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ORIGINAL PAPER

Continued increase in the number of black-browed albatrosses (*Thalassarche melanophris*) at Diego Ramírez, Chile

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Abstract Black-browed albatrosses (*Thalassarche melanophris*) are killed incidentally in commercial fishing operations. Aerial surveys in 2002 and 2011 revealed the number of black-browed albatrosses at the Diego Ramírez and Ildefonso islands, Chile, increased by 52 and 18 %, respectively. The increases were attributed to reduced mortality in the longline fishery for Patagonian toothfish (*Dissostichus eleginoides*) following fleet conversion to a new gear configuration with much higher average hook sink rates. A new survey in 2014 revealed the number of black-browed albatrosses at Ildefonso was about the same as in 2011, but the number at Diego Ramírez had increased by a further 29 % (8.8 %/year). The number of grey-headed albatrosses (*Thalassarche chrysostoma*) at Diego Ramírez also increased, by 23 %, in the same time period. In 2014, Ildefonso held an estimated 54,284 breeding pairs of black-browed albatrosses. The populations of black-browed albatrosses at two more northern sites, the Evangelistas and Leonard islets, stood at 4818 and 545 breeding pairs, respectively. The total number of breeding pairs of both albatross species at Diego could not be determined because not all islands in the archipelago were surveyed.

Keywords Black-browed albatross · Grey-headed albatross · Mortality in fisheries · Population trends

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Introduction

The continued existence of 15 of the world's 22 species of albatrosses is threatened (IUCN 2016). The key threat to survival is incidental mortality in commercial fishing operations, such as longline and trawl fisheries, which has driven population decreases over the past few decades (Poncet et al. 2006; Anderson et al. 2011). Two species taken incidentally are the black-browed albatross (*Thalassarche melanophris*) and grey-headed albatross (*Thalassarche chrysostoma*); these species are listed globally as 'near threatened' and 'endangered', respectively. The islands of southern Chile hold globally important populations of both these species. Collectively, the Chilean islands hold the largest population of black-browed albatrosses after the Falkland Islands/Islas Malvinas and the largest population of grey-headed albatrosses after South Georgia/Islas Georgias del Sur (Robertson et al. 2007). Aerial censuses in 2002 and 2011 revealed that the number of black-browed albatrosses at Ildefonso and Diego Ramírez, the islands with the largest populations, increased by 52 and 18 %, respectively (Robertson et al. 2014). In the same period no change was detected in the population size of grey-headed albatrosses. The increases were attributed

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to reduced mortality in the Patagonian toothfish (*Dissostichus eleginoides*) longline fishery by Spanish system vessels. In 2006 and 2007 traditional Spanish system vessels converted to a new method of fishing, the Chilean system (Moreno et al. 2008), to minimise toothfish depredation by toothed whales. A positive side effect of the new gear configuration was a fivefold increase in hook sink rates, from 0.15 to 0.80 m/s. The rapid sink rate proved an effective deterrent to black-browed albatrosses (and other seabird species), reducing mortality from an estimated 1555 albatrosses in 2002 (the year bycatch was thoroughly quantified) to zero in 2011 (see Robertson et al. 2014) with positive effects on population growth.

In addition to Ildefonso and Diego Ramírez, the southern-most breeding sites in the region, there are four other known sites in Chile where albatrosses breed. These sites were not surveyed in 2011 (or in 2012, the year of the last attempted air survey). Three of these sites (see Fig. 1) are situated close to the Chilean mainland and Andes mountain range, and in the mid-incubation period (October), the preferred time for the censuses (Robertson et al. 2008) is frequently subjected to high wind turbulence, which limits opportunities to conduct surveys from aircraft. Hence, it was not known whether the population increases observed at Ildefonso and Diego Ramírez from 2002 to 2011 were confined to those sites or occurred throughout the region. To rectify this situation, and to determine whether the increases at Diego Ramírez and Ildefonso were being sustained, the colonies were re-surveyed in 2014. This paper reports the results of these surveys.

