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SHORT NOTE

Study of fauna population changes on Penguin Island and Turret Point Oasis (King George Island, Antarctica) using an unmanned aerial vehicle

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Abstract

An unmanned aerial vehicle (UAV) as an alternative to manned aircrafts is an excellent, less invasive, safe tool, especially in sensitive polar regions. Here we used a fixed-wing UAV to collect data on seabird and pinniped populations in hardly accessible Antarctic areas. The implementation of an auto-piloted UAV equipped with a digital camera (Canon EOS 700D, 35 mm f/2.0 lens) allowed us to collect high-quality material applicable to a quantitative analysis of the fauna populations. A successful photogrammetric mission, at an altitude of 550 m above sea level, was accomplished during one Beyond Visual Line of Sight flight above hard-to-access Penguin Island and Turret Point Oasis (King George Island). Obtained selected RGB images were processed to generate a panoramic image stitch with resolution of 0.07 m ground sampling distance. A total of 4290 (SD = 33.08) breeding individuals of two penguin species, Adélie (*Pygoscelis adeliae*) and chinstrap (*Pygoscelis antarcticus*), 426 (SD = 7.78) individuals of the southern elephant seal (*Mirounga leonina*) and 6 individuals of the Weddell seal (*Leptonychotes weddellii*) were identified in both study areas. Additionally, 222 (SD = 2.0) individuals of the southern giant petrel (*Macronectes giganteus*) and 76 (SD = 1.0) of the Antarctic shag (*Phalacrocorax atriceps bransfieldensis*) in the Turret Point area were recognized. The presented observations on the natural history of the investigated fauna together with the available literature may be useful in future research on population trends. A comparison with available historical data for both investigated areas suggests a decrease of 68.29% in both penguin species in the 1980–2016 period. The presented results confirmed that UAVs are useful for remote census work for Antarctic seabirds.

Keywords Remote sensing · South Shetlands · *Pygoscelis* · Pinnipeds · BVLOS flight · Antarctica

Introduction

Penguin Island is situated in front of Turret Point, which is one of the oases of King George Island, South Shetland Islands, Maritime Antarctica (Birkenmajer 1982; Pudełko 2008). Both sites are sporadically visited by researchers, more frequently by tourists (Pfeiffer and Peter 2004; Sander et al. 2007). Until 2015, the Penguin I site qualified as an Important Bird Area (Harris et al. 2015). Studies of Penguin I fauna were reported by Sladen et al. (1968), Croxall and Kirkwood (1979), Jabłoński (1980, 1984), Trivelpiece et al. (1987), Shuford and Spear (1988), Pereira et al. (1990), Naveen et al. (2000) Pfeiffer and Peter (2004), Sander et al. (2007) and Korczak-Abshire et al. (2012). The latest information on the fauna inventory was recorded in 2013 (Harris et al. 2015). Data on the bird and pinniped populations of Turret Point have been published only by a few authors

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(Croxall and Kirkwood 1979; Jabłoński 1984, 1987; Trivelpiece et al. 1987; Pereira et al. 1990; Naveen et al. 2000; Korczak-Abshire et al. 2011). According to Pfeiffer and Peter (2004), 11 bird species nest on Penguin I, among which the most abundant species are Adélie (*Pygoscelis adeliae*) and chinstrap penguins (*Pygoscelis antarcticus*). On Turret Point, just eight species of breeding birds were recognized (Pereira et al. 1990). In both areas, i.e., Penguin I and Turret Point oasis, a few species of pinnipeds have their breeding, moulting and resting sites (Jabłoński 1980, 1987).

