Census of the Black-browed Albatross population of the Falkland Islands 2000 and 2005

Nic Huin & Tim Reid
Falklands Conservation
June 2006

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Registered office: 1 Princes Avenue, Finchley, London N3 2DA, UK
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SUMMARY

The first two complete censuses of the Black-browed Albatross population of the Falkland Islands were conducted in November 2000 and 2005. The albatross breeds on twelve different islands to the west and south of the archipelago. Colony size ranged from 30 to 181,000 breeding pairs. The total number of breeding pairs in the Falklands changed from 414,268 ± 12,160 in 2000 to 399,416 ± 9,743 in 2005. This represents a decline of 0.7% per annum of original numbers. Although no previous complete census exists, combining historical data showed that the population consisted of around 437,855 pairs in 1995. This represents a total loss of 38,439 pairs in the last ten years, or a decrease of just below 1% per annum. Such changes are not consistent between seasons and sites. The creation of a photographic database helped in identifying areas of the colonies that have shrunk due to the reduction in breeding numbers. The Falkland Islands now holds 65% of the world population of this species, which should retain its status of Endangered species. This decrease is linked with increased mortality at sea due to fishing activities such as longlinning and trawling, not only in Falklands waters, but throughout its range in the southern hemisphere. The reduction of such mortality to negligible levels (as recently achieved through improved management in Falkland Islands waters) is an essential condition for the survival of the Black-browed Albatross.

INTRODUCTION

Concerns have been raised about the current status of most species of albatross and petrels, due to the population declines of many species (Gales 1998). Many of these declines have been attributed to mortality in fisheries, including longline (e.g. Brothers 1991; Nel et al. 2002) and trawl fisheries (Bartle 1991; Sullivan et al. in press a). Due to these declines, 19 of 21 species of albatross have been listed as globally threatened by the IUCN (BirdLife International 2005); hence the albatrosses have become the most threatened bird family.

One species, the Black-browed Albatross, *Thalassarche melanophris*, breeds in the Falkland Islands. It has the largest population of any species of albatross, with a population that was estimated at over 682,000 pairs worldwide, and with the majority of the population breeding within the Falkland Islands (Gales 1998). Birds breed at two very large colonies, the largest on Steeple Jason (Thompson & Rothery 1991) and the second on Beauchêne Island (Prince 1982), which together represent 70% of the islands population, with the rest of the birds breeding at a further 10 sites around the west of the Falkland Islands (Woods & Woods, 1997). Although no full census had been conducted before 2000, most of the breeding sites had been visited and their numbers estimated either by scientists, Falklands Conservation staff or private landowners with interests in the species (e.g. West Point Island and New Island). Studies of the albatross population of the Falkland Islands have slowly increased the knowledge of this species. It started with basic monitoring of population size and breeding success at a few sites, coupled with diet studies (Thompson 1992, Thompson and Riddy 1995) and followed by studies of foraging range (Huin 2002a and 2002b). The first full island census was conducted in 2000 (Huin 2001). Studies on the interaction between albatrosses and the fishing industry in Falkland Islands waters also started in 2000 and are still carried out to determine the impact of such interactions and the development and use of mitigation measures to diminish such impacts (e.g. Sullivan et al., in press a and b, Reid et al. 2004).

The first census of 2000 revealed that like in other parts of the world (Croxall et al. 1998, Weimerskirch and Jouventin 1998), the Black-browed Albatross population was decreasing in the Falkland Islands. Such a decline could be caused by a wide range of problems, but is predominantly linked to increased mortality at sea. Such mortality is due to interactions with fishery activities (longlining and trawling). These interactions are also diverse and can affect birds at different times, areas and birds of different ontogenic stages (males, females, juveniles, summer or winter for example) and with no long term demographic studies as yet yielding results, there is no way to determine which part of the population is the most affected.
In this report we present results from the latest five-yearly census conducted in November 2005 and reassess numbers obtained from the 2000 census in view of new methods developed here to measure colony areas more accurately. Recent trends in population size are then re-examined and historical records analysed to assess changes within the past ten years in the Falkland Islands population of Black-browed Albatross. A photographic database has also been created to record changes in colony sizes for future reference.

METHODS

The first census was conducted between 21 October and 30 November 2000 by Nic Huin with the help of Andy Black, Mike Morisson and Craig Westlaig. The second census was conducted between 02 November 2005 and 30 November 2005 by Nic Huin, Tim Reid, Oli Yates, Mike Morisson, Alan Henry, Sarah Crofts and Cleo Small. In both seasons all twelve islands where Black-browed Albatross breed were visited. Saunders Island (See Figure 1 for locations mentioned in the text) was reached by plane and other islands were reached by boat (Penelope in 2000 and Condor in 2005, Mike Clarke owner/skipper). Surveys techniques employed were consistent between censuses and comprised of a suite of three 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 appropriate (i.e. small to medium size). 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 differences between observers were less than 5%.

Photographic Method

In both censuses, photographs were taken of colonies that spread out on cliff faces at West Point, South Jason and New islands and Grave Cove. To reduce time on land in 2005, photographs were also taken of the cliff faces of North Island and of parts of the colonies of Grand Jason Island. In 2000, 320 black and white print photographs were taken. Photographs were overlaid with transparent sheets and overlaps between pictures marked and nests counted. In 2005 a total of 1,250 digital high definition colour photographs were 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 survey of Southern Giant Petrels, *Macronectes giganteus*, Survey in 2004 (Reid & Huin, 2005). All photographs were detailed enough to identify standing and non-breeding birds from the counts. The accuracy of the photographic counts is 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 Beauchêne Island and Steeple Jason Island in both the 2000 and 2005 seasons and for some parts of Grand Jason Island in 2000.The principle behind this method is to measure the area of a colony, measure 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 by ground survey rather than by aerial photography and that strip transects to estimate density were made rather than circular plots.

Colony area

In 2000, the perimeter of colonies was measured with a rope marked every two metres and a compass marked every 2 degrees. In 2005, the rope was replaced with a laser range finder (Leica DISTO™ lite[5]), with an accuracy of 3mm. 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 the rope or range finder. At this point distance and direction from one point to the next were recorded and the second person joined the first person and so on 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 points in essence are relative polar coordinates and were transformed to positive absolute orthogonal coordinates from which the total area of each colony can be calculated (see appendix 1).

The problem with this method is that each point is dependent of the previous point and 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 having started 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). This method of averaging multiple simulations (thereafter referred to as colony spinning) to calculate area was only recently developed and was not originally employed for the 2000 census. Thus a re-calculation of results previously presented (Huin 2001) was needed. Also in 2005, 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. In 2000, six small sized colonies (<5,000 nests) on Beauchêne Island were counted both by this method and by direct count to compare results between methods.

Density

The density of nests within the colonies was estimated by conducting strip transects (Croxall and Prince 1979). This method was preferred to circular plots 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 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 (Rockhopper penguins, *Eudyptes chrysocome*, and King cormorants, *Phallacrocorax 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.

In using the second method of measuring area, errors come from inaccuracies in range and direction of compass between consecutive points. Such error is cumulative as each point is located 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:

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

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 up 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 then 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:

$(N_2-N_1)/N_1/n_{years}*100$ or when mentioned in the text were compounded:

$(N_2-N_1)/average(N_1,N_2)/n_{years}*100$.

Table 1: Black-browed Albatross counts from Beauchêne Island in 2005.

Black-browed Albatross Beauchêne Island 2005

Colony	GPS area	Area		Average Density		Size	Date		Empty nests			Total	Direct Count	Date	Breeding pairs	%	CV%	95%CI
	m2	m2	N	Nest/m2	CV%			N	empty/m2	total	%	CV%				of Total		
Area A: big colony															**78,230**	71.78		
BigColony	135,279.50	134,790.25	114 (in 4)	0.497	31.89	67,017	5-Nov	236	0.083	11,162	14.28	3.17	52	6-Nov	78,230		3.17	4,873
Area B:east colonies													2,071		**2,071**	1.90	4.22	171
Little north				too tiny						too tiny			273	7-Nov	273		5	27
Big				too tiny						too tiny			1,727	7-Nov	1,727		5	169
Tiny				too tiny						too tiny			71	7-Nov	71		5	7
Area C:arenas															**18,025**	16.54	5.23	1,810
South Arena	29,516.44	31,163.61	52 (in 2)	0.362	49.88	11,291	4-Nov	93	0.072	2,229	16.49	6.83	13	4-Nov	13,533		6.83	1,715
North Arena	7,719.74	7,157.25	25	0.515	29.67	3,687	4-Nov	70	0.112	802	17.86	6.09	3	4-Nov	4,492		6.09	578
Area D: citadel													3,313		**4,359**	4.00	4.91	420
Bottom	3,443.49	3,419.72	17 (in 2)	0.247	50.31	845	4-Nov	25	0.059	201	19.23	12.91	3		1,049		12.87	267
Rest				too convoluted						too convoluted			3,310	7-Nov	3,310		5	324
Area E: North end													1,597		**6,209**	5.70	7.63	928
Big	10,203.95		20	0.404	42.48	4,122	9-Nov	24	0.048	490	10.62	10.20	61	9-Nov	4,673		10.07	922
Little				too tiny						too tiny			705	9-Nov	705		5	69
Bigmissing				too tiny						too tiny			780	9-Nov	780		5	76
Littlemissing				too tiny						too tiny			51	9-Nov	51		5	5
East Cliffs				too dangerous						too dangerous			89	3-Nov	**89**	0.08	5	9
Total		**202,014***													**108,984**		**2.48**	**5,300**

*includes estimates of colonies not measured

Average density		
occupied	empty	total
0.442	**0.079**	**0.521**

Table 2: Black-browed Albatross counts from Beauchêne Island in 2000.

Black-browed Albatross Beauchêne Island 2000

Colony	New Area	Area		Average Density		Size		Date		Empty nests				Total	Direct Count	Date	Breeding pairs	%	new	CV%	95%CI
	m2	m2	N	Nest/m2	CV%	old	new		N	empty/m2	total	newtotal	%	CV%				of Total	pairs		
Area A: big colony																	**70,710**	68.62	**70,684**	3.10	4,297
BigColony	106,426.08	106,937.82	174(in 8)	0.612	31.78	65,416	65,103	23-Oct	183	0.042	4,499	4,477	6.43	3.14	too big		69,915		69,581	3.14	4,287
BigExtension	1,935.66	1,395.12	8	0.540	25.66	753	1,045	28-Oct	6	0.030	42	58	5.26	13.70	not counted		795		1,103	13.70	296
Area B:east colonies				ratio: area/directcount		1.456	1.388								2,243		**2,243**	2.18	**2,243**	4.18	184
Little north	897.67	885.54	12	0.486	36.31	430	436	26-Oct	12	0.040		36	6.78		344	21-Oct	344		344	5	34
Big	5,350.14	5,671.58	12	0.486	36.31	2,756	2,600	26-Oct	12	0.040		214	6.78		1,844	21-Oct	1,844		1,844	5	181
Tiny				too tiny							too tiny				55	21-Oct	55		55	5	5
Area C:arenas																	**19,445**	18.87	**19,763**	4.71	1,826
South Arena	26,243.08	23,584.12	37	0.516	32.13	12,162	13,533	23-Oct	36	0.039	918	1,021	7.02	5.70	too big		13,080		14,554	5.70	1,626
North Arena	9,169.48	11,206.07	30	0.528	32.53	5,917	4,841	23-Oct	30	0.040	448	367	7.04	8.13	too big		6,365		5,208	8.13	830
Area D: citadel				ratio: area/directcount		1.093	0.945								4,474		**4,474**	4.34	**4,474**	3.85	337
Bottom	3,379.49	3,907.86	16	0.358	56.39	1,397	1,208	29-Oct	4	0.010		34	2.72		1,278	21-Oct	1,278		1,278	5	125
Rest				too convoluted							too convoluted				3,196	21-Oct	3,196		3,196	5	313
Area E: North end				ratio: area/directcount		1.035	1.103								5,978		**5,978**	5.80	**5,978**	3.91	458
Big	10,782.08	9,299.37	18	0.462	40.72	4,298	4,984	27-Oct	14	0.031		335	6.31		4,572	22-Oct	4,572		4,572	5	448
Little	1,668.74	2,234.34	12	0.333	36.30	745	556	27-Oct	6	0.020		33	5.66		496	22-Oct	496		496	5	49
Bigmissing	1,830.99	2,003.90	8	0.540	42.46	1,082	989	27-Oct	8	0.040		73	6.90		849	22-Oct	849		849	5	83
Littlemissing				too tiny							too tiny				61	22-Oct	61		61	5	6
East Cliffs				too dangerous							too dangerous				200	21-Oct	**200**	0.19	**200**	5	20
Total		**174,016***															**103,050**		**103,341**	**2.32**	**4,707**

*includes estimates of colonies not measured

Average density				Comparison transect to direct count			
occupied	empty	total	N	Transect	Direct count	ratio	%
0.555	**0.038**	**0.593**	6	10,508	9,383	**1.12**	**11.30**

Table 3: Black-browed Albatross counts from Steeple Jason in 2005.

Black-browed Albatross Steeple Jason 2005

Colony	GPS area	Area		Average Density		Size	Date		Empty nests			Total	Direct Count	Date	Breeding pairs	%	CV%	95%CI
	m2	m2	N	Nest/m2	CV%			N	empty/m2	total	%	CV%				of Total		
S1	57,536.22	62,489.44	71 (in 4)	0.579	40.41	36,156	22-Nov	191	0.108	6,191	15.68	4.63	1,074	22-Nov	**43,421**	25.35	4.51	3,582
S2	17,463.65	17,320.49	31 (in 2)	0.454	28.81	7,867	22-Nov	55	0.071	1,229	13.51	5.26	56	22-Nov	**9,152**	5.34	5.23	946
S3	103,521.93	90,254.73	77 (in 4)	0.408	36.88	36,805	24-Nov	209	0.109	11,240	21.03	4.09	465	24-Nov	**48,510**	28.32	4.05	4,280
S4				too convoluted									6,531	24-Nov	**6,531**	3.81	5	640
S5	85,154.02		76 (in 6)	0.464	42.92	39,485	25-Nov	244	0.128	10,936	21.69	4.85	1,263	25-Nov	**51,683**	30.17	4.73	4,796
S6				too convoluted									11,989	25-Nov	**11,989**	7.00	5	1,175
Total		**302,449***													**171,286**		**2.21**	**7,539**

*includes estimates of colonies not measured

Average density		
occupied	empty	total
0.478	**0.110**	**0.587**

Table 4: Black-browed Albatross counts from Steeple Jason in 2000.

