Falkland Islands
Penguin Census
2005/06

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FALKLANDS CONSERVATION

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SUMMARY

This report covers the results of the third whole island census of the penguin populations of the Falkland Islands conducted during the austral summer of 2005/2006. It followed the previous two censuses of 2000/01 and 1995/96 and thus a 10-year overview is possible for the first time. The methodologies have also been improved, enabling more accurate and comparable censuses in he future, especially with respect to the area measurement of the large breeding colonies.

- King penguins have a healthy population, though increases of the last two decades may now be stabilising at an annual productivity of around 300 chicks.
- The gentoo penguin population currently stands at fewer than 66,000 breeding pairs and while much reduced from 2000, is still slightly above 1995 level and in line with historical data from the 1930s. The sharp decrease over the last five years due to the effect of the Harmful Algae Bloom (HAB) of 2002/03. Important systematic differences between colonies in East and West Falklands were identified for the first time but overall the pattern of major population fluctuations is not atypical of the species.
- The rockhopper penguin population has declined by nearly 100,000 pairs since last census (at a rate of 5.9% per annum), mainly due to the HAB event of 2002/03, negating the small recovery between 1995 and 2000, leaving a total population of 210,000 breeding pairs. The situation for this globally threatened species continues to deteriorate and urgent action is now needed to improve protection and management of breeding sites and to minimise threats at sea in their feeding and migrating areas.
- The small population of macaroni penguins, breeding amongst rockhopper penguins, was counted for the first time, giving a total of 24 breeding pairs in the Falkland Islands. Historical records indicate that this small population might be in decline like the rockhopper penguins it is associated with.

INTRODUCTION

This report presents results of the third consecutive census of penguins breeding over the whole of the Falkland Islands. Each census was conducted every five years. The species counted were king penguin, *Aptenodytes patagonicus*, gentoo penguin, *Pygoscelis papua*, rockhopper penguin, *Eudyptes chrysocome chrysocome*, and macaroni penguin, *Eudyptes chrysolopus*. Magellanic penguins, *Spheniscus magellanicus*, were not counted because it breeds in burrows dispersed over most of the Falkland Islands coastline. In terms of conservation status king penguin is classified as Least Concerned, whilst gentoo penguin is Near Threatened and both macaroni and rockhopper penguins are classified as Vulnerable (Birdlife 2006). The Falkland Islands hold a significant proportion (between 30 and 50%) of the world populations of gentoo and rockhopper penguins and changes in population numbers in the islands are crucial for the overall trends of these species. The king and macaroni penguins populations breeding in the Falkland Islands are marginal populations of these species, which have much larger populations farther south, especially in nearby South Georgia.

This latest census was conducted three years after the population crash that mainly affected gentoo and rockhopper penguins and was due to a HAB event (Uhart et al. 2004). This will provide an indication of the extent of the effects to the penguin populations, both in terms of numbers and also geographically. These latest results will also be examined in relation to the two previous full island censuses of 1995/1996 and 2000/01. An examination of historical records for gentoo and rockhopper penguins is also conducted. This will help to ascertain trends for the different penguin populations of the Falkland Islands and, for the two most numerous and widespread species (gentoo and rockhopper penguins), to check how homogenous the populations are within the islands.

METHODS

This whole island penguin census was conducted between 02 November 2005 and 30 November 2005. The islands were divided in three parts and were counted by different teams. The first part, mainland East Falkland, was counted by Andrea and Gus Clausen, Sam Miller, Darren Christie and Ruben Fijn. The second part, mainland West Falkland, was counted by Helen Otley, Dee Masters and Peter Nightingale. The third, all the remaining offshore islands, was counted by Nic Huin, Tim Reid, Oli Yates, Mike Morisson, Alan Henry, Sarah Crofts and Cleo Small. Most of the islands were reached by boat (Condor, Mike Clarke owner/skipper) apart from Saunders, Pebble, Speedwell and Lively islands which were reached by plane and Kidney and Cochon islands which were visited on day trips from Stanley by launch. All known colonies of king and macaroni penguins were visited and only one colony of rockhopper penguins (0.05% of the total) and two colonies of gentoo penguins (2% of the total, but one with a rough estimate) were missed. Survey timing and techniques were consistent between this census and the previous one of 2000 and comprised of a suite of methods developed to suit the breeding colonies of seabirds in the Falkland Islands (Huin 2001, Clausen and Huin 2003 and Reid and Huin 2005). Three methods were used to count the total number of breeding pairs at each site.

Direct Method

This method was used in preference when access was feasible, when there was enough time on an island to conduct it and where colony size was not too large. Each nest with a bird or pair incubating an egg was counted using a tally counter. Each observer made up to three counts and each colony was counted by up to three observers. Counts were stopped when an accuracy of 5% was reached between counts and/or observers. This method was used in all counts of gentoo, king and macaroni penguins and for all the mainland colonies of rockhopper penguin. As king penguin laying dates extend from November until February, counts of last season surviving chicks were made at all sites, plus a count of adults present in November for most sites and of adults actually on eggs in February at the two main colonies (Volunteer Green and Lagoon Sands).

Photographic Method

Photographs were taken of mixed colonies of rockhopper penguin and black-browed albatross, *Thalassarche melanophris*, that spread out on cliff faces of West Point, South Jason, Grand Jason and New islands as well as Grave Cove. A total of 1,250 digital high definition colour photographs was taken. Using the bezier tool in CorelDraw 8, overlaps within sets of pictures were drawn and nests were highlighted on the screen by the cursor and marked points were automatically tallied. A sub sample of the photographs was counted twice by the same person and a third time by another person. This method was tested extensively during the southern giant petrel, *Macronectes giganteus*, survey in 2004 (Reid & Huin, 2005). All photographs were detailed enough to remove standing and non-breeding birds from the counts. The accuracy of the photographic counts was as good as in direct counts and for the purpose of this report was fixed at 5% (see Reid and Huin 2005 for details).

Area and Density Method

Some of the breeding colonies in the Falkland Islands are too large for either of the two previous methods to be used. Therefore a third method was used, relying on area and nest density measurements. This method was used for the large colonies of rockhopper penguin and black-browed albatross on Beauchêne Island and Steeple Jason Island. The principle behind this method is to measure the area of a colony, estimate the density of nests within this same colony and multiply the two measures to obtain the total number of nests within the colony. This method differs from previous counts of such big colonies on Beauchêne Island (Prince 1982) and Steeple Jason (Thompson & Rothery 1991), mainly by the fact that measurements of the colony areas were made on land rather than by aerial photography and that transects to estimate density were made in lines rather than circles.

Colony area

The perimeter of colonies was measured with a laser range finder (Leica DISTO™ lite[5]), with an accuracy of 3mm and a compass marked every 2 degrees. Two people, one in front of the other, walked along the edge of the colony until there was a change of direction or the person in front was out of range of rope or range finder. At this point distance and direction from one point to the next were recorded and the second person moved to the first person spot and so forth until the entire perimeter was

measured. The distances that we were capable of measuring with the range finder were quite small, but improved with the use of a reflective white board shaded from direct sunlight. Thus for each colony measured, we obtained for each point a set of distances and angles from the previous point. These can be thought of as relative polar coordinates for each point that were transformed to positive absolute orthogonal coordinates from which the total area of each colony can be calculated (see Huin and Reid 2006 for more details).
The problem with this method is that each point is dependent on the previous point and that any error in measurements will be cumulative. However, the choice of the start point of each colony is totally arbitrary (often, the easiest point of access to the colony) and one could have started from anywhere along the edge of the colony. Therefore, if a colony perimeter was measured with ***n*** points, there will be ***n*** possible ways of starting to measure the colony and ***n*** possible ways of measuring the colony area. A simple computer program was written in Sigmaplot to calculate automatically each possible way of measuring a colony area and all results were stored to obtain an average colony area (and its error). It is referred thereafter as colony "spinning". This method of averaging multiple simulations to calculate area was only recently developed and was not originally employed for the 2000 census. Thus a re-calculation of results previously presented (Clausen and Huin 2003) was needed. Also during this census, all colonies measured by this method were also measured using a handheld GPS (Garmin GPS 72) to provide comparison between the two methods. Two colonies (one on Beauchêne Island and one on Steeple Jason) were only measured by GPS due to time constraints.

Density
The density of nests within the colonies was estimated by conducting strip transects (Croxall and Prince 1979). This method was preferred to circle transect as it takes into account the lower densities associated with the borders of the colonies. Both occupied and empty nests were counted to compensate for nests that failed before our visit and to provide results comparable with previous censuses (Prince 1982 and Thompson & Rothery 1991). The number of transects was dependent on the size and configuration of the colony. Each transect line was five meters wide and was divided into a succession of contiguous five meters squares (each of an area of 25 m^2), using a marked tape and paint on the ground. Two people counted all the nests in each square, repeating the count if observers differed by more than two nests. All counts were then averaged to produce an overall estimate of the breeding density in each colony. Cumulative average and CV% of all transects combined were also produced for each season and for each of Beauchêne Island and Steeple Jason. This was done to assess the accuracy of the transects in calculating the overall density of birds within the colonies (i.e. how many transects are needed to achieve a robust enough estimate of density, whilst keeping disturbance within the colonies to a minimum).

Error
Sources of error come from natural variation in breeding density throughout each colony and from sampling error in the measurement of the areas. Counts of nests within each $25m^2$ were very accurate and changes in density are the true results of changes in density between squares. Such changes are due to differences in density from the edge of the colony towards the centre, changes in abundance of other breeding birds within the colony (black-browed albatross and king cormorants,

Phalacrocorax albiventer) and changes in quality of the terrain (stones, mud, water for example).
Errors in measuring areas of colonies changed with the method employed. A single tracing of the colony contour was done using a handheld GPS. The overall accuracy of the device provided by the manufacturer is stated as being less than 15 meters. However, this is the overall accuracy for plotting a position accurately on the globe. Much of the variation is due to the number of satellite in sight and changes in atmospheric conditions and interferences with the GPS satellite transmissions (Ross Chaloner pers.comm.). Considering that distances measured for each colony were quite small and were done within two hours from start to finish, errors from one coordinate to the next within the sampling method are very small (i.e. the colony position on earth might be misplaced by up to 15 m away, but the shape of the colony and therefore its area will be much more accurate). There is no way to determine its exact accuracy, but the error should be less than the one obtained by laser and compass. The minimum error for this second method was a CV of 3% and we can assume an error of around 1% for the GPS method.
Whilst using the second method of measuring area, errors come from uncertainty in range and direction of compass between consecutive points. Such error is cumulative as each point is placed relative to the previous one. The spinning of the colonies takes into account all the inaccuracies and provides each measurement of a colony with an average and error rate.
We follow the calculations from Thompson and Rothery (1991) to estimate the variance V of the estimated number of nests N for each colony i, modified to take into account the changes in how many times each colony was measured.
This produced the following formula:

$$V[N_i] = A_i^2 * s_i^2 / n_i + s_{ai}^2 * \left(x_i^2 + s_i^2 / n_i\right) / n_{spin}$$

Where n_i is the number of quadrats; x_i and s^2_i are the sample mean and variance of the density of nests; A_i and s^2_{ai} are the estimated mean and variance of the colony area; and n_{spin} is the number of times the colony area was measured by changing the start point, whilst using the laser and compass method. When area was measured with the GPS, $n_{spin}=1$. The first term in the equation is the variance due to natural variation in density between quadrats within colony area and the second term is due to the variance arising from multiple estimates of the colony area.
Once the variance was calculated, it can be transformed to a coefficient of variation CV as being:

$$CV = \frac{\sqrt{V[N_i]}}{N_i} * 100$$

And then to a 95% confidence interval as being:

$$95\%CI = N_i * \frac{CV}{100} * 1.96$$

Statistical comparisons

When summing multiple colony numbers for a single site, to calculate the overall error for this site, variances first had to be added and then from the single variance,

CV and 95%CI are calculated (not adding CV or 95%CI directly). This applied, even whilst using different methods within a site (area and transect, photographs or direct counts; for the last two methods, error is fixed at 5% and stands for each individual CVs that are to be back-transformed to variance, before being added up).
Comparisons of colony areas and numbers calculated by different methods were made using standard paired T-tests. Comparisons of sites between the last two censuses and of overall population were made using the variances calculated and can be expressed as:

$$d = \frac{N_2 - N_1}{\sqrt{V[N_1] + V[N_2]}}$$

Where N_1 and N_2 are the two mean population sizes to be compared and $V[N_1]$ and $V[N_2]$ are their variances and d is following the normal distribution (i.e. at p=0.05, d=1.96).
Rates of change per annum were normally calculated from the original number:
$(N_2\text{-}N_1)/N_1/n_{years}*100$ or when mentioned in the text were compounded:
$(N_2\text{-}N_1)/\text{average}(N_1,N_2)/n_{years}*100$.

