Agreement on the Conservation of Albatrosses and Petrels

Third Meeting of Advisory Committee

Valdivia, Chile, 19 – 22 June 2007

To determine the proportion of shy (*Thalassarche cauta*) and white-capped albatrosses (*T. steadi*) killed in South African pelagic longline fisheries

Author: Australia

FINAL REPORT

Project Title: To determine the proportion of shy (*Thalassarche cauta*) and white-capped albatrosses (*T. steadi*) killed in South African pelagic longline fisheries

Authors: Michael C. Double[1,4], Peter J. Ryan[2], Nadeena R. Beck[1] and Isobel Booksmythe[3]

[1]Wildwinds Consulting, GPO Box 237, Canberra, ACT 2601.

[2]DST/NRF Centre of Excellence at the Percy FitzPatrick Institute, University of Cape Town, Rondebosch, 7701, South Africa.

[3]School of Botany and Zoology, Australian National University, Canberra, ACT 0200.

[4] Current address: Australian Antarctic Division, 203 Channel Highway, Kingston, Tasmania 7050, Australia. Mike.Double@aad.gov.au

Summary

Pelagic longline and trawl fisheries are known to kill large numbers of albatrosses worldwide. However, the impact on individual species and populations has rarely been assessed, often because many albatross species are difficult to identify. Shy albatrosses (*Thalassarche cauta*), an Australian endemic species, are thought to encounter fisheries that kill large numbers of seabirds (particularly in waters around southern Africa), but because these albatrosses are very similar to white-capped albatrosses (*T. steadi*) the impact on this species is not known. This project successfully applied a simple DNA-based species identification test to 254 tissue samples collected from shy-type (shy and white-capped) albatrosses killed by longline fisheries operating in South African waters. Of these, 13 (5.1%) were identified as shy albatrosses and the remaining 241 (94.9%) as white-capped albatrosses. These data imply that shy and white-capped albatrosses display fundamentally different dispersal behaviours which in turn influence their exposure to fisheries with high rates of seabird bycatch. Based on the bycatch rates presented here it is estimated that approximately 300 shy and 5,000 white-capped albatrosses are killed annually in South African fisheries and, in total, 400 shy and 8,000 white-capped albatrosses are killed in the world's fisheries each year.

Introduction

Seabird deaths arising from fisheries interactions have been linked to population declines in many species (Weimerskirch and Jouventin, 1987; Croxall et al., 1990; de la Mare and Kerry, 1994; Prince et al., 1994; Weimerskirch et al., 1997; Gales, 1998; Weimerskirch and Jouventin, 1998; Tuck et al., 2001; Nel et al., 2002). While there has been an attempt in recent years to address these concerns in some fisheries (e.g. Environment Australia, 1998; CCAMLR, 2004), bycatch information is limited for those species that are difficult to identify using morphometric or plumage characteristics. This information is essential in assessments of the impact of fisheries-related mortality on individual seabird species.

Shy and white-capped albatrosses, *Thalassarche cauta* and *T. steadi* respectively, are closely related and phenotyically similar species (Abbott and Double, 2003a, b; Double et al., 2003). Shy albatrosses breed only in Australia, on three islands around Tasmania, whereas white-capped albatrosses breed on islands in the Auckland and Antipodes Islands group in New Zealand's subantarctic. The global population sizes of shy and white-capped albatrosses are estimated to be approximately 12,250 and 76,000 annual breeding pairs, respectively (Gales, 1998). These species were classified as Vulnerable by Croxall and Gales (1998) using IUCN criteria but are listed as Near Threatened by Birdlife International, who only recently recognised the white-capped albatross as a separate species. Both species are known to suffer fisheries-related bycatch mortality across a wide spatial scale, including in Australian, New Zealand, and South African waters (Brothers, 1991; Murray et al., 1993; Gales et al., 1998; Ryan et al., 2002; Robertson et al., 2004; Abbott et al., 2006).

Previously, it has not been possible to assess the extent or scale of impact of bycatch mortality on shy and white-capped albatrosses, in part due to an inability to identify bycatch shy-type albatross carcasses to species level. However, Abbott et al. (2006) recently used DNA-based species assignment methods to distinguish shy-type albatross carcasses obtained from fisheries bycatch in Australia, New Zealand, and South African waters. This provided novel information on the geographic distributions of these species, and provided an index of relative abundance of each species across continental shelf regions known to be heavily exploited by shy-type albatrosses (Bartle, 1991; Gales, 1998; Ryan et al., 2002). They found that shy and white-capped albatrosses had vastly different at-sea distributions. Shy albatrosses were only detected in southern Australian waters whereas both juvenile and adult white-capped albatrosses were recovered from New Zealand, southern Australian and South African waters. These data are in concordance with banding and satellite-tracking studies of shy albatrosses that indicate juveniles shy albatrosses forage predominantly in the waters off southern Australia (but also occur off southern Africa) whereas adult shy albatrosses remain close to their breeding colonies throughout the year (Brothers et al., 1998; Hedd et al., 2001; Hedd and Gales, 2005). To date, there have been no banding or satellite-tracking studies of white-capped albatrosses.