Black-browed Albatross Steeple Jason Island 2000

Colony	New area	Area	Average Density			Size		Date	Empty nests					Total	Direct Count	Date	Breeding pairs	%	new	CV%	95%CI
	m2	m2	N	Nest/m2	CV%	old	new		N	empty/m2	total	new	%	CV%				of Total	pairs		
S1	57,956.27	42,503.55	35 (in 2)	0.747	30.57	31,768	43,318	11-Nov	142	0.162	6,898	9,405	17.84	4.74	646	11-Nov	**39,312**	25.47	**53,370**	4.68	4,897
S2	14,081.63	19,185.36	21	0.354	58.59	6,797	4,989	14-Nov	30	0.057	1,096	805	13.89	13.66			**7,893**	5.11	**5,794**	13.66	1,551
S3	84,328.52	62,484.47	46 (in 3)	0.524	43.40	32,764	44,217	15-Nov	96	0.083	5,216	7,040	13.73	6.55			**37,980**	24.61	**51,257**	6.55	6,577
S4															5,898	13-Nov	**5,898**	3.82	**5,898**	5	578
S5	87,277.65	73,662.96	45 (in 4)	0.604	33.61	44,460	52,677	15-Nov	135	0.120	8,840	10,473	16.58	4.95	1,323	12-Nov	**54,622**	35.39	**64,473**	4.85	6,124
S6															8,635	13-Nov	**8,635**	5.59	**8,635**	5	846
Total		271,870*															**154,340**		**189,427**	**2.80**	**10,402**

*includes estimates of colonies not measured

Average density of nest

occupied	empty	total
0.577	**0.110**	**0.687**

Table 5: Black-browed Albatross counts from Grand Jason in 2000.

Black-browed Albatross Grand Jason Island 2000

Colony	new Area	Area	Average Density			Size		Date	Empty nests					Total	Direct Count	Date	Breeding pairs	%	new	CV%	95%CI
	m2	m2	N	Nest/m2	CV%	old	new		N	empty/m2	total	new	%	CV%				of Total	pairs		
Eastend						**9,450**	**9,087**				**1,375**	**1,318**			**7,164**		**17,989**	34.13	17,569	4.11	1,415
Top big	5,652.43	5,451.93	11	0.287	32.84	1,566	1,624	16-Nov	9	0.033	178	185	10.23	10.70						10.70	379
Top little															41	16-Nov				5	4
Slope															2,158	16-Nov				5	211
Bottom															1,825	16-Nov				5	179
Flat top															3,140	16-Nov				5	308
Big bottom	21,658.02	22,875.96	26 (in 2)	0.345	44.06	7,883	7,464	16-Nov	34	0.052	1,197	1,133	13.18	7.71						7.71	1,299
Middle Big Colony															**1,769**		**1,769**	3.36	1,769		
															1,769	17-Nov				5	173
Western complex															**32,941**		**32,941**	62.51	32,941	4.96	3,201
Far West															276	17-Nov				5	27
Rest					very low density and highly convoluted										32,665	17-Nov				5	3,201
Total																	**52,699**		**52,279**	**3.42**	**3,505**

RESULTS

Area and density of large colonies

In 2005, colony areas measured on Beauchêne Island (Table 1) and Steeple Jason (Table 3) 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., see Figure 1). Similarly in 2000, on Beauchêne Island (Table 2), there was no significant difference in the total number of breeding pairs between direct counts and values obtained by the area/density method (paired T-test: $t_{1,5}$=1.88, p=0.12, n.s., see Figure 2). However, colonies where comparison between direct and area/density methods were made, were relatively small (less than 5,000 pairs) and it is not known if such comparison would be valid for larger colonies. It is harder to compare values of areas obtained between 2005 and 2000 (Tables 1 to 5) 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 using a much larger number of waypoints, increasing the number of possible colony spinning (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. The difference 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. Such difference is not significant (paired T-test, t=1.47, p=0.20, n.s.). In the first census of the island conducted, the colonies covered an area of 31.8 ha in 1988.

The density of nests within the large colonies fluctuated between censuses, being one of the lowest in 2005, but with no significant trend. On Beauchêne Island the density changed from 0.59 nest.m^{-2} in 2000 to 0.52 in 2005. This compares with 0.70 nest.m^{-2} in 1981, 0.60 in 1991 and 0.68 in 1996. On Steeple Jason the nest density was 0.59 nest.m^{-2} in 2005, lower when compared to 0.69 in 2000, 0.76 in 1995 and 0.66 in 1988, but higher than in 2003 when it stood at 0.503 (FC unpublished). Such variations between years were significant both for Beauchêne Island ($F_{4,19}$=5.39, p<0.005) and Steeple Jason ($F_{4,19}$=3.71, p<0.05). The density of empty nests on Steeple Jason remained the same in both 2000 and 2005 at 0.1 nest.m^{-2}. As the density was lower in 2005, this represents an increase from 16% to 19% of all nests being empty. On Beauchêne Island the density of empty nests was lower, standing at 0.04 nest.m^{-2} in 2000 and at 0.08 in 2005. This represents an increase from 6% of all nests being empty in 2000 to 15% in 2005.

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 3 and 4). The average number of nests per 25m^2 stabilises after a sample size of 60 squares, although little jumps occur throughout due to nests occurring at a lower density at the edges of the colonies. Similarly, variation stabilises after 60 to 80 samples and remains high at about 35 to 40% due to natural variations in density within the colonies.

Table 6: Total number of breeding pairs of Black-browed Albatross in the Falkland Islands during the 2005 season, with associated error.

Black-browed Albatross
Falkland Islands 2005

Total: **399,416** 1.24 9,743

Island	Area	Colony	Date start	Date end	Method	Counts	Breeding pairs	CV%	95%CI
Beauchêne Island			4-Nov	10-Nov	Direct + Transect		**108,984**	2.48	5,300
	see details	14				see details			
Bird Island			13-Nov	14-Nov	Direct		**9,990**	3.16	618
		main				5,321		5	521
		little				1,088		5	107
		medium				3,194		5	313
		ledge				106		5	10
		saddle				281		5	28
New Island			17-Nov		Photo		**10,177**	2.76	550
	North Bluff	North				1,640		5	161
		South				2,197		5	215
	Precipice Hill	north side				4,569		5	448
	to Cliff Peak	south side				1,771		5	174
North Island			18-Nov		Direct+photos		**20,083**	3.46	1,360
	Main Group	top				12,786		5	1,253
		slopes				5,129		5	503
	South cliffs					609		5	60
	Northwest cliffs					1,559		5	153
West Point Island			16-Nov		Photo		**13,928**	3.76	1,026
	Cape Terrible to Mount Ararat					1,177		5	115
	Devil's Nose					1,943		5	190
	Cliff Mountain to Mount Misery					10,206		5	1,000
	Mount Misery east					602		5	59
Grave Cove			9-Nov		Direct+photo		**285**	3.69	21
	Penguin Point					185		5	18
	Grave Cove					100		5	10
Steeple Jason Island			21-Nov	25-Nov	Direct + Transect		**171,286**	2.25	7,539
	see details	6				see details			
Grand Jason Island			27-Nov	28-Nov	Direct + photos		**49,462**	2.50	2,424
	westend	6 to 8				9,894		5	970
	eastofwest					5,389		5	528
	middlebit					17,093		5	1,675
	lonely					1,871		5	183
	East complex					13,662		5	1,339
	topEastBlob					1,553		5	152
Elephant Jason Island			28-Nov		Direct		**1,120**	3.14	69
	Inland	Big				538		5	53
		Small				441		5	43
	Coast	Big				78		5	8
		Small				63		5	6
South Jason Island			29-Nov		Photo		**1,738**	4.27	145
	Main					1,456		5	143
	Bottom					282		5	28
Saunders Island			4-Nov	5-Nov	Direct		**10,740**	3.36	708
	Rookery					6,131		5	601
	Neck					3,708		5	363
	Holy City					901		5	88
Keppel Island			30-Nov		Direct		**1,623**	3.69	118
	West side					1,057		5	104
	East side					566		5	55

Table 7: Total number of breeding pairs of Black-browed Albatross in the Falkland Islands during the 2000 season, with associated error.

Black-browed Albatross Falkland Islands 2000							**Total:** **414,268**	1.50	12,160
Island	**Area**	**Colony**	**Date start**	**end**	**Method**	**Counts**	**2000 census revised**	**CV%**	**95%CI**
Beauchêne Island			21-Oct	29-Oct	Direct + Transect		**103,341**	2.32	4,707
	see details	14				see details			
Bird Island			2-Nov	3-Nov	Direct		**10,189**	3.28	656
		main				6,184		5	606
		little				967		5	95
		medium				2,283		5	224
		ledge				131		5	13
		saddle				624		5	61
New Island			6-Nov		Photo		**10,191**	2.76	551
	North Bluff	North				1,379		5	135
		South				2,210		5	217
	Precipice Hi	north side				4,526		5	444
	to Cliff Peak	south side				2,076		5	203
North Island			6-Nov		Direct		**17,737**	4.74	1,647
	Main Group					16,787		5	1,645
	South cliffs					250		5	25
	Northwest cliffs					700		5	69
West Point Island			9-Nov		Photo		**14,561**	3.83	1,094
	Cape Terrible to Mount Ararat					1,054		5	103
	Devil's Nose					2,116		5	207
	Cliff Mountain to Mount Misery					10,902		5	1,068
	Mount Misery east					489		5	48
Grave Cove			9-Nov		Direct+photo		**226**	3.60	16
	Penguin Point					134		5	13
	Grave Cove					92		5	9
Steeple Jason Island			11-Nov	15-Nov	Direct + Transect		**189,427**	2.80	10,402
	see details	6				see details			
Grand Jason Island			16-Nov	17-Nov	Direct + Transect		**52,279**	3.42	3,505
	see details	6 to 8				see details			
Elephant Jason Island			18-Nov		Direct		**1,699**	3.31	110
	Inland	Big				963		5	94
		Small				564		5	55
	Coast	Big				141		5	14
		Small				31		5	3
South Jason Island			18-Nov		Photo		**1,745**	5.00	171
	Main+bottom					1,745			
Saunders Island			28-Nov	30-Nov	Direct		**11,004**	3.36	725
	Rookery					6,268		5	614
	Neck					3,809		5	373
	Holy City					927		5	91
Keppel Island			19-Nov		Direct		**1,869**	3.79	139
	West side					1,295		5	127
	East side					574		5	56

Colony counts

There are twelve sites in the Falkland Islands where Black-browed Albatross breed. Tables 1 to 5 above show the details of the three major sites for 2005 and 2000 and Tables 6 and 7 shows all the counts of all the colonies with their associated error (Coefficient of Variation and 95% Confidence Interval). Overall, the population size dropped from 414,268 ± 12,160 in 2000 to 399,416 ± 9,743 in 2005. This represents a decrease in numbers of 14,852 in the last five years or a rate of decline of 0.72% per annum (0.73% compounded). However, this decline is not constant across all sites. Three sites have increased in the last five years. These are Beauchêne Island (+5.5%), North Island (+13.2%) and Grave Cove (+26.1%). All other nine sites decreased from –0.1% (New Island) to –34.1% (Elephant Jason). Even within site, changes were uneven, only on North Island and Grave Cove did all the colonies increase and only on Saunders and Keppel islands did all the colonies decrease; at all other eight sites some of the colonies increased and some decreased. The main colony on Steeple Jason was arbitrarily sub-divided into five areas. Although we tried to keep such boundaries consistent between censuses, finding the identical line is almost impossible and changes in size of areas and breeding number, should take into account the full results of all five areas combined. Looking at the geographical distribution of the colonies around the Falkland Islands (Figure 5), there is no apparent pattern in the distribution of colonies that increased or decreased.

Using the variance of results obtained, the difference, of 14,852 less breeding pairs, in the total population size between 2000 and 2005 is just above the level of significance ($d=1.87$, $p=0.07$). Of the three sites that increased, only North Island ($d=2.15$, $p<0.05$) and Grave Cove ($d=4.44$, $p<0.001$) show significant increase, but not Beauchêne Island ($d=1.56$, n.s.). Only three of nine sites that showed a decrease had a significant difference. These were Keppel Island ($d=2.65$, $p<0.02$), Steeple Jason ($d=2.77$, $p<0.01$) and Elephant Jason ($d=8.73$, $p<0.001$).

Comparison with previous records

Although the censuses of 2000 and 2005 were the first two complete censuses of the Falkland Islands, there exist partial historical counts of some of the colonies. Thus, there was one previous count each for Beauchêne Island (Prince 1982) and Steeple Jason (Thompson & Rothery 1991) and other counts by Falklands Conservation (various internal reports from monitoring schemes) and Ian Strange of New Island South Conservation Trust.

Beauchêne Island

The first census of this island was conducted in the 1980/81 season by Prince (1982) estimating a total of 162,360 breeding pairs. Results from the last two censuses show that the overall number of breeding birds on this island has declined by about 56,000 pairs (35% decline) due to a reduction to both the area and density of the colonies. Between the last five years, changes in colony area are not significant but the density was lower in 2005 than in 2000. Although the island was visited in 1991 and 1995, only density was measured, assuming that the colony size did not change. This assumption has subsequently been shown to be incorrect and thus no estimate of the population size during these intervening years can be made confidently.

Bird Island
No proper census of this island was conducted prior to 2000, but three rough estimates exist. The first one comes from Roddy Napier (*pers. comm.*) in 1939 when 8,000 eggs were collected for consumption out of a probable 10,000 pairs. In 1995 it was estimated that between 15,000 and 20,000 pairs bred on the island (Mike Riddy, FC unpublished), whilst in 1996 Sally and Jerome Poncet estimated the numbers to be between 5,000 and 15,000 breeding pairs. These are similar to the counts obtained in the last two censuses around 10,000 breeding pairs, but it is not possible to infer any change in population size.

New Island
Two previous counts exist. The first in 1992/93 estimated a total of 8,910 breeding pairs (Kate Thompson, FC unpublished); in 1994/95 Ian Strange estimated the population at 10,500 pairs. Both owners of the island (Ian Strange and Tony Chater) estimate that some colonies of the island have increased steadily since the mid 1980s, although the last two censuses suggest that such a trend may have stopped with a population stable at over 10,000 pairs.

North Island
Only one previous count of this island has been made, by Ian Strange in 1994/95, when he estimated a total of 14,625 breeding pairs. This island is one of the few sites that is steadily increasing with numbers now reaching 20,000 breeding pairs.

West Point Island
This island possesses the most records with four previous full counts and two colonies surveyed every year between 1989 and 1994. Roddy Napier did the first count in 1962, with 6,000 breeding pairs on the island. This increased to 12,050 in 1989 and stabilised in 1993 to 15,200 and in 1994 to 15,400 (FC unpublished). In the last two censuses numbers decreased to around 14,000. At this site, colony changes are not consistent across the island, with the study colony on Devil's Nose only decreasing between 2000 and 2005, whereas the other study colony has decreased since 1993.