Materials and methods

Breeding sites

In Chile black-browed albatrosses breed at six known sites: Islas Diego Ramírez (56°31′S, 68°43′W), Islas Ildefonso

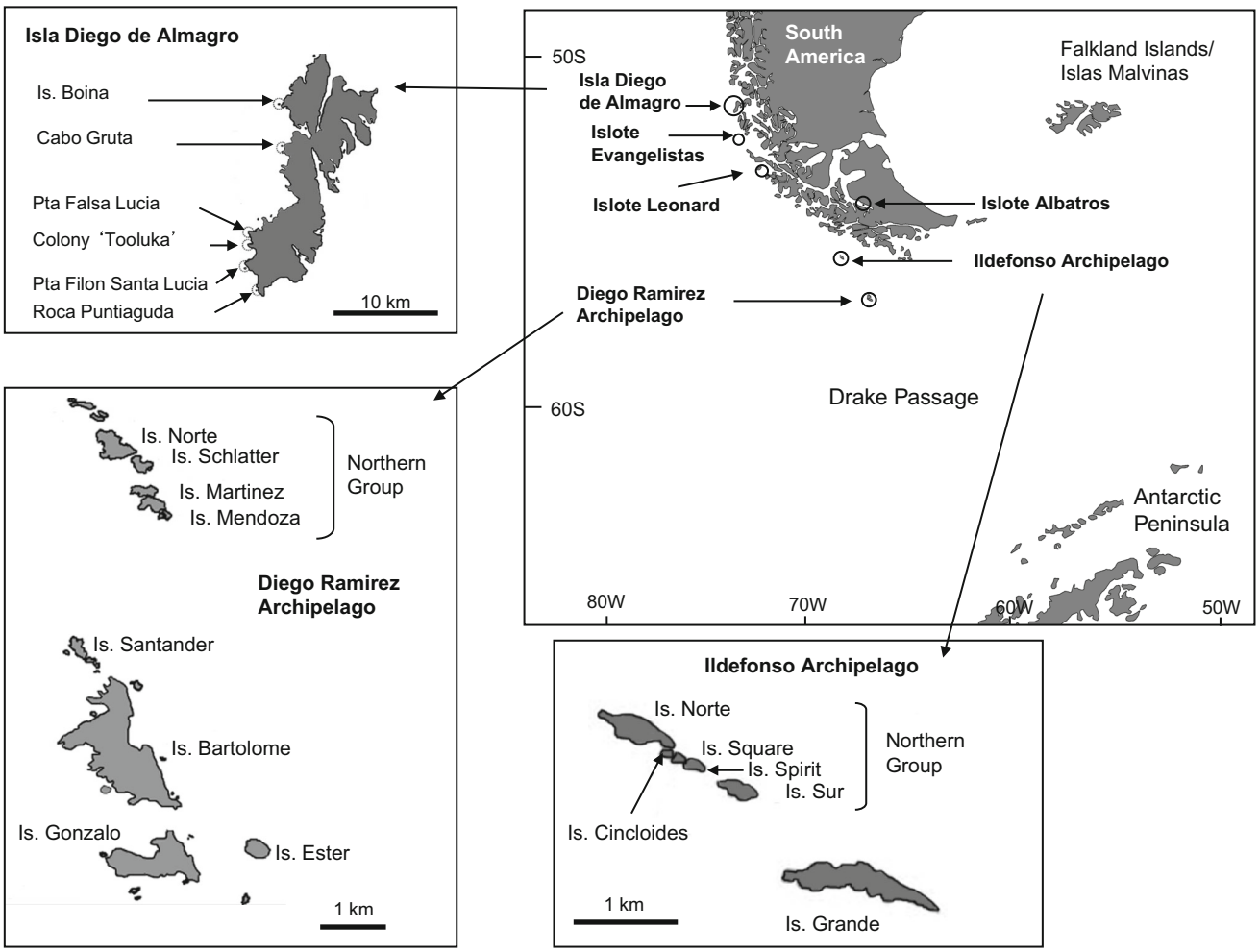

Fig. 1 Locations of the six known albatross breeding sites in Chile. The map of Isla Diego de Almagro shows the locations of the black-browed albatross colonies (denoted by *arrows*). The maps of Diego Ramírez and Ildefonso show the northern and southern groups in the archipelagos, their proximity to one another and relative sizes

(55°48′S, 69°24′W), Islote Albatros (54°27′S, 69°01′W), Islote Leonard (53°23′S, 74°04′W), Islotes Evangelistas (52°24′S, 75°05′W) and Islas Diego de Almagro (51°32′S, 75°20′W) (Fig. 1). Except for a few pairs at Ildefonso (Robertson et al. 2008), the entire grey-headed albatross population is located at Diego Ramírez. In 2014 all breeding sites except Diego de Almagro and Islote Albatros were surveyed. No attempt was made to survey Diego de Almagro because on the previous attempt in 2012 the aircraft encountered severe (and dangerous) wind sheer which caused the survey to be aborted. Islote Albatros was not surveyed because the colony holds relatively few birds is visited occasionally by ground parties (e.g. Arata et al. 2014) who are able to census the population, and because of fiscal constraints on flying time. This was the first aerial survey of Islote Leonard and the second survey at Evangelistas since the albatross colonies on these islands were discovered to science in 2005 (Marin and Oehler 2007) and in 2002 (Arata et al. 2003), respectively.

