Breeding phenology, distribution and conservation status of Markham's Storm-Petrel *Oceanodroma markhami* in the Atacama Desert

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Markham's Storm-Petrel *Oceanodroma markhami* is one of the least known seabirds in the world. Between 2013 and 2017, we conducted an extensive ground based survey to locate nests, confirm nesting colonies and, whenever possible, characterize Markham's Storm-Petrel breeding phenology. The survey was conducted in the Atacama Desert, northern Chile, covering the area between Arica (18.240°S, 70.509°W) and Taltal (25.050°S, 70.486°W). Our study led to the discovery of two new colonies and to a six-fold increase in the estimate of the breeding population at the previously known Arica colony: a more accurate estimate of 55,308 pairs. Prior to this study, 9362 breeding pairs were known to occur in two colonies. Currently, the colonies of Arica (34,684 nests), Pampa La Perdiz (624 nests) and Salar Grande (20,000 nests) represent almost 95% of the known breeding population. We found that the colony of Arica has a different breeding phenology to that of the Pampa Perdiz and Salar Grande colonies, which could be due to differences in their food phenology. None of the colonies lie within designated protected areas and they strongly overlap with current and planned mining, wind farms and power plants in northern Chile. Apart from the disturbance caused by destruction of habitat and nests, these developments are also important sources of artificial light that cause the grounding of fledglings, after which many of them probably die from the collision impact or predation. It is vital to ensure the conservation of this species by protecting their breeding grounds and by reducing the light pollution not only in the colonies, but also at the access points to the colonies and at the big cities nearby.

Key words: *Hydrobates markhami*, Atacama Desert, Procellariiformes, Storm-Petrels, distribution, breeding phenology, light pollution

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Markham's Storm-Petrel *Oceanodroma markhami* is found mainly in tropical waters of the Pacific Ocean, between 16.55°N and 29.90°S, and 71.00°W and 118.02°W (Murphy 1936, Spear & Ainley 2007). The species' distribution in pelagic waters varies seasonally, concentrating in higher densities off the coast of central Peru during austral autumn, and changing markedly during austral spring, when two large concentrations are observed: one off the coasts of southern Peru and northern Chile, and the second 1700 km further west (Spear & Ainley 2007).

The size of its population remains unclear, although two recent estimates range from 10,000 pairs and 30,000 individuals (Carboneras *et al.* 2018) to more than 50,000 individuals (BirdLife International 2018). Spear & Ainley (2007) estimated much higher numbers