Grave Cove
Two previous counts were made on this small site situated on cliffs on mainland West Falkland. In 1987 120 pairs were counted and this increased to 170 pairs in 1992 (FC unpublished). Numbers are still on the increase in the last two censuses, with numbers now reaching almost 300 pairs.

Steeple Jason
The only previous full count of the island, in 1987 (Thompson & Rothery 1991), revealed a total population size of 214,648 breeding pairs. Visits in 1995 and in 2003 only measured nest density but not the colony area. Figures from the three complete surveys of the island reveal a steady decline with a loss of 43,000 pairs (20%) between 1987 and 2005.

Grand Jason
Only one rough estimate was made of the population on this island, by Sally and Jerome Poncet, suggesting a total of 50,000 to 100,000 pairs. No comparison can be made between this number and the last two censuses. The breeding density on this island is much lower than on Steeple Jason or Beauchêne Island. This is due to birds

breeding on tussac slopes rather than on flat ground at the edge of the tussac grassland.

Elephant Jason
Only one previous count is available for this island. Ian Strange counted a total of 600 pairs in 1985. Numbers increased to 1,700 pairs in 2000 but diminished to 1,120 in 2005.

South Jason
One previous count of this island, in 1984 by Ian Strange, revealed a total of 350 breeding pairs. This population increased to more than 1,700 in 2000 and stabilised at this level in 2005. Between the last two censuses the island caught fire in January 2001 with no apparent ill effects to the colony.

Saunders Island
Two previous counts exist for this island. This first was made in 1992 (K. Thompson, FC unpublished) and estimated 12,505 breeding pairs. The second count was conducted in 1995 (M. Riddy, FC unpublished) and revealed that numbers were more or less stable at 12,265 pairs. Since then numbers decreased to about 11,000 pairs.

Keppel Island
Only one previous count exists for this island. Kate Thompson (FC unpublished) estimated that a total of 2,085 pairs bred on the island in 1987. Since then numbers have declined to around 1,600 pairs in the last census.

Combination of previous estimates
To be able to combine the previous estimates into a single whole island population, we had to take into account that previous counts were conducted in different years and that there were no reliable counts for either Grand Jason or Bird Island (see Figure 6). For each site with a reliable historical count, the annual trend between the time of the count until the 2000 census was calculated. The weighted average of all trends was then calculated, using the original colony size of each site as the weighing factor (bigger colonies have more importance in the final trend). This produced an annual trend of –1.08%. From this trend and the total number of birds breeding in 2000, we can then calculate an estimate of the number of birds breeding in 1995. The 1995 population is estimated at 437,855 pairs (Figure 7). Unfortunately, using such a method prevents calculating confidence interval for this extrapolated number and no statistical test can be conducted. This value can still be used to assess general trends, from which it appears that the rate of decline during the last five years (0.72%) is less than in the previous five years period (1.08%), the average decrease over the last ten years being 0.9% per annum.

Photographic library

In order to maintain a record of population changes in Falkland Islands colonies, all photographs taken during the last two censuses have been archived for future reference. In addition we have acquired several additional sets of photographs to 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 in 1979 by Ron Lewis-Smith and Peter Prince are held for reference. During both 2000 and 2005, fixed point photography to match the 1980 photography positions was conducted and they clearly show the reduction in colony size that has taken place on this island (see Appendix 2). 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 colony reduction for this island.

DISCUSSION

Colony area and density

Colonies nest density and area were measured in the large colonies on Beauchêne Island and Steeple Jason in order to estimate the total number of breeding pairs. Two methods were used to measure the colony areas, one using GPS and the second one using a compass and a measuring device (a measuring tape in 2000 and a laser range finder in 2005). Both methods gave comparable results, but the GPS is easier and faster to use in the field and results are obtained directly, whilst the other method subsequently required a lot of data manipulation. To obtain meaningful estimates of the colony areas with the point to point bearing and distance method, it is required to develop a system that takes into account the fact that errors in measurements are cumulative and that each point taken is dependent on the previous one. Originally, for the 2000 census (Huin 2001), colony areas were measured as taken and the error was estimated by calculating the ratio of the closing distance over the total perimeter (the closing distance being the distance separating the final point from the starting point, which with no error should be zero). However, this is less accurate than the new method of iteratively changing the starting point and taking the average and standard deviation of all possible combinations (termed colony "spinning") and it was therefore required to reanalyse the raw data from the 2000 census. This explains the change in the number of breeding birds reported here compared to the previous report (Huin 2001). Numbers presented here are considered to be the most accurate. Examination of the running average and variation of the density of breeding birds with increasing number of transects, show that for both sites and both censuses, we collected a big enough sample size, so that both the average density and its natural variation are fairly represented (Figures 3 and 4).
Most of the changes in the number of breeding pairs are due to a reduction in the colony areas. Such diminution is not homogenous, but varies from colony to colony and even from one part of a colony to another. This is obvious both from the actual measurements of the colonies and from the examination of photographs available of the different sites. Combining the areas of the colonies on Beauchêne Island and Steeple Jason, this represents a loss of around 73,000m^2 (13%) from the original estimates. Comparing results from the last two censuses, there was no significant difference in the areas of the colonies measured, although they were slightly bigger in 2005 than in 2000. This might be due to the fact that in 2005, colonies were measured with a greater number of waypoints, so that results are more accurate and the shapes of the colonies are more convoluted. The density within colonies in 2005 was also lower, so the areas estimated by back calculation from direct counts for comparison are bigger, for the same amount of breeding birds.

Although no trend was detected in the density of breeding birds, such density was lower in the last two censuses than the overall average of 0.63 nest.m^{-2} for Beauchêne Island and Steeple Jason combined. Such reduction in the breeding density also contributed to the decrease in the total number of breeding birds. At both sites, changes in breeding density between years occurred in the same way for most of the colonies, apart for the colony on the southern part of Beauchêne Island, which decreased more than the rest. The breeding density was also consistently higher on Steeple Jason than on Beauchêne Island. The few transects conducted on Grand Jason revealed that birds breed here at the lowest density recorded, utilising the tussac covered slopes more than the flat areas close to the shore as on the other two islands.
This reduction in the density of breeding pairs was accompanied in 2005 with an increase in the proportion of empty nests within the colonies. This increase can be attributed to a higher rate of failure before the census was conducted. However, both censuses were conducted at the same dates in the breeding season to minimise discrepancies between censuses. Latest figures on the breeding success in 2005, obtained from Steeple Jason (FC unpublished), indicate a normal breeding success, standing at around 45%, which is no different from the long-term average recorded of 47%. We can then disregard breeding success as a factor contributing to this higher rate of empty nests. Instead, it might the result of a dynamic balance between colony area and density for a declining population that is played as follows. At first, the number of breeding birds decline, but the colony size stays the same, with a higher proportion of empty nests. This is followed by a degradation of the unused nests and a decline in the nest density within the colony. Breeding birds then move into the colony to fill the gaps to an optimal breeding density (either birds move from the less productive outskirts of the colony, or this is actual recruitment of new breeding birds inside the colony). It is then followed by desertion of the nests on the outside and progressively the colony diminishes in area.

Falkland Island population and trends

The Falkland Islands population of Black-browed Albatross of 399,416 breeding pairs in 2005 is spread across twelve sites, with no new site or loss of old site known. The majority of the colonies are situated on the west side of the Falkland Islands, with the exception of Beauchêne Island, the southernmost island of the archipelago.
Breeding sites can be divided in three categories. The first consists of sites with massive colonies, which includes Beauchêne Island, Steeple Jason and Grand Jason and represents 82.6% of the Falkland Islands population. The second consists of sites with numbers in the order of 10,000 to 20,000 pairs. This includes Bird, New, North, West Point and Saunders islands and represents 16.2% of the total population. The last category consists of sites with fewer than 5,000 pairs and includes Grave Cove (the only site on mainland West Falklands), Elephant Jason, South Jason and Keppel islands and represents 1.2% of the Falkland Islands population. The total population declined from 414,268 pairs in 2000 to 399,416 pairs in 2005(0.72% per annum). The rate of decline was slightly higher before 2000, standing at 1.08% per annum. The decline varied from site to site and from colony to colony within sites, with some colonies even increasing. There is no apparent relationship between colony size or geographical position and its rate of change. Unfortunately, there is a paucity of available counts before the last two censuses, making it impossible to assess accurately any previous trend. Five out of six sites with data obtained between the 1980's and early 1990's increased during that period, but they represent less than 7%

of the Falkland Islands total population and we cannot know if they are representative of the full population. Examination of old photographs has proved invaluable to show clearly the reduction in area of portions of the big colonies on Steeple Jason and on Beauchêne Island. They also showed that tussac grass quickly colonised the nutrient-rich empty spaces creating the appearance that the colonies are full without extensive surrounding bare ground at the margins. All photographs taken during the two most recent censuses have been kept for future examinations and we are still attempting to secure additional archive pictures to increase our knowledge of changes in colony sizes.

World Status

Combining all numbers currently available, the world population of Black-browed Albatross now stands at 618,513 breeding pairs, the most numerous of all albatross species (Gales 1998). The Falkland Islands population represents 64.7% of the world total, with the two other main sites situated in Southern Chile (123,000 pairs or 19.9% of the total (Valencia et al. 2004)) and South Georgia (90,600 or 14.7% of the total (Poncet et al. *in press*)). Four other breeding sites exist in the Indian Ocean and hold 4,824 pairs or less than 0.8% of the total population and a further five sites exist south of New Zealand and Australia, with a total of 313 pairs, or less than 0.1% of the total population (Gales 1998, BirdLife International 2006). We have shown that the Falkland Islands population is declining at a rate of around 1% per annum. There is no trend available for the population in Chile, as it was found that previous counts were not reliable (Valencia et al. 2004). The population on South Georgia was counted in full recently and shows a decline rate of 4% per annum over the last ten years (Poncet et al. *in press*). In the Indian Ocean, the population on Heard Island (Woehler et al. 2002) increased from 200 to 600 pairs between 1947 and 2000 (3.8% per annum), whilst the population on Kerguelen Island is either stable or decreasing (Weimerskirch and Jouventin, 1998). Trends at all other sites are unknown. Of all the populations, there are at least 79% that are decreasing, with the majority of the remaining being of unknown status. This species thus still qualify under the IUCN criteria to be classified as an Endangered species (IUCN 2001).

Causes of decline

There could be many causes for such a decline and they can be classified in three categories:

1. Problems on land at the breeding sites
2. Problems in the marine environment close to the breeding colonies
3. Problems in the marine environment away from the colonies

There is currently little or no disturbance at Black-browed Albatross breeding colonies. Although there was an active collection of eggs for consumption, the practice gradually diminished, was under license since the 1980’s and was banned in 2004 (FIG 2004). A total of 91% of the breeding population is situated on uninhabited islands, which are all protected. Nearly 48% of the population inhabits islands with no introduced predator and nowadays 94% of the population inhabits islands without grazing animals. Of the 6% in contact with farming, most breed on inaccessible cliffs.
In recent years, tourism has greatly increased in the Falkland Islands. Albatross colonies visited by tourists include Steeple Jason (2 to 4 visits a year), West Point Island, New Island and Saunders Island. However, only one or two colonies per site

are accessed and these under strict regulations limiting the approach distance, time of visit, number of visitors and visits per day. Overall, this represents less than 5% of the population being visited by tourists.
Another potential threat to birds on land comes from infection by disease. Avian poxvirus was identified positively at an unknown colony in 1987 and was suspected on West Point Island in 1962. No record since then exists of Black-browed Albatross being affected by such a virus, although some Gentoo Penguins, *Pygoscelis papua*, were affected in March 2006 (FC, unpublished data). Such infrequent occurrence of this disease is unlikely to have much impact in the overall population and trend of this species. However, a recent study suggested that the Black-browed Albatross from the Falkland Islands have rarely been in contact with any of the most common avian diseases and therefore do not possess any of the associated antibodies making them highly vulnerable to any outbreak (Uhart et al. 2004).

Inshore waters near the breeding colonies are all protected, with a 3 nautical mile fishing exclusion zone around the entire Falkland Islands coastline. In the summer of 2002/03, Black-browed Albatross and other seabirds feeding close offshore the west of the Falkland Islands were affected by a Harmful Algae Bloom, thereafter referred to as HAB (Uhart et al. 2004). This resulted in the lowest breeding success recorded yet for the albatross (Huin 2003) and with dead adults found in the colonies and observed floating on surrounding waters and washed ashore on beaches. There is no way to assess the quantity of adult birds that have been affected, but it must have played a significant role in the observed decline that occurred between the last two censuses. Birds were only affected after December 2002, when they started to feed in local waters (Huin 2002a). It appears that the albatrosses from Beauchêne Island were not affected by the HAB, as with the Rockhopper Penguins breeding there (Huin, unpublished data), probably because these birds feed in different areas from the birds from other colonies in the Falkland Islands (Huin 2002a). Although this is the first time that such a HAB has been positively identified in Falkland Islands waters, it might be a reflection of the global tendency for such events to occur more frequently. Apart from such events, waters around the Falkland Islands are normally very productive, as reflected by the average high breeding success that albatross experience (around 40 to 60%, FC unpublished) and its associated high chick growth rate (Huin 1999).

Black-browed Albatross spend most of their life at sea, with breeding birds spending only 17% of their time on land (Huin 2002b). The main area used by birds from the Falkland Islands is the Patagonian shelf, ranging from the Cape Horn north to Peninsula Valdez. Adult distribution extends farther north during the winter, often over deeper waters, especially for the smaller females that travel to the middle of the Atlantic ocean and visit the coast of Chile (Huin 2002b and in BirdLife International 2004). Juvenile birds disperse further than the adults and reach southern Brazilian waters, whilst a few (less than 1.5%) cross the Atlantic to South Africa, all within the first three months after fledging (Sullivan & Huin, 2002). After this period they are able to travel all around the southern oceans before coming back to land to breed at the age of ten. Whilst foraging at sea they interact with numerous fishing activities, including long-lining, trawling and jigging that occur both in economic exclusion zones (EEZ) and over international waters. Some of these fisheries, especially the trawl fisheries, were thought to be beneficial, as they provide surplus food resources (as discards of offal and bycatch) that would not be naturally available to the albatross

(Thompson 1992; Thompson and Riddy 1995). However, there is also a mortality associated with trawl fisheries that has just been discovered around the Falkland Islands (Sullivan et al. in press a), where around 1,500 birds per year were being killed in the Falkland Islands EEZ alone, with no figure available for the rest of the Patagonian Shelf. Similarly, large numbers of birds, mostly originating from the Falkland Islands population, have been recorded killed in longline fisheries from Brazil (Neves and Olmos 1998), Uruguay (Jimenez et al 2004), Argentina (Schiavini et al. 1998; Gandini et al. 2004) and the Falkland Islands (Brothers 1996, Sullivan and Reid 2004). Although difficult to quantify accurately, it probably amounts to tens of thousands birds being killed annually. Slowly, mitigation measures are being developed to help reduce such mortality in longline fisheries and in some areas, like in the Falkland Islands EEZ, seabird mortality has recently been reduced by a factor of 100, from 0.54 birds/1000 hooks to the current level of only 0.005 birds/1000 hooks or 45 birds per annum in 2004 (Reid et al 2004, FIFD 2005). Regarding mortality associated with trawl fisheries, the development of simple mitigation measures and its deployment across the finfish fleet in the Falkland Islands EEZ was successful and resulted in a 90% reduction in seabird mortality to 169 birds per year (Sullivan et al in press b and FIFD unpublished report). The squid jigging fleet impact is more complicated to evaluate as these boats tend not to attract and kill birds during normal fishing practices, but early results show that some vessel's crew participate in capturing albatross for consumption. Even if numbers per boats are low, the fleet deployed over the Patagonian shelf comprises around 300 boats and may have an adverse impact on the albatross population (Yates, Reid and Crofts, FC report in prep).