Censuses

The Ildefonso and Diego Ramírez islands were surveyed on 18 October 2014, and the Evangelistas and Leonard islets were surveyed on 19 October 2014; these dates coincided with the mid-incubation period for black-browed albatrosses (Robertson et al. 2007). All four islets in the Evangelistas group were surveyed, including Pan de Azùcar, which was not surveyed in the previous (and only) air census in 2002 (Arata et al. 2003) due to inclement weather. At Ildefonso, the entire archipelago was surveyed, and at Diego Ramírez only the northern group of islets and Gonzalo Island were overflown following Robertson et al. (2014). The aerial photographic censuses followed the same standard methods of Robertson et al. 2014 (and references therein). Briefly, we used the same aircraft (twin otter), same altitude (300–500 m), same viewing angle (perpendicular to the ground) and same photographer as previously. The photographs were taken with a Nikon 610 camera (image area: 6016 × 4016 pixels) and 70–200 mm f2.8 image stabilised lens set at 150 mm. For reasons of accuracy, and to allow comparison with previous censuses un-confounded by time-of-day of the overflights, the censuses were conducted between on 1 h before and 4 h after solar noon. This is the period when the proportion of black-browed albatrosses sitting on nests is highest and the proportion not on nests (partner birds and non-breeders) is lowest (Robertson et al. 2008). The overlapping photographic images were downloaded onto a computer and stitched into a collage using Adobe Photoshop image processing software, and albatrosses counted on the computer screen. The counts at Ildefonso were conducted by KL, and BW counted the birds at the other sites. Counts by both counters of a discrete portion of Ildefonso holding >9000 black-browed albatrosses differed by just 0.4 % indicating that both counters identified the same birds.

The censuses at each island or island group varied in accordance with areas surveyed (entire archipelagos or part thereof) and whether birds on nest (as against birds loafing in colonies) could be identified and counted on the photographs. The approaches taken are summarised in Table 1 and the reasons for the different approaches are explained below.

Data treatment

The clearest photographs are taken when the light is overcast but bright which reduces the contrast between highlights and shadows. Photographs that are technically sound, taken from an angle perpendicular to the ground and in overcast (but bright) light conditions, enable black-browed and grey-headed albatrosses to be identified and counted, and birds on nests (proxy for breeding pairs) to be separated from partner birds and birds 'loafing' in colonies. This enables both the total number of birds and the number of breeding pairs to be estimated. The light over Evangelistas and Leonard (and Diego Ramírez) was ideal during the surveys, and the number of breeding pairs was estimated directly from the photographs. Ildefonso was fully sunlit with a high degree of contrast between well-lit and poorly lit (shadow) areas. While albatrosses in shadows were identifiable, it was not possible to categorise them as described above. Hence, the number of breeding pairs at Ildefonso was estimated as the total number of birds counted (raw counts) minus 5 %, with the correction derived from simultaneous aerial photography and ground truthing at Ildefonso in 2002 (Robertson et al. 2008). At Diego Ramírez, the total number of breeding pairs could not be determined because not all islands in the archipelago were included in the survey. Thus, the estimates for Diego Ramírez pertain to the total number of individual birds present (raw counts). Assessment of the raw counts for Diego Ramírez and also for Ildefonso satisfies one of the aims of the study, which was to determine if the observed increases from 2002 to 2011 in Robertson et al. (2014) were sustained in the period 2011–2014. For this comparison, it was important the expression of results be consistent with Robertson et al. (2014) who presented raw counts (numbers neither rounded up/down nor corrected). The expression of results as raw counts is not meant to infer the aerial photographic method is accurate to the nearest individual albatross (see Robertson et al. 2008 for an assessment of some sources of error with the photo census method).

