POPULATION TRENDS OF GENTOO PENGUINS *PYGOSCELIS PAPUA* BREEDING AT THE FALKLAND ISLANDS

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SUMMARY

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The fourth archipelago-wide census of Gentoo Penguins *Pygoscelis papua* breeding at the Falkland Islands was conducted from 24 October to 8 December 2010. The number of Gentoo Penguins breeding in 2010 was estimated to be 132 321 ± 2 015, the highest number of breeding pairs recorded for this species at the Falkland Islands since the first survey in 1933. The global population of Gentoo Penguins is conservatively estimated to be about 384 000 breeding pairs, of which the Falkland Islands accounts for 34%, probably the largest component of the global population. Annually monitored study colonies accounted for 20% of the total number of Gentoo Penguin breeding pairs at the Falkland Islands in 2010 and proved to be a reliable proxy for archipelago-wide changes in the number of breeding pairs. Recent trends at annually monitored study colonies, combined with archipelago-wide trends, indicate that the number of Gentoo Penguins breeding at the Falkland Islands has increased between 2005 to 2010. However, annual monitoring data also revealed large inter-annual variability in the number of breeding pairs, which makes assessing systematic population changes challenging.

Key words: South Atlantic, seabirds, long-term monitoring, population census

INTRODUCTION

Gentoo Penguins *Pygoscelis papua* are one of the most widely distributed penguin species, being found from 46°S to 65°S (Woehler 1993). The global population is conservatively estimated to be about 317 000 breeding pairs, two-thirds of which breed on islands in the sub-Antarctic including the Falkland Islands (Woehler 1993, Ellis *et al.* 1998). The remainder of the population is confined to the Antarctic Peninsula and associated islands (Woehler 1993). Although Gentoo Penguins are increasing at breeding sites in the Antarctic (e.g. Lynch *et al.* 2008), declines at some sub-Antarctic breeding sites have prompted the species to be listed as Near Threatened based on IUCN Red List criteria (Jouventin & Weimerskirch 1990, Woehler & Croxall 1997, Woehler *et al.* 2001, Crawford *et al.* 2003, Lescroël & Bost 2006, BirdLife International, 2011). Long-term population monitoring, particularly at the larger sub-Antarctic breeding sites, is therefore core to conservation and management because population changes at these sites influence the global conservation status of the species.

The Falkland Islands support a significant proportion of the global population of Gentoo Penguins (Pistorius *et al.* 2010). Since 1990, annual counts at selected breeding colonies have been undertaken to monitor trends in the number of breeding pairs and trends in breeding success. In addition to annual monitoring, archipelago-wide censuses have been undertaken at five-year intervals since 1995 (i.e. in 1995, 2000 and 2005). The aims of these censuses are to estimate the total breeding population at the Falkland Islands and to assess whether fluctuations at annually monitored study colonies are representative of changes for the Falkland Islands population as a whole. In this paper, we present the results of the 2010 Falkland Islands archipelago-wide census. We assess (1) the population status of Gentoo Penguins breeding at the Falkland Islands, and (2) whether annually monitored study colonies reflect archipelago-wide trends in the number of breeding pairs.

METHODS

The Falkland Islands are located approximately 600 km east of mainland South America, in the southwest Atlantic Ocean between 51°S to 53°S and 57°W to 62°W (Fig. 1). Gentoo Penguins breed at 84 sites around the Falkland Islands (Pistorius *et al.* 2010; Fig. 1). Egg laying is highly synchronous (Williams 1990) and is usually completed by late October at the Falkland Islands (Otley *et al.* 2005). The archipelago-wide census is timed to take place during the incubation period.

The fourth archipelago-wide census was conducted from 24 October to 8 December 2010. The census was conducted over an extended period due to logistical constraints, and some breeding pairs had probably failed before counting. Although correction factors are not available for the Falkland Islands, Croxall and Rothery (1995) reported that an average of 4% of breeding pairs failed before egg-laying was completed at South Georgia. This implies that our count may underestimate true values; however, the 2010 census was consistent with previous archipelago-wide censuses, which were conducted over similar time spans (24 October to 15 December in 1995, 21 October to 30 November in 2000 and 2 November to 30 November in 2005; Huin 2006).