Photographic library

In order to maintain a record of population changes in Falkland Islands colonies, all pictures taken during the last three censuses have been kept for future reference. We also have collected several other sets of photographs that help to show changes in colony size. The full series of vertical aerial photographs used for the counts on Beauchêne Island in 1980, as well as land-based photography taken there by R.I. Lewis-Smith and P.A. Prince in 1979 are held for reference. During both 2000 and 2005, fixed point photography to match the 1980 photography positions was conducted; this clearly show the reduction in colony size that has taken place on this island (see Appendix 1). Similarly, we hold a full set of vertical aerial photographs of Steeple Jason taken in 2003 as well as a full set of oblique aerial photographs taken in 1996. We also have some land and boat based photographs taken on the islands during the last two censuses and in 2003, plus a few additional old photographs taken in the early 1980s (see Appendix 2), which show similar reduction in colony size for this island.

RESULTS & DISCUSSION

King penguin

King penguins are known to breed or to have bred at sixteen different sites around the Falkland Islands. Table 1 shows the number of chicks produced at all these sites during the last three censuses and the number of adults present during the 2005 census. The majority of chicks produced are at the main colony at Volunteer Green with the rest situated on mainland East Falkland and a few smaller islands (Figure 1). All of the smaller colonies are associated with gentoo penguin colonies and tend to have between one and five breeding pairs, typically producing between zero and three chicks. The overall number of chicks produced tends to be lower than in the last two censuses. The number of chicks at Lagoon Sands was high in 2000 compared to the 1995 and 2005 censuses, but the number of incubating birds has been constant in the last four years with 33 adults on egg in 2002, 35 in 2004 and 33 again in 2006. Thus the number of chicks produced might be more a reflection of changes in breeding success rather than actual numbers of breeding birds.

Table 1: Counts of chicks and adults king penguin breeding in the Falkland Islands during the 1995, 2000 and 2005 censuses.

Place	Date start	Date end	Counts Adults	2005 Chicks	% of total	2000 census	Changes %	1995 census	Changes %	1995 to 2005
Total				**268**		**275**	**-2.55**	**339**	**-18.88**	**-20.94**
1. Islands										
New Island	17-Nov			**0**	0.00	**0**		**1**	-100.00	-100.00
Saunders Island	3-Nov			**2**	0.75	**2**	0.00	**3**	-33.33	-33.33
SeaLion Island	17-Nov			**0**	0.00	**0**		**1**	-100.00	-100.00
2. East										
SandHills	09-Nov		1							
Elephant Beach	11-Jan		1							
Lorenzo Pond	11-Jan		1							
Paloma Beach	12-Nov		4	**1**	0.37	**0**		**1**	-100.00	0.00
Concordia Beach	14-Nov		1	**1**	0.37	**0**		**1**	-100.00	0.00
Ellen Point	14-Nov		2							
Bluff Cove	18-Nov		5	**1**	0.37	**1**	0.00	**0**		
Swan pond	19-Nov		4							
Volunteer Green	25-Nov	07-Feb	763	**260**	97.01	**258**	0.78	**330**	-21.82	-21.21
Lagoon Sands	25-Nov	07-Feb	33	**1**	0.37	**12**	-91.67	**0**		
Cow Bay	25-Nov			**0**	0.00	**1**	-100.00	**0**		
Murrell Farm				**2**	0.75	**1**	100.00	**2**	-50.00	0.00
3. West										
Albemarle	10-Nov		1							

Figure 1: Number of King penguins breeding in the Falkland Islands during the 2005 census

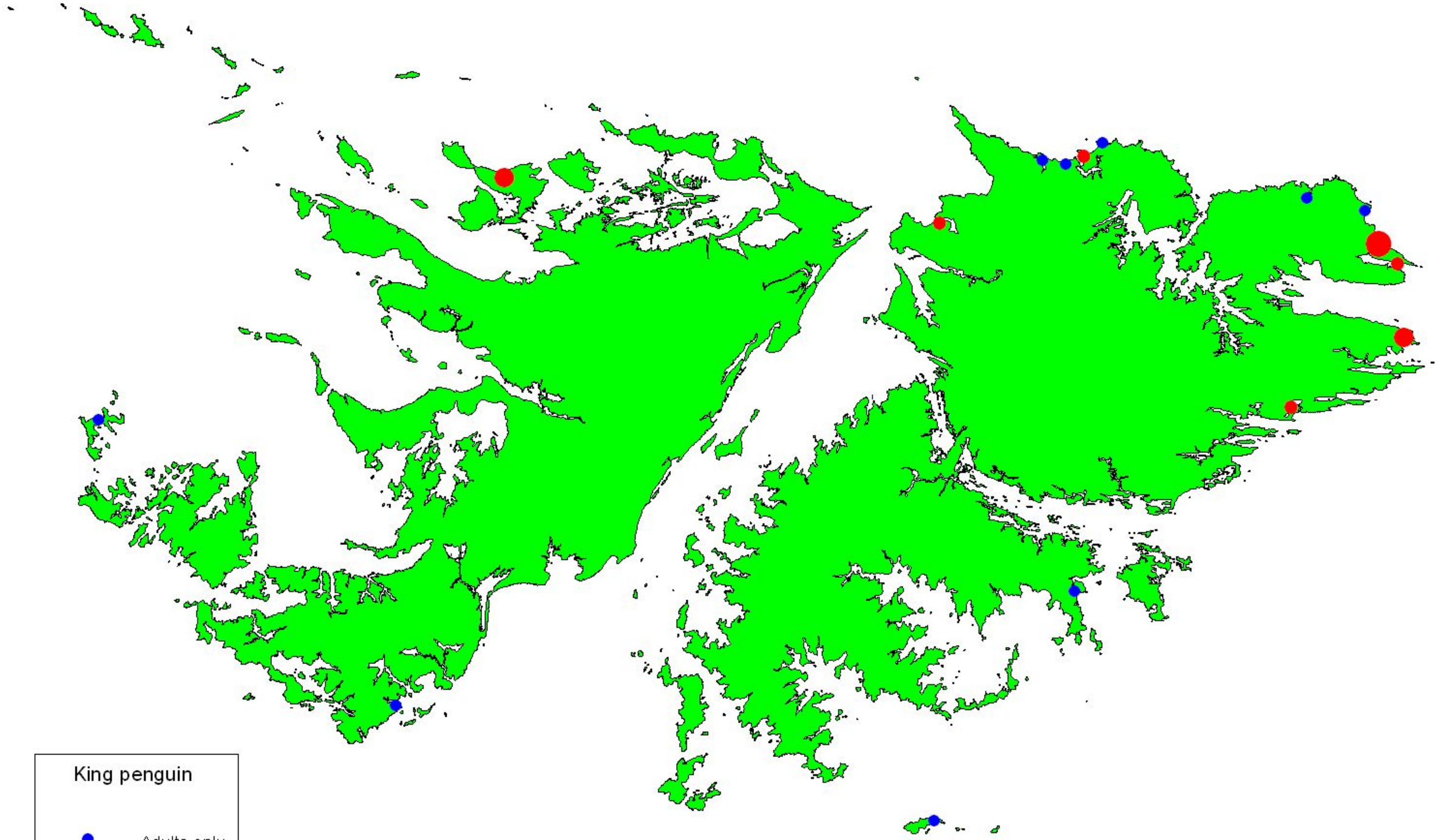
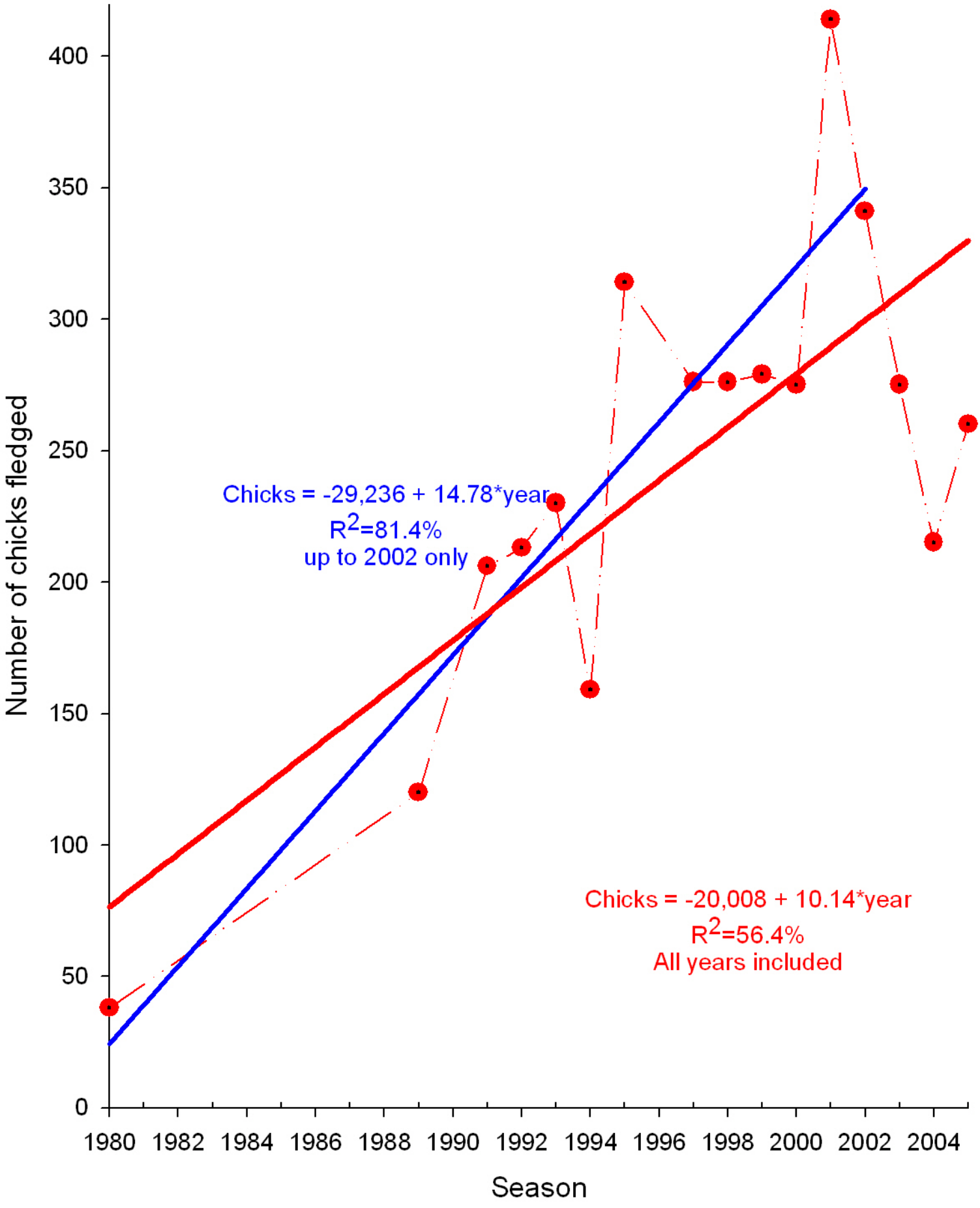


Figure 2: King Penguin Chick numbers at Volunteer Green



Similarly the number of chicks present in 2005 and 2000 was lower than in 1995 by around 70 chicks. However, there were 733 adults on egg in February 2003 and 763 adults in February 2006. The main colony has been monitored closely since 1980 as part of the Falkland Islands Seabird Monitoring Programme and although the numbers seem to have stabilised in the last five years, there is still a positive trend in the colony size (Figure 2). We have no explanation as the reason why the population increase should have recently stabilised. Compared to a world population estimated at 2 million birds (BirdLife International 2006), the population of the Falkland Islands is negligible, but still needs to be monitored regularly to detect any change in future trend, especially in view of the large number of tourists visiting the Volunteer Green colony.