Because the results for grey-headed albatrosses at Diego Ramírez were unexpected and because this site holds a mix

Table 1 List of know albatross breeding sites in Chile, names of those included in the 2014 census, area surveyed at each site and site-specific difference in the expression of results (see text)

Location	Area surveyed	Estimates expressed as
Diego de Almagro	Not surveyed	
Evangelistas	Whole archipelago	Number of BPs
Leonard	Whole island	Number of BPs
Albatros	Not surveyed	
Ildefonso	Whole archipelago	Raw count and number of BPs
Diego Ramírez	Gonzalo Is. and northern group only	Raw count

Raw count = The total (uncorrected) number of birds counted on photographs

BP Breeding pairs

of both species of albatrosses, which could potentially be confused on the photographs, the counts of grey-headed albatrosses were repeated on a high definition 4K monitor with twice the pixel density of the monitor used for the first count (distance between pixels: 0.1554 mm [4 k] vs 0.270 mm).

Results

New findings

The photographs of the western face of Elcano Islet, Evangelistas, showed two birds sitting on nests that were not black-browed albatrosses. The photographs lacked the acuity to allow positive identification, but the markings on the heads of both birds suggest they could be grey-headed albatrosses or Salvin's albatrosses (*T. salvini*; see Arata 2003). Also, two Andean condors (*Vultur gryphus*) were evident on the ground (and one in flight) on the photographs taken of Islote Leonard. Due to their large size and markings, these birds are unmistakeable. It is possible this species bred on Leonard in 2014.

Censuses

The trends in the total number of black-browed and grey-headed albatrosses in the surveyed areas of Diego Ramírez from 2011 to 2014 and black-browed albatrosses at Ildefonso from 2011 to 2012 (northern group only) to 2014 are shown in Table 2. In the three years from 2011 to 2014, the total number of black-browed albatrosses in the surveyed areas of Diego Ramírez increased by 29 or 8.8 %/year (the vast majority [16,888] were identified as nesting adults with only 586 additional birds considered partner birds or loafers). In the same time period, the total number of black-browed albatrosses at Ildefonso (all islets surveyed) decreased by 2 %. The table includes an estimate of the number of breeding pairs of black-browed albatrosses at Ildefonso following application of the correction factor mentioned above. The numbers of breeding pairs of black-browed albatrosses at Evangelistas and Leonard in 2014 are also shown in Table 2. The counts of grey-headed albatrosses on the high definition monitor yielded 1.03 % fewer birds than the conventional monitor (6565 vs 6497). The difference is minor and was due mainly to a small number of black-browed albatrosses being mistaken for grey-headed albatrosses on photographs that were slightly blurred (the misidentified grey-headed albatrosses were added to the totals for black-browed albatrosses). In 2014 the total number of grey-headed albatrosses in the surveyed portion of Diego Ramírez was 23 % higher than in 2011. As mentioned, is not possible to provide an estimate of the number of breeding pairs of both species of albatrosses for Diego Ramírez because not all islands in the archipelago were surveyed.

Fishing effort

Figure 2 shows the trend in hook deployments for the industrial longline fisheries considered by Robertson et al. (2014) to be the key drivers of population change from the commencement of the fisheries (1986) to the time of the previous census (2011 for Diego Ramírez and 2012 for Ildefonso) and the time of the current study (2014). Updated (2012-2014) effort data for the three industrial trawl fleets in Robertson et al. (2014), which have also impacted black-browed albatrosses (Robertson et al. 2014), are presented in Fig. 3.

Discussion

Fishing effort

Since the population increases from 2002 to 2011 were ascribed to reduced mortality in the Patagonian toothfish longline fishery following phase-out of the Spanish system, any reversion to the Spanish system and/or major change in effort by other fishing practices would have implications for survival and population trends. As shown in Fig. 2, there was no observed evidence of the use of the traditional

Table 2 Estimated total number of black-browed albatrosses (BBA) and grey-headed albatrosses (GHA) at Diego Ramírez (selected islands only; see Fig. 1) and Ildefonso (whole archipelago) in the 2002, 2011, 2012 and 2014 breeding seasons