Consistent with methods used in the previous three censuses, the number of breeding pairs in each colony was counted with the aid of a tally counter by scanning from outside the colonies (Pistorius *et al.* 2010). At least three direct counts of nests occupied by adults were made by a minimum of two observers. In some cases large colonies were photographed from vantage points, and breeding pairs were subsequently counted from digital photographs. Counts were repeated if they differed by more than 5%, and were averaged once within this range (Thompson & Riddy 1993). Trends in the number of breeding pairs (i.e. the breeding population) are regarded as an index of Gentoo Penguin population size and are the only practical means available to estimate patterns of relative population abundance.

Annual monitoring at study colonies followed the same methods as those used to census breeding colonies during the archipelago-wide census. From 1990 to 2010, between two and 17 Gentoo Penguin study colonies were monitored each year, with 18 different colonies being monitored in total over the decade. The selection of annually monitored study colonies reflects a compromise between accessibility, size and the spatial distribution of breeding colonies. Since 2003, annual counts have been undertaken at the same 15 colonies (Fig. 1). These 15 annually monitored study colonies accounted for 16.8% of the total number of breeding pairs at the time of the last archipelago-wide census in 2005 (Huin 2006). To assess whether changes in the number of Gentoo Penguins breeding at annually monitored study colonies reflected archipelago-wide trends, we compared the percentage change (at five-yearly intervals) in the number of breeding pairs at study colonies with the percentage change in the total number of breeding pairs between archipelago-wide censuses. Normality was tested using the Kolmogorov–Smirnov test, and, because of non-normal distribution of data, non-parametric Mann-Whitney U-tests were subsequently used. If variances were unequal, data were first ranked and significance tested using the unequal variance *t*-test (Ruxton 2006). Significance was assumed at $P < 0.05$. All values are presented as estimates ± 95% CI unless otherwise stated.

RESULTS

A total of 126 367 ± 1 995 breeding pairs were counted at 79 colonies in the 2010 archipelago-wide census. We were unable to count five Gentoo Penguin breeding colonies. In 2005, there were an estimated 5 954 ± 298 breeding pairs at these five breeding colonies. Assuming that the five missed breeding colonies remained stable between 2005 and 2010, the conservative estimate for the Falkland Islands population would be 132 321 ± 2 015 breeding pairs. This is not an unreasonable assumption, given that the minimum increase across annually monitored study colonies was 32% between 2005 and 2010 and the average change across all breeding colonies (including annually monitored study colonies) was 107% ± 84% (range -78% to 376%). If the five missed breeding colonies increased by an average of 107%, then the estimate for the missed breeding colonies would be 12 325 breeding pairs, and the total population would be 138 692 breeding pairs. We used the