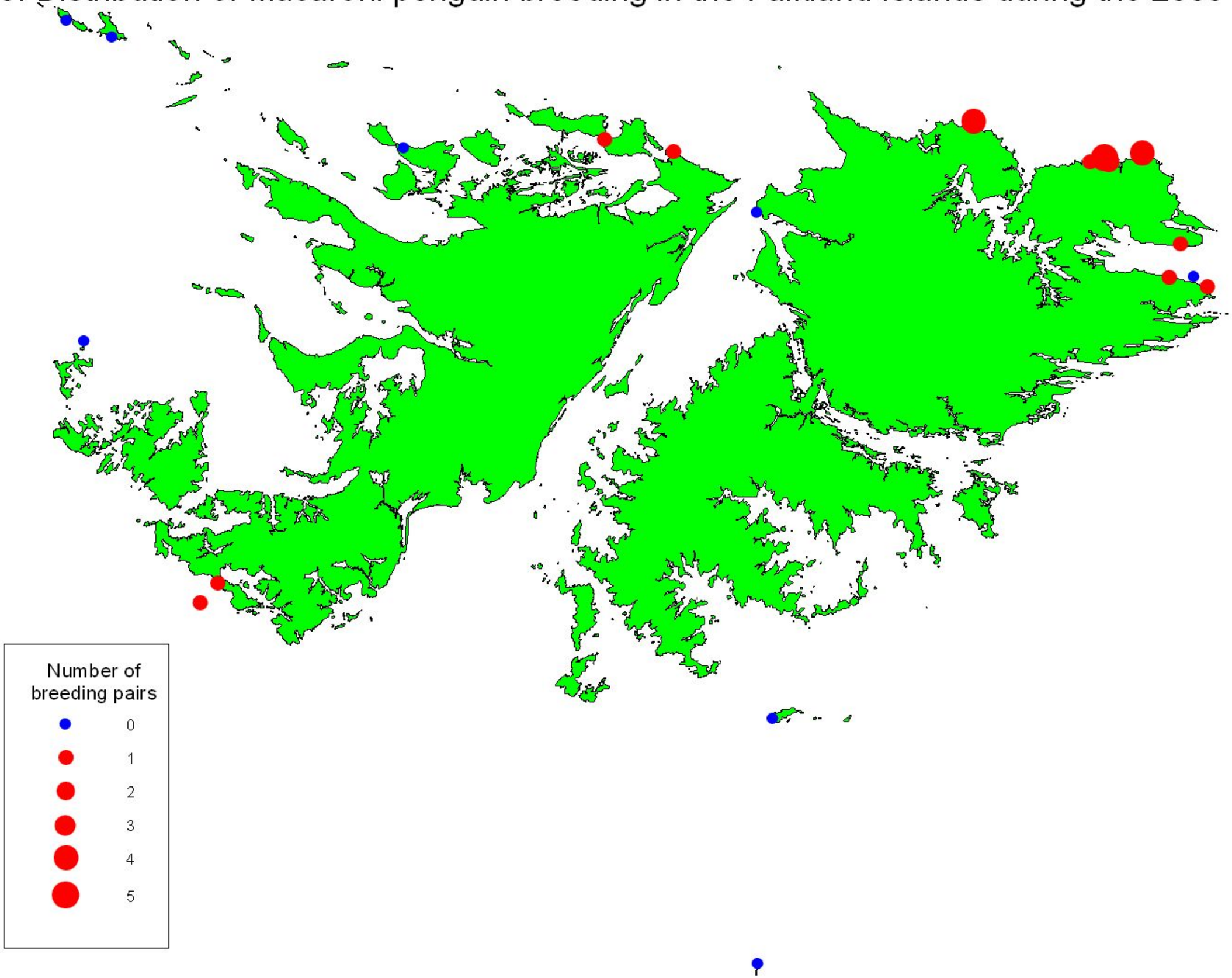
Macaroni penguin

Although breeding regularly in small numbers in the Falkland Islands, no accurate census of this species was conducted before 2005. Numbers and distribution of this species breeding in the Falkland Islands in 2005 are summarised in Table 2. They are always associated with rockhopper penguins and in a few cases some mixed species pairs occur (White & Clausen 2002).

Table 2: Numbers of macaroni penguin breeding in the Falkland Islands during the 2005 census.

Place	Date start	Date end	Breeding pairs	% of total
Total			**24**	
1. Islands				
Beauchêne Island	4-Nov	9-Nov	**0**	0.00
Kidney Island	10-Jan		**1**	4.17
Cochon Island	11-Jan		**0**	0.00
Bird Island	13-Nov	14-Nov	**1**	4.17
Pebble Island	19-Nov		**1**	4.17
North Island	18-Nov		**0**	0.00
Jason islands	20-Nov	30-Nov	**0**	0.00
Saunders Island	5-Nov		**0**	0.00
SeaLion Island	17-Nov		**0**	0.00
2. East				
Fanning Head	12-Nov		**0**	0.00
Cape Bougainville	14-Nov		**4**	16.67
Murrell	18-Nov		**1**	4.17
McBride Head	19-Nov		**4**	16.67
Seal Bay	20-Nov		**3**	12.50
Rabbit Rincon	20-Nov		**5**	20.83
Campa Menta	20-Nov		**1**	4.17
Eagle Hill	21-Nov		**1**	4.17
3. West				
Stephens Peak	12-Nov		**1**	4.17
Tamar Point	17-Nov		**1**	4.17

Figure 3: Distribution of Macaroni penguin breeding in the Falkland Islands during the 2005 census



A total of 24 pairs of macaroni penguin was found breeding at twelve different sites in the Falkland Islands during the 2005 census (Table 2 and Figure 3). At a further seven sites where they used to breed (FC unpublished), no birds were found. Although there is no previous census to compare figures with, numbers have clearly decreased at a number of known locations where macaroni penguin used to breed, but were not found during 2005. The most noticeable is Beauchêne Island, where none was breeding in 2005, compared to 16 pairs in 1981 (Lewis Smith & Prince 1985). Overall the Falkland Islands population is trivial compared to the huge numbers breeding in South Georgia.

Gentoo penguin

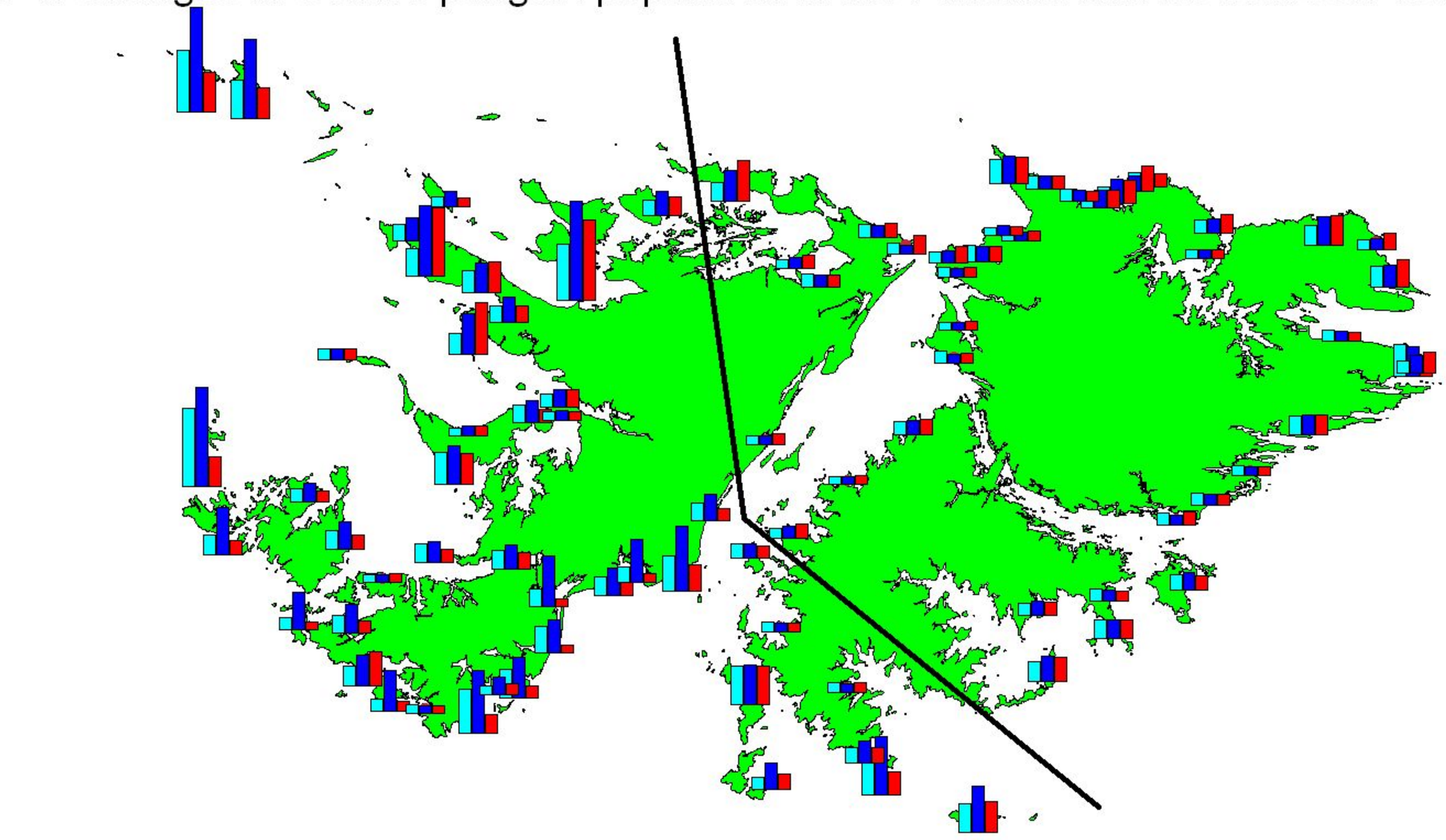
Gentoo penguins breed in colonies situated all around the shores of the Falkland Islands. Colony size ranges from seven to around 7,000 pairs (Table 3 and Figure 4). Of the 85 sites visited, four had no birds breeding in 2005 and one new colony was discovered. The total number of breeding pairs changed massively between censuses, from 64,426 ± 1,052 (0.83%CV) in 1995 to 113,571 ± 1,578 (0.71%CV) in 2000 and back down again to 65,857 ± 923 (0.72%CV) in 2005. The differences between 1995 and 2000 ($d=50.8$, $p<0.0001$) and between 2000 and 2005 ($d=51.1$, $p<0.0001$) are highly significant and the overall increase between 1995 and 2005 is just significant ($d=2.00$, $p<0.05$). This would suggest that the population of gentoo penguin of the Falkland Islands in the last ten years has shown no clear trend in size.
Such changes are not homogenous, but vary between colonies. Between 1995 and 2000, when the population more than doubled, 21 out of 81 colonies (26%) declined and between 2000 and 2005 when the population nearly halved, 21 out of 84 colonies (37%) still increased. Geographically, the population is more evenly distributed in 2005 than it was in 2000 (Clausen & Huin 2003). Now a total of 22,604 pairs breed on 17 sites on outlying islands, 20,030 pairs breed at 36 sites on mainland East Falkland and the remaining 23,223 pairs breed at 32 sites on mainland West Falkland. Looking at the distribution of the colonies in the Falkland Islands (Figure 4) and their changes in sizes over the three censuses, the islands can be divided in two parts by a line going first north-west from the west of Bleaker Island to the north of Great Island in Falkland Sound, then just west of north to the western tip of Pebble Island. The general trend of colonies situated to the east of this line is a steady increase in numbers from 15,815 pairs in 1995 to 20,897 in 2000 (6.4% per annum) and to 24,292 pairs in 2005 (3.3% per annum) producing an overall increase of 5.4% per annum over the last ten years. Trends in the colonies west of this line are quite different, with a huge increase from 48,301 pairs in 1995 to 92,674 pairs 2000 (18.4% per annum), followed by a sharp decrease between 2000 and 2005, when only 41,565 pairs bred (11.0% per annum decrease). This resulted in an overall decrease of 1.4% per annum over the last ten years.
Most, if not all, of the decrease in population between 2000 and 2005 can be attributed to the mass mortality event of the summer 2002/03 (Huin 2003). This mortality was due to a Harmful Algae Bloom (HAB; Uhart et al. 2004) and affected birds mainly from the western colonies. The total number of birds affected by this HAB is unknown as no census was conducted directly afterwards, but the figures obtained from this last census give a potential indication of the scale of the loss. Thus a total of 47,714 pairs, or 95,428 birds, could be considered to have died as a result of the HAB. This is a minimum estimate, because between the census of 2000 and 2002 the population was on the increase and between 2002 and 2005, data from the

Table 3: Gentoo penguin breeding population of the Falkland Islands in the 2005, 2000 and 1995 censuses