Use of unmanned aerial vehicles (UAVs) to collect environmental data is a relatively new phenomenon in Antarctica, but it has already proved to be a very effective tool for ecosystem monitoring purposes (e.g., Turner et al. 2012; Watts et al. 2012; Funaki et al. 2014; Bollard-Breen et al. 2015; Dąbski et al. 2017; Mustafa et al. 2017; Weimerskirch et al. 2018). Owing to remote sensing, it is possible to detect environmental changes occurring over large and difficult-to-reach areas and whenever the collection of field data is very difficult or impossible. UAVs, including Vertical Take-Off & Landing (Goebel et al. 2015; Krause et al. 2017; Mustafa et al. 2017) and small unmanned aircraft systems (according to Watts et al. 2012), can operate at lower altitudes and thus can collect higher resolution images at a lower cost than satellites or conventional airplanes (e.g., Berni et al. 2009; Anderson and Gaston 2013). The first tests on the suitability of multicopters and fixed-wing UAVs for conducting censuses of penguins were very promising (Trathan et al. 2014; Goebel et al. 2015; Ratcliffe et al. 2015; Zmarz et al. 2015) and offered a non-invasive method to study Antarctic wildlife (Korczak-Abshire et al. 2016; Rümmler et al. 2016).

Here we used a fixed-wing UAV to collect data on seabird and pinniped populations in remote and hardly accessible Antarctic areas in an effort to add natural history observations to the available literature that may be useful in future research on population trends. We lend further credence to the notion that UAVs are useful for remote census work for Antarctic seabirds and pinnipeds.

Materials and methods

The study area covers Penguin Island (62°06′S, 57°56′W) and Turret Point Oasis (62°06′S, 57°56′W) (Fig. 1a). According to Pfeiffer and Peter (2004), 11 bird species nest on Penguin I, among which the Adélie penguin, chinstrap penguin and southern giant petrel (*Macronectes giganteus*). The same species of penguins and the southern giant petrel nest on Turret Point Oasis, together with four other flying bird species, including the Antarctic shag (*Phalacrocorax atriceps bransfieldensis*) (Pereira et al. 1990). In both study areas, three species of pinnipeds occur, namely the southern elephant seal (*Mirounga leonina*), Antarctic fur seal (*Arctocephalus gazella*) (Jabłoński 1987) and Weddell seal (*Leptonychotes weddellii*) (Antarctic Treaty 2006).

In this research, we used a long-range fixed-winged UAV, i.e., PW-ZOOM (maximum take-off weight 23 kg, combustion engine), designed and implemented by the Warsaw University of Technology (Goetzendorf-Grabowski and Rodzewicz 2016; Rodzewicz et al. 2017). UAV was equipped with an auto-pilot enabling autonomous flight and with digital cameras (Canon EOS 700D digital camera with Canon 35 mm f/2.0 lens) (see also Zmarz et al. 2015). Beyond the Visual Line of Sight flight was performed at an altitude of 550 m above sea level on 1 December 2016. Locations for take-offs and landings for the UAVs were set close to the Henryk Arctowski Polish Antarctic Station, approximately 30 km away in a straight line from the goal (Fig. 1a). The flight plan depends on the size of the area, atmospheric conditions on the day of the flight and flight characteristics of the UAV. The trajectory of the PW-ZOOM flight was programmed with HORIZON^{mp} software (MicroPilot, Stony Mountain, Canada) (see also Witczuk et al. 2017). To stitch a complete map together, the image overlapping (forward and side lap) ranged at least 60% between adjacent image frames. The task flight was performed in 2 h 14 min (with an average speed of 103 km/h) over a total distance of 230 km (Fig. 1a).

In the presented study, except for the literature data, historical unpublished data were used to document the population census of the investigated fauna. Ground censuses of bird populations from Penguin I and Turret Point were conducted in December 2008 using CEMP (the Commission for the Conservation of Antarctic Marine Living Resources Ecosystem Monitoring Program) standard methods (A3 breeding population size Procedure A, Ground count) (CCAMLR 2014). Both sites were also visited in January 2007 and 2009, when a record of the observed fauna was carried out. During these visits, all seal individuals were counted along an accessible stretch of the shore by the authors, in accordance with the methods of long-term monitoring carried out in the Admiralty Bay, King George Island (Salwicka and Sierakowski 1998; Salwicka and Rakusa-Suszczewski 2002; Ciaputa and Siciński 2006).