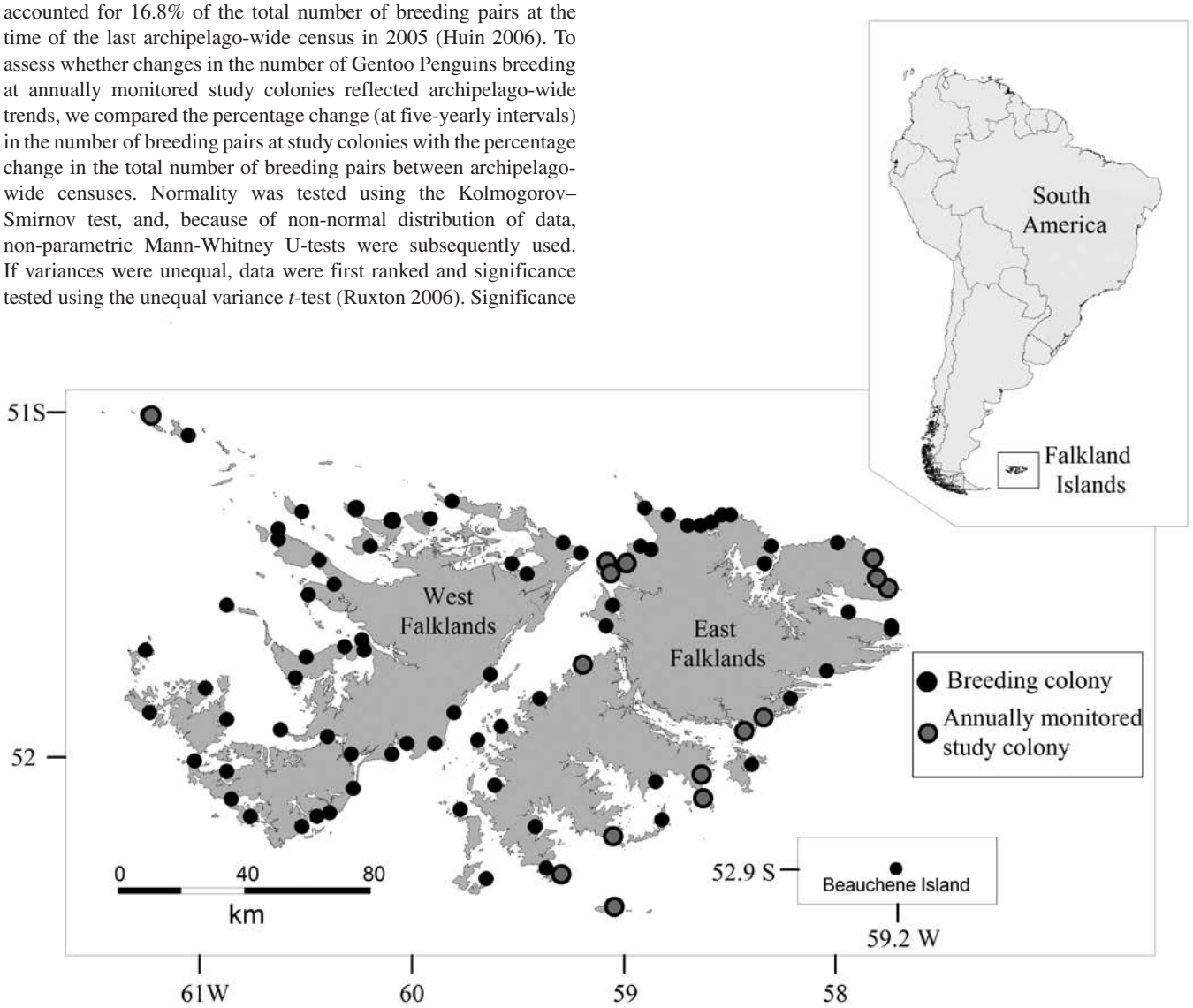

Fig. 1. Location of Gentoo Penguin breeding colonies at the Falkland Islands, including breeding colonies that are monitored annually.

conservative population estimate of 132 321 breeding pairs for further analyses because of the large variability among breeding colonies in the extent and direction of population changes at five-year intervals and the inherent inaccuracy when attempting to interpolate counts between 2005 to 2010.

The conservative 2010 estimate represents an increase of 101% over the number of Gentoo Penguin breeding pairs counted during the 2005 archipelago-wide census (65 860 ± 1 052 breeding pairs). This equates to an annual intrinsic growth rate of 6.1%. Similarly, the 2010 estimate was 105% larger than the 1995 estimate of 64 430 ± 923 breeding pairs and 16.5% larger than the 2000 estimate of 113 570 ± 1 578 breeding pairs (Fig. 2).