A limitation of the study by Abbott et al. (2006) was that only 24 bycatch samples of shy-type albatrosses were available from South African fisheries vessels. All of these samples were identified to be white-capped albatrosses. Although this sample size was large enough to imply that a greater proportion of white-capped albatrosses traverse the Indian Ocean to South African waters compared to shy albatrosses (Abbott et al., 2006), it could not provide as estimate of the ratio of shy to white-capped albatrosses occurring off South Africa. In late 2005 a research team led by Peter Ryan (University of Cape Town) began an examination of seabirds caught on tuna longline vessels in South African waters. This analysis yielded 257 tissue samples of shy-type albatrosses caught predominantly in 2005. Here we present the results from DNA-based species and sex identification tests applied to these samples. The results from these samples will provide a more accurate estimate of the number of Australian shy albatrosses killed each year in South African fisheries.

Methods

Nomenclature

In the taxonomic revision of albatrosses suggested by Robertson and Nunn (1998), the shy albatross complex was split into four species: Salvin's albatross (*Thalassarche salvini*); Chatham albatross (*T. eremita*); white-capped albatross (*T. steadi*) and the shy albatross (*T. cauta*). The recognition of the latter two taxa as separate species was supported by later morphometric, phylogenetic and population genetic studies (Abbott and Double, 2003a, b; Double et al., 2003). We therefore use the names 'shy albatross' and 'white-capped albatross' and refer to them as species. The term 'shy-type' is used to refer to these two taxa collectively.

By a country's 'waters' we refer to its Exclusive Economic Zone (EEZ), which usually extends 200 nautical miles from the country's coastline.

Samples

A total of 257 tissue samples were collected from shy-type albatrosses returned from tuna longline vessels operating in South African waters. For most samples there were associated capture data (time, location, vessel). Tissue samples were initially stored in either 70% ethanol or a solution of Dimethyl sulfoxide (DMSO). All samples initially stored in DMSO were transferred to 70% ethanol before being sent by courier to Australia. Samples were returned from at least 18, mostly Korean, longline vessels and most samples (N=216) were returned by fisheries observers in 2005 but some were also collected in 1992 (N=19), 2004 (N=7) and 2006 (N=15).

DNA was extracted from all tissue samples using the ammonium acetate based protocol described by Nicholls *et al*. (2000).

DNA-based species test (SNP test)

Molecular species identification was performed using a simple, PCR and restriction digest assay as described by Abbott & Double (2003a). The test is based on a single nucleotide polymorphism (SNP) in Domain I of the mitochondrial control region of shy and white-capped albatrosses.

PCR amplifications for the SNP test generated a 183 bp fragment using the mismatched forward primer (TEST F4t 5'-CACTTAAACGGATTAAACCCATGAYT-3') and GluR7. Reactions consisted of 50 ng of genomic DNA, 200 μM dNTPs, 3.2 mM $MgCl_2$, 2 pmol of each primer, 0.5 U of AmpliTaq DNA Polymerase (Applied Biosystems) in 1x reaction buffer in a 10 μl reaction volume. PCR cycles were 2 min at 94ºC; a 'touchdown' of 25 s at 94 ºC, 25 s at 65 ºC to 55 ºC (dropping 5ºC per 2 cycles), 25 s at 72 ºC; 30 cycles of 25 s at 94 ºC, 25 s at 50 ºC, 25 s at 72 ºC and one final cycle of 3 min at 72 ºC. PCR products were digested with 3 U of *Hinf*I (Pharmacia Biotech) at 37 ºC for at least one hour in a 15 μl reaction volume. Digestion products were run in a 3% agarose gel to resolve the 26 bp difference between cut products produced by shy albatross samples and uncut products produced by white-capped albatross samples. At least four samples of shy and white-capped albatrosses, sampled at the breeding sites, were included in each PCR run as internal positive controls for the SNP test.