Even if, once the problems are fully quantified, measures are put in place to reduce the widespread bird mortality associated with fishing activities, there will still be the problem of extending such mitigation measures to international waters and of tackling bycatch of albatrosses in Illegal, Unregulated or Unreported fisheries. These steps will have to be undertaken if the decline in the Black-browed Albatross demonstrated by these last two censuses is to be stopped.

ACKNOWLEDGEMENTS

The project was funded by the United Kingdom Overseas Territories Environmental Program (OTEP) and the Falkland Islands Government. Many thanks to all the landowners that allowed us to access their land on Steeple and Grand Jason (Wildlife Conservation Society), New Island (Tony Chater), West Point Island (Roddy Napier), Saunders Island (David and Suzan Pole-Evans), Keppel Island (Lionel Fell) and all the other sites owned by the Falkland Islands Government. Many thanks also to Mike Clarke, owner of the Penelope and Condor and his crew for ferrying us around the islands.

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APPENDIX 1

Calculations for measuring colony area.

length	direction	yrelative	xrelative	Xabsolute	Yabsolute	Xabspos	Yabspos	ya-yb	xa-xb	area
				0.00	0.00	55.00	204.00			
23	180	-23.00	0.00	0.00	-23.00	55.00	181.00	23.00	0.00	1,265.00
9	132	-6.04	6.67	6.67	-29.04	61.67	174.96	6.04	-6.67	352.57
12	172	-11.87	1.76	8.43	-40.91	63.43	163.09	11.87	-1.76	742.46
8	248	-3.06	-7.39	1.04	-43.98	56.04	160.02	3.06	7.39	182.87
52	158	-48.04	19.90	20.94	-92.02	75.94	111.98	48.04	-19.90	3,170.18
52	152	-45.86	24.51	45.45	-137.88	100.45	66.12	45.86	-24.51	4,044.58
13	166	-12.61	3.16	48.61	-150.49	103.61	53.51	12.61	-3.16	1,286.64
30	180	-30.00	0.00	48.61	-180.49	103.61	23.51	30.00	0.00	3,108.28
26	208	-22.93	-12.26	36.35	-203.42	91.35	0.58	22.93	12.26	2,235.24
11	278	1.61	-10.88	25.47	-201.80	80.47	2.20	-1.61	10.88	-138.67
52	307	30.98	-41.77	-16.29	-170.83	38.71	33.17	-30.98	41.77	-1,845.84
25	293	9.57	-23.10	-39.39	-161.26	15.61	42.74	-9.57	23.10	-259.81
40	338	36.96	-15.31	-54.70	-124.30	0.30	79.70	-36.96	15.31	-293.96
40	25	36.16	17.10	-37.60	-88.15	17.40	115.85	-36.16	-17.10	-320.08
52	8	51.44	7.63	-29.97	-36.71	25.03	167.29	-51.44	-7.63	-1,091.40
27	17	25.84	7.84	-22.13	-10.87	32.87	193.13	-25.84	-7.84	-748.04
2	79	0.39	1.96	-20.17	-10.48	34.83	193.52	-0.39	-1.96	-13.21
close loop						55.00	204.00	-10.48	-20.17	-470.75

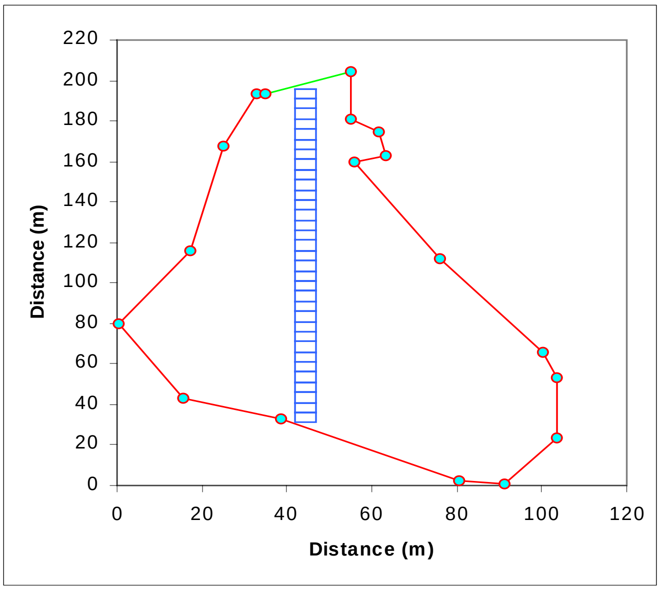
Total
11,206.07

The first two columns are measurements taken in the field and represent the direction and distance between consecutive points. These give coordinate in a polar representation. The yrelative and xrelative columns represent coordinate in a normal orthogonal representation. Formulas used for the conversions are as follow:

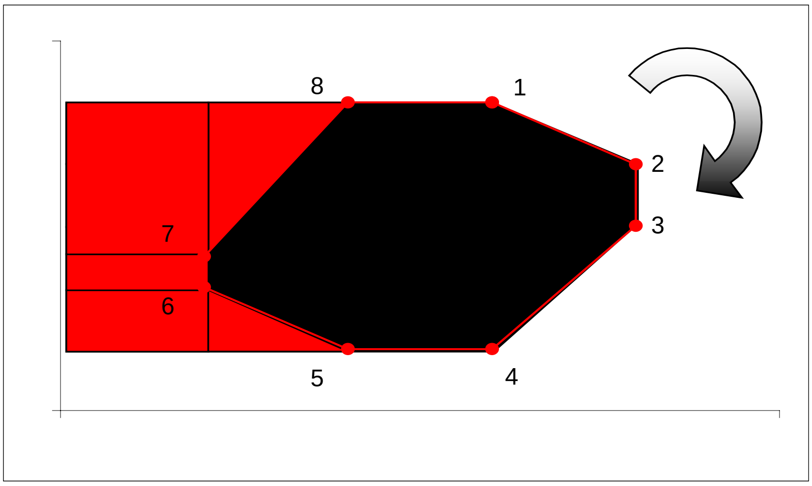
yrelative = cos(direction)*length

xrelative = sin(direction)*length.

Relative coordinates are then converted to absolute ones by removing the value of the previous set (starting from the origin at 0,0). In order to simplify further calculations, values are then transformed so that all are positives (Xabspos and Yabspos). A picture of the colony contours is then drawn using this latest set of values:



The green line in the contour drawn is the cumulative error of all field measurements. When the total area of the colony is calculated, the coordinates of the starting point are added to the end in order to add or subtract the area included into the overall imprecision of the method. The total area is then calculated by measuring the corresponding rectangles and triangles that are formed by two consecutive sets of coordinates measured. The formula used to calculate the overall area assumed that areas were measured clockwise and have to take into account parts that are within the colony (positive value, black area) and parts that are between the colony boundaries and the axis of reference (here Y axis has been chosen, see below, negative values, red area).



Area #	Rectangle		Triangle	Type
1 to 2	$(y_A-y_B)*x_A$	+	$(y_A-y_B)*(x_B-x_A)/2$	Positive
	$(y_A-y_B)*x_A$	-	$(y_A-y_B)*(x_A-x_B)/2$	
2 to 3	$(y_A-y_B)*x_{AB}$		none	Positive
	$(y_A-y_B)*x_{AB}$			
3 to 4	$(y_A-y_B)*x_B$	+	$(y_A-y_B)*(x_A-x_B)/2$	Positive
	$(y_A-y_B)*x_B$	+	$(y_A-y_B)*(x_A-x_B)/2$	
4 to 5	0	+	0	nil as flat
5 to 6	$(y_B-y_A)*x_B$	+	$(y_B-y_A)*(x_A-x_B)/2$	Negative
	$(y_A-y_B)*x_B$	+	$(y_A-y_B)*(x_A-x_B)/2$	
6 to 7	$(y_B-y_A)*x_{AB}$		none	Negative
	$(y_A-y_B)*x_{AB}$			
7 to 8	$(y_B-y_A)*x_A$	+	$(y_B-y_A)*(x_B-x_A)/2$	Negative
	$(y_A-y_B)*x_A$	-	$(y_A-y_B)*(x_A-x_B)/2$	
8 to 1	0	+	0	nil as flat

$x_A > x_B$ (3 to 4 – 5 to 6)

$x_A = x_B$ (2 to 3 – 6 to 7)

$x_A < x_B$ (1 to 2 – 7 to 8)

Blue formula when using only the two differences (y_A-y_B) and (x_A-x_B)

All the eight existing formulae can be seen as four different pairs. One member of the pair gives a positive area value, the other one a symmetrical negative value. One of the four pairs gives an area of nought value and can be ignored. Furthermore, by using only the two differences (y_A-y_B) and (x_A-x_B) as in columns 9 and 10, the formula within each pair are identical with the criterion to use a specific formula depending solely on the difference (x_A-x_B) being either positive or negative. In practice only two formula were kept in use as follows:

- If $x_A - x_B > 0$, then use $(y_A-y_B)*x_B + (y_A-y_B)*(x_A-x_B)/2$;
- If $x_A - x_B < 0$, then use $(y_A-y_B)*x_A - (y_A-y_B)*(x_A-x_B)/2$;
- If $x_A - x_B = 0$, then use either of the above formula as the second part is nil and
- If $y_A - y_B = 0$, then use either of the above formula as the whole formula is nil.

Furthermore the first two formulae can be expanded and become:

1. $y_Ax_B - y_Bx_B + ½y_Ax_A - ½y_Ax_B - ½y_Bx_A + ½y_Bx_B = ½y_Ax_B - ½y_Bx_B + ½y_Ax_A - ½y_Bx_A$
2. $y_Ax_A – y_Bx_A - ½y_Ax_A + ½y_Ax_B + ½y_Bx_A - ½y_Bx_B = ½y_Ax_A - ½y_Bx_A + ½y_Ax_B -½y_Bx_B$

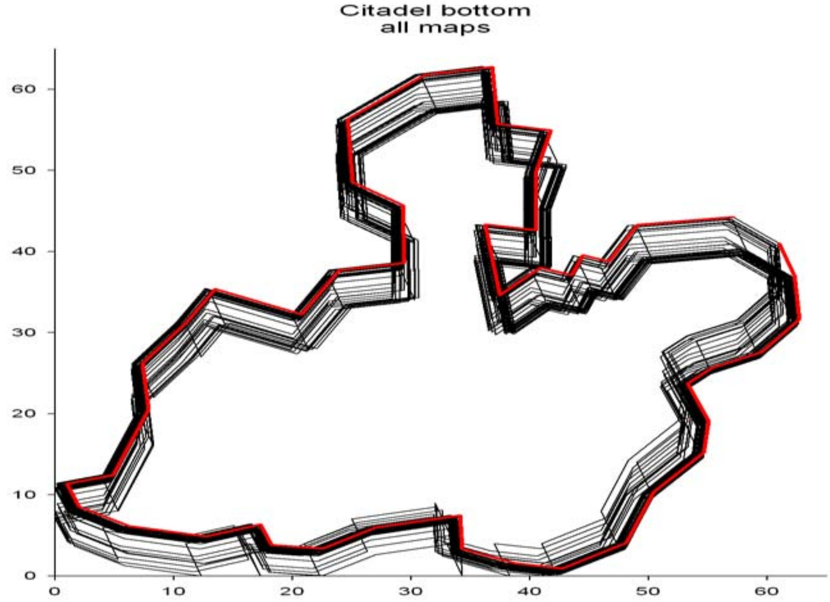
It clearly shows that both formulae are identical and only one (either of them) needs to be used to calculate each area covered between two points. If the colony perimeter was measured anticlockwise, the overall area value will be negative, but needs only transforming back to a positive one.

Colony “spinning”

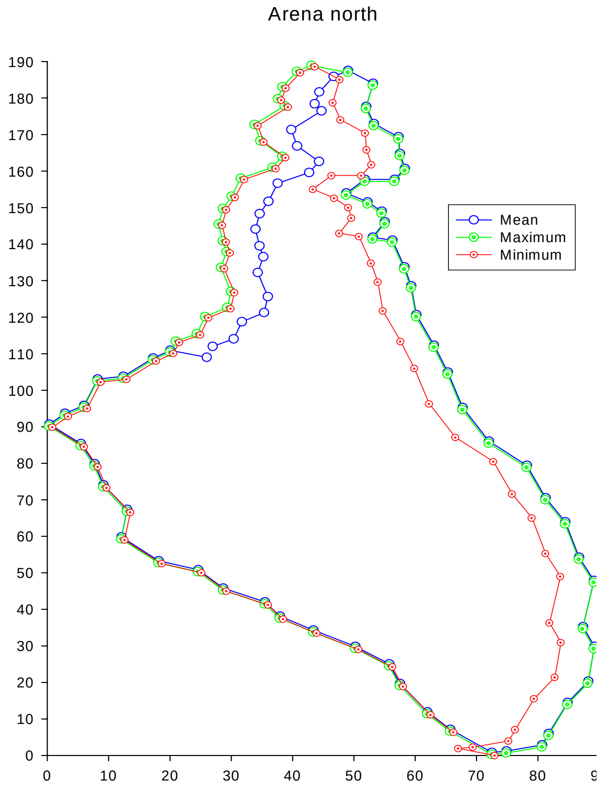
As each point drawn by this method is dependent on the previous one, so will the errors be cumulative. However, the choice of a start point is purely arbitrary and has no biological meaning. To investigate how much effect it has in calculating a colony area, we developed a simple program (see below) to rotate the order of each point by repeating the above calculations by moving the first point to the last until all points along the perimeter of the colony have been once in the front. In the example above, this involved recalculating the area 17 times.