Data analysis

A total of 1630 RAW images in RGB (red, green, blue) taken from the UAV during the task flight were converted and saved as TIFF files in Digital Photo Professional. Subsequently, the selected images were processed with Open-source software Image Composite Editor, version 2.0.3.0 (64 bit) (Microsoft 2015), to generate a panoramic image stitch. All the collected data have a resolution of 0.07 m ground sampling distance (GSD), expressed as a geometric

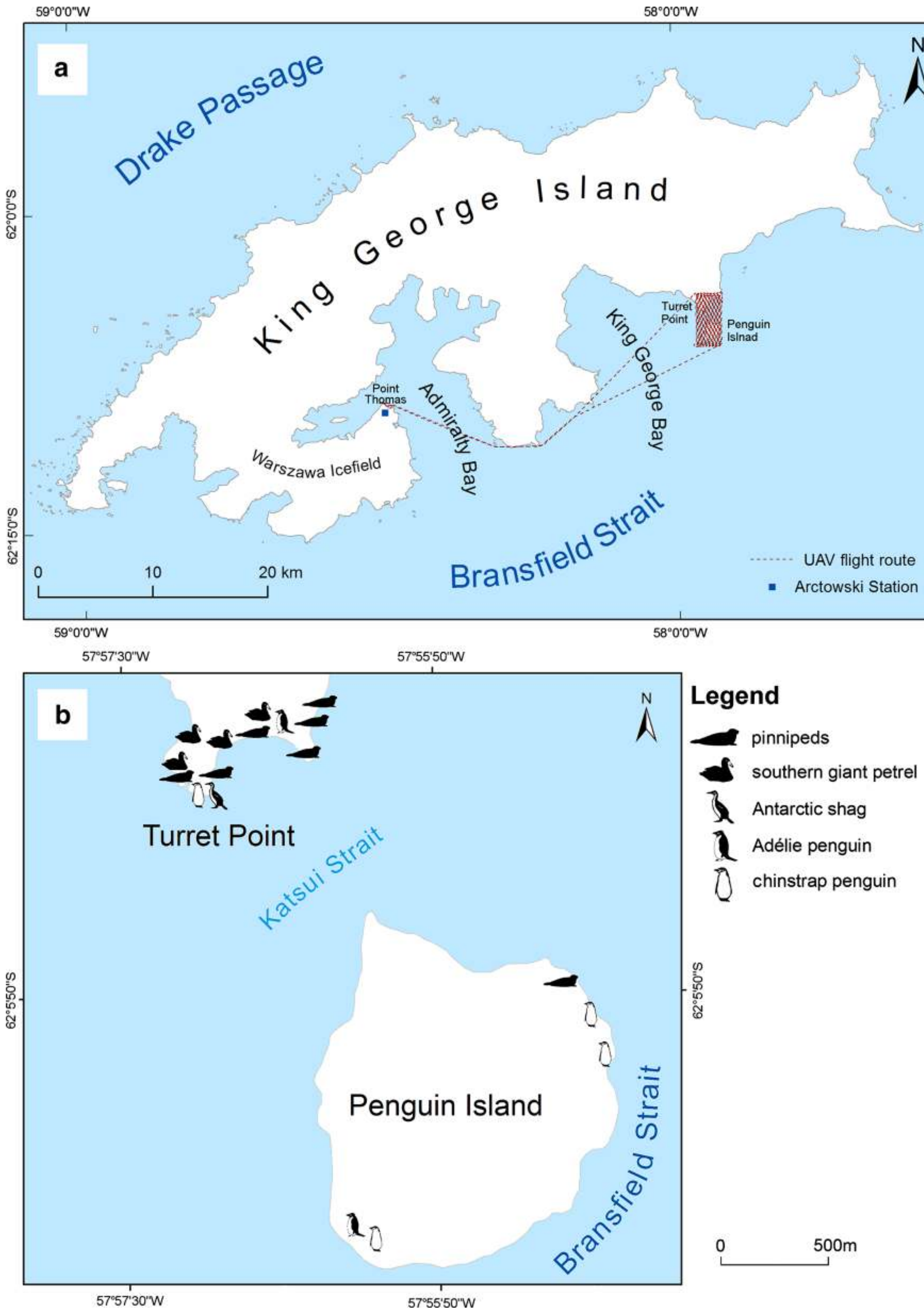

Fig. 1 The study area, **a** Turret Point ice-free oasis located at King George Island and Penguin Island, South Shetlands, Antarctica. GPS trajectory record of the flight plan carried out by the PW-ZOOM UAV (1 December 2016) above the study area marked by the dotted line. **b** Localization of gathering places of investigated bird and pinniped species in Turret Point (King George Island) and on Penguin Island in season 2016, based on UAV-derived material

projection of the sensor through the lens to the ground. On images obtained on 1 December 2016, the number of occupied nests (equal to the number of breeding pairs) in the study areas was estimated on the basis of photographic interpretation using ArcGIS 10.5 (Environmental Systems Research Institute 2016) software. A standardized process for photo interpretation was used to ensure that the counting process has a low probability of missing nests (systematic grid searching) (e.g., Hodgson et al. 2016). The date of UAV census was determined using the breeding chronology of chinstrap and Adélie species on the basis of direct filed observations in easily accessible penguin colonies situated in the vicinity of the Arctowski Station (Point Thomas) (Fig. 1a). The breeding chronology was estimated according to CEMP method A9 (CCAMLR 2014). At this stage, most non-breeding penguins left, and the breeding population remaining at the site was comprised almost entirely of single adult individuals on their nests incubating eggs. Three separate counts of individuals incubating eggs (members of pairs standing between nests