Place	Area	Colony	Date start	Method	Counts	Breeding pairs	% of total	2000 census revised	Changes %	1995 census	Changes %	1995 to 2005
Total						**65,857**		**113,571**	**-42.01**	**64,426**	**76.28**	**2.22**
1. Islands												
Barren Island		5	7-Nov	Direct		**548**	0.83	**1,353**	-59.50	**326**	315.03	68.10
Beauchêne Island			6-Nov	Direct		**390**	0.59	**749**	-47.93	**490**	52.86	-20.41
	runway	1										
Beaver Island		1	18-Nov	Direct		**495**	0.75	**2,842**	-82.58	**892**	218.61	-44.51
Bleaker Island		6	4-Nov	Direct		**1,189**	1.81	**1,265**	-6.01	**875**	44.57	35.89
Carcass Island		1	19-Nov	Direct		**120**	0.18	**610**	-80.33	**180**	238.89	-33.33
Fourth Passage Island					missing	*300*	0.46	*300*	missing	**300**	0.00	0.00
Grand Jason			28-Nov	Direct		**1,636**	2.48	**5,226**	-68.69	**2,196**	137.98	-25.50
	SE point	1			524		*2,611*					
	Shanty	1			704		*1,557*					
	West Bay	1			408		*1,058*					
Great Island		2	6-Nov	Direct		**320**	0.49	**451**	-29.05	**490**	-7.96	-34.69
Keppel Island		1				**816**	1.24	**1,248**	-34.62	**560**	122.86	45.71
Lively Island		1	31-Jan	Chick		**424**	0.64	**652**	-34.97	**490**	33.06	-13.47
New Island				Direct		**1,637**	2.49	**6,668**	-75.45	**5,100**	30.75	-67.90
	Bold point			missing	*200*		*640*					
	North beach			missing	*1000*		*5,528*					
	south end		6-Nov		437		*500*	*missing*				
Pebble Island						**2,408**	3.66	**1,669**	44.28	**754**	121.35	219.36
	Marble Shanty		19-Nov	Direct	804		*665*					
	Middle Mountain		19-Nov	Direct	1,015		*650*					
	Tamar		18-Nov	Direct	589		*354*					
Saunders Island						**5,327**	8.09	**6,679**	-20.24	**3,510**	90.28	51.77
	The Neck		3-Nov	Direct	3,315		*3,367*					
	Sugar Loaf		5-Nov	Direct	218		*325*					
	Penguin Island		6-Nov	Direct	823		*1,362*					
	Penarrow Point		6-Nov	Direct	971		*1,625*					
SeaLion Island		6	17-Nov	Direct		**1,701**	2.58	**2,813**	-39.53	**1,484**	89.56	14.62
Speedwell Island		13	26-Jan	Chick		**2,209**	3.35	**2,335**	-5.40	**2,229**	4.76	-0.90
	Annie Is point				488		*560*					
	Phillips point		all colonies declined after r		504		*550*					
	Centre camp west		2000 census own counts d		738		*500*					
	Centre camp east				479		*725*					
Steeple Jason						**2,319**	3.52	**7,079**	-67.24	**3,923**	80.45	-40.89
	House	6	23-Nov	Direct	1,367		*4,348*					
	The Neck	1	24-Nov		952		*2,731*					
Weddell Island						**765**	1.16	**2,300**	-66.74	**1,220**	88.52	-37.30
	Mark point	1	15-Nov	Direct	492		*1,450*					
	Bold Roads	1	18-Nov	Direct	273		*850*					
2. East												
Bertha'sBeach		1	3-Nov	Direct		**227**	0.35	**216**	5.21	**310**	-30.32	-26.69
Fox Point		1	3-Nov	Direct		**412**	0.63	**226**	82.41	**378**	-40.21	9.06
Pleasant Roads		1	Nov	Direct		**42**	0.06	**54**	-22.22	**123**	-56.10	-65.85
New Haven		1	6-Nov	Direct		**518**	0.79	**472**	9.75	**400**	18.00	29.50
Egg Harbour		1	6-Nov	Direct		**82**	0.12	**0**		**7**	-100.00	1073.02
Port King		2	7-Nov	Direct		**527**	0.80	**354**	48.95	**208**	70.19	153.49
Moffit Harbour		1	7-Nov	Direct		**64**	0.10	**47**	36.17	**130**	-63.85	-50.77
Lion Creek		1	7-Nov	Direct		**159**	0.24	**65**	144.62	**110**	-40.91	44.55
Bull Point		5	8-Nov	Direct		**1,173**	1.78	**3,719**	-68.46	**2,230**	66.77	-47.40
Bull Roads		1	8-Nov	Direct		**577**	0.88	**1,065**	-45.82	**564**	88.83	2.30
LowBay		1	8-Nov	Direct		**400**	0.61	**456**	-12.28	**330**	38.18	21.21
Motley Point		3	9-Nov	Direct		**780**	1.18	**743**	4.98	**800**	-7.13	-2.50
Sand Hills		2	9-Nov	Direct		**203**	0.31	**249**	-18.47	**330**	-24.55	-38.48
Elephant Beach		1	11-Nov	Direct		**175**	0.27	**261**	-32.95	**304**	-14.14	-42.43
Lorenzo Pond		3	11-Nov	Direct		**721**	1.09	**723**	-0.28	**0**		
Cape Dolphin		4	11-Nov	Direct		**1,338**	2.03	**1,447**	-7.53	**1,148**	26.05	16.55
Moss Side		1	11-Nov	Direct		**442**	0.67	**443**	-0.23	**379**	16.89	16.62
Paloma Beach		1	12-Nov	Direct		**572**	0.87	**540**	5.93	**601**	-10.15	-4.83
Swan Pond		1	13-Nov	Direct		**147**	0.22	**170**	-13.53	**0**		
Murdos Cave		1	13-Nov	Direct		**131**	0.20	**110**	19.09	**137**	-19.71	-4.38
Rookery Sands		6	12-Nov	Direct		**654**	0.99	**325**	101.08	**249**	30.52	162.45
Fanning Harbour		1	12-Nov	Direct		**191**	0.29	**102**	87.25	**160**	-36.25	19.38
Concordia		1	14-Nov	Direct		**1,162**	1.76	**1,274**	-8.78	**701**	81.74	65.79
Ellen Point 1		1	14-Nov	Direct		**426**	0.65	**609**	-30.01	**531**	14.69	-19.73
Ellen Point 2		1	14-Nov	Direct		**1,238**	1.88	**573**	116.08	**54**	961.11	2192.90
Brazo del Mar		2	15-Nov	Direct		**792**	1.20	**495**	60.00	**357**	38.66	121.85
Toggle Point		1	15-Nov	Direct		**42**	0.06	**52**	-19.23	**44**	18.18	-4.55
Bluff Cove		4	18-Nov	Direct		**921**	1.40	**959**	-3.96	**850**	12.82	8.35
Long Island		1	18-Nov	Direct		**87**	0.13	**137**	-36.50	**176**	-22.16	-50.57
Swan Pond		7	19-Nov	Direct		**1,627**	2.47	**1,519**	7.11	**875**	73.60	85.94
Ajax Bay		1	23-Nov	Direct		**112**	0.17	**1**	11100.00	**14**	-92.86	700.00
Rookery Point		1	23-Nov	Direct		**195**	0.30	**73**	167.12	**300**	-75.67	-35.00
Volunteer Point		6	25-Nov	Direct		**1,458**	2.21	**1,091**	33.64	**970**	12.47	50.31
	Volunteer Green				1,057		*766*					

Lagoon sands				401		*325*					
Cow Bay	1	25-Nov	Direct		**634**	0.96	**277**	128.88	**117**	136.75	441.88
Kidney Cove	1				**850**	1.29	**1,625**	-47.69	**1,730**	-6.07	-50.87
Sparrow Cove	1				**950**	1.44	**750**	26.67	**300**	150.00	216.67
3. West											
Lucas peninsula					**278**	0.42	**2,390**	-88.37	**1,457**	64.04	-80.92
Lucas Hill	3	09-Nov	Direct	278		*1,601*					
Lucas Rincon	0	09-Nov	Direct	do not exists any more		*789*					
Rodeo Point	1	09-Nov	Direct		**240**	0.36	**743**	-67.70	**120**	519.17	100.00
Port Richards	2	13-Nov	Direct		**664**	1.01	**1,246**	-46.71	**830**	50.12	-20.00
Albemarle	2	10-Nov	Direct		**763**	1.16	**4,002**	-80.93	**2,626**	52.40	-70.94
Hoste Inlet					**0**	0.00	**0**		**66**	-100.00	-100.00
Cape Orford	0	11-Nov	Direct		**0**	0.00	**2,157**	-100.00	**311**	593.57	-100.00
Stephens Peak					**1,885**	2.86	**1,659**	13.62	**894**	85.57	110.85
Wood cove	3	12-Nov	Direct	819		*917*					
Indian Village	1	12-Nov	Direct	1,066		*742*					
Ten Shilling Bay	1	12-Nov	Direct		**140**	0.21	**2,432**	-94.24	**342**	611.11	-59.06
Fox Point	2	13-Nov	Direct		**334**	0.51	**1,566**	-78.67	**751**	108.52	-55.53
Gladys Cove	1	13-Nov	Direct		**74**	0.11	**0**		**0**		
Port Edgar	0	13-Nov	Direct		**0**	0.00	**1,830**	-100.00	**1,408**	29.97	-100.00
Port North	3	14-Nov	Direct		**683**	1.04	**1,291**	-47.10	**705**	83.12	-3.12
Shag Cove	1	15-Nov	Direct		**169**	0.26	**65**	160.00	**16**	306.25	956.25
Gladstone Valley	3	16-Nov	Direct		**386**	0.59	**317**	21.77	**410**	-22.68	-5.85
Long Point	1	16-Nov	Direct		**402**	0.61	**279**	44.09	**52**	436.54	673.08
Little Mountain	1	17-Nov	Direct		**473**	0.72	**278**	70.14	**375**	-25.87	26.13
Leopard Bay	1	17-Nov	Direct		**784**	1.19	**46**	1604.35	**270**	-82.96	190.37
Town Point	8	18-Nov	Direct		**737**	1.12	**701**	5.14	**416**	68.51	77.16
North Beach	1	18-Nov	Direct		**75**	0.11	**153**	-50.98	**103**	48.54	-27.18
Narrows	6	19-Nov	Direct		**408**	0.62	**1,052**	-61.22	**738**	42.55	-44.72
Dunnose Head	1	19-Nov	Direct		**143**	0.22	**87**	64.37	**0**		
Queen Point	4	20-Nov	Direct		**445**	0.68	**1,001**	-55.54	**832**	20.31	-46.51
Fox Bay West	1	21-Nov	Direct		**748**	1.14	**1,435**	-47.87	**855**	67.84	-12.51
Fox Bay East	1	21-Nov	Direct		**80**	0.12	**2,574**	-96.89	**534**	382.02	-85.02
Carcass Bay	4	22-Nov	Direct		**1,357**	2.06	**4,219**	-67.84	**2,039**	106.92	-33.45
Hill Gap	1	23-Nov	Direct		**315**	0.48	**1,387**	-77.29	**728**	90.52	-56.73
Big Seal Rookery	0	21-Nov	Direct	no more	**0**	0.00	**3,137**	-100.00	**716**	338.13	-100.00
Stevelly Bay	1	Nov	Direct		**1,721**	2.61	**1,614**	6.63	**1,071**	50.70	60.69
Hope Point	1	Nov	Direct		**585**	0.89	**1,110**	-47.30	**654**	69.72	-10.55
Grave Cove	1	Nov	Direct		**4,422**	6.71	**4,640**	-4.70	**1,434**	223.57	208.37
Whaler bay	3	26-Nov	Direct		**3,207**	4.87	**2,431**	31.92	**1,000**	143.10	220.70
Shallow Bluff	2	Nov	Direct		**1,705**	2.59	**2,268**	-24.82	**1,737**	30.57	-1.84

Figure 4: Changes in Gentoo penguin population of the Falkland Islands between 1995 and 2005



Falkland Islands Seabird Monitoring Programme (FISMP) showed that some of the colonies affected, were increasing again with high breeding success (Huin 2005). There is no clear explanation why the increase in population size between 1995 and 2000 occurred mainly at gentoo penguin colonies situated to the west of the islands (but this may reflect differences in local oceanography and ocean productivity).

Table 4: Changes in Falkland Islands gentoo penguin numbers (breeding pairs) comparing recent censuses with Bennett (1933).

Census	1932	1995	2000	2005	
1. Islands	**81,750**	**25,019**	**44,239**	**22,604**	**-----**
Beauchêne Island	no data	490	749	390	**?**
Bleaker Island	1,600	875	1,265	1,189	**-**
Carcass Island	200	180	610	120	**+/-**
Passage Islands	1,000	300	300	300	**-**
Jason Islands*	35,000	6,119	12,305	3,955	**---------**
Keppel Island	no data	560	1,248	816	**?**
Lively Island	2,400	490	652	424	**-**
New Island	2,500	5,100	6,668	1,637	**+/-**
Pebble Island	1,000	754	1,669	2,408	**+/-**
Saunders Island	1,900	3,510	6,679	5,327	**+**
SeaLion Island	18,000	1,484	2,813	1,701	**----------**
Speedwell Island*	6,150	3,045	4,139	3,077	**-**
Weddell Island*	12,000	2,112	5,142	1,260	**----------**
2. East	**17,800**	**15,917**	**21,222**	**20,031**	**+/-**
Fitzroy*	200	1,661	1,455	1,603	**+**
North Arm	2,900	3,649	5,722	3,100	**+**
Walker Creek*	1,400	1,460	1,448	1,383	**+/-**
Douglas Station	200	0	723	721	**+**
San Carlos North*	7,900	2,978	3,398	3,650	**-**
Salvador*	1,000	1,687	3,003	3,661	**+**
Port Louis	1,000	875	1,519	1,627	**+/-**
San Carlos South*	300	314	74	307	**+/-**
Johnsons Harbour*	2,500	1,087	1,368	2,092	**-**
Sparrow Cove*	400	2,206	2,512	1,887	**+**
3. West	**16,470**	**23,490**	**48,110**	**23,223**	**+**
Spring Point*	2,700	2,378	5,384	1,109	**+/-**
Port Stephens*	5,300	7,975	16,779	3,714	**+/-**
Roy Cove*	1,900	4,864	11,086	10,618	**+**
Port Howard*	570	1,123	985	2,214	**+**
Dunnose Head*	4,000	2,994	4,261	3,068	**+/-**
Fox Bay*	2,000	4,156	9,615	2,500	**+**
Total	**116,020**	**64,426**	**113,571**	**65,858**	-

* sum of different sites from last three censuses

+	increase
+/-	stable/fluctuate
-	decrease
---------	major decrease
?	No data in 1932

Prior to the three recent censuses, the only comprehensive survey was by Bennett (1933), which estimated a population size of 116,020 breeding pairs of gentoo penguin during the 1932/33 season (Table 4). Although there is no way to judge the accuracy of the counts reported by Bennett, they can be used as an indication of potential population changes since then. On West Falkland three sites have increased and three sites were more or less stable, producing an overall increase for this part of the Falkland Islands. On East Falkland, five sites have increased, three sites were stable and two sites decreased, leaving this part of the islands stable overall. On the outlying islands, two sites were not surveyed, one site increased, three sites were stable, four sites decreased and the remaining three sites decreased substantially. Whether this large decrease actually occurred or comes from a reporting error is not known. Taking the results of 1932 at face value suggests that the gentoo penguin population of the Falkland Islands has experienced large fluctuations, but without obvious trend. On the other hand, ignoring for all censuses the sites that were not counted in 1932 and the three sites in 1932 that experienced huge, feasible but unlikely, decreases, the population would have fluctuated from 51,020 in 1932 to 53,661 in 1995 to 91,314 in 2000 and finally to 57,736 breeding pairs in 2005. This would show a less fluctuating population that is slightly increasing. Results from the FISMP show that gentoo penguin breeding success is highly variable, ranging from total breeding failure to producing a maximum of 1.6 chicks per pair. Such variation readily translates to high fluctuations in breeding population size. The Falkland Islands population still represents 27% of the world population of this species, which is notable for fluctuations in population size at all sites.