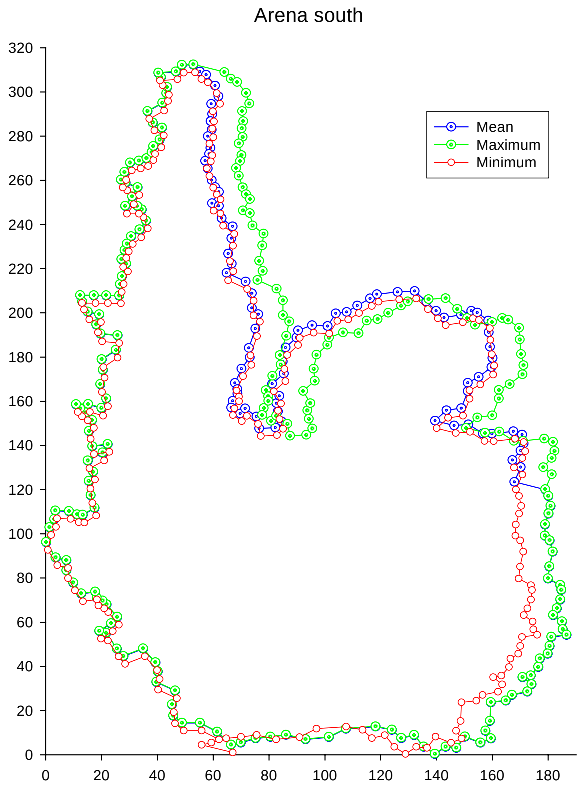
```
 'when importing new data, leave first row blank!!
w=size(col(1))
cell(6,1) = 5000
cell(7,1) = 5000
for j = 1 to (w-1) do
'do all calcs for areas
   col(4) = col(2)*sin(col(3))
   col(5) = col(2)*cos(col(3))
   for k = 1 to size(col(1)) do
         cell(6,k+1) = cell(4,k+1)+cell(6,k)
         cell(7,k+1) = cell(5,k+1)+cell(7,k)
         cell(8,k+1) = cell(7,k)-cell(7,k+1)
         cell(9,k+1) = cell(6,k)-cell(6,k+1)
         cell(10,k+1) = cell(8,k+1)*cell(6,k)-cell(9,k+1)*cell(8,k+1)/2
   end for
'restore last line to origin
      cell(6,w+1) = 5000
      cell(7,w+1) = 5000
      cell(8,w+1) = cell(7,w)-5000
      cell(9,w+1) = cell(6,w)-5000
      cell(10,w+1) = cell(8,w+1)*cell(6,w)-cell(9,w+1)*cell(8,w+1)/2
'store each area in one cell below previous
   cell(11,j) = total(col(10))
'store xy coordinates
'   col(14+2*j)=col(6)
'   col(15+2*j)=col(7)
'put first record at the end
   for i = 1 to (w-1) do
         cell(12,i+1) = cell(2,i+2)
         cell(13,i+1) = cell(3,i+2)
   end for
```

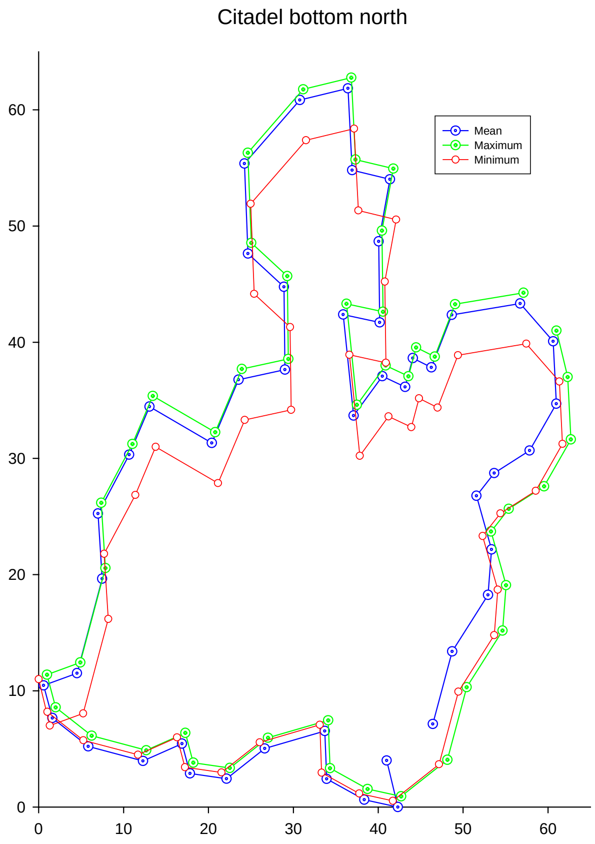
```
  cell(12,w) = cell(2,2)
  cell(13,w) = cell(3,2)
  col(2)=col(12)
  col(3)=col(13)
end for
```

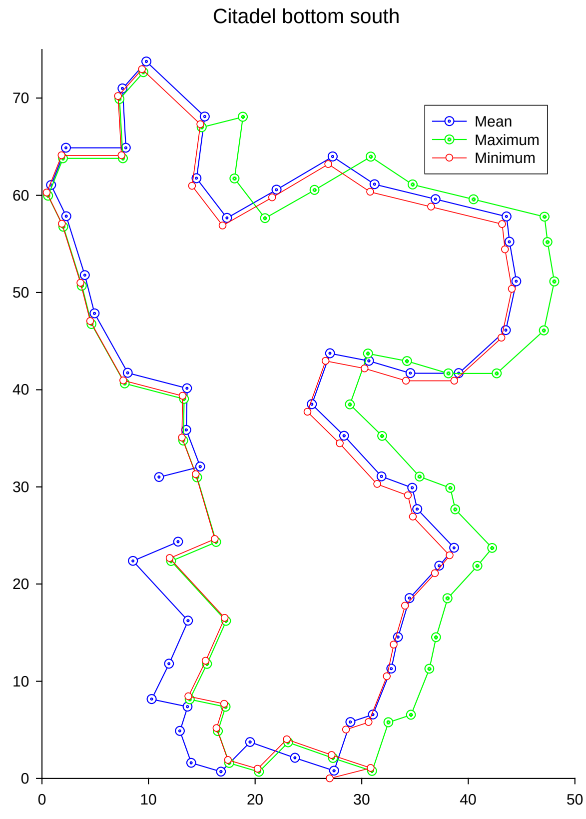


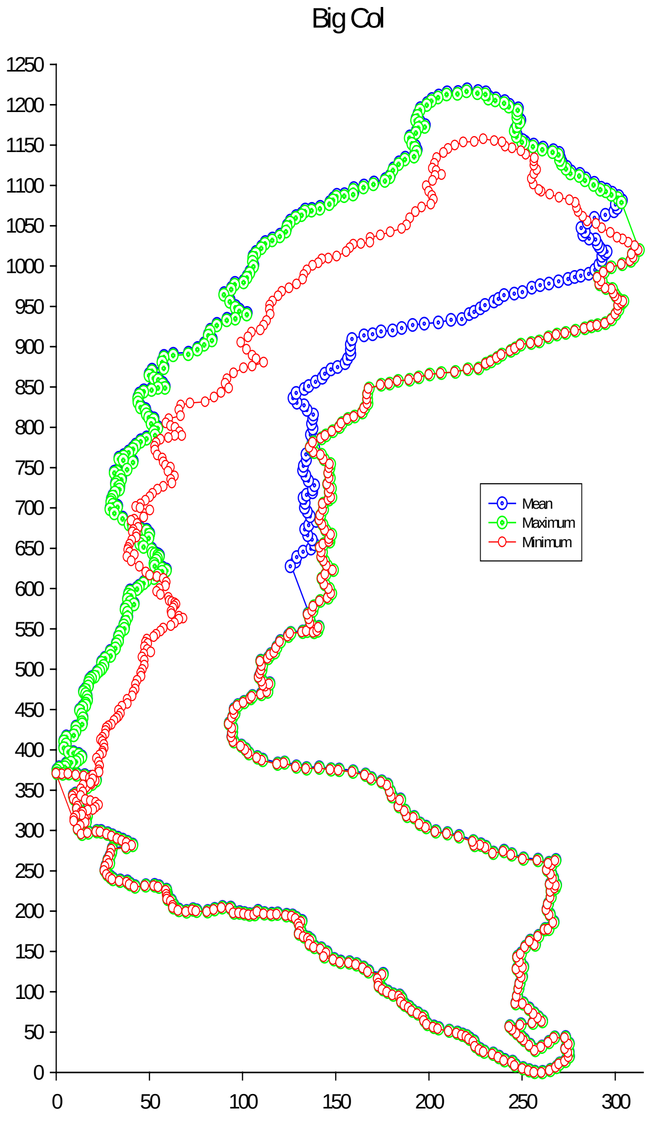
The graph above shows the 46 possible drawing of a colony on Beauchêne Island in 2005 and with the drawing closest to the average colony area drawn in red. This method was used for all colonies measured by this method on all islands and during both censuses. The following set of graphs show the average, minimum and maximum areas obtained for all colonies measured in the 2005 census.

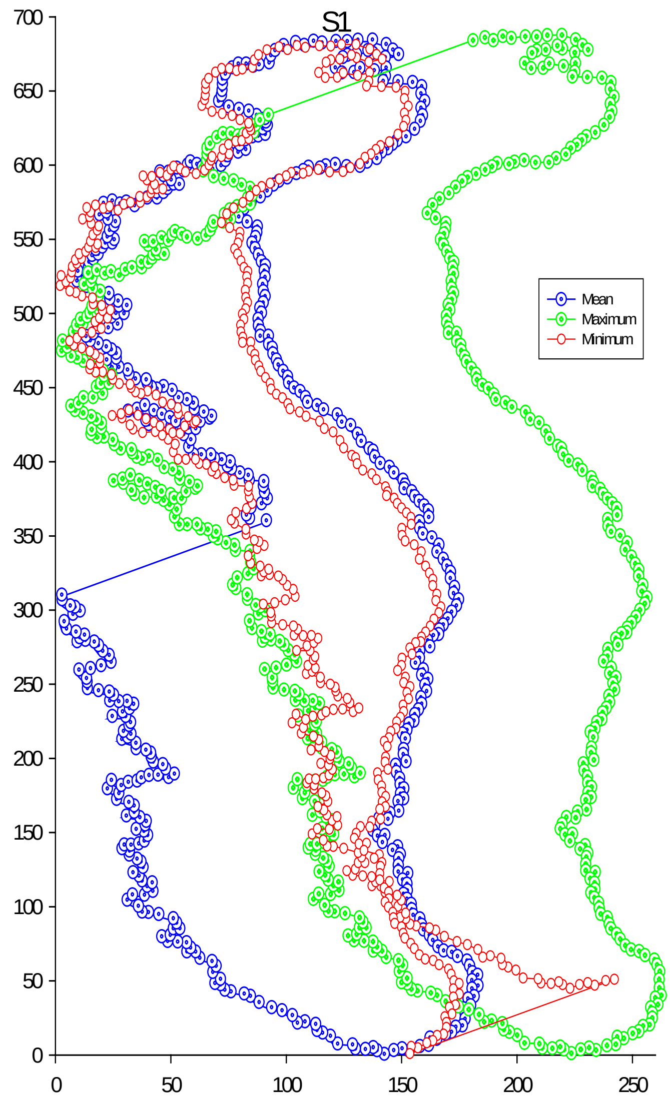


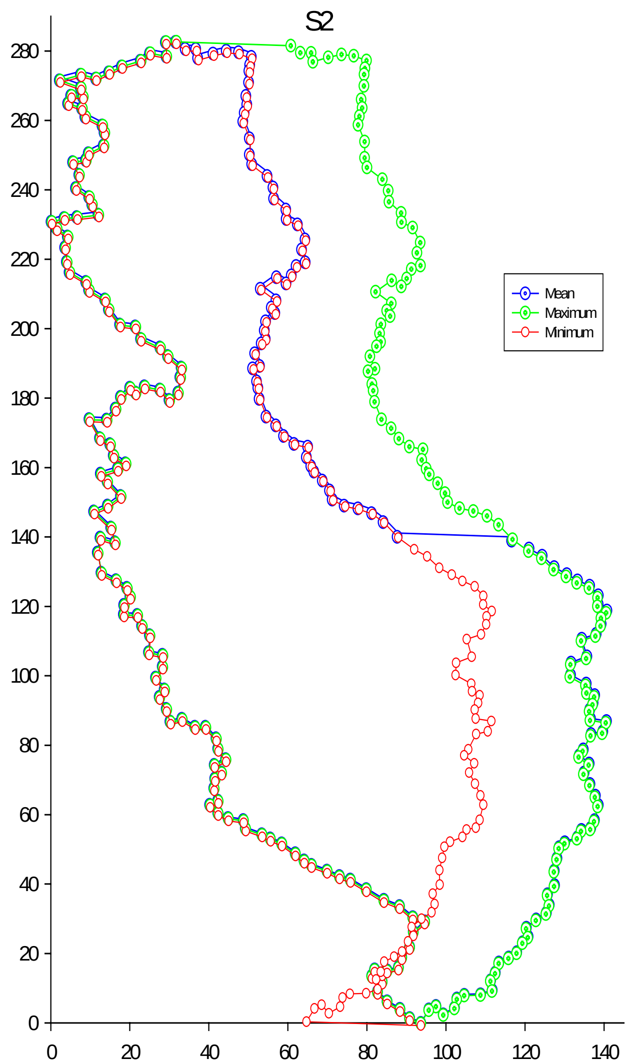


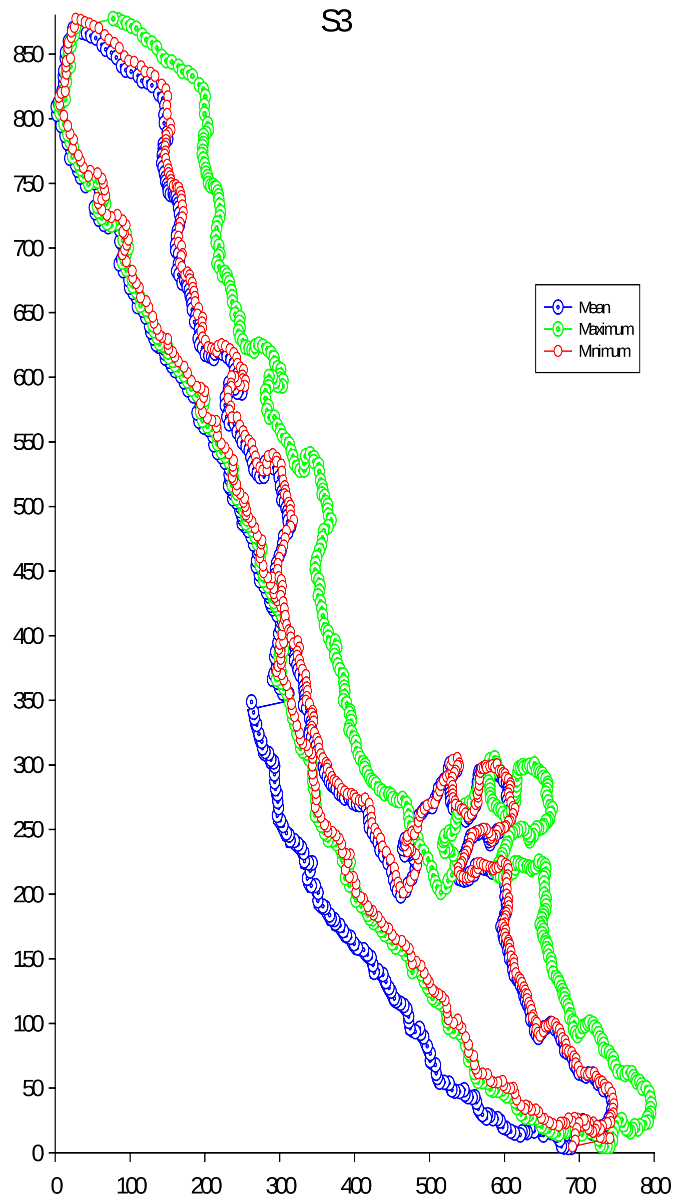

Citadel bottom north
Mean
Maximum
Minimum
0
10
20
30
40
50
60


Citadel bottom south
Mean
Maximum
Minimum
0
10
20
30
40
50
60
70


Big Col
Mean
Maximum
Minimum
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100
1150
1200
1250


S1
Mean
Maximum
Minimum
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700


S2
Mean
Maximum
Minimum


S3
Mean
Maximum
Minimum

APPENDIX 2

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).

