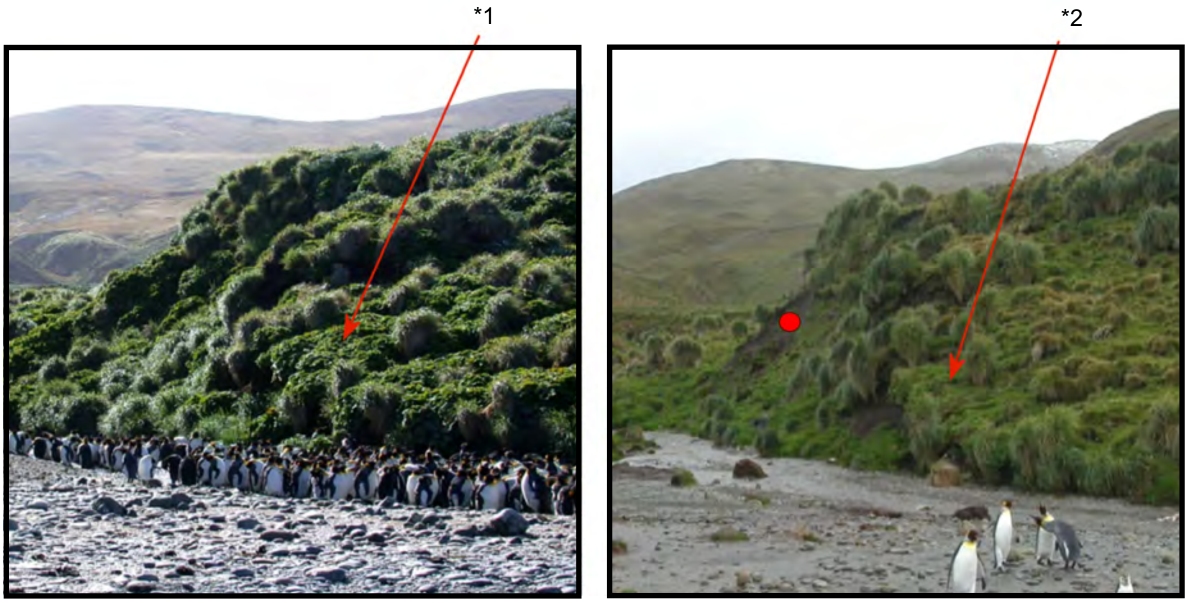


Figure S2. Changes in spectral reflectance at Finch Creek.
This figure shows an image subset of the Bauer Bay to Finch Creek area which highlights changes in spectral reflectance (CVA Magnitude) and vegetation (NDVI Change). The NDVI Change image shows a strong decrease in vegetation, mainly on the coastal slopes. Our field observations on the eastern side of the image showed significant reduction of tall vegetation corresponding to the change detection results.



a. Finch Creek 2001

b. Finch Creek 2007

c. Finch Creek 2007

e. Finch Creek 2001

f. Finch Creek 2007

Figure S3. Comparative images (2001-2007) for Finch Creek outlet and coastal area. In the paired images (a) 2001 and (b) 2007 it can be seen that in 2007 there had been a loss of the megaherb *Stilbocarpa polaris* *1 and reduction in extent of the tussock grass *Poa foliosa*. *Stilbocarpa polaris* has been replaced predominantly with the alien grass *Poa annua* *2. The 2007 panorama image (c) is taken from a different perspective and highlights the regime shift to short grasslands, Dominated by *P. annua.* The red spot marks the same location in both b and c. Erosion is evident in the 2007 images. The star in c. marks the same location in d. and e. This area (d) beside Finch Creek is a pathway between a Royal Penguin *Eudyptes schlegeli* colony and the sea. The vegetation used to form a canopy across much of the pathway. The loss of plant species such as *S. polaris* has left the pathway without cover (e) and the penguins exposed to predators.

a. MI049 Green Gorge 2001

b. MI049 Green Gorge 2007

Figure S4. This steep coastal slope (Site MI049) was covered in *Poa foliosa* tall tussock in the summer of 2001/02 (a). By 2007 (b), rabbit grazing had resulted in the loss of this vegetation and increased slope instability. The colonizing vegetation consists of a thin carpet of herbaceous species.