Rockhopper penguin

Estimating the total number of breeding pairs of rockhopper penguin was more difficult and involved using the three methods of counting. As the more complex method of area and density measurements was further developed for this report, breeding numbers previously published for the 2000 census had to be re-analysed, together with the estimates for the 1995 census (which were dependent on the values for 2000).

Area and density of large colonies

Table 5: Counts of rockhopper penguin breeding pairs on Beauchêne Island in 2005.

Colony	GPS area m2	Area m2	Average Density N	Nest/m2	CV%	Size	Total CV%	Date	Direct Count	Date	Breeding pairs	% of Total	CV%	95%CI
Area A: big colony											**47,373**	43.47		
BigColony	135,279.50	134,790.25	114 (in 4)	0.351	85.63	47,295	8.03	5-Nov	78	6-Nov	47,373		8.01	7,441
Area B:east colonies									1,960		**1,960**	1.80	4.16	160
Little north				too tiny					338	7-Nov	338		5	33
Big				too tiny					1,597	7-Nov	1,597		5	157
Tiny				too tiny					25	7-Nov	25		5	2
Area C:arenas											**13,798**	12.66	9.67	2,616
South Arena	29,516.44	31,163.61	52 (in 2)	0.332	81.56	10,332	11.32	4-Nov	53	4-Nov	10,385		11.26	2,291
North Arena	7,719.74	7,157.25	25	0.477	94.20	3,413	18.85	4-Nov	0	4-Nov	3,413		18.85	1,261
Area D: citadel									1,125		**2,123**	1.95	12.73	529
Bottom	3,443.49	3,419.72	17 (in 2)	0.292	109.12	998	26.48	4-Nov	0		998		26.48	518
Rest				too convoluted					1,125	7-Nov	1,125		5	110
Area E: North end									1,031		**5,888**	5.40	12.58	1,452
Big	10,203.95		20	0.476	67.83	4,857	15.24	9-Nov	240	9-Nov	5,097		14.52	1,451
Little				too tiny					330	9-Nov	330		5	32
Bigmissing				too tiny					421	9-Nov	421		5	41
Littlemissing				too tiny					40	9-Nov	40		5	4
Rocky pond				too tiny					202	9-Nov	**202**	0.19	5	20
Total		**202,014***									**71,343**		**5.75**	**8,039**

*includes estimates of colonies not measured

Average density occupied **0.367**

Table 6: Counts of rockhopper penguin breeding pairs on Beauchêne Island in 2000.

Colony	New Area m2	Area m2	Average Density N	Nest/m2	CV%	Size old	Size new	Total CV%	Date	Direct count	Date	Breeding pairs	new pairs	% of Total	CV%	95%CI
Area A: big colony												**39,854**	**40,243**	64.68	3.66	2,886
BigColony	106,426.08	106,937.82	174(in 8)	0.359	34.3	38,375	38,191	3.76	23-Oct	too big		38,375	38,191		3.76	2,818
BigExtensior	1,935.66	1,395.12	8	1.060	40.14	1,479	2,052	15.47	28-Oct	not counted		1,479	2,052		15.47	622
Area B:east colonies												**3,713**	**3,679**	5.91	8.68	626
Little north	897.67	885.54	12	0.583	28.72	517	524	8.35	26-Oct	not counted		371	524		8.35	86
Big	5,350.14	5,671.58	12	0.583	28.72	3,308	3,121	10.13	26-Oct	too big		3,308	3,121		10.13	620
Tiny				too tiny						34	28-Oct	34	34		5	3
Area C:arenas												**9,551**	**9,418**	15.14	9.36	1,727
South Arena	26,243.08	23,584.12	37	0.231	74.09	5,440	6,053	12.63	28-Oct	too big		5,440	6,053		12.63	1,498
North Arena	9,169.48	11,206.07	30	0.367	60.50	4,111	3,364	13.03	28-Oct	too big		4,111	3,364		13.03	859
Area D: citadel												**2,011**	**1,948**	3.13	4.14	158
Bottom	3,379.49	3,907.86	16	0.120	13.9	469	406	5.78	29-Oct	not counted		469	406		5.78	46
Rest				too convoluted						1542	29-Oct	1,542	1,542		5	151
Area E: North end												**6,372**	**6,782**	10.90	6.89	916
Big	10,782.08	9,299.37	18	0.447	35.59	4,154	4,816	9.00	27-Oct	235	27-Oct	4,389	5,051		8.59	850
Little	1,668.74	2,234.34	12	0.230	72.33	514	384	22.55	27-Oct	not counted		514	384		22.55	170
Bigmissing	1,830.99	2,003.90	8	0.705	32.37	1,413	1,291	11.65	27-Oct	not counted		1,413	1,291		11.65	295
Littlemissing				too tiny						56	27-Oct	56	56		5	5
Rocky pond				inside tussock						150	27-Oct	**150**	**150**	0.24	5	15
Total		**174,016***										**61,651**	**62,218**		**2.91**	**3,545**

*includes estimates of colonies not measured
Average density **0.468**

Table 7: Counts of rockhopper penguin breeding pairs on Steeple Jason in 2005.

Colony	GPS area m2	Area m2	Average Density N	Nest/m2	CV%	Size	Date	Total CV%	Direct Count	Date	Breeding pairs	% of Total	CV%	95%CI
S1	57,536.22	62,489.44	71 (in 4)	0.235	131.63	14,681	22-Nov	131.63	147	22-Nov	**14,828**	25.12	15.59	4,175
S2	17,463.65	17,320.49	31 (in 2)	0.294	112.09	5,096	22-Nov	112.09	0	22-Nov	**5,096**	8.63	20.22	2,036
S3	103,521.93	90,254.73	77 (in 4)	0.207	175.19	18,707	24-Nov	175.19	0	24-Nov	**18,707**	31.69	20.09	8,448
S4				too convoluted					3,175	24-Nov	**3,175**	5.38	5	311
S5	85,154.02		76 (in 6)	0.152	168.41	12,908	25-Nov	168.41	668	25-Nov	**13,576**	23.00	18.53	4,931
S6				too convoluted					3,490	25-Nov	**3,490**	5.91	5	342
The neck				too tiny					162	25-Nov	**162**	0.27	5	16
Total		**302,449***									**59,033**		**9.37**	**10,838**

*includes estimates of colonies not measured
Average density **0.209**

Table 8: Counts of rockhopper penguin breeding pairs on Steeple Jason in 2000.

Colony	New Area m2	Area m2	Average Density N	Nest/m2	CV%	Size old	Size new	Date	Total CV%	Direct Count	Date	Breeding pairs	New pairs	% of Total	CV%	95%CI
S1	57,956.27	42,503.55	35 (in 2)	0.232	142.23	9,861	13,446	11-Nov	24.36	333	11-Nov	**10,194**	**13,779**	12.65	23.77	6,420
S2	14,081.63	19,185.36	21	0.187	138.60	3,581	2,629	14-Nov	31.51			**3,581**	**2,629**	2.41	31.51	1,624
S3	84,328.52	62,484.47	46 (in 3)	0.476	93.78	29,721	40,111	15-Nov	13.96			**29,721**	**40,111**	36.81	13.96	10,978
S4										5,876	13-Nov	**5,876**	**5,876**	5.39	5	576
S5	87,277.65	73,662.96	45 (in 4)	0.453	105.36	33,394	39,566	15-Nov	15.74	445	12-Nov	**33,839**	**40,011**	36.72	15.57	12,209
S6										5,280	13-Nov	**5,280**	**5,280**	4.85	5	517
The Neck										1,269	13-Nov	**1,269**	**1,269**	1.16	5	124
Total		**271,870***										**89,760**	**108,954**		**8.30**	**17,722**

*includes estimates of colonies not measured
Average density **0.370**

Table 9: Counts of rockhopper penguin breeding pairs on Grand Jason in 2000.

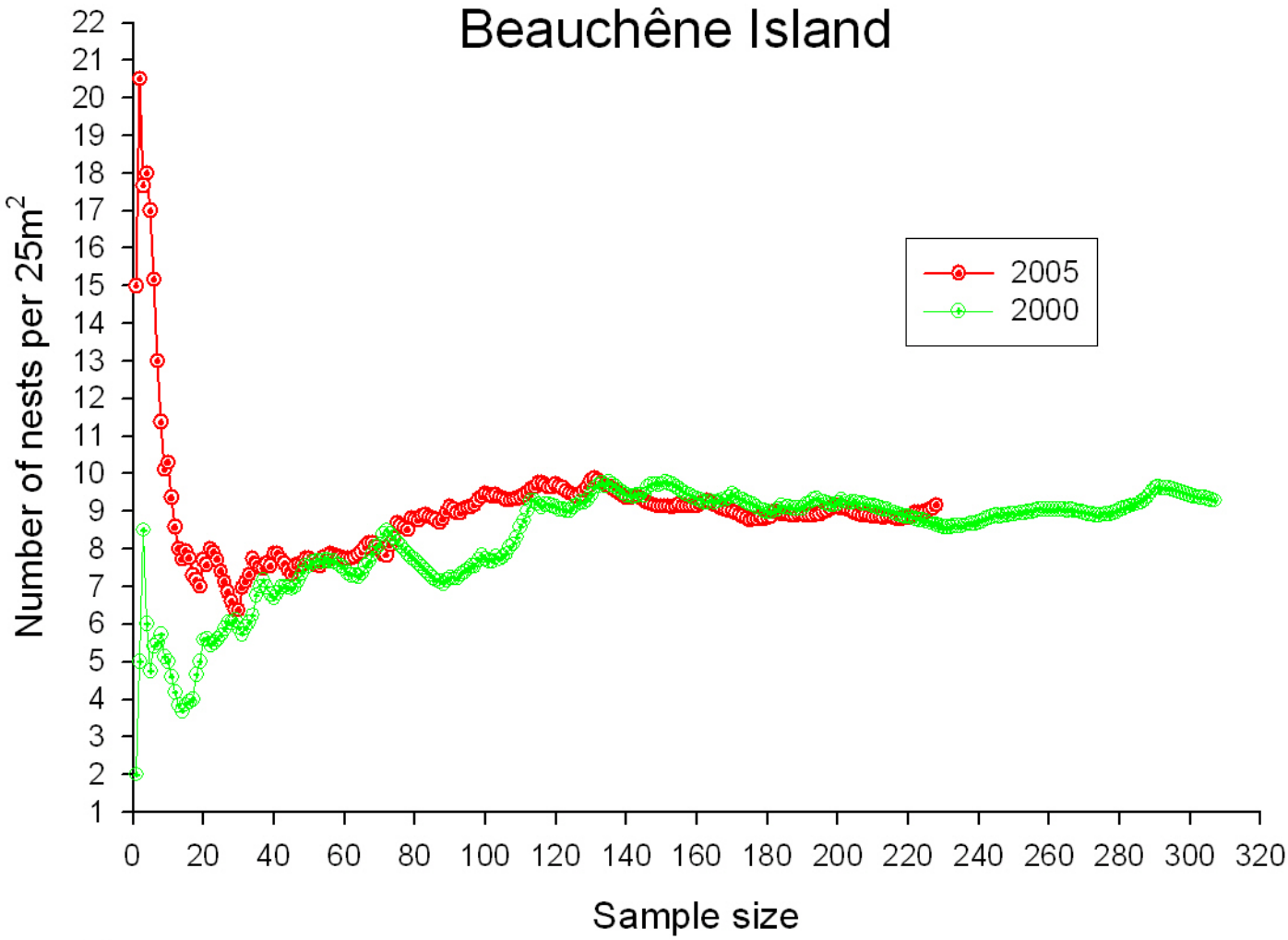
Colony	new Area m2	Area m2	Average Density N	Nest/m2	CV%	Size old	Size new	Total CV%	Date	Direct count	Date	Breeding pairs	new pairs	% of Total	CV%	95%CI
Eastend						**28,850**	**27,871**			**4,680**		**33,530**	**32,551**	**67.25**	8.55	5,456
Top big	5,652.43	5,451.93	11	1.135	37.69	6,185	6,413	11.37	16-Nov						11.37	1,430
Top little										627	16-Nov				5	61
Bottom										1,122	16-Nov				5	110
Flat top										2,931	16-Nov				5	287
Big bottom	21,658.02	22,875.96	26 (in 2)	0.991	63.66	22,665	21,458	12.50	16-Nov						12.50	5,256
Middle Big Colony										**4,505**		**4,505**	**4,505**	**9.31**	5	441
										4,505	17-Nov					
Western complex										**11,348**		**11,348**	**11,348**	**23.44**	4.84	1,076
Far West										373	17-Nov				5	37
Rest			very low density and highly convoluted							10,975	17-Nov				5	1,076
Total												**49,383**	**48,404**		**5.88**	**5,579**