Annually monitored study colonies accounted for 20% of the total number of Gentoo Penguins breeding at the Falkland Islands in 2010. The number of breeding pairs counted at annually monitored study colonies was highly variable between some years (Fig. 2). For example, breeding pairs declined by 30% between 2008 and 2009 and then increased by 67% between 2009 and 2010 (Fig. 2). Nevertheless, trends from annually monitored study colonies broadly reflected archipelago-wide trends, with the number of breeding pairs increasing from 9 956 breeding pairs in 2003 to 26 318 breeding pairs in 2010 (Fig. 2, Table 1).

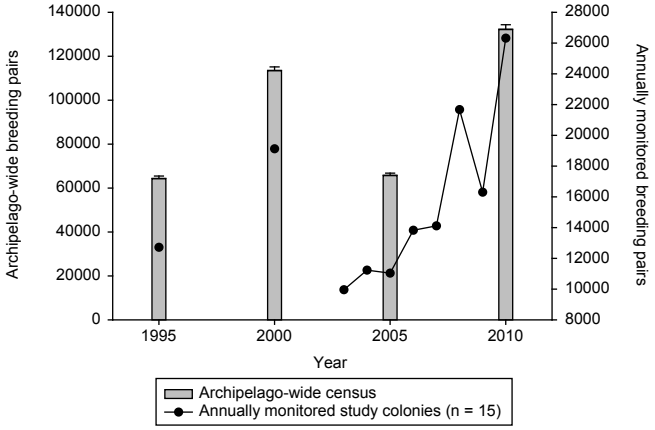

Fig. 2. Estimates of the number of Gentoo Penguin breeding pairs at the Falkland Islands. Presented are archipelago-wide census results (bar), and census results for a subset of 15 annually monitored study colonies (line).

DISCUSSION

Our conservative estimate of 132 321 Gentoo Penguin breeding pairs in 2010 is the highest number of breeding pairs ever recorded at the Falkland Islands, surpassing the estimate of 116 000 breeding pairs in 1932 (Bennett 1933). In 2005, the number of Gentoo Penguin breeding pairs at the Falkland Islands was estimated to account for about 21% of the global Gentoo Penguin population (Pistorius *et al.* 2010). Based on the 2010 archipelago-wide census, the conservative global population is now about 384 000 breeding pairs. The Falkland Islands accounts for 34% of the global population estimate and probably supports the largest number of breeding pairs in the world, followed by South Georgia, where the most recent census in 1996 estimated 105 000 breeding pairs (Clarke *et al.* 2012), and the Kerguelen Islands, which support about 35 000 breeding pairs (Woehler 1993).

Trends from study colonies that were monitored annually between 2003 and 2010 were consistent with archipelago-wide results, which indicated that the number of Gentoo Penguin breeding pairs increased at the Falkland Islands between 2005 to 2010 (following a decline between 2000 to 2005). Therefore, our study confirms that the current subset of annually monitored study colonies provides a good proxy for archipelago-wide changes in the number of breeding pairs (see also Pistorius *et al.* 2010), despite the geographical bias in the location of annually monitored study colonies (only one West Falklands breeding colony is currently monitored annually). However, results from annually monitored study colonies also revealed large inter-annual fluctuations in the number of breeding pairs, as is evident across many other Gentoo Penguin breeding locations (Croxall *et al.* 1988, Croxall & Williams 1991, Woehler & Croxall 1997, Trathan *et al.* 2006). Short-term population fluctuations complicate the detection of long-term population trends and, therefore, the extent to which the breeding population at the Falkland Islands has increased remains unclear.

Indeed, fluctuations in the number of Gentoo Penguin breeding pairs at the Falkland Islands over short temporal scales have resulted in a wide range of population estimates and uncertainty in regard to population trajectories (Bingham 1998, Pütz *et al.* 2001, Clausen and Huin 2003, Pistorius *et al.* 2010). For example, we report a doubling in the number of breeding pairs between the 2005 and 2010 archipelago-wide censuses. However, our results are unlikely to represent a doubling of the Falkland Islands population

TABLE 1
Change in Gentoo Penguin breeding pairs between 1995 and 2010[a]