Morphological and DNA-based sex identification

Sexes were determined by autopsy or by molecular sexing. All autopsies were conducted in South Africa by a team led by Peter Ryan (University of Cape Town). All DNA-based sex tests were performed in Australia. For each DNA-based sex test, a 260 bp region on each sex chromosome was PCR amplified using primers P2 and P3 from Griffiths & Tiwari (1995). PCR reactions were 10 μl in volume and contained 50-100 ng of genomic DNA, 200 μM dNTPs, 2 pmol of each primer, 3.2 mM $MgCl_2$, and 0.5 U of *AmpliTaq* DNA Polymerase (Applied Biosystems) in 1x Opti-Prime PCR buffer (Stratagene). PCR cycles were 3 min at 94 ºC; 35 cycles of 25 s at 94 ºC, 25 s at 55 ºC, and 25 s at 72 ºC; and one final cycle of 3 min at 72 ºC. PCR products were digested with 2 U of *Hae*III, and run through a 3% agarose gel. Three-band and two-band patterns were generated for females and males, respectively. At least four samples of known-sex were included in each PCR run as internal positive controls for the sex-identification test.

We classified all birds yet to acquire any body characteristics of adults as 'immature'; birds with some but not complete adult plumage as 'subadult'; and birds with no immature plumage as 'adults'.

Statistical analyses

Most statistical analyses were performed using Genstat 9th Edition for Windows (Payne et al., 2006). Binomial distributions and 95% confidence intervals were calculated in MS Excel (NIST/SEMATECH, 2007). The following binomial equation was used to calculate the probability of the observed number of shy and white-capped albatrosses in our samples:

$$P = \frac{n!}{k!(n-k)!}(p^k)(q^{n-k})$$

where *k* is the number of shy albatrosses in the sample of *n* birds when *p* and *q* are the proportions of shy and white-capped albatrosses within the assemblage respectively.

Results

Species detection

The SNP test produced reliable results for 254 of the 257 samples. Of these, 13 (5.1%) were identified as shy albatrosses and the remaining 241 (94.9%) as white-capped albatrosses (X^2=122, df=1, p<0.001; Table 1). Test failures were probably due to some samples yielding heavily degraded DNA. Combined with the data previously presented by Abbott et al. (2006), 13 shy albatrosses have been detected among a sample of 278 shy-type albatrosses sampled in South African waters.

Table 1. A summary of the results by species and sex from the 257 bycatch samples.

Species	**Sex**			
	Male	Female	Not identified	Totals
Shy albatross	4	7	2	13
White-capped albatross	117	108	16	241
Not identified	1	1	1	3
Totals	122	116	19	257

If the ratio of shy to white-capped albatrosses off South Africa is proportional to the most recent population estimates for these species (see Methods) then the probability of detecting only 13 shy albatrosses from a sample of 278 birds is <0.0001 (95% confidence interval: 29 to 52 shy albatrosses; Figure 1).

Assuming the shy albatross population estimate is relatively reliable, binomial analyses suggest that the observed results would be most probable if the size of the white-capped albatross population was approximately 250,000 breeding pairs (95% confidence interval: 160,000 to 410,000 breeding pairs; Figure 2).

Age and sex identification

The age distribution of shy and white-capped albatrosses were similar with immature and subadult birds dominating each sample (X^2=2.77, df=2, p=0.25; Figure 3). No adult shy albatrosses were caught while approximately 10% (22/218) of the white-capped albatrosses caught were adults.

DNA-based tests and morphological examinations classified the sex of 238 samples (122 males, 116 females; X^2 = 0.08, df = 1, p = 0.78; Table 1). Sex could not be identified for 19 of the 257 samples again probably due the extraction of heavily degraded DNA or because of the poor condition of the carcasses. There was no indication of a sex-bias among the bycatch specimens for either species (shy albatross: 4 v. 7, X^2 = 0.42, df = 1, p = 0.52; white-capped albatross: 117 v. 108, X^2 = 0.18, df = 1, p = 0.67).

Temporal distribution

The majority of aged and identified shy and white-capped albatrosses were caught between July and October (82% and 86% respectively; Figure 4) when most hooks in the South African longline fishery are set (Ryan et al., 2002; Baker et al., in press). Despite this, the monthly bycatch distribution for these species appeared to differ (X^2=28.9, df=11, p=0.002), with a relatively high percentage (18% v. 0.4%) of shy albatrosses caught in March. However, this result may simply be an anomaly due to the small number of shy albatrosses detected in this study.