Vegetation group	Site description	Site code	Rabbit +/- 2007	Taxa or feature with % cover change	% cover change	# taxa gained	# taxa lost	# taxa with cover gain	# taxa with cover loss
Short herbfield	Gadget mixed herbfield (2001 + 2007)	MI002	+ g	*Acaena magellanica*	21	4	3	10	7
				bryophytes	-52				
	Green Gorge Pleurophyllum herbfield (2001 + 2007)	MI041	+ g,f	bryophytes	-20	2	0	8	5
				Coprosma perpusilla	-12				
				Luzula crinita	-18				
	Mt Elder - 365m (2001 + 2007)	MI003	+ b	bryophytes	-37	1	0	8	3
	Mt Elder 200m (2001 + 2007)	MI004	+ f	bryophytes	-20	1	0	4	6
	Mt Elder 10 m short (2001 + 2007)	MI053	+ g,f	*Agrostis magellanica*	-25	3	0	6	4
	Green Gorge Luzula grassland (2001 + 2007)	MI043	-	bryophytes	-54	2	0	6	4
				Juncus scheuchzerioides	22				
				Luzula crinita	-18.				
Fellfield	Mt Power east fellfield (2001 + 2007)	MI006	-	—	0	0	0	6	6
	Mt Elder West 385 (2001 + 2007)	MI051	-	bryophytes*	-22	0	0	3	5
				bare ground*	25				
Blechnum fernbrake	Blechnum/ Uncinia fernbrake Finch Creek (2001 + 2007)	MI010	+ b,g	*Acaena magellanica*	18	2	0	6	6
				Acaena minor	-15				
				Blechnum penna-marina	19				
				Uncinia divaricata	-29				
	Green Gorge Blechnum (2001 + 2007)		+ b,g,f	*Blechnum penna-marina*	-53	1	0	6	6
				bryophytes	-30				
coastal vegetation	Mt Elder 100m mixed coastal (2001 + 2007)	MI054	+ g	*Stilbocarpa polaris*	-23	1	1	9	5
grazed vegetation coastal (01) to severely grazed (07)	Finch Creek mixed coastal (2001)	MI009	+ g,f	*Agrostis magellanica*	28	7	0	14	6
				bryophytes	-39				
				Epilobium pedunculare	43				
				Stilbocarpa polaris	-45				
coastal (01) to severely grazed (07)	Green Gorge 10 m tussock (2001)	MI048	+ b	*Luzula crinita*	37	4	0	13	5
				Poa foliosa	-64				
coastal (01) to severely grazed (07)	Green Gorge 100 m tussock (2001)	MI049	+ g	bryophytes	41	6	0	14	5
				Epilobium pedunculare	18				
				Poa foliosa	-83				
fernbrake (01) to severely grazed (07)	Polystichum fernbrake Finch Creek (2007)	MI040	+ g,b	*Epilobium pedunculare*	81	7	1	10	3
				Polystichum vestitum	-85				
fernbrake (01) to severely grazed (07)	Polystichum fernbrake Green Gorge (2007)	MI047	+ g,b,f	*Epilobium pedunculare*	30	2	0	14	1
				Polystichum vestitum	100				
				bare ground	21				
Stilbocarpa monostand	Stilbocarpa herbfield, Mt Elder 10m (2001 + 2007)	MI005	+ f,g	—	0	0	0	2	2
Pleurophyllum monostand	4-ways Pluerophyllum monostand (2001 + 2007)	MI008	+ g	*Pleurophyllum hookeri*	-31	11	0	12	1

g = grazing. b = burrowing, f = faeces, * = change artefact of random sampling across patterned ground

Table S1. Major vegetation changes at each of the 18 field sites (% cover change, number of taxa gained or lost, number of taxa with cover gain or lost). Colour coding is used to highlight the vegetation groups identified in the classification process and matches that in Fig. 2.

CVA Magnitude Change Class	% Area of the Island	% Area of the Coastal Slopes
No change (0 – 17%)	63.6%	50.1%
Minor change (17 – 25%)	18.9%	18.0%
Moderate change (25 – 40%)	13.2%	17.0%
Change (40 – 60%)	3.2%	8.2%
Severe change (60 – 100%)	1.1%	6.7%

Table S2. Percentage area of the island and of coastal slopes for each of the CVA magnitude change classes.

NDVI change class	% Area of Island	% Area of the Coastal Slopes
Major chlorophyll loss (-1.28 – -0.25)	6.5%	9.1%
Chlorophyll loss (-0.25 – -0.1)	15.9%	16.1%
No change (-0.1– 0.1)	59.2%	43.6%

Table S3. Percentage area of the island and for coastal slopes for each of the NDVI change classes.