Species	Location	Group/islet	Years					Change (%)	
			2002	2005	2011	2012	2014	Total	Mean/year
BBA	Diego	Northern group							
	Ramirez	Islote Cabezas	0		0	n.s.	0		
		Islote Penailillo	0		0	n.s.	0		
		Islote Norte	1316		3826	n.s.	5001	30.0	9.3
		Islote Schlatter	178		204	n.s.	273	34.0	10.2
		Islote Martinez	286		227	n.s.	98	−57.0	−24.4
		Islote Mendoza	143		128	n.s.	383	199.0	44.0
		Total	1923		4385		5755	31.0	9.5
		Southern group							
		Isla Gonzalo	6966		9164	n.s.	11,133	21.0	6.7
		Total (see caption)	8889		13,549		17,474	29.0	8.8
	Ildefonso	Northern group							
		Isla Norte	10,920		13,920	14,799	13,795	−0.9	−0.3
		Isla Cinclodes	775		871	1029	1014	16.0	5.2
		Isla Square	488		528	593	504	−4.5	−1.5
		Isla Spirit	1383		1447	1747	1571	8.5	2.8
		Isla Sur	5222		7053	7276	6822	−3.5	−1.1
		Total	18,788		23,819	25,444	23,706	−0.5	−0.1
		Southern group							
		Isla Grande	30,680		34,358	n.s.	33,437	−2.6	−0.9
		Total birds	49,468		58,177		57,143	−2.0	−0.6
		Total breeding pairs					54,284		
	Evangelistas	Evangelistas	0				0		
		Elcano	3285				3325		
		Lobos	1384				1472		
		Pan de Azucar	n.s.				22		
		Total					4818	3.5	
	Leonard			594			545	−8.0	
GHA	Diego	Northern group							
	Ramirez	Islote Cabeza	0		0	n.s.	0		
		Islote Penailillo	0		0	n.s.	0		
		Islote Norte	463		476	n.s.	765	60.7	17.1
		Islote Schlatter	97		76	n.s.	120	57.9	16.4
		Islote Martinez	69		49	n.s.	35	−28.6	−10.5
		Islote Mendoza	174		279	n.s.	285	2.2	0.7
		Total	803		870		1205	38.5	11.5
		Southern group							
		Isla Gonzalo	4523		4413	n.s.	5292	19.9	6.2
		Total (see caption)			5293		6497	22.7	7.1

Estimates for these two island groups are raw (uncorrected) counts. Estimates for 2002, 2011 and 2012 are from Robertson et al. (2014). Values for Ildefonso in 2014 include an estimate of the number of breeding pairs derived from the raw counts corrected downwards by 5 % following Robertson et al. 2008. The period of the current study is from 2011 to 2014. Change % is the difference in raw counts for the period 2011–2014. Mean change/year calculated following Robertson et al. (2014). Also included are estimates of the number of breeding pairs of black-browed albatrosses at Evangelistas and Leonard in 2014 in relation to estimates from previous surveys at these sites

n.s. Not surveyed

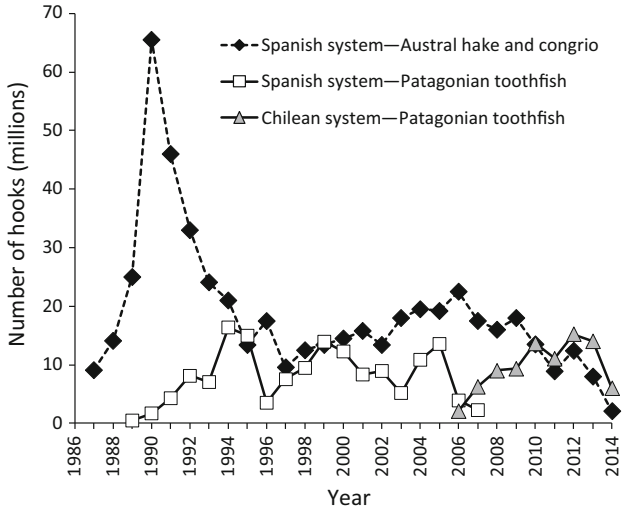

Fig. 2 Trend in fishing effort by the industrial Austral hake and congrio longline fishery, and the Patagonian toothfish longline fishery by Spanish system and Chilean system vessels from 2012 to 2014. Effort from 1986–2011 is from Robertson et al. (2014) and is included for comparative purposes. Data from 2011 to 2014 from the current study. Data sources: Fisheries Development Institute (Austral hake and congrio) and the Chilean Undersecretariat for Fisheries and Aquaculture (Patagonian toothfish)

Spanish system in the period 2011-2014. Furthermore, effort in the longline fishery for Austral hake (*Merluccius australis*) and congrio (*Genypterus blacodes*), which in the past has taken appreciable numbers of black-browed albatrosses (Robertson et al. 2014), decreased greatly since 2012 as did effort by longline vessels targeting toothfish with the Chilean system. Reduction in the fish catch quotas for these two fisheries is the reason for the reduction in effort since 2012 (C. Moreno, unpublished data). Effort for the three trawl fleets also decreased since 2012, with effort in 2013 being 28 % less than that in 2012.