The catch distribution across all months did not appear to differ for the age categories of white-capped albatrosses (X^2=30.8, df=22, p=0.1) with the largest proportions of birds caught between July and October for all age categories (Figure 5). Even so, 45% of all adult white-capped albatrosses were caught in September whereas the other age categories show a more even distribution between July and October. The small sample size of shy albatrosses precludes statistical analysis but the catch distributions of immature and subadult shy albatross are similar to white-capped albatross with the exception of the two immature birds caught in March.

Discussion

This study detected 13 shy albatrosses among a sample of 254 shy-type albatrosses returned by fisheries observers on longline vessels operating in South African waters. Combined with the data presented by Abbott et al. (2006), overall 13 (4.7%) shy albatrosses have been detected among the 278 South African bycatch samples analysed successfully thus far. Previously, Abbott et al. (2006) reported that approximately 3% of bycatch samples initially identified as shy albatrosses by the SNP test employed here were later identified to be white-capped albatrosses by a more sophisticated and accurate genetic testing method. They detected no error associated with samples identified to be white-capped albatrosses by the SNP test. Therefore, given this low error rate, the data indicate that approximately 5% of shy-type albatrosses killed in South African waters are shy albatrosses.

If shy and white-capped albatrosses show equal propensity to visit South African waters at all ages, and are equally likely to be caught on longlines, then based on estimated breeding populations of shy and white-capped albatrosses (12,250 and 76,000 pairs respectively, Brothers et al., 1998; Gales, 1998) one would expect approximately 13.8% of bycatch specimens to be shy albatrosses. Given these assumptions, the observed proportion of shy albatrosses (~5%) is highly improbable ($p<0.0001$). This result may therefore suggest that: 1) shy albatrosses are less likely to be caught on longlines; 2) the population estimates are inaccurate; 3) shy albatrosses have a lower propensity to visit South African waters. We address these three possible explanations below.

It seems unlikely that so few shy albatrosses are caught on longlines around South Africa because their behaviour reduces interactions with longlines. In Australian waters, shy albatross are common and dominate shy-type bycatch (Abbott et al., 2006). Perhaps where the white-capped albatross are more abundant they out-compete the smaller shy albatross (Double et al., 2003), however, if size alone affects the chance of capture, one would also expect a sex-bias in the bycatch sample, however, none was detected here.

It is reasonable to suggest the population estimates given in the review by Gales (1998) are inaccurate. No systematic surveys of any white-capped albatross colony have been published and unpublished data from aerial surveys suggest the population estimate of 72,000 breeding pairs on Disappointment Island may underestimate this colony's size by many thousands of pairs (K. Walker, personal communication). In contrast, the population estimates for two of the three colonies of shy albatrosses are likely to be accurate because Pedra Branca is a small colony of less than 300 breeding pairs and complete nest counts are taken annually on Albatross Island. The Mewstone colony is more difficult to survey and a reliable aerial survey method is still being developed, so it is possible that the reported size of 7,000 breeding pairs is inaccurate (Gales, 1998). Assuming the population counts for shy albatross to be relatively accurate, and that each species is equally likely to visit South African waters, then our analyses suggest that the white-capped albatross population is much larger than the current estimate of 76,000 pairs and is in fact somewhere in the region of 200,000 to 400,000 pairs. To underestimate the size of the white-capped albatrosses so dramatically seems improbable.

It seems most likely that the small number of shy albatrosses in the South African bycatch is because relatively fewer shy albatrosses make the journey across the Indian Ocean to forage off South Africa. Comprehensive satellite tracking and monitoring data show adult shy albatrosses stay around eastern and southern Australia even when not feeding chicks (Brothers et al., 1998; Hedd et al., 2001; Hedd and Gales, 2005) and this is why no adult shy albatrosses were detected in the bycatch sample. Similarly satellite tracking data of recently fledged shy albatrosses show that the majority remain within the Australian waters. However, the tracks available for these young birds are relatively short and perhaps it is the older immature or subadult birds that venture to Southern Africa. Together, the tracking and bycatch data strongly suggest a fundamental difference in the distribution and dispersal behaviour of shy and white-capped albatrosses. Even though white-capped albatrosses must travel through the core distribution of shy albatrosses (Brothers et al., 1997; Abbott et al., 2006) a higher proportion of white-capped albatrosses occur off South Africa and unlike shy albatrosses, they return to South Africa as adults (Ryan and Rose, 1995; Ryan et al., 2002). Why white-capped albatrosses repeatedly traverse the Indian Ocean to reach Southern Africa when shy albatrosses can be so sedentary remains unclear.