as well as birds standing or 'floating' around the colony were ignored) in each of the breeding groups in the colony visible on the image were carried out by an experienced photo interpreter. Each of the results obtained differed by no more than 10%, and the mean value [$\bar{X}$] and standard deviation [SD] were calculated. This method is a modification of the CEMP standard methods for estimation of penguin breeding population size, including method A3A—ground counts of nests and method A3B—using aerial photography (CCAMLR 2014). Analogically, counts of pinniped individuals visible on the images were analyzed. Species of fauna were identified based on the analysis of the following traits: plumage, pelage patterns and colours, shape and size of the body visible in the image. Available historical data for both investigated areas were summarized and are presented in.

Results and discussion

During one PW-ZOOM UAV flight, digital image data sufficient to cover the area of Penguin I and Turret Point (total 3.2183 km^2) were collected. Analysis of the panoramic image stitch allowed for identification of seabird breeding colonies and individuals of pinnipeds gathering on the shore. It was possible to classify individuals of penguin species: chinstrap and Adélie (Figs. 1b, 2, 3 and Table 1, Online Resource 1) as well as the southern giant petrel (Figs. 1b, 2 and Table 2) and Antarctic shag (Figs. 1b, 2 and Table 3) on the aerial material. Additionally, individuals of the southern elephant seal (Figs. 1b, 2 and Table 4) and Weddell seal (Figs. 1b, 3 and Table 4) occurring on the shore of both sites were identified.

On UAV derived material, eight breeding groups of Pygoscelid penguins were identified on Penguin I and three breeding groups on Turret Point. Based on direct ground observation of fauna in previous summer seasons, it was assumed that on Penguin I chinstraps formed four groups in the NE part of the island and four groups in the SW part of the island consisted of chinstraps and Adélies nesting together (see also, e.g., Sander et al. 2007). On Turret Point,