Population trends

One of the reasons for the current study was to determine whether the population increases at Ildefonso and Diego Ramírez from 2002 to 2011 occurred throughout the region. In 2014 the number of breeding pairs of black-browed albatrosses at Evangelistas was 3.5 % greater than in the initial survey in 2002, and the number of breeding pairs at Leonard was 8 % less than in the initial survey in 2005. These are minor variations that could reflect normal interannual variation in breeding attendance, perhaps influenced by fluctuations in food availability or other environmental factors; they are not indicative of substantial change in numbers at either site. This finding suggests the large increases at Diego Ramírez and Ildefonso from 2002 to 2011 most likely did not occur at Evangelistas and Leonard. Judging by the habitat (bare rock) and apparent scarcity of available nesting space, colonies at Evangelistas appear to have limited capacity for expansion. At Leonard, the colony covers a small area of the island which could feasibly support a larger population of albatrosses. Whether populations at Diego de Almagro, the northern-most site in

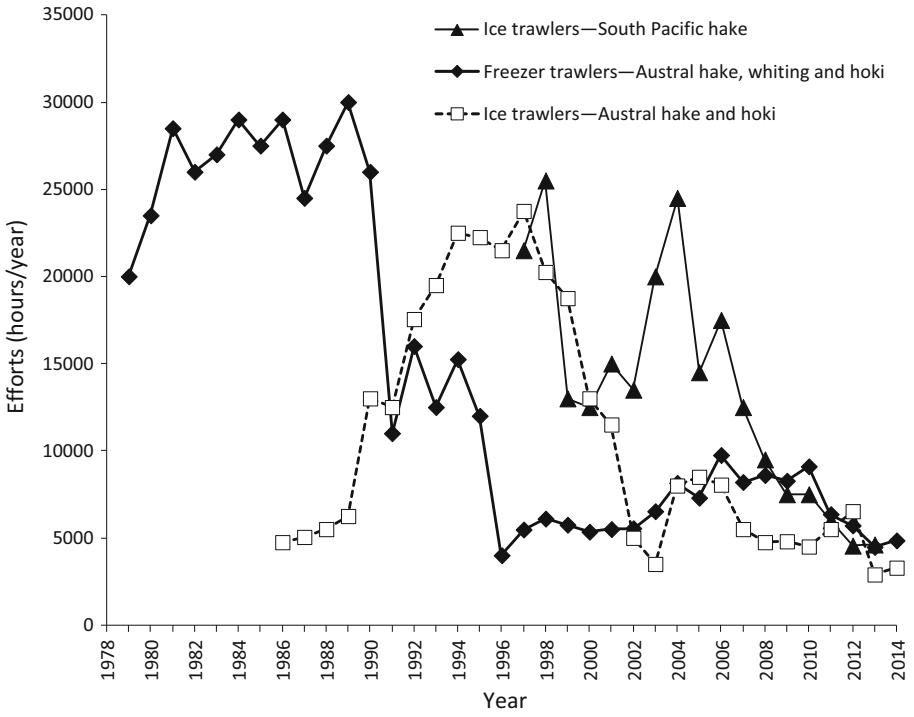

Fig. 3 Trend in fishing effort for the three industrial trawl fleets operating in the foraging ranges of black-browed albatrosses in southern Chile. Species targeted are Austral hake (*Merluccius australis*), South Pacific hake (*M. gayi*), southern blue whiting (*Micromesistius australis*) and hoki (*Macruronus magellanicus*). Data from 1979 to 2011 after Robertson et al. (2014). Data from 2011 to 2014 from the current study

the region and with different habitats to Evangelistas, have changed since the last census in 2001 (Lawton et al. 2003) remains unknown.

At Ildefonso, the total number of birds counted in 2014 was 2 % lower than in 2011. This difference is minor and could reflect sampling error and/or normal fluctuation in breeding attendance as mentioned above and is not necessarily indicative of a decrease. Still, the average annual change (<−1 %) contrasts sharply with the 6.8 % rate of increase at the northern group of Ildefonso between 2011 and 2012 (Robertson et al. 2014). Evidently, the increase has either slowed, ceased or is continuing with birds emigrating undetected to new or existing breeding sites. In 2014 Ildefonso held an estimated 54,284 breeding pairs of black-browed albatrosses.