	Five-year change (% ± SD)				
	Total number of breeding pairs		Average number of breeding pairs		
Year	Archipelago-wide change	Change at annually monitored study colonies	Archipelago-wide change *(excluding annually monitored study colonies)*	Change at annually monitored study colonies	Significance
1995–2000	76.3	50.4	101 ± 150	36 ± 67	t = -1.7, df =23.7, P = 0.08
2000–2005	-42.0	-42.3	8 ± 212	15 ± 63	U = 371, Z = -1.6, P = 0.10
2005–2010	100.9	140.1	111 ± 87	124 ± 58	U = 341, Z = -1.0, P = 0.30

[a] Values were calculated for five-yearly archipelago-wide censuses and for a subset of 15 annually monitored study colonies (for corresponding years only).

because the proportion of the population that attempted to breed (and therefore the proportion counted) is unlikely to have been the same for any two censuses (see Link & Sauer 1998). While large population changes over short temporal scales have been reported in other penguin species (e.g. Woehler *et al.* 2001), the large inter-annual changes in the number of Gentoo Penguins breeding at the Falkland Islands indicate that the archipelago-wide population estimate could vary by over 60% from one year to the next (e.g. 30% decline at annually monitored study colonies between 2008 and 2009 followed by a 67% increase between 2009 and 2010).

Although the primary purpose of the archipelago-wide census at the Falkland Islands is to validate whether annually monitored study colonies are a good representation of archipelago-wide trends, differences in the number of Gentoo Penguin breeding pairs between consecutive archipelago-wide censuses are often misinterpreted as population changes. Our results indicate that trends in the number of breeding pairs derived from the five-yearly archipelago-wide censuses alone may not be a good surrogate for assessing changes in population size and highlight the importance of implementing a long-term Gentoo Penguin monitoring program at a subset of breeding colonies on an annual basis. At the Falkland Islands, monitoring breeding colonies annually provides the capacity to detect and better understand Gentoo Penguin population variability over both short and long time-scales and thus affords a more informed assessment of population trends over time (e.g. Baylis *et al.* 2012).

A number of factors have been proposed to explain the temporal variability in the number of Gentoo Penguins breeding at the Falkland Islands. These include egg-collection, competition with commercial fisheries and disease (i.e. factors influencing survival) (Woods & Woods 1997, Bingham 1998, Pütz *et al.* 2001). Most recently, the decline in the number of breeding pairs between 2000 and 2005 was attributed to adult mortality associated with a harmful algal bloom event in 2002 (Pistorius *et al.* 2010). However, not all colonies were affected by the algal bloom (Uhart *et al.* 2004), implying that other factors should also be considered when interpreting archipelago-wide population trends. For example, at South Georgia, Williams and Rodwell (1992) reported significant inter-annual variation over a four-year study in the number of marked Gentoo Penguins that abstained from breeding (range 3% to 25%); mediated at least in part by environmental variability affecting prey availability (Croxall *et al.* 1988, Croxall & Williams 1991, Croxall & Rothery 1995). Further, Croxall and Rothery (1995) demonstrated that breeding abstention, combined with immigration, could account for much of the variability in the number of Gentoo Penguins breeding at South Georgia during their study period (1978 to 1992). Therefore, breeding abstention may (to some degree) explain the inter-annual variation observed in the number of pairs attempting to breed at the Falkland Islands. However, to test this hypothesis, we would need to account for the proportion of adult Gentoo Penguins that breed in a particular year. Unfortunately, this ratio is not known for the Falkland Islands.

Ideally, a demographic study that assesses survival, breeding frequency and recruitment should be integrated into future population studies at the Falkland Islands, as this will facilitate the interpretation of changes in the breeding population and provide a more accurate measure of population change. Although the use of flipper bands may not be appropriate (Saraux *et al.* 2011), transponders (e.g. Gendner *et al.* 2005) could be used at selected breeding colonies where Gentoo Penguins travel along a defined pathway to access the breeding colony. Future population studies could also address the geographic bias in the location of annually monitored study colonies by including additional West Falkland breeding colonies in the annual monitoring program.

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