Figure 1: Difference between areas measured by GPS and Laser

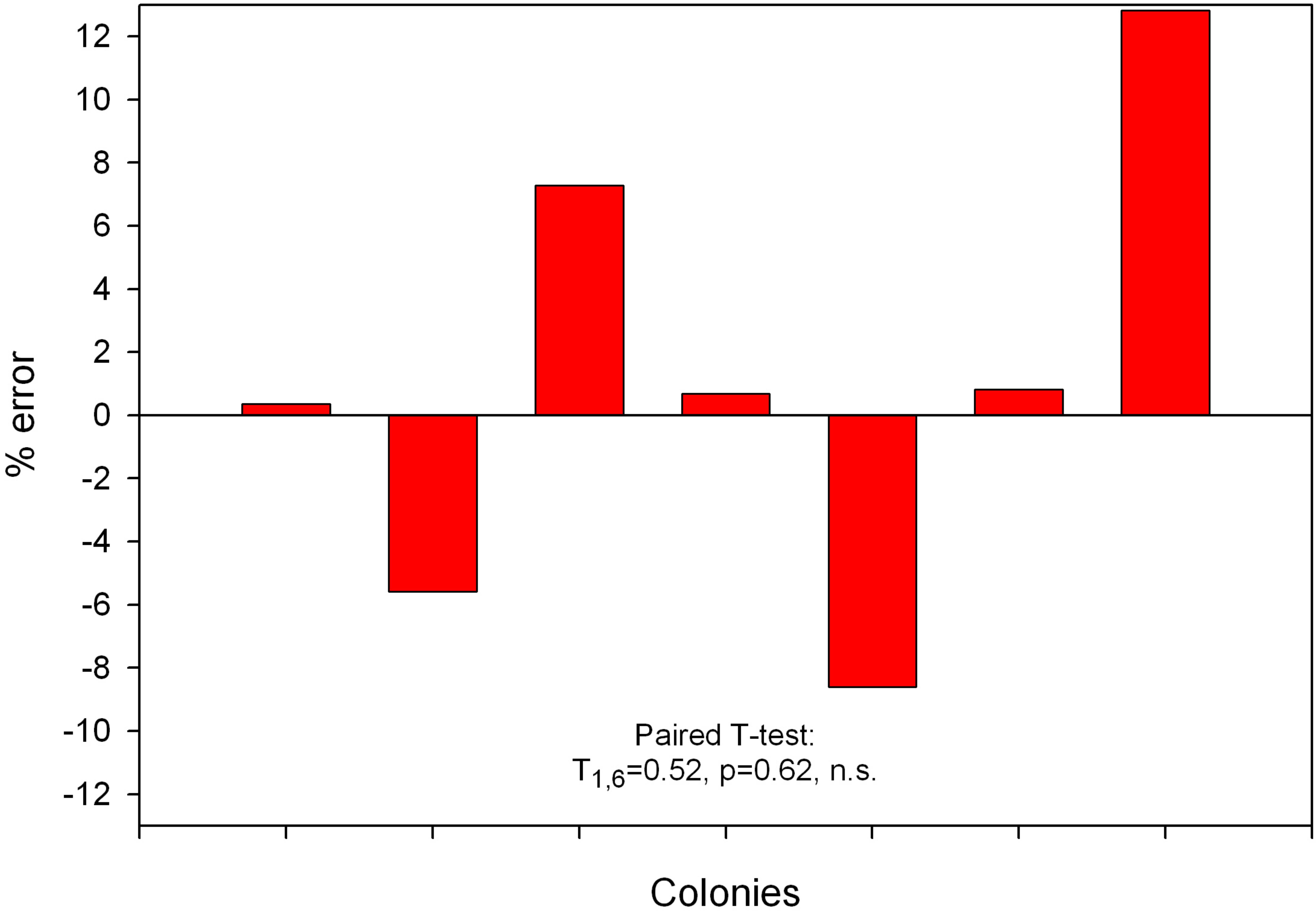


Figure 2: Difference between direct counts and area/density method

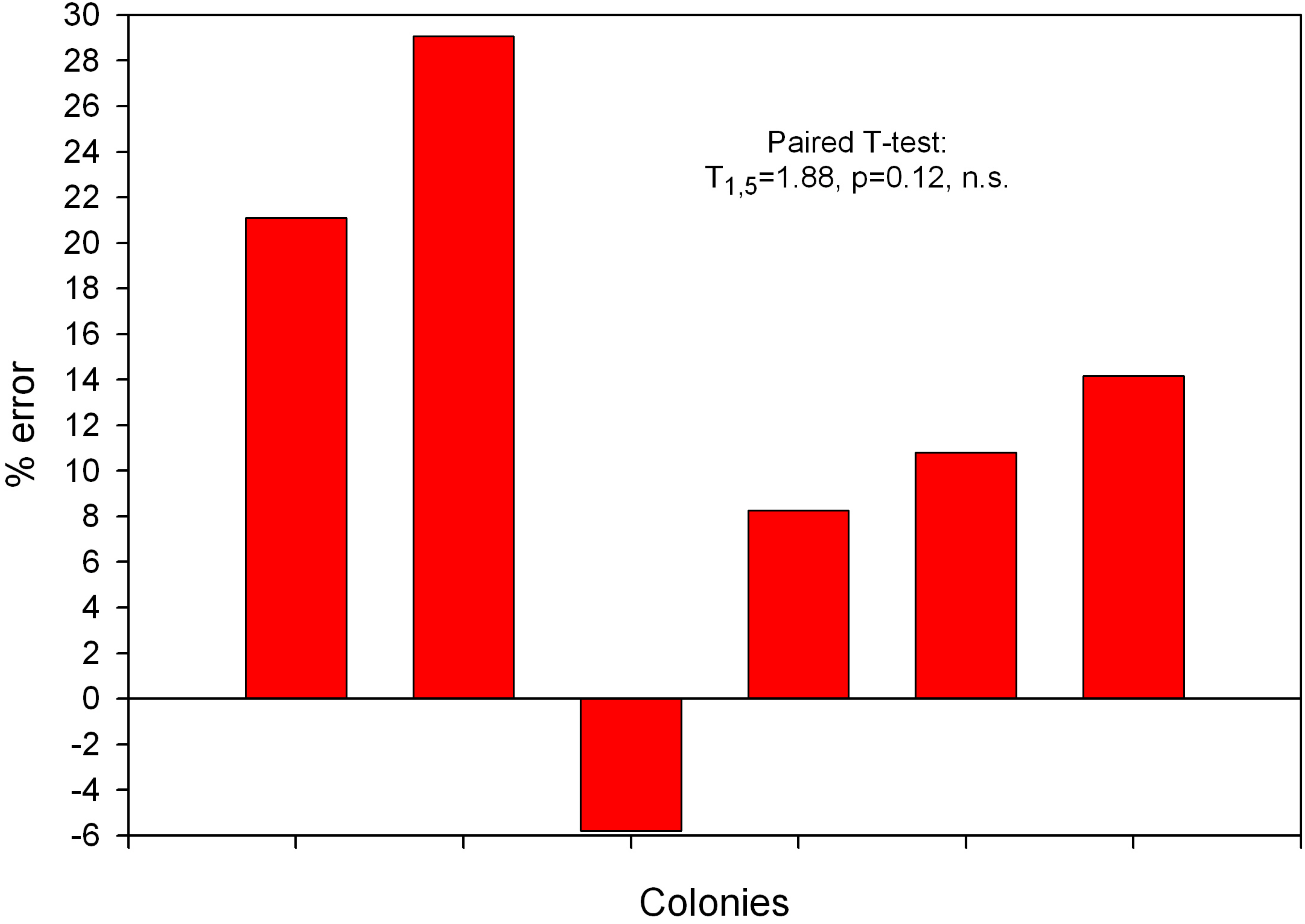
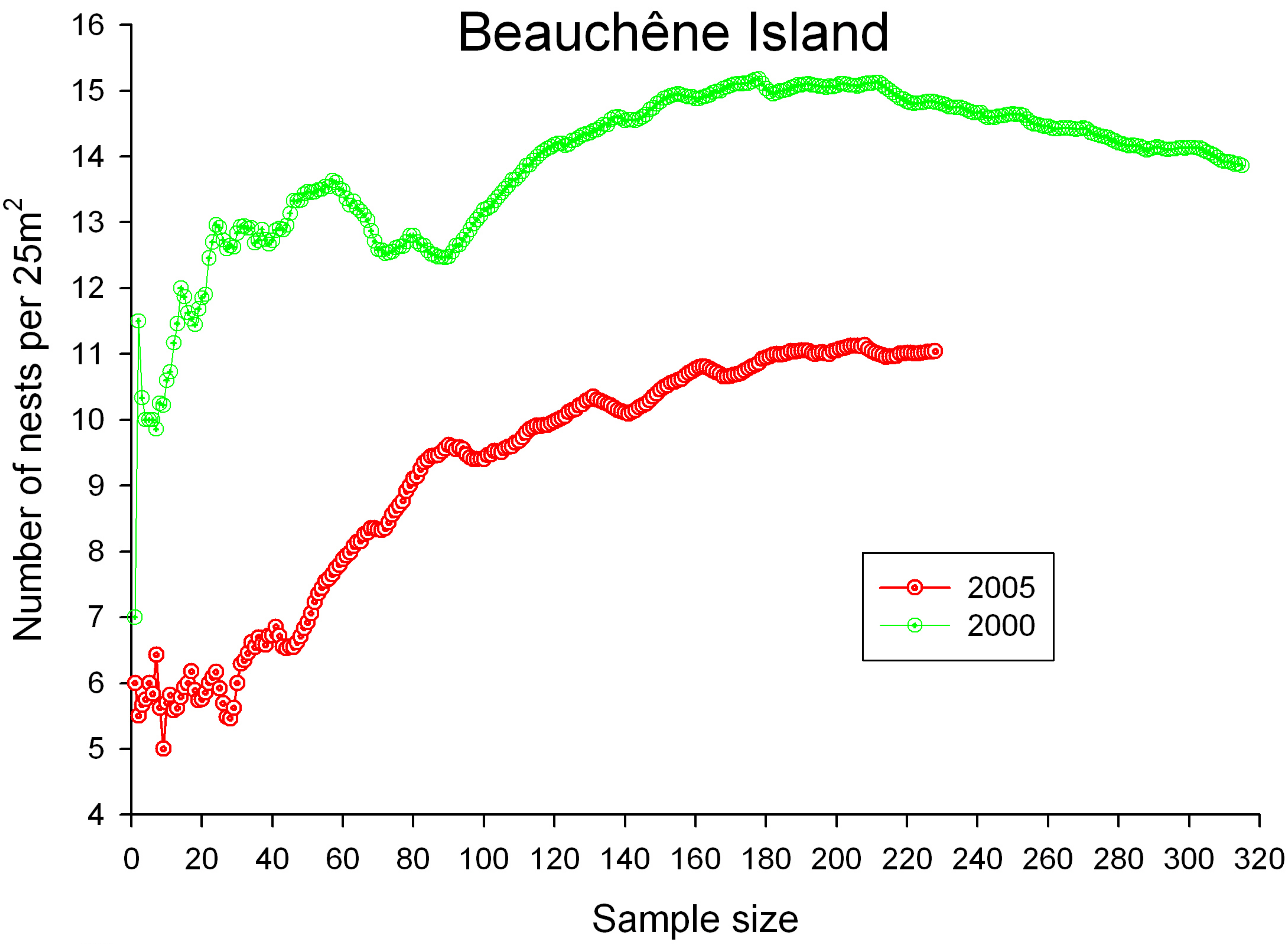