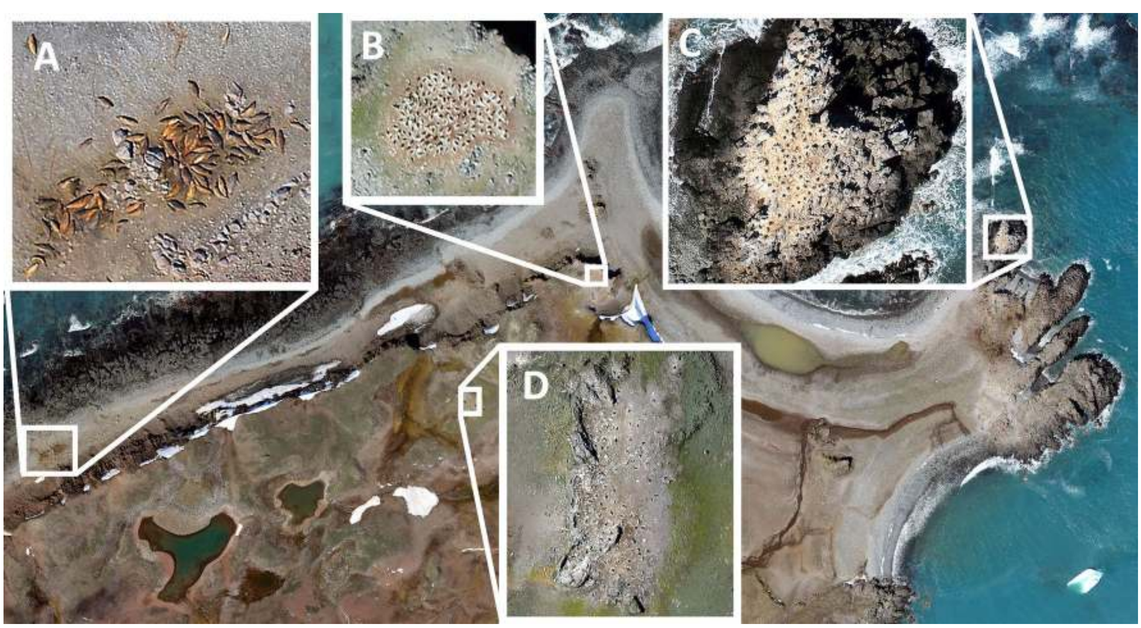

Fig. 2 Example of compilation of high-resolution (0.07 m GSD) aerial images of Turret Point (King George Island), presetting selected concentrations of investigated fauna species: *a* southern elephant seal; *b* Adélie penguin; *c* Antarctic shag; *d* southern giant petrel