In 2005, colony areas measured on Beauchêne Island (Table 5) and Steeple Jason (Table 7) by laser and compass were similar to measurements obtained by GPS. In fact, the difference between the two methods was not significant (paired T-test: $t_{1,6}$=0.52, p=0.52, n.s.). It is harder to compare values of areas obtained between 2005 and 2000 (Tables 6 to 9) as some colony areas changed during the five years, but the results obtained in 2005 have less error than in 2000 as they were obtained from a much larger number of waypoints, increasing the number of possible colony spins (Average Coefficient of Variation of all colonies measured is 10.2% in 2005 compared to 14.6% in 2000). No comparison of area between the two censuses can be made for colonies that were counted directly. On Beauchêne Island the total area occupied by all the colonies was 20.2 ha in 2005 and 17.4 ha in 2000. This difference in area between the two censuses is not significant (paired T-test, t=1.08, p=0.33, n.s.). The areas are reduced from the first census in 1981, when the colonies covered a total area of 23.0 ha. Similarly on Steeple Jason the area covered by the colonies was 30.2 ha in 2005 and 27.2 ha in 2000. This difference is not significant (paired T-test, t=1.47, p=0.20, n.s.). In the first (1988) census of the island conducted, the colonies covered an area of 31.8 ha.

The density of nests within the large colonies fluctuated between censuses and intermediate counts conducted by FC (unpublished data). On Beauchêne Island the density changed from 1.30 nest.m^{-2} in 1981 (Lewis Smith & Prince 1985) to 0.30 in 1991, to 0.32 in 1995, to 0.47 in 2000 and to 0.37 in 2005. Although the decline in density was not significant ($F_{1,3}$=4.07, p=0.14), the trend line explained 57.6% of the variation in density. On Steeple Jason the nest density was 0.60 nest.m^{-2} in 1988 (Thompson & Rothery 1991) and steadily decreased to 0.36 in 1995, 0.37 in 2000, 0.10 in 2003, and 0.21 in 2005. Such decline was significant ($F_{1,3}$=14.9, p<0.05) and explained 83.3% of the variation in nest density.

The breeding density is estimated by transects which were conducted across sections of the colonies. Such a method is a trade-off between having a robust enough estimate of the true density and minimising the disturbance to breeding birds. To assess the quality of our estimates, we plotted the cumulative average and coefficient of variation of the number of nests within each 25m^2 squares by combining all transect lines together both at Beauchêne Island and Steeple Jason (Figures 5 and 6). The average number of nests per 25m^2 stabilises after a sample size of 120 squares, although anomalies occur throughout due to nests occurring at a lower density at the edges of the colonies. Similarly, variation stabilises after 120 samples and remains very high at between 90 to 140%. Such high variation is a cause for concern and rise doubts as to the validity of the method in counting accurately the total number of birds

Figure 5: changes in nest density of Rockhopper penguin with sample size



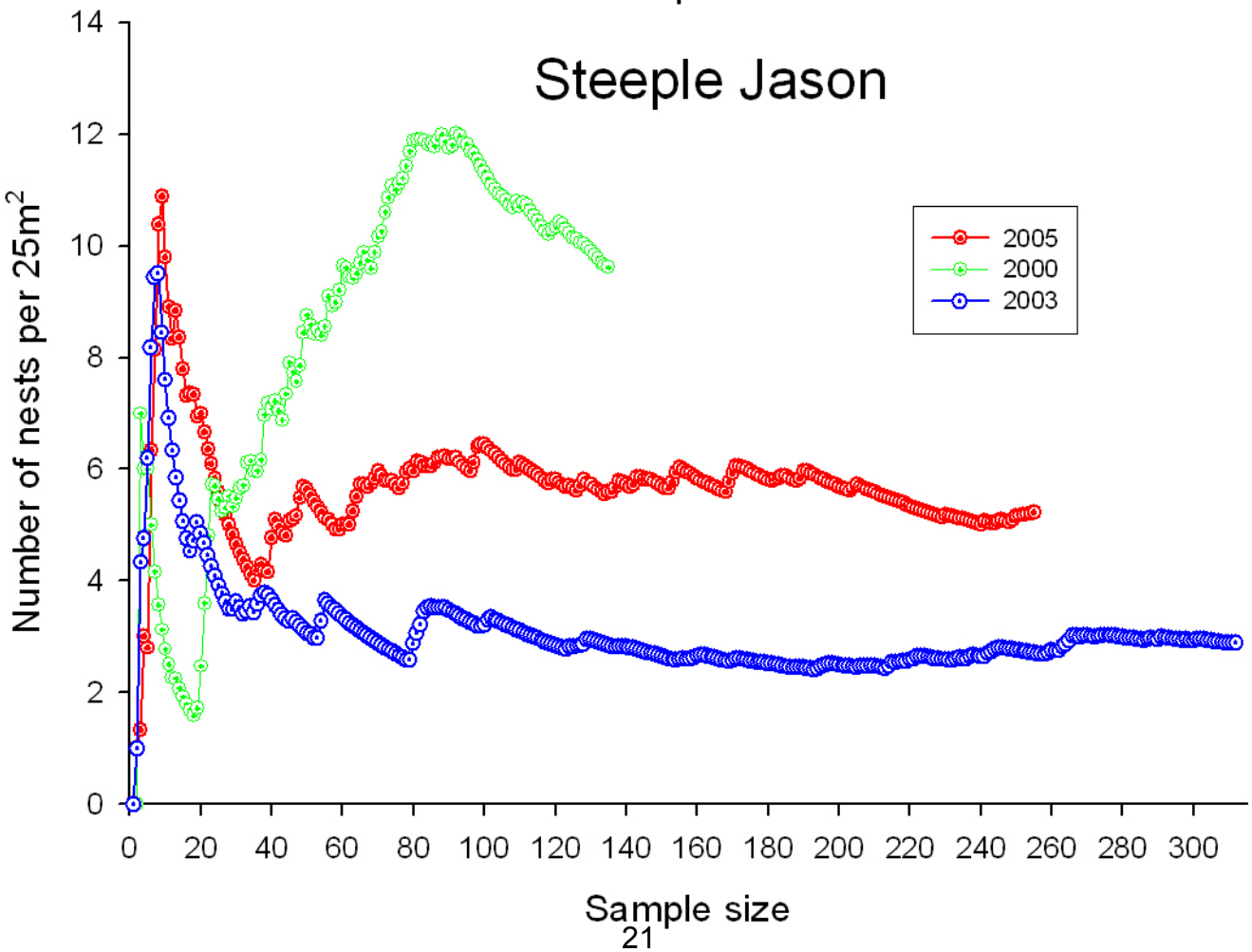
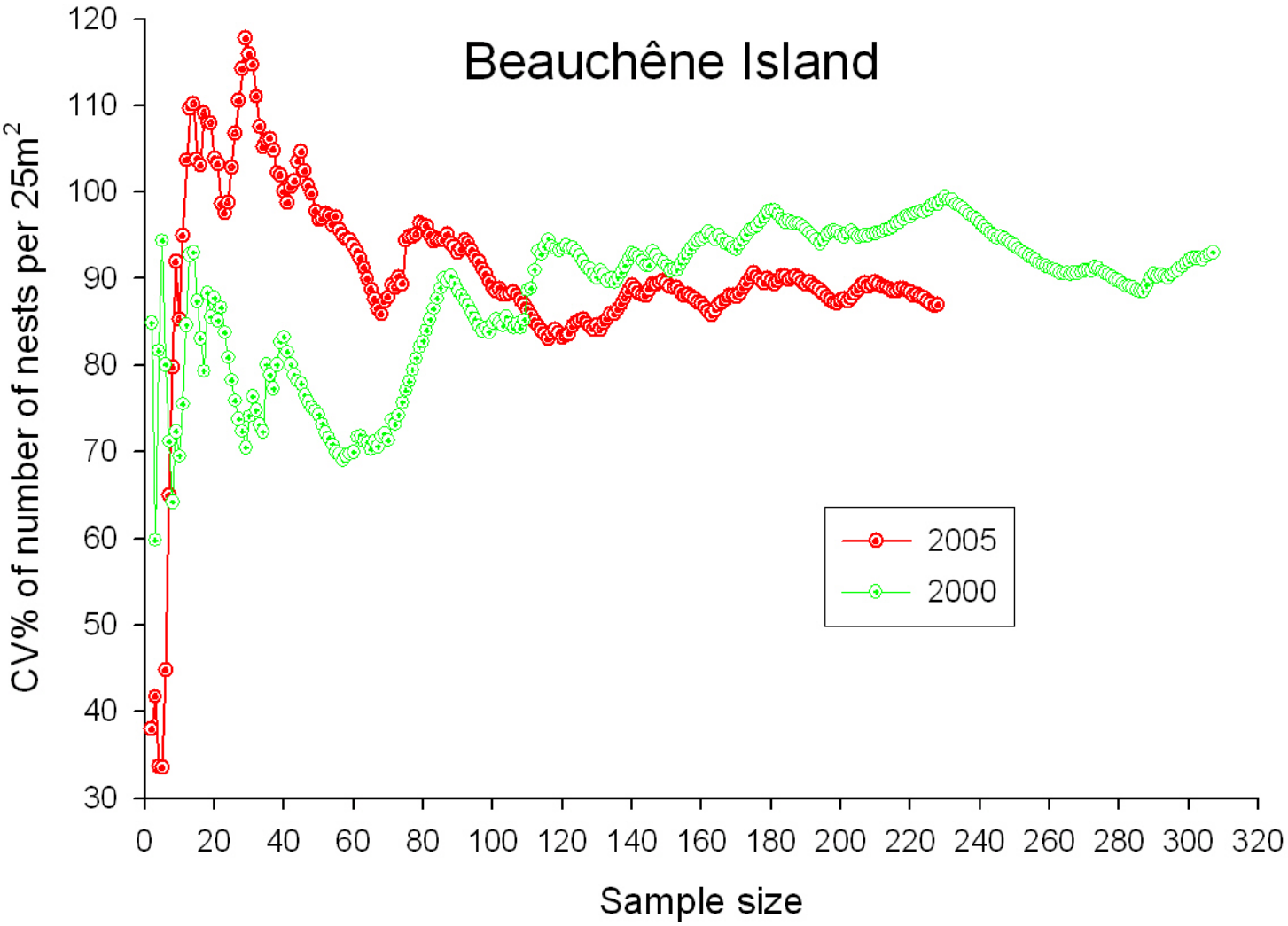
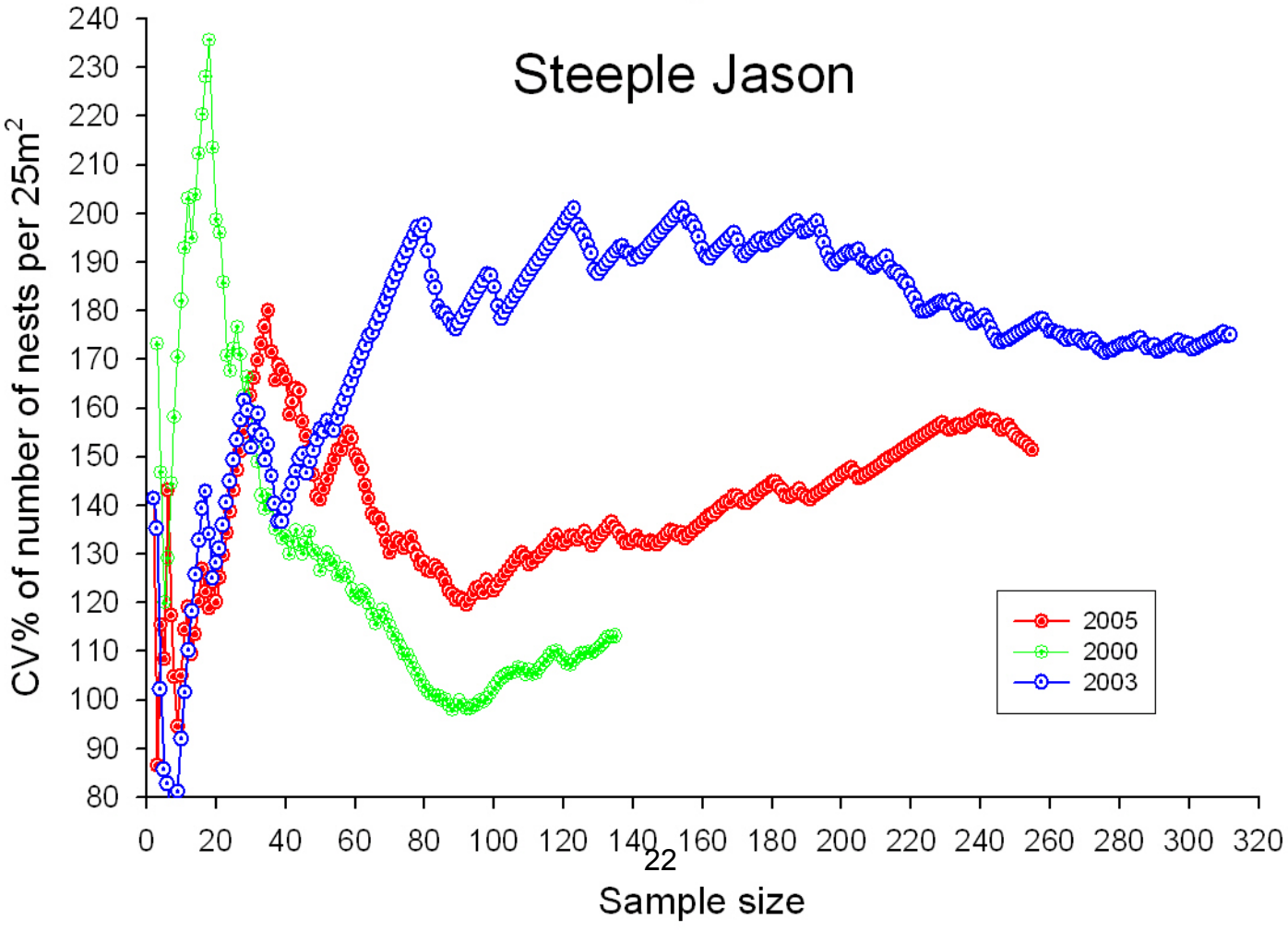