Figure 3: changes in nest density with sample size



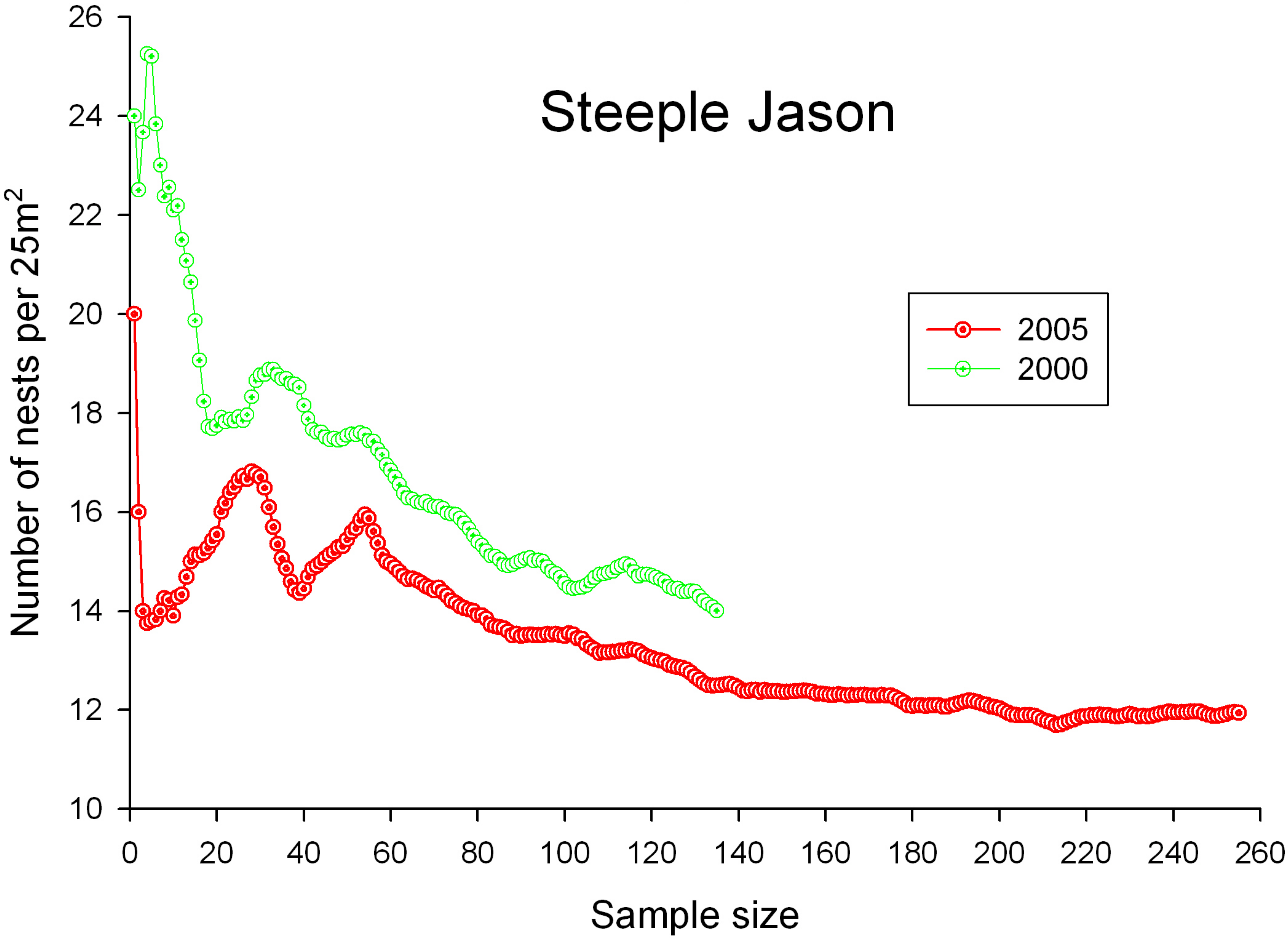
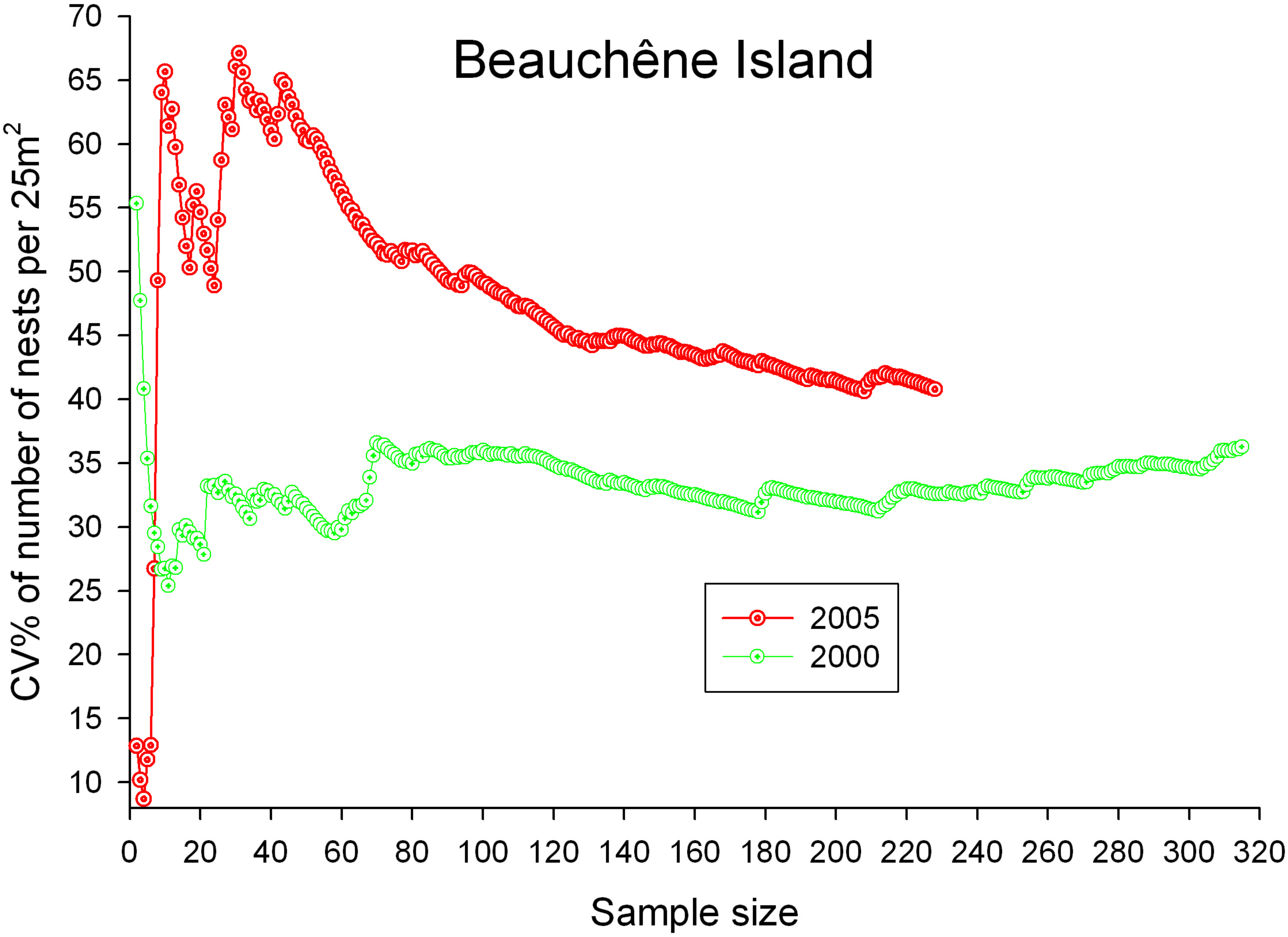
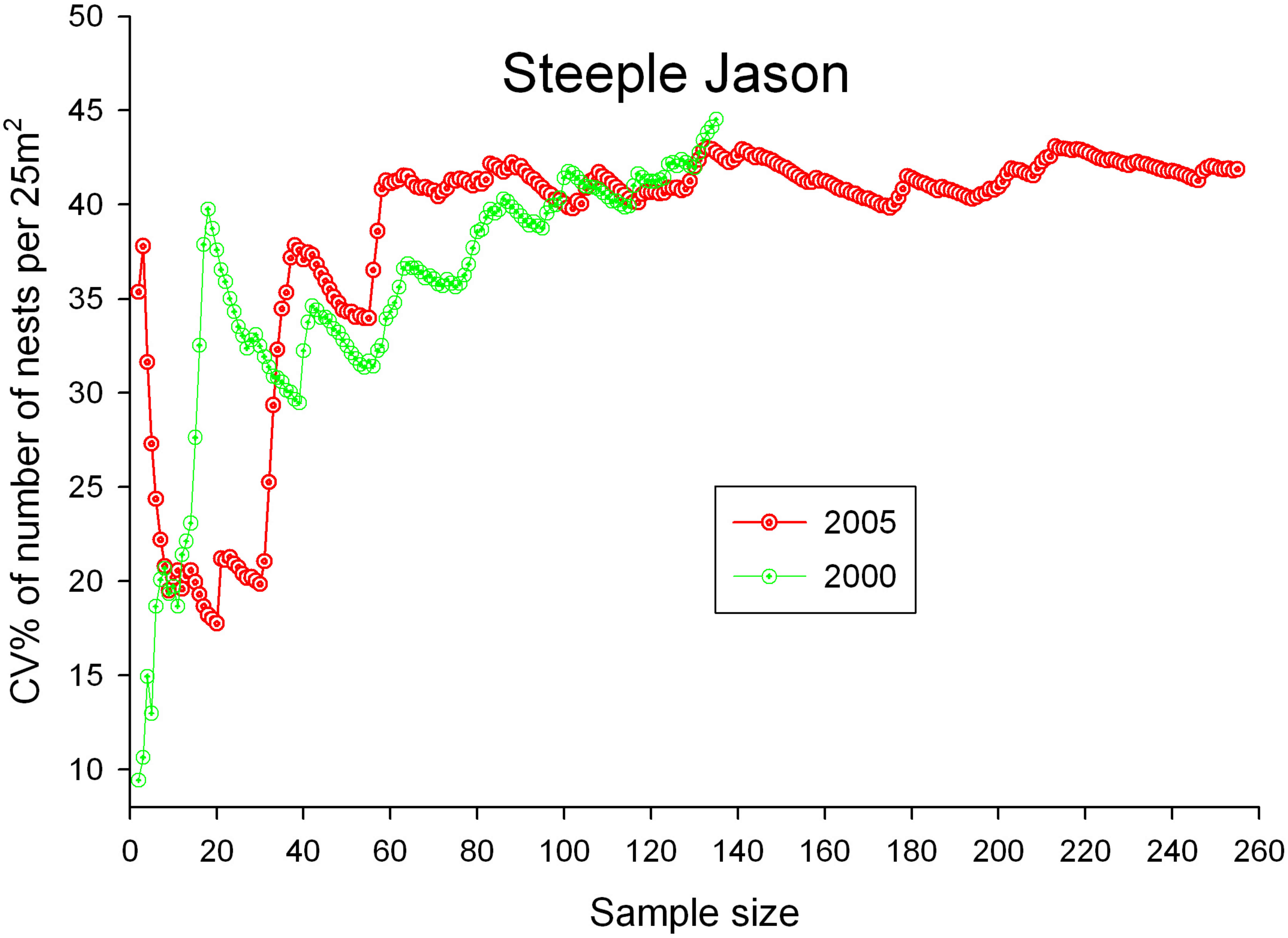


Figure 4: changes in CV% of nest density with sample size





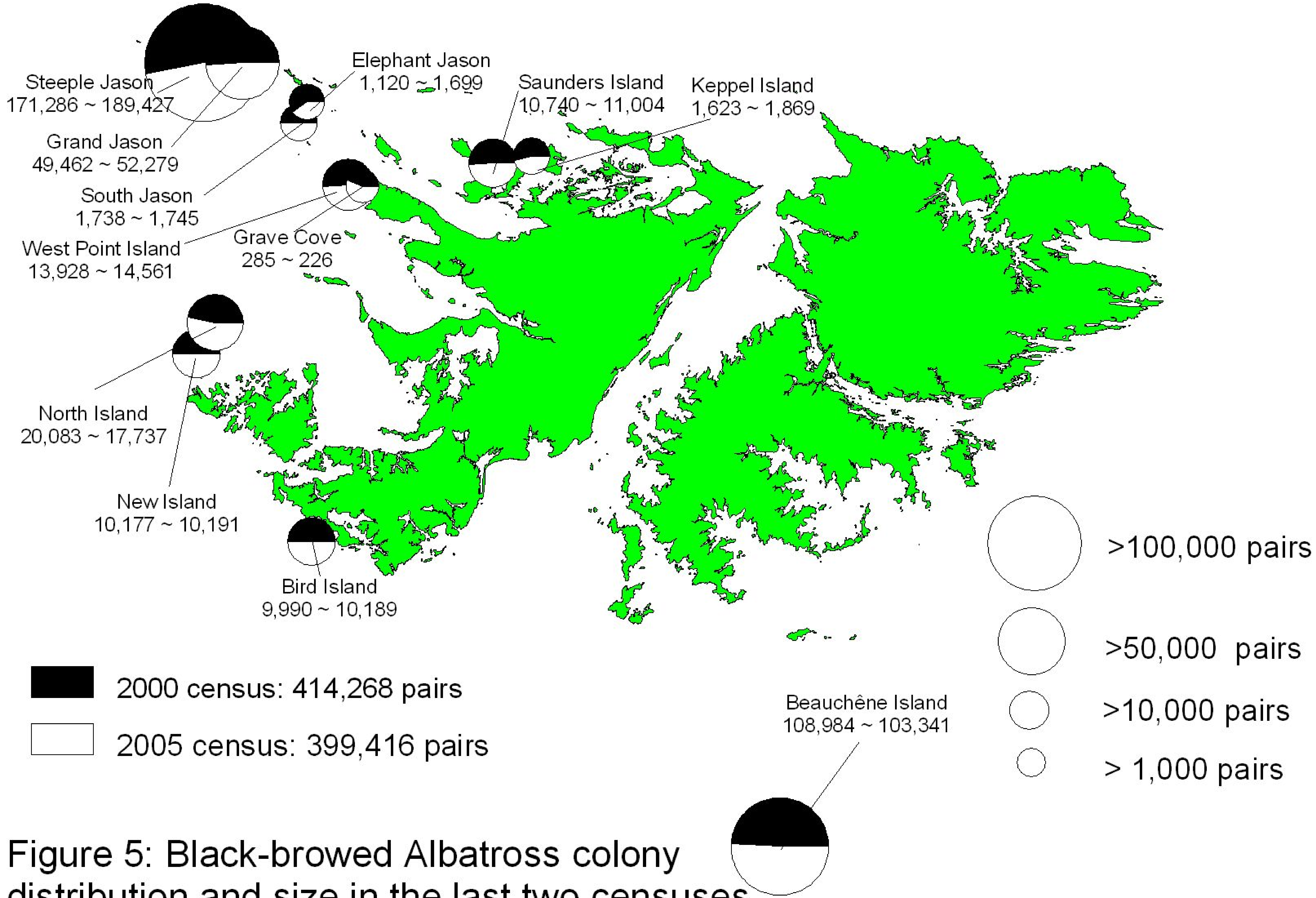


Figure 5: Black-browed Albatross colony distribution and size in the last two censuses