In contrast, the number of black-browed albatrosses at Diego Ramírez still seems to be increasing rapidly. From 2002 to 2011, the number in the surveyed portion of the archipelago increased by 52 %, or 4.8 %/year (Robertson et al. 2014), and from 2011 to 2014 by 29 % (8.8 %/year). The growth in the latter period is too large to be explained by sample error or nuance of survey methodology, and there are no known land-based agents of mortality the alleviation of which could contribute to the observed increases. Given the apparent continued use of the seabird-friendly Chilean method of longlining for Patagonian toothfish and reduced effort in the Austral hake/congrio longline fishery and trawl fleets, it seems plausible that higher survivorship following reduced mortality contributed substantially to the increase. Immigration may also have contributed to the observed increase. The mean growth of nearly 9 %/year is exceptionally high for a procellariiform (see Ryan et al. 2006) and possibly near the limit of biological plausibility. Immigration rates as high as 10.1 %/year have been reported at other colonies of *Thalassarche* sp. albatrosses (Rolland et al. 2009 and references therein), so it is possible new breeders arrived at Diego Ramírez before the census in 2014.

The total number of grey-headed albatrosses at Diego Ramírez also increased, by 23 % overall (7.1/year). As was the case for black-browed albatrosses, the majority of birds (6202) in surveyed areas were judged to be nesting adults, not partners or loafers, which constituted only 295 additional birds. Thus, an influx of a large number of non-nesting birds cannot explain the observed increase. This result contrasts with those for the two previous surveys in 2002 and 2011 which were virtually the same (Robertson et al. 2014). Understanding the reasons for the increase is more difficult than with black-browed albatrosses. Most grey-headed albatrosses do not breed every year (Ryan et al. 2007), and surveys conducted infrequently and at irregular intervals may not yield a very accurate picture of the total population size, especially if birds are in a cycle of high and low breeding attendance. Another complicating factor is the absence of known fisheries impacts—or other sources of mortality—in the birds' foraging zones that may have recently ceased, which would 'release' birds into the population. During the breeding season, grey-headed albatrosses tend to avoid the Chilean continental shelf and shelf break regions were most commercial fishing (and incidental bycatch) occurs. Instead, they forage over ocean frontal zones well to the south and west of Diego Ramírez and along the western flank of the Antarctic Peninsula. There are no known fisheries operating in these regions that could impact survival (Robertson et al. 2014). In the absence of more regular population surveys, long-term demographic studies and knowledge of factors affecting survival at sea, it would be prudent to treat the observed increase in grey-headed albatross numbers with caution. The determination of the provenance of the birds and more frequent surveys, including surveys in consecutive years, and the instigation of long-term demographic studies will add to the better understanding of the events observed at Diego Ramírez in 2014.

Comparison with other sites

The Falkland Islands/Islas Malvinas, the islands of southern Chile and South Georgia/Islas Georgias del Sur hold the majority of the world's black-browed albatrosses, and South Georgia/Islas Georgias del Sur and Diego Ramírez hold most of the world's grey-headed albatrosses. While the number of black-browed albatrosses at the Falkland Islands/Islas Malvinas is increasing at around 4 %/year (Catry et al. 2011; Wolfaardt 2013), numbers of both species of albatrosses at South Georgia/Islas Georgias del Sur have been decreasing consistently since the 1970s (Poncet et al. 2006). In the 11 years between the last two censuses, in 2003 and 2014, South Georgia/Islas Georgias del Sur black-browed and grey-headed albatross populations decreased by 18 % (mean rate: 1.8 %/year) and 44 % (5.1 %/year), respectively (Poncet et al. unpublished report). The contrasting trends for the Falkland Islands/Islas Malvinas and Chilean populations, and those at South Georgia/Islas Georgias del Sur, most likely reflect site-specific differences in foraging ranges and migration routes (see Birdlife International 2006; Robertson et al. 2014) and associated different levels of threat from commercial longline and trawl fishing operations. Until such time as effective compliance monitoring to agreed seabird conservation measures is developed by relevant fisheries management bodies, and punitive incentives are established for non-compliance, the fisheries-related contributions to the situation at South Georgia/Islas Georgias del Sur are likely to continue.

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