Although adult white-capped albatrosses were detected in the bycatch sample, the majority (over 90%) were immature or subadult birds. That so few adults were returned by fisheries observers is surprising because in a previous study over 30% (N=37) of the shy-type albatrosses returned from this region were classified as adults (Ryan et al., 2002). It is known that the presence of adult shy-type albatrosses of southern Africa is seasonal and that adults are scarce during the (Austral) summer months (Ryan and Rose, 1995). But this does not explain why so few adults were found in the sample analysed here when most birds were returned from boats operating the Austral winter and spring (May to October) when adults are supposedly more common.

In a recent global review of fisheries-related mortality of shy and white-capped albatrosses Baker et al. (in press) found that of the estimated 8,500 shy-type albatrosses killed annually over half were killed in the South African trawl and longline fisheries. The data presented here show that the vast majority of these birds are white-capped albatrosses. Using contemporary fishing effort data and the bycatch data from Abbott et al. (2006) and this study, Baker et al. (in press) estimates the overall annual fisheries-related mortality for shy and white-capped albatrosses is 400 and 8,000 birds respectively. These data make it clear that the results of the recently initiated projects to acquire accurate population estimates and trends for white-capped albatross populations are essential to assess the impact of these fisheries operations on this species and it is imperative that effective seabird bycatch mitigation measures are adopted immediately by South African fisheries.

References

Abbott, C.A., Double, M.C., Baker, G.B., Gales, R., Lashko, A., Robertson, C.J.R., Ryan, P.G., 2006. Molecular provenance analysis for shy and white-capped albatrosses killed by fisheries interactions in Australia, New Zealand and South Africa. Conservation Genetics 7, 531-542.

Abbott, C.L., Double, M.C., 2003a. Phylogeography of shy and white-capped albatrosses inferred from mitochondrial DNA sequences: implications for population history and taxonomy. Molecular Ecology 12, 2747-2758.

Abbott, C.L., Double, M.C., 2003b. Genetic structure, conservation genetics, and evidence of speciation by range expansion in shy and white-capped albatrosses. Molecular Ecology 12, 2953-2962.

Baker, G.B., Double, M.C., Gales, R., Tuck, G.N., Abbott, C.L., Ryan, P.G., Petersen, S.L., Robertson, C.J.R., Baird, S.J., Alderman, R., in press. A global assessment of the impact of fisheries related mortality on shy and white-capped albatrosses: conservation implications. Biological Conservation.

Bartle, J.A., 1991. Incidental capture of seabirds in the New Zealand subantarctic squid fishery, 1990. Bird Conservation International 1, 351-359.

Brothers, N., 1991. Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. Biological Conservation 55, 255-268.

Brothers, N., Gales, R., Hedd, A., Robertson, G., 1998. Foraging movements of the shy albatross *Diomedea cauta* breeding in Australia - implications for interactions with longline fisheries. Ibis 140, 446-457.

Brothers, N.P., Reid, T.A., Gales, R.P., 1997. At-sea distribution of shy albatrosses *Diomedea cauta cauta* derived from records of band recoveries and colour-marked birds. Emu 97, 231-239.

CCAMLR, 2004. Report of the working group on fish stock assessment. Report of the twenty-third meeting of the Scientific Committee of the Commission for the Conservation of Marine Living Resources. Commission for the Conservation of Marine Living Resources, Hobart.

Croxall, J.P., Rothery, P., Pickering, S.P.C., Prince, P.A., 1990. Reproductive performance, recruitment and survival of wandering albatrosses *Diomedea exulans* at Bird Island, South Georgia. Journal of Animal Ecology 59, 775-795.

de la Mare, W.K., Kerry, K.R., 1994. Population dynamics of the Wandering Albatross (*Diomedea exulans*) on Macquarie Island and the effects of mortality from longline fishing. Polar Biology 14, 231-241.

Double, M.C., Gales, R., Reid, T., Brothers, N., Abbott, C.L., 2003. Morphometric comparison of Australian shy and New Zealand white-capped albatrosses. Emu 103, 287-294.

Environment Australia, 1998. Threat abatement plan for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations. Environment Australia, Canberra.

Gales, R., 1998. Albatross populations: status and threats, In: Robertson, G., Gales, R. (Eds.), Albatross Biology and Conservation. Surrey Beatty & Sons, Chipping Norton pp. 20-45.

Gales, R., Brothers, N., Reid, T., 1998. Seabird mortality in the Japanese tuna longline fishery around Australia, 1988-1995. Biological Conservation 86, 37-56.

Griffiths, R., Tiwari, B., 1995. Sex of the last wild Spix's macaw. Nature 375, 454.