Figure 6: changes in CV% of nest density of Rockhopper penguin with sample size





breeding in such large colonies. Some of the variation can be explained by the natural variations in density within the colonies, but it also increased in years when density was low. This may reflect changes in penguin dispersion in these mixed species colonies, whereby rockhopper penguins now occur mainly in high-density pockets within the areas occupied by black-browed albatrosses, leaving former breeding areas untenanted.
Nevertheless, multiplying colony areas by their breeding densities revealed that the population on Beauchêne Island increased from 62,218 pairs in 2000 to 71,343 in 2005. Such difference is just significant ($d=2.04$, $p<0.05$). In contrast the population breeding on Steeple Jason decreased from 108,954 pairs in 2000 to 59,033 pairs in 2005. This difference is highly significant ($d=4.71$, $p<0.0001$).

Colony counts

Rockhopper penguins currently breed at a total of 35 sites in the Falkland Islands. Tables 5 to 9 give full details for the three major sites for 2005 and 2000; Table 10 shows all the counts of all the colonies from the last three censuses of 2005, 2000 and 1995, with modified numbers due to the new colony spinning method and extrapolation of numbers from missing colony counts. Overall, the population size (pairs) changed from 287,799 in 1995 to 298,496 ± 18,976 in 2000 and to 210,418 ± 13,584 in 2005. (There is no associated error to the values of 1995, as the method used to count large colonies is not given). This represents an increase in numbers of 10,697 pairs between 1995 and 2000 (at a rate of increase of 0.74% per annum), but a decrease of 88,078 pairs between 2000 and 2005 (at a rate of decline of 5.9% per annum). Overall, over the last ten years, this represents a loss of 77,381 pairs or a rate of decline of 2.7% per annum.
However, these changes are not constant across all sites as can be seen from Figure 7. Between 1995 and 2000 when the population increased, 13 out of 35 sites decreased (37%). There was no geographical pattern to the distribution of the sites that increased or decreased. Between 2000 and 2005 when the population decreased, 10 out of 35 sites increased (28%). Apart from Beauchêne Island, most of the sites that increased were situated in the centre of the north coast between Saunders Island in the west and Fanning Head in the east. Compared to the gentoo penguin, it is difficult to assess which part of the islands where affected by the HAB event of 2002/2003 as there are areas where rockhopper penguins were affected, but not gentoo penguin; like in the north-east of the islands, doubtless reflecting interspecies differences in foraging area. Rockhopper penguins tend to forage further out to sea than gentoo penguins and therefore had more opportunities for contact with the HAB event, whereas gentoo penguins tend to stay close to their breeding colonies (Pütz et al. 2003b).
Between 67% (in 2005) and 75% (in 1995) of the population breed at the three major sites. These are Beauchêne, Steeple and Grand Jason islands. In terms of the overall Falklands population, the proportions varied as follows: Beauchêne Island from 24% in 1995, to 21% in 2000 and to 34% in 2005; Steeple Jason from 38.5% in 1995 to 36.5% in 2000 and to 28% in 2005; Grand Jason from 12% in 1995 to 16% in 2000 and to 5% in 2005. Although these three big colonies follow the same trend as the rest of the islands, the difficulty in counting these massive colonies must be stressed, especially with regard to the irregular dispersion of the penguins within the colonies (producing a large coefficient of variation in nest density). This is compounded by the previous difficulties in measuring accurately the colony areas. However, this problem

Table 10: Rockhopper penguin breeding population of the Falkland Islands in the 2005, 2000 and 1995 censuses

Place	Area	Colony	Date start	end	Method	Counts	Breeding pairs 2005	% of total	2000 census revised	Changes %	1995 census revised	Changes %	1995 to 2005
Total							**210,418**		**298,496**	**-29.51**	**287,799**	**3.72**	**-26.89**
1. Islands													
Arch Island		5	8-Nov	9-Nov	Direct		**462**	0.22	**698**	-33.81	**411**	69.83	12.41
Beauchêne Island			4-Nov	9-Nov	Direct+Transect		**71,343**	33.91	**62,218**	14.67	**69,227**	-10.12	3.06
	see details	14				see details							
Bird Island			13-Nov	14-Nov	Direct		**7,365**	3.50	**7,858**	-6.27	**10,600**	-25.87	-30.52
		main				4,261		*5209*					
		little				497		*1390*					
		medium				1,749		*in above*					
		furseals				858		*1259*					
Bleaker Island		1	4-Nov		Direct		**766**	0.36	**746**	2.68	**700**	6.57	9.43
Clump Island		2	9-Nov		Direct		**214**	0.10	**209**	2.39	**83**	151.81	157.83
Cochon Island		1	11-Jan		Chick		**384**	0.18	**264**	45.45	**515**	-48.74	-25.44
Elephant Jason			28-Nov		Direct		**859**	0.41	**844**	1.78	**100**	744.00	759.00
Grand Jason			27-Nov	28-Nov	Direct+photos		**10,496**	4.99	**48,404**	-78.32	**34,000**	42.36	-69.13
	Eastern					6,504		*32,551*					
	Middle					731		*4,505*					
	Western					3,261		*11,348*					
Hummock Island			19-Nov		Direct		**73**	0.03	**871**	-91.62	**540**	61.30	-86.48
Keppel Island			30-Nov		Direct		**1,047**	0.50	**782**	33.89	**1,168**	-33.05	-10.36
Kidney Island		1	10-Nov		Chick		**253**	0.12	**257**	-1.56	**100**	157.00	153.00
New Island			17-Nov		Photo+direct+scan		**5,667**	2.69	**7,413**	-23.55	**5,500**	34.78	3.04
	North Bluff					549		*1,847*					
	shanty					81		*311*					
	precipice hill					226		*262*					
	Landsend bluff					103		*293*					
	settlement					4,708		*4700*	*missing*				
North Island			18-Nov		Direct		**3,314**	1.57	**3,462**	-4.27	**3,472**	-0.29	-4.55
Passage islands							**272**	0.13	**456**	-40.35	**392**	16.33	-30.61
	First		19-Nov		Direct	147		*311*		267			
	Second		15-Nov		Photos	125		*145*		125			
Pebble Island							**8,583**	4.08	**6,778**	26.63	**6,702**	1.13	28.07
	Marble Mountain		19-Nov		Direct	5,106		*3,070*					
	Tamar Pass		18-Nov		Direct	3,477		*3,708*					
Rabbit Island			19-Nov		Direct		**301**	0.14	**793**	-62.04	**600**	32.17	-49.83
Saunders Island							**9,126**	4.34	**6,912**	32.03	**5,781**	19.56	57.86
	The Neck		3-Nov		Direct	5,076		*3,801*					
	Holy City		4-Nov		Direct	1,421		*1,294*					
	Rookery Mt		5-Nov		Direct	2,629		*1,817*					
SeaLion Island		4	18-Nov		Direct		**360**	0.17	**484**	-25.62	**504**	-3.97	-28.57
South Jason		1	30-Nov		Photos		**453**	0.22	**889**	-49.04	**300**	196.33	51.00
Steeple Jason			20-Nov	25-Nov	Direct+Transect		**59,033**	28.06	**108,954**	-45.82	**111,171**	-1.99	-46.90
	see details	6				see details							
West Point Island			16-Nov		Direct+photos		**2,085**	0.99	**5,004**	-58.33	**4,042**	23.80	-48.42
	Cape Terrible	1				91		*687*					
	Devil's nose	3				360		*1,574*					
	Mt Misery	5				1,634		*2,743*					
White Rock					photos	missing	*100*	0.05	**100**	0.00	**150**	-33.33	-33.33
2. East													
Fanning Head		2	12-Nov		Direct		**1,317**	0.63	**1,273**	3.46	**1,071**	18.86	22.97
		1				386							
		2				931							
Cape Bougainville		8	14-Nov		Direct		**1,385**	0.66	**1,723**	-19.62	**1,943**	-11.32	-28.72
Berkeley Sound South							**1,445**	0.69	**2,455**	-41.14	**1,910**	28.53	-24.35
	Murrell	3	18-Nov		Direct	385		*2,080*					
	extra colonies					810							
	Long Island	3	18-Nov		Direct	250		*375*					
McBride Head		9	19-Nov		Direct		**3,073**	1.46	**4,868**	-36.87	**4,146**	17.41	-25.88
Seal Bay			20-Nov		Direct		**8,734**	4.15	**9,931**	-12.05	**8,487**	17.01	2.91
	Seal Bay	13				5,405		*6,387*					
	Rabbit Rincon	7				3,329		*3,544*					
Campa Menta		1	20-Nov		Direct		**450**	0.21	**482**	-6.64	**380**	26.84	18.42
Diamond Cove		3	21-Nov		Direct		**148**	0.07	**152**	-2.63	**155**	-1.94	-4.52
Berkeley Sound North			21-Nov		Direct		**1,909**	0.91	**2,334**	-18.21	**2,460**	-5.12	-22.40
	Rugged Hill	5				741							
	Eagle Hill	10				1,168							
3. West													
Stephens Peak		8	11-Nov		Direct		**1,250**	0.59	**2,574**	-51.44	**2,504**	2.80	-50.08
Tamar Point		4	17-Nov		Direct		**2,300**	1.09	**1,988**	15.69	**2,566**	-22.53	-10.37
Carcass Point		2	22-Nov		Direct		**2,896**	1.38	*3,300*	missing	**3,783**	-12.77	-23.45
Penguin Point			15-Nov		Direct		**219**	0.10	**242**	-9.50	**93**	160.22	135.48
	north	2				67							
	south					152							
Hope Harbour		3					**2,736**	1.30	**2,778**	-1.51	**2,243**	23.85	21.98
	Death Head Ridge		Nov		Direct	468		*576*					
	Death Head		Nov		Direct	1,786		*1,677*					
	Boxwood Point		Nov		Direct	482		*525*					

Figure 7: Changes in Rockhopper penguin population of the Falkland Islands between 1995 and 2005