Linear regression	Timespan	n	df	R-squared	p-value	Direction	Magnitude
Total Annual Precipitation (mm) ~ Time	1949-2006	58	56	0.2034	0.000381*	Increase	3.30 mm/year
Total Summer Precipitation (mm) ~ Time	1949-2007	59	57	0.006067	0.558	-	
Total Autumn Precipitation (mm) ~ Time	1949-2006	58	56	0.135	0.0042*	Increase	1.10 mm/year
Total Winter Precipitation (mm) ~ Time	1948-2006	59	57	0.1791	0.0008396*	Increase	1.36 mm/year
Total Spring Precipitation (mm) ~ Time	1948-2006	59	57	0.05374	0.0773	-	
Annual Mean Air Temperature (deg C) ~ Time	1951-2006	56	54	0.1273	0.006954*	Increase	0.0083 deg C/year
Annual Mean Maximum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.1423	0.00416*	Increase	0.0090 deg C/year
Annual Mean Minimum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.09705	0.0194*	Increase	0.0076 deg C/year
Summer Mean Air Temperature (deg C) ~ Time	1951-2007	57	55	0.07461	0.0398*	Increase	0.0105 deg C/year
Summer Mean Maximum Air Temperature (deg C) ~ Time	1951-2007	57	55	0.08581	0.027*	Increase	0.0118 deg C/year
Summer Mean Minimum Air Temperature (deg C) ~ Time	1951-2007	57	55	0.06082	0.0644		
Autumn Mean Air Temperature (deg C) ~ Time	1951-2006	56	54	0.06607	0.0558		
Autumn Mean Maximum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.09982	0.0177*	Increase	0.0100 deg C/year
Autumn Mean Minimum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.03933	0.143		
Winter Mean Air Temperature (deg C) ~ Time	1951-2006	56	54	0.02167	0.279		
Winter Mean Maximum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.03157	0.19		
Winter Mean Minimum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.01274	0.408		
Spring Mean Air Temperature (deg C) ~ Time	1951-2006	56	54	0.09506	0.0208*	Increase	0.0089 deg C/year
Spring Mean Maximum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.09138	0.0236*	Increase	0.0086 deg C/year
Spring Mean Minimum Air Temperature (deg C) ~ Time	1951-2006	56	54	0.0835	0.0308*	Increase	0.0092 deg C/year

	Timespan	n	df	R-squared	p-value	Direction	Magnitude
Total Annual Precipitation (mm) ~ Time	2000-2006	7	5	0.00195	0.925	-	-
Total Summer Precipitation (mm) ~ Time	2000-2007	8	6	0.08338	0.488	-	-
Total Autumn Precipitation (mm) ~ Time	2000-2006	7	5	0.3807	0.1032	-	-
Total Winter Precipitation (mm) ~ Time	2000-2006	7	5	0.4615	0.0932	-	-
Total Spring Precipitation (mm) ~ Time	2000-2006	7	5	0.1027	0.484	-	-
Annual Mean Air Temperature (deg C) ~ Time	2000-2006	7	5	0.06361	0.585	-	-
Annual Mean Maximum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.04395	0.652	-	-
Annual Mean Minimum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.08564	0.524	-	-
Summer Mean Air Temperature (deg C) ~ Time	2000-2007	8	6	0.008208	0.831	-	-
Summer Mean Maximum Air Temperature (deg C) ~ Time	2000-2007	8	6	0.001221	0.935	-	-
Summer Mean Minimum Air Temperature (deg C) ~ Time	2000-2007	8	6	0.0318	0.673	-	-
Autumn Mean Air Temperature (deg C) ~ Time	2000-2006	7	5	0.585	0.0452*	Increase	0.1232 deg C/year
Autumn Mean Maximum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.6664	0.0251*	Increase	0.1059 deg C/year
Autumn Mean Minimum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.4723	0.088		
Winter Mean Air Temperature (deg C) ~ Time	2000-2006	7	5	0.3174	0.188		
Winter Mean Maximum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.01221	0.814		
Winter Mean Minimum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.6603	0.0263*	Decrease	-0.1155 deg C/year
Spring Mean Air Temperature (deg C) ~ Time	2000-2006	7	5	0.5246	0.0656		
Spring Mean Maximum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.637	0.0315*	Decrease	-0.2071 deg C/year
Spring Mean Minimum Air Temperature (deg C) ~ Time	2000-2006	7	5	0.4315	0.109		

Table S4. Trends in climate indices for 1949-2006 and 2000-2006/07. Significant p-values marked with*. Although there are long-term trends of warming and increased precipitation on the island only autumn temperatures have shown significant warming during 2000 – 2006/07.