Hedd, A., Gales, R., Brothers, N., 2001. Foraging strategies of shy albatross *Thalassarche cauta* breeding at Albatross Island, Tasmania, Australia. Marine Ecology Progress Series 224, 267-282.

Hedd, A., Gales, R., 2005. Breeding and overwintering ecology of shy albatrosses in southern Australia: year-round patterns of colony attendance and foraging trip durations. Condor 107, 375-387.

Murray, T.E., Bartle, J.A., Kalish, S.R., Taylor, P.R., 1993. Incidental capture of seabirds by Japanese southern bluefin tuna longline vessels in New Zealand waters, 1988-1992. Bird Conservation International 3, 181-210.

Nel, D.C., Ryan, P.G., Crawford, R.J.M., Cooper, J., Huyser, O.A.W., 2002. Population trends of albatrosses and petrels at sub-Antarctic Marion Island. Polar Biology 25, 81-89.

Nicholls, J.A., Double, M.C., Rowell, D.M., Magrath, R.D., 2000. The evolution of cooperative and pair breeding in thornbills *Acanthiza* (Aves: Pardalotidae). Journal of Avian Biology 31, 165-176.

NIST/SEMATECH, 2007. e-Handbook of Statistical Methods. NIST/SEMATECH. http://www.itl.nist.gov/div898/handbook/

Payne, R.W., Murray, D.A., Harding, S.A., Baird, D.B., Soutar, D.M., 2006. GenStat for Windows (9th Edition) Introduction. VSN International, Hemel Hempstead.

Prince, P.A., Rothery, P., Croxall, J.P., Wood, A.G., 1994. Population dynamics of black-browed and grey-headed albatrosses *Diomedea melanophris* and *D. chrysostoma* at Bird Island, South Georgia. Ibis 136, 50-71.

Robertson, C.J., Nunn, G.B., 1998. Towards a new taxonomy for albatrosses, In: Robertson, G., Gales, R. (Eds.), Albatross biology and conservation. Surrey Beatty & Sons, Chipping Norton pp. 13-19.

Robertson, C.J.R., Bell, E., Scofield, P., 2004. Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 October 2001 to 30 September 2002. Department of Conservation Science Internal Series 96,

Ryan, P.G., Rose, B., 1995. Migrant seabirds, In: Payne, A. I. L., Crawford, R. J. M. (Eds.), Oceans of Life off Southern Africa. Vlaeberg, Cape Town pp. 274–287.

Ryan, P.G., Keith, D.G., Kroese, M., 2002. Seabird bycatch by longline fisheries off southern Africa, 1998-2000. South African Journal of Marine Science 24, 103-110.

Tuck, G.N., Polacheck, T., Croxall, J.P., Weimerskirch, H., 2001. Modelling the impact of fishery by-catches on albatross populations. Journal of Applied Ecology 38, 1182-1196.

Weimerskirch, H., Jouventin, P., 1987. Population dynamics of the wandering albatross, *Diomedea exulans*, of the Crozet Islands: causes and consequences of the population decline. Oikos 49, 315-322.

Weimerskirch, H., Brothers, N., Jouventin, P., 1997. Population dynamics of wandering albatross *Diomedea exulans* and Amsterdam albatross *D. amsterdamensis* in the Indian Ocean and their relationships with long-line fisheries - conservation implications. Biological Conservation 79, 257-270.

Weimerskirch, H., Jouventin, P., 1998. Changes in population sizes and demographic parameters of six albatross species breeding on the French sub-Antarctic islands, In: Robertson, G., Gales, R. (Eds.), Albatross: Biology and Conservation. Surrey Beatty & Sons, Chipping Norton, NSW, Australia pp. 84-91.