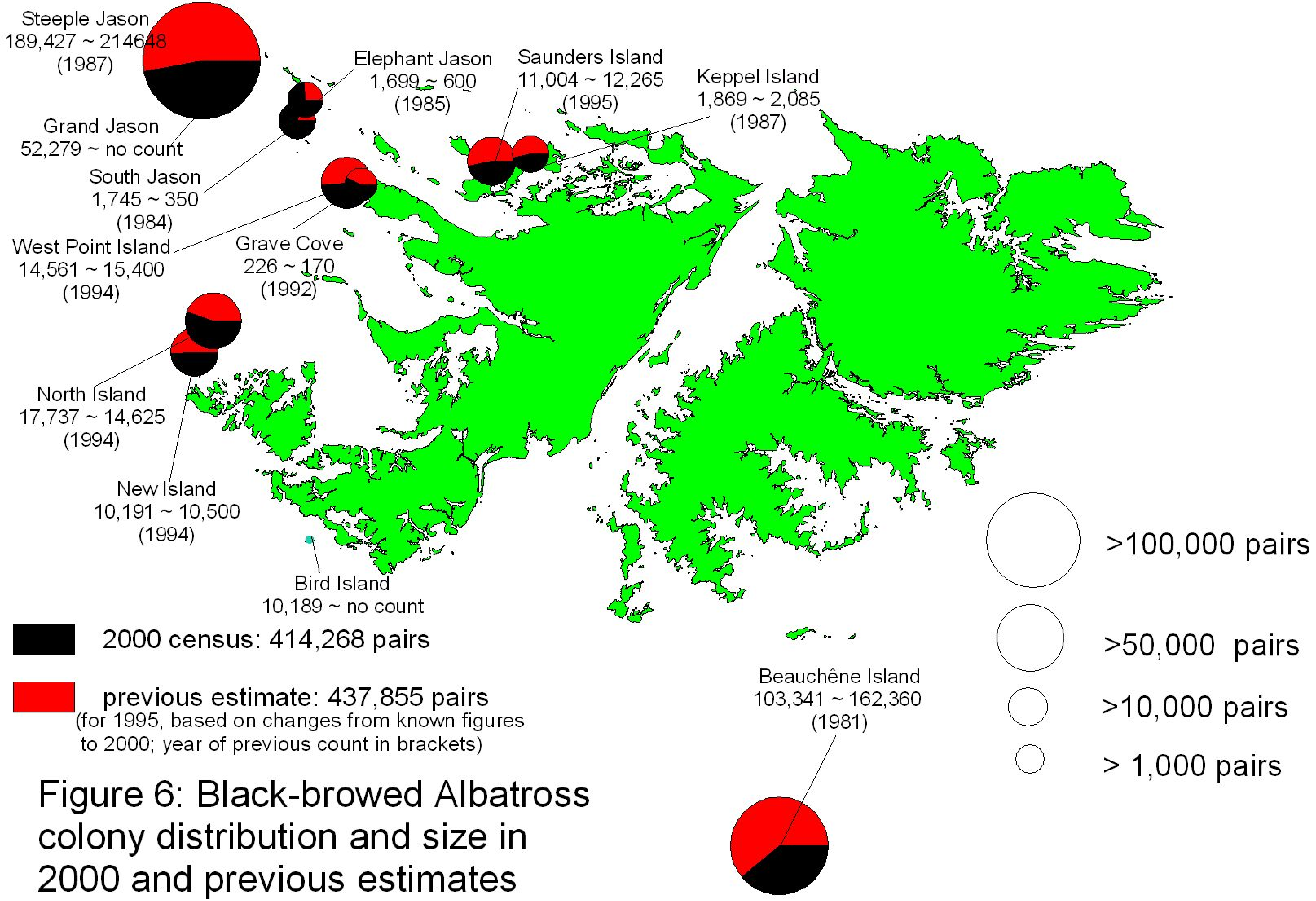
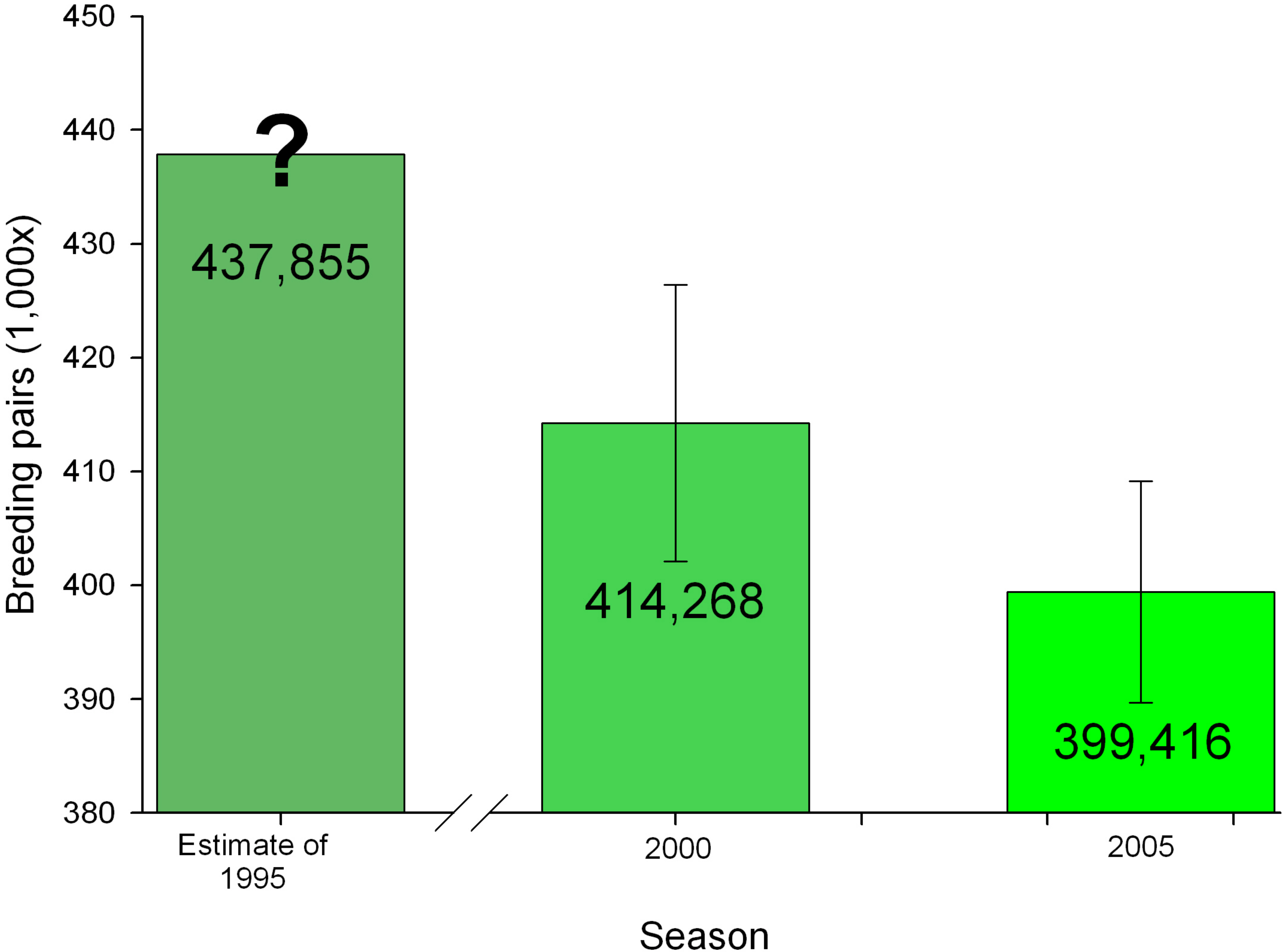
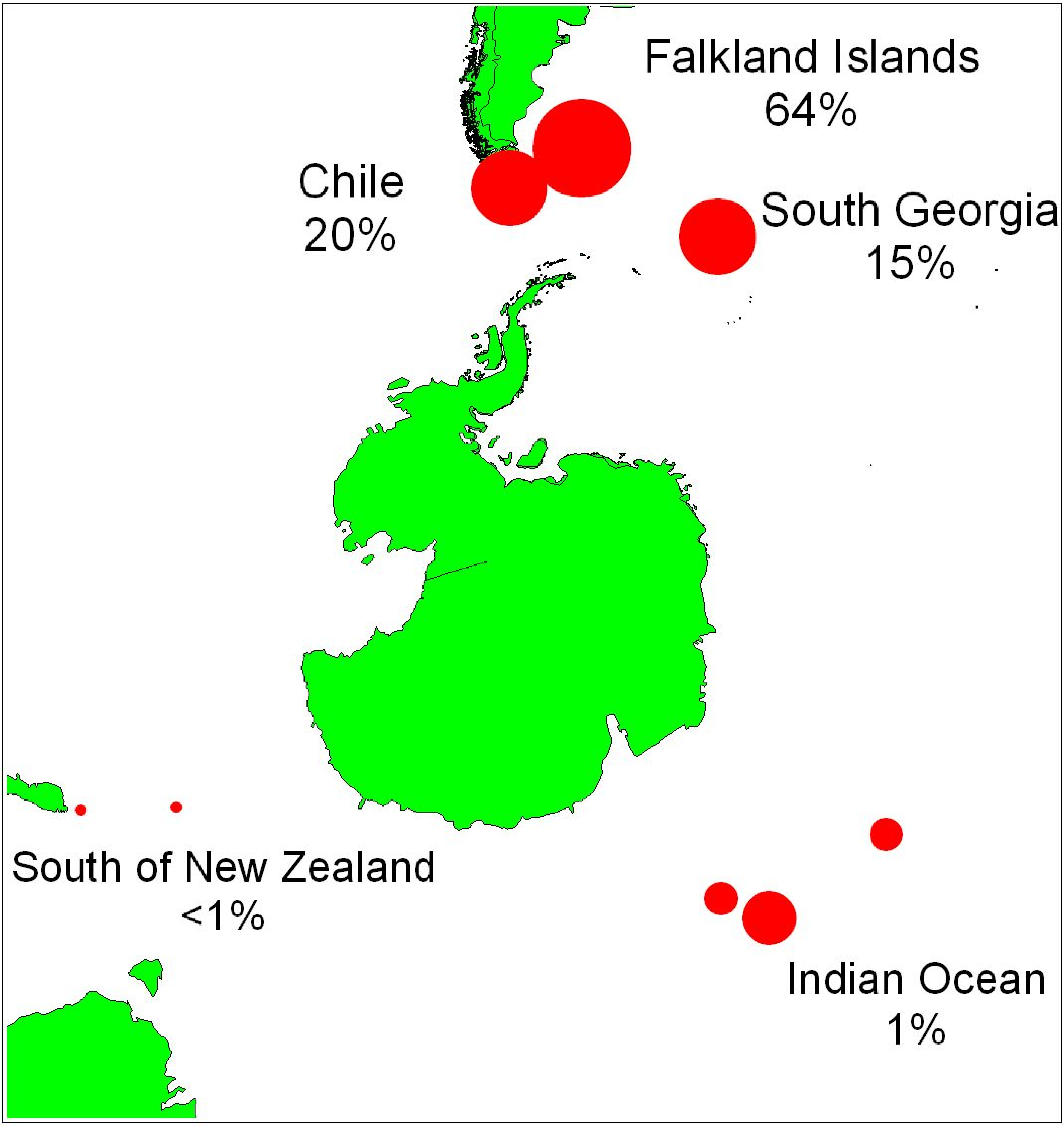


Figure 6: Black-browed Albatross colony distribution and size in 2000 and previous estimates

Figure 7: Reconstructed trends in the Falkland Islands Black-browed Albatross population





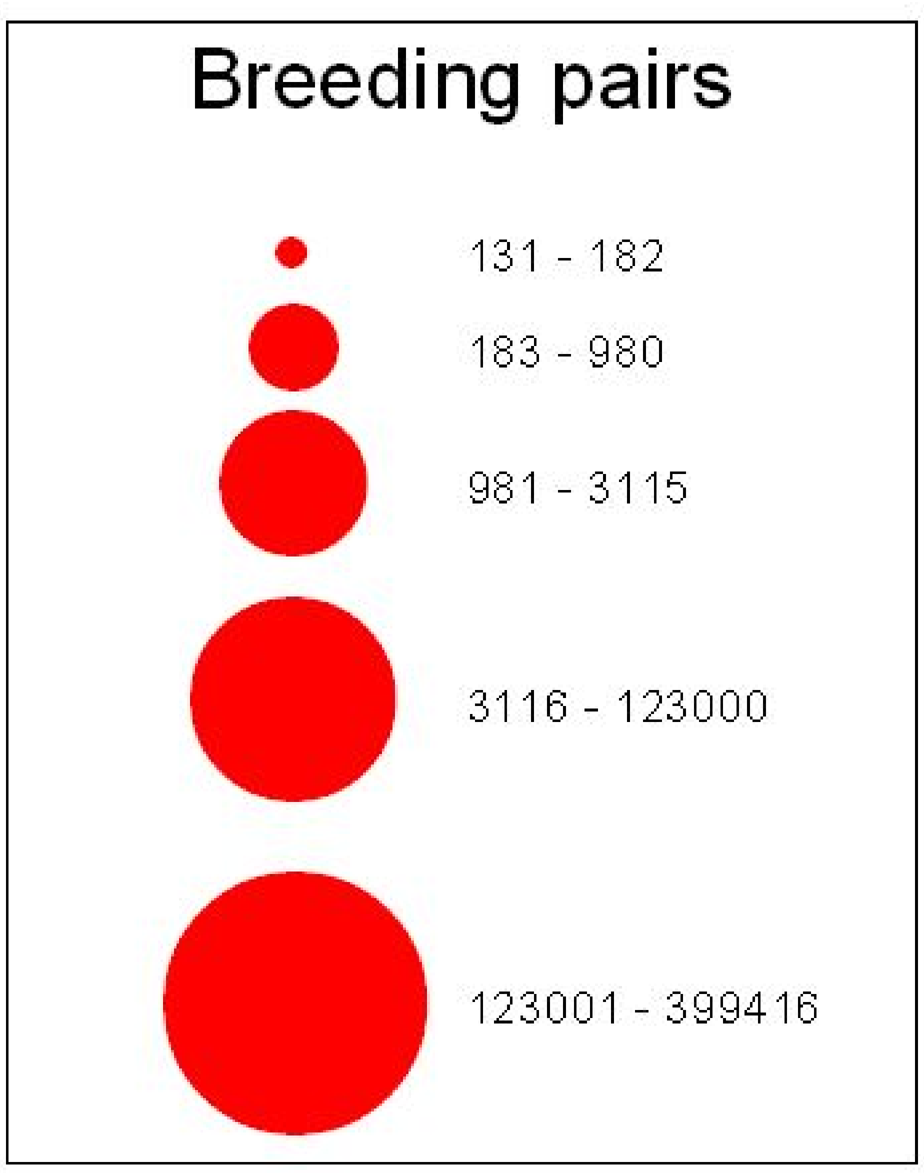


Figure 8: Black-browed Albatross
World Distribution
618,153 pairs