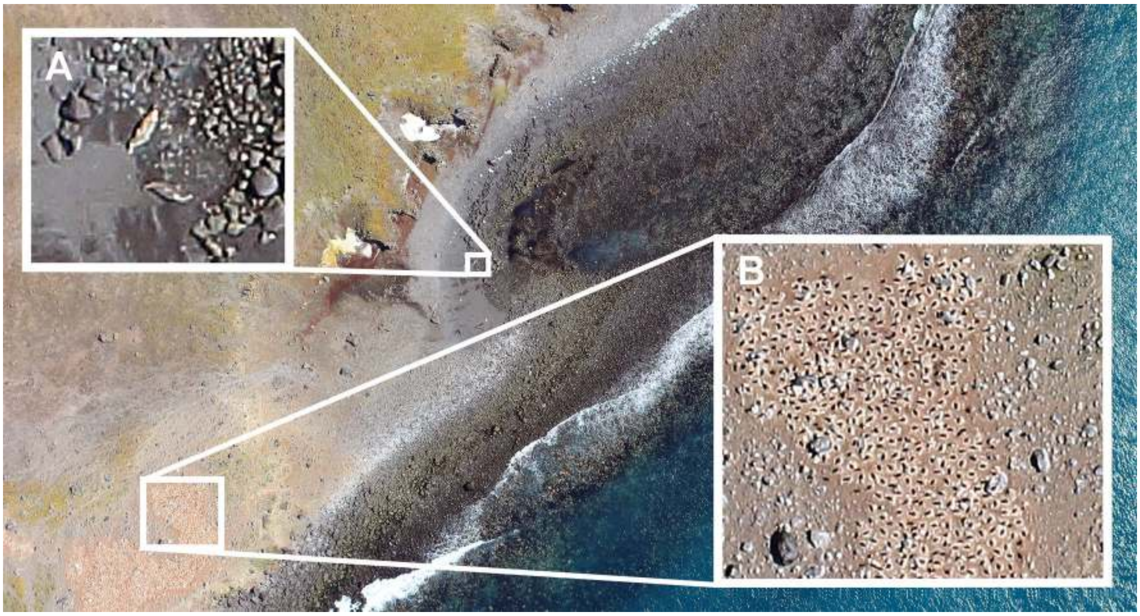

Fig. 3 Example of compilation of high-resolution (0.07 m GSD) aerial images of Penguin Island, presetting selected concentrations of investigated fauna species: *a* Weddell seal; *b* chinstrap penguin breeding group

Table 1 Number of total breeding pairs of chinstraps and Adélies on Penguin Island (PI) and Turret Point (TP) on King George Island in the summer seasons

Period	Species				Total		Reference
	Chinstrap		Adélie				
	PI	TP	PI	TP	PI	TP	
1966 (January)	5155	400	400[a]	223[a]	na	na	Croxall and Kirkwood (1979)
1979 (January)	7058	nd	1710	nd	8768	na	Jabłoński (1980)
1980a (December)	7581	917	3114	1918	10,695	2835	Jabłoński (1984)
1980b (December)	8794	nd	3425	nd	12,219	na	Trivelpiece et al. (1987)
1996 (November)	Not counted	nd	1966	nd	na	na	Naveen et al. (2000)
1997 (November)	nd	Not counted	nd	1077	na	na	Naveen et al. (2000)
1997 (December)	Not counted	nd	2441	nd	na	na	Naveen et al. (2000)
2000 (January)	3774	nd	2390[a]	nd	na	na	Pfeiffer and Peter (2004)
2000 (December)	3296	nd	792	nd	4088	na	Pfeiffer and Peter (2004)
2003 (December)	2672	nd	684	nd	3356	na	Sander et al. (2007)
2007 (January)	nd	89	nd	182[a]	na	na	Personal observation
2008 (December)	4161	80	556	246	4717	326	Personal observation
2013	1545	nd	54	nd	1599	na	Harris et al. (2015)
2016 (December)	na[b]	28	na[b]	153	4109	181	Recent study

Historical published data (to 2003) on PI populations are presented according to Sanders et al. (2007)

nd no data available, *na* not applicable

[a]Only young chicks in crèches were counted

[b]Distinguishing penguin species in UAV images (0.07 m GSD) were not possible

two breeding groups of Adélies and one of chinstraps were identified (Figs. 1b, 2). The structure and distribution of individuals occupying nests identified in the breeding groups within analyzed UAV material correspond with the characteristic for preferences of identified species. The inter-nest distances in the case of Adélie (43.2 ± 1.3 cm) and chinstraps

Table 2 Number of breeding pairs of the southern giant petrel on Penguin Island (PI) and in Turret Point (TP) on King George Island

Year	PI	TP	Total	Reference
1979 (January)	512	nd	na	Jabłoński (1980)
1997 (December)	507	nd	na	Naveen et al. (2000)
1998 (December)	578	nd	na	Naveen et al. (2000)
1999 (January)	439	nd	na	Naveen et al. (2000)
1999 (December)	634	nd	na	Naveen et al. (2000)
2008 (December)	721	338	1059	Personal observation
2012	288	nd	na	Harris et al. (2015)
2016 (December)	nd	222	na	Recent study

nd no data available, *na* not applicable

Table 3 Number of breeding pairs of the Antarctic shag in Turret Point colony on King George Island

Year	Nests	Chicks	Reference
2007 (January)	48	92	Personal observation
2008 (December)	55	98	Personal observation
2016 (December)	76	nd	Recent study

nd no data available

(59.2 ± 2.2 cm) are comparable and significantly shorter than for the third *Pygoscelis* species breed in this region, gentoo (74.3 ± 3.8 cm) (Volkman and Trivelpiece 1981).