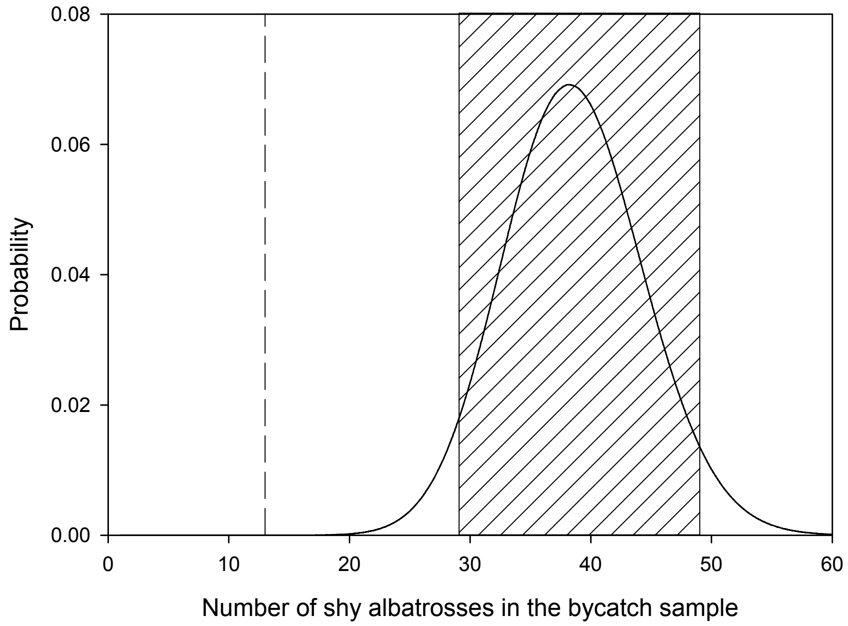

Figure 1. Probability distribution for the expected number of shy albatrosses assuming the number caught is proportional to the estimated breeding populations for shy and white-capped albatrosses of 12,250 and 76,000 breeding pairs respectively. The dashed line gives the actual number of shy albatrosses within the bycatch sample of 278 birds. The shaded region represents the 95% confidence interval for the distribution.

2D Graph 8

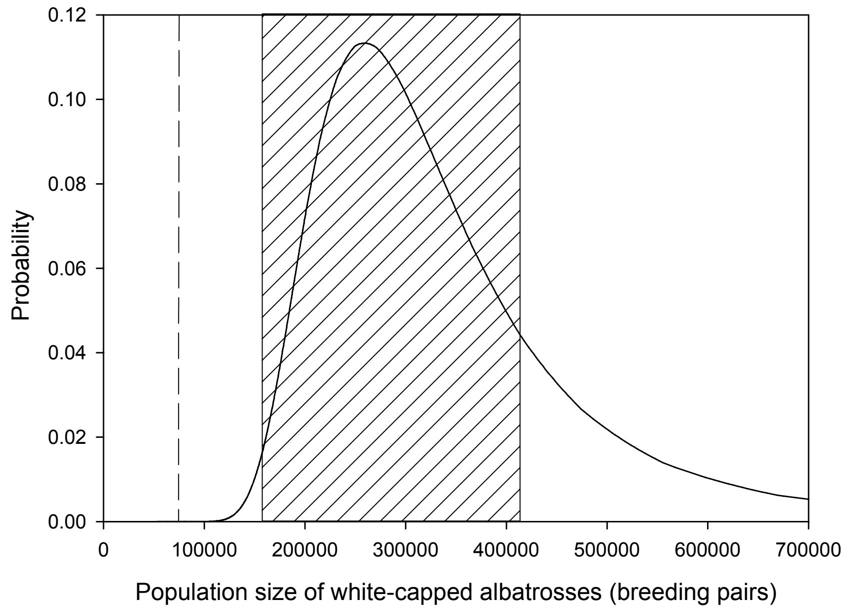

Figure 2. Probability distribution for the size of the white-capped albatross population assuming the bycatch and population size ratios are identical and the size of the shy albatross population is 12,250 breeding pairs. The dashed line represents the estimated population for white-capped albatrosses of 76,000 breeding pairs. The shaded region represents the 95% confidence interval for the distribution.