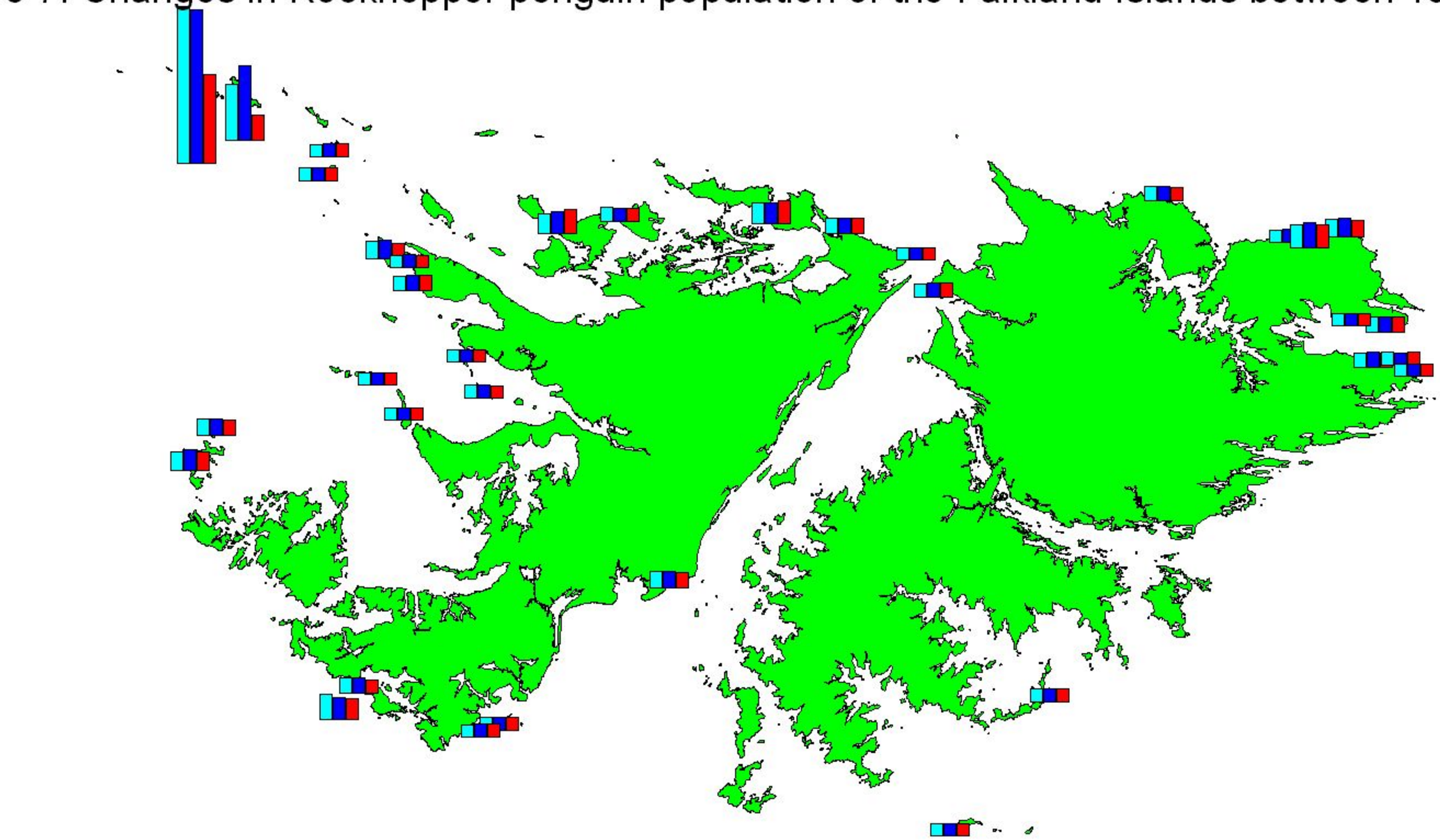
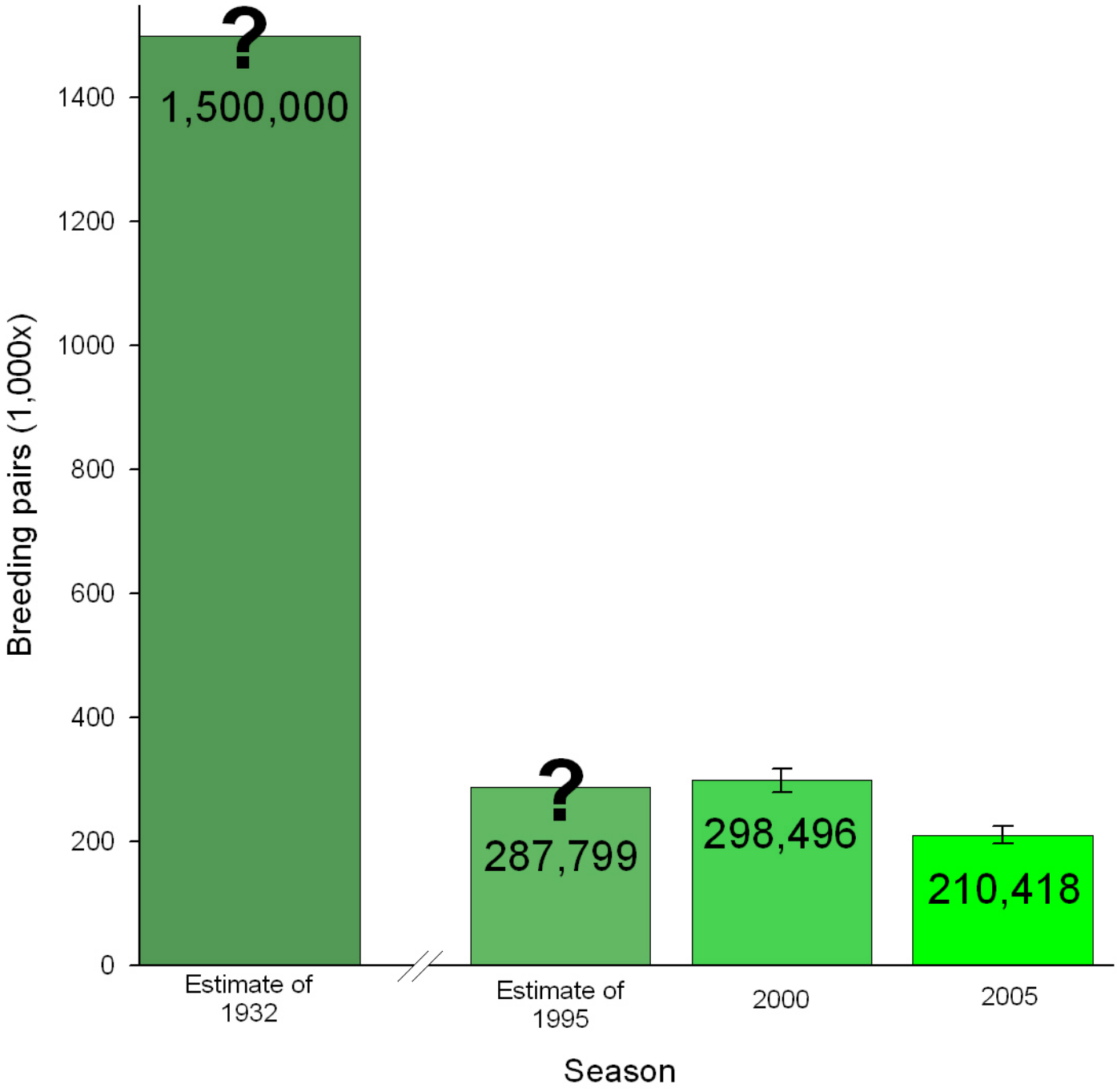


Figure 8: Reconstructed trends in the Falkland Islands Rockhopper penguin population



has now been solved, either by spinning the colonies or by using a GPS unit to measure them accurately.

Comparison with previous records

Prior to the last three censuses, there is only one record of a comprehensive survey (Bennett 1933). This census had some errors, but the main ones have recently been rectified (Pütz et al. 2003a). Thus in 1932 the estimated population of rockhopper penguins breeding in the Falkland Islands was around 1.5 million pairs. The current population of 210,418 pairs in 2005 thus represents an 86% decline over the last 73 years at an annual rate of decrease of 1.18% (Figure8). However, this decline was unlikely to have been constant across the years. Originally one of the main reasons for the decline was massive collection of eggs for food consumption (tens of thousands per year), which virtually stopped after the 1950s (Woods and Woods 1997). There are few data between the 1950s and 1980s. In the 1985/86 season a mass mortality event took place late in the season, associated with lack of food just before the moulting period (Keymer et al. 2001). Since then the rockhopper penguins seemed to recover slowly, increasing in number between the 1995 and 2000 censuses (Huin 2005). This latest recovery stopped with the mass mortality associated with the HAB event of 2002 (Uhart et al. 2004). In between such irregular and unpredictable mortality events, rockhopper penguins appear able to maintain or increase slightly their numbers, but without being able to achieve any sustainable recovery towards their original numbers. Such inability to recover from population crashes and the associated decline of this species has been suggested to relate to long-term changes in primary productivity of the oceans and a shift in prey to lower trophic levels (Hilton et al. 2006).

This substantial decrease in the Falkland Islands population to 210,418 breeding pairs will affect the world population of southern rockhopper penguin. There are only four other major sites in South America and at all of them population numbers have also been re-evaluated recently. The colony on Staten Island in Argentina has only been recently discovered (1998) and it was estimated that 173,793 pairs breed on this island (Schiavini 2000). The three islands in southern Chile where rockhopper penguins breed have been visited recently and their population size estimated. On Isla Noir a total of 134,000 pairs were counted in 2003, on Isla Ildefonso a total of 86,400 pairs and on Isla Diego Ramirez a total of 132,721 pairs were estimated to breed in 2002 (Kirkwood et al., in press). The combination of new counts in South America and new decline in the Falkland Islands means that Chile holds 47.9% of the population with a further 28.5% breeding in the Falkland Islands and 23.6% breeding in southern Argentina. This brings the total population breeding in southern America to an estimated 737,332 pairs.

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REFERENCES

Bennett, AG. 1933. The Penguin population of the Falkland Islands in 1932/33. Government Press, Falkland Islands. 4 pages.

BirdLife International 2006. Species fact sheets for penguins. Downloaded from http://www.birdlife.org.

Clausen, AP. & Huin, N. 2003. Status and numerical trends of King, Gentoo and Rockhopper penguins breeding in the Falkland Islands. Waterbirds 26(4): 389-402.

Croxall, JP. & Prince, PA. 1979. Antarctic seabird and seal monitoring studies. Polar Record 19: 573-595.

Hilton, GM., Thompson, DR., Sagar, PM., Cuthbert, RJ., Cherel, Y. & Bury, SJ. 2006. A stable isotopic investigation into the causes of decline in a sub-Antarctic predator, the rockhopper penguin *Eudyptes chrysocome*. Global Change Biology 12: 611- 625.

Huin, N. 2001. Census of the Black-browed Albatross population of the Falkland Islands 2000/2001. Falklands Conservation Report.

Huin, N. 2003. Falkland Islands Seabird Monitoring Programme Annual Report 2002/2003. Falklands Conservation report. 52pp.

Huin, N. 2005. Falkland Islands Seabird Monitoring Programme Annual Report 2003/2004 & 2004/2005. Falklands Conservation report. 82pp.

Huin, N. & Reid, TA. 2006. Census of the Black-browed Albatross population of the Falkland Islands 2000 and 2005. Falklands Conservation Report.

Keymer IF., Malcolm, HM., Hunt, A. & Horsley, DT. 2001. Health evaluation of penguins (Sphenisciformes) following mortality in the Falklands (South Atlantic). Diseases of Aquatic Organisms 45: 159-169.

Kirkwood, R., Lawton, K., Merono, C., Valencia, J., Schlatter, R. & Robertson, G. in press. Estimates of Southern Rockhopper and Macaroni Penguin numbers at the

Ildefonso and Diego Ramírez Archipelagos, Chile, using quadrat and distance-sampling techniques. Waterbirds.

Lewis Smith, RI. & Prince, PA. 1985. The natural history of Beauchêne Island. Biological Journal of the Linnean Society 24: 233-283.

Pütz, K, Clausen AP., Huin, N. & Croxall, JP. 2003a. Re-evaluation of historical Rockhopper penguin population data in the Falkland Islands. Waterbirds 26: 169-175.

Pütz, K, Smith, JG., Ingham, RJ. & Lüthi, H. 2003b. Satellite tracking of male Rockhopper penguins *Eudyptes chrysocome* during the incubation period at the Falkland Islands. Journal of Avian Biology 34: 139-144.

Prince, PA. 1982. The Black-browed Albatross *Diomedea melanophris* population at Beauchêne Island, Falkland Islands. Comité National Français des Recherches Antarctiques 51: 111-117.

Reid, TA. & Huin, N. 2005. Census of the Southern Giant Petrel population of the Falkland Islands 2004/2005. Falklands Conservation Report.

Schiavini, A. 2000. Staten Island, Tierra del Fuego: the largest breeding ground for Southern Rockhopper Penguins. Waterbirds 23: 286-291.

Thompson, KR. & Rothery, P. 1991. A census of the Black-browed Albatross *Diomedea melanophris* population on Steeple Jason Island, Falkland Islands. Biological Conservation 56: 39-48.

Uhart, M., Karesh, W., Cook, R., Huin, N., Lawrence, K., Guzman, L., Pacheco, H., Pizarro, G., Mattsson, R. & Mörner, T. 2004. Paralytic Shellfish poisoning in Gentoo penguins (*Pygoscelis papua*) from the Falkland (Malvinas) Islands. In 2004 proceedings of the AAZV, AAWV, WDA joint conference. pp 481- 486.

White, RW, & Clausen, AP. 2002. Rockhopper *Eudyptes chrysocome chrysocome* x Macaroni *E. chrysolophus* penguin hybrids apparently breeding in the Falkland Islands. Marine Ornithology 30: 40-42.

Woods, RW. & Woods, A. 1997. Atlas of the breeding birds of the Falkland Islands. Anthony Nelson, Oswestry, UK.

Appendix 1

Example of photographs held in the photographic library

1. Fixed point photographs on Beauchêne Island taken in 1980 (top left side) and 2000 (bottom right side).

2. Photographs of the east side of the main colony on Steeple Jason taken in 1982 (top left side) and 2005 (bottom right side).