In each group, the number of occupied nests (individuals incubating eggs) was censused, ranging from 16 to maximum 2017. In total, 4290 (SD = 33.08) occupied nests were recorded, namely 3532 (SD = 48.3) nests of chinstraps, 153 (SD = 1.2) nests of Adélies and 605 (SD = 19.6) nests of chinstraps and Adélies in a mixed colony. Comparison of UAV-derived material and ground census data with the already published historical figures are presented in Table 1 and Online Resource 1. A summary of these results indicates that the investigated penguin breeding populations decreased significantly for both penguin species, Adélie (84.06%) and chinstrap (50.09%), in the 1980–2008 period. This trend in penguin population size seemed to continue. In 2016, there were 68.29% penguins less than in 1980 in both study areas. This result reflects the trends in populations from different localities on King George Island (e.g., Chwedorzewska and Korczak 2010; Korczak-Abshire et al. 2013; Braun et al. 2017; Sierakowski et al. 2017; Znój et al. 2017) as well as trends in the whole Antarctic Peninsula region (e.g., Hinke et al. 2007; Lynch et al. 2012; Lyver et al. 2014). Moreover, some authors suggest that further reductions in the ice-dependent Adélies population are likely if the frequent climate anomalous events continue (Ainley et al. 2010; Hinke et al. 2017).

The population of southern giant petrel on Penguin I was stable and was even increasing until 2008 (Table 2). In 2012, Harris et al. (2015) reported only 288 nests on Penguin I, which suggests there were fewer birds than previously recorded. Unfortunately, there was impossible to identify the individuals of this species by photo-interpretation in the aerial images of Penguin I in 2016. The reason for this could be an indistinguishable colour of southern giant petrel plumage on the rock background, other than on Turret Point where 222 (SD = 2.0) clearly visible individuals in total were identified in the aerial material (Fig. 2, Table 2). Personal observations suggest a decrease in the southern giant petrel breeding population size in this area.

A different population trend was observed for the Antarctic shag species. The breeding group on Turret Point, totaling 76 (SD = 1.00) nests, clearly visible in Fig. 3, is the only breeding colony of this species in the whole investigated area. Data indicate that since 2008 the number of breeding populations of the Antarctic shag has increased.

In the region of King George Island, the greatest number of fur seals is observed in February and March (Jabłoński 1987; Salwicka and Sierakowski 1998; Salwicka and Rakusa-Suszczewski 2002), and they are hardly ever recorded on the shores in December. No fur seals were identified on aerial images taken in December, although the ground census conducted in January 2009 on Turret Point amounted to 203 individuals (Table 4). Jabłoński (1987) reported 102 and 169 + 3 juvenile individuals of this species on Turret and Penguin I, respectively, in March 1981. However, lack of data obtained at the same time of the year does not allow us to identify a trend in the population size of the fur seal. In the present study, 426 (SD = 7.78) elephant

Table 4 Individuals of pinniped species identified on shores of Penguin Island (PI) and Turret Point (TP) on King George Island

Year	Southern elephant seal		Weddell seal		Antarctic fur seal		Reference
	PI	TP	PI	TP	PI	TP	
2007 (January)	nd	482	nd	0	nd	6	Personal observation
2008 (December)	8	464	3	0	1	1	Personal observation
2009 (January)	25	414	2	1	401	203	Personal observation
2016 (December)	3	423	3	3	0	0	Recent study

nd no data available

seals, mostly on Turret Point, and 6 (SD = 0) individuals of Weddell seals (Table 4) were identified. Sporadic census of pinnipeds conducted in both areas suggests that the population of elephant seals is stable, and Turret Point might be a significant breeding site of this species.

Censuses of the breeding and resting populations of both investigated areas are made sporadically. Our study has shown that the use of UAVs to monitor the fauna in hardly accessible areas seems highly efficient and suitable for monitoring of bird and pinniped populations. Moreover, planned implementation of advance techniques, such as automatic estimation of the objects, will increase the efficiency and accuracy of analyses (e.g., Zmarz et al. 2015).

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