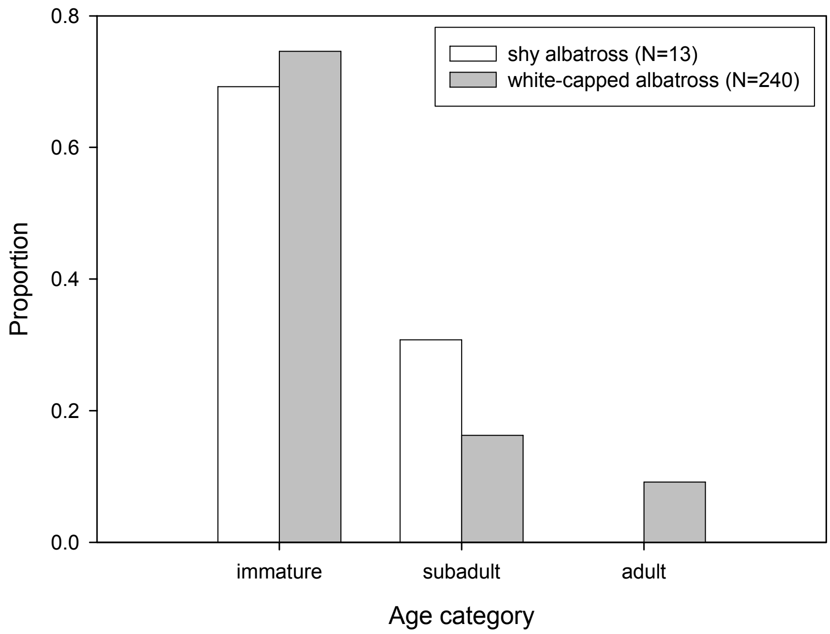

Figure 3. Age distribution of shy and white-capped albatrosses among the bycatch samples. Age or species identification data were not available for four of the 257 samples.

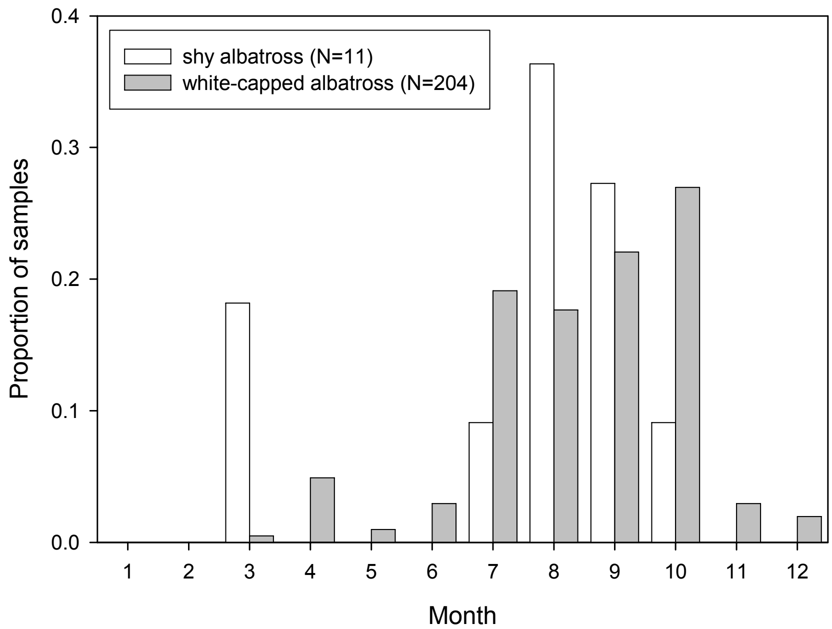

Figure 4. Monthly capture distribution for shy and white-capped albatrosses. Capture information or species identification data were not available for 42 of the 257 samples. Month 1 = January.

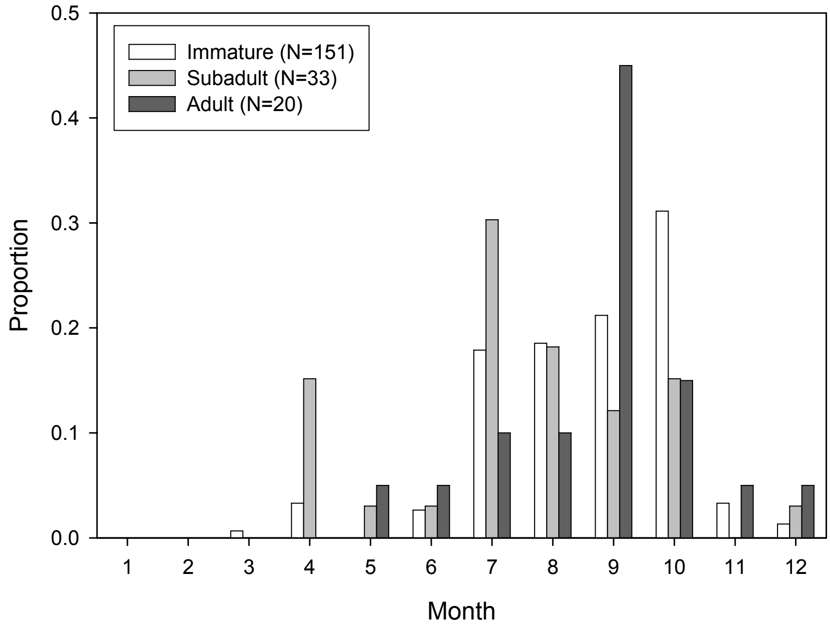

Figure 5. Monthly capture distribution for the three age categories of white-capped albatrosses. Capture information or age identification data were not available for 37 of the 241 samples of white-capped albatrosses. Month 1 = January.