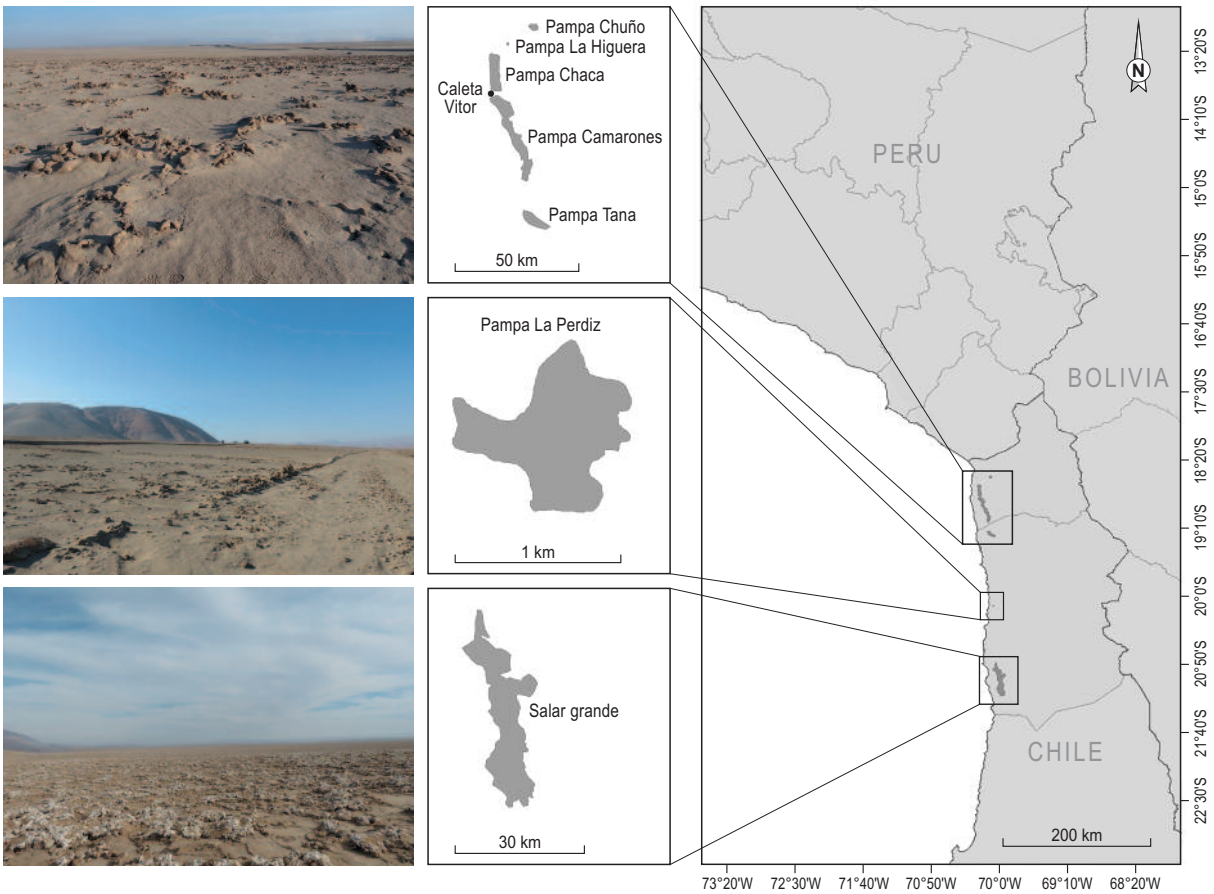

Figure 1. Map showing the three colonies described in this study. From north to south, the Arica Colony with its sub-colonies, the Pampa la Perdiz Colony and the Salar Grande Colony.

from surveys at sea, calculating a population of 700,000–1,000,000 individuals in the austral spring and 1,000,000–1,600,000 individuals in the austral autumn. In the absence of a consensus on population size and the lack of information on locations of breeding colonies, the degree of threat to the species is undetermined. Therefore, it is valuable to generate a population estimate, optimally carried out through the counting of pairs in breeding colonies (Carboneras & Bonan 2017) for calculating the population size used by the IUCN, which only includes the mature individuals (IUCN 2012).

To date, four breeding areas have been reported: Jahncke (1993, 1994) documented the discovery of an area in the Paracas peninsula, department of Ica, Peru (13.901°S, 76.382°W), estimating 2305–4362 reproductive pairs. Torres-Mura & Lemus (2013) found a colony south of the Acha valley, province of Arica, Chile (18.642°S, 70.254°W), where they estimated a population of 5000 pairs. Also, part of our team described the finding of two breeding areas: one in Pampa Camarones, province of Arica (18.893°S, 70.189°W) and another in Salar Grande, province of Iquique (21.037°S, 69.983°W; Schmitt *et al.* 2015). The same was found by Brooke (2000), who in April/May 1999 discovered a possible colony of Markham's Storm-Petrels near Salar Grande, based on the presence of juveniles attracted by the lights of a salt mine, pellets with Storm-Petrel feathers and tracks on the surface of the salt pan. Juveniles grounded by lights far inland from the coast in other areas (Arica, Iquique) suggest the existence of more colonies in the Atacama Desert (Tobías *et al.* 2006, Drucker & Jaramillo 2013).

Due to its unknown population size, poor knowledge of its nesting sites and the unknown threats to which it is vulnerable, this species is one of the few seabirds classified globally as 'Data Deficient' (Croxall *et al.* 2012, BirdLife International 2018). Therefore, it

has been proposed that efforts focus on the active search for and characterization of their breeding colonies, and the identification of their threats, in order to specify measures that might be necessary for their conservation (Tobías *et al.* 2006, BirdLife International 2018).

Here, we report newly described nesting colonies of Markham's Storm-Petrel, giving information on densities and estimates on the number of pairs for each of these colonies. In addition, we provide new information on their reproductive phenology and of characteristics of nests and describe some of the main threats they incur while on land.

METHODS

The ground surveys took place between 2013 and 2017 and were conducted all through the year in the Atacama Desert, northern Chile, covering the area between Arica (18.240°S, 70.509°W) and Taltal (25.050°S, 70.486°W). A linear distance of c. 780 km of coastline was covered, from sea level to 1700 m.a.s.l. (Figure 1). The area covered was constrained by the presence of roads or vehicular paths allowing access to the sites. A total of 12 expeditions with teams of two to four people were carried out, comprising a sampling effort of 984 h. Considering that petrels reduce their activity on bright nights (Watanuki 1986), surveys were conducted at and around new moon nights (from five nights before to five nights after).

The identification of areas with higher nesting potential was based on the interpretation of satellite images, selecting for habitat characteristics similar to previously found breeding areas in Peru (Jahncke 1994). Also, we visited the breeding areas described by Torres-Mura & Lemus (2013) and by us in Schmitt *et al.* (2015). Furthermore, we did a spatial analysis of historical data on fledglings grounded by artificial lights. To estimate the optimal time to visit potential colonies, dates of fledglings grounded by artificial lights in each area were analysed, and we then visited the sites five months in advance, when vocalization rates were expected to be at their peak according to the phenology described by Jahncke (1994). The main sources of records of grounded fledglings were The Agricultural and Livestock Service (Servicio Agricola y Ganadero, SAG) of the Tarapacá region, the Gaviotín Chico Foundation for the Mejillones area, observations in eBird (2017), and observations by the authors for other areas. Within the areas identified as potential breeding sites, cavities were searched for signs of breeding (i.e. tracks, odour, faeces, feathers and bones), occasionally using an endoscopic inspection camera (RIDGID micro CA-300). During previous studies, vocalizations of the species were recorded at nests (record ML83166671, Macaulay Library); during the current study these were played back at the entrance of the cavities to confirm activity in the nests, since adults are responsive to conspecific calls.

To define the boundaries of each colony, the criterion of IUCN (2012) was used, which considers a locality as 'a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present'. Apart from threats at breeding colonies, we also considered potential threats at the access points to the colonies from the sea, which could be flightpath bottlenecks (see below). Therefore, we surveyed the flightpaths of groups of adults flying inland by seawatching at dusk, between 19:30 and 21:30, during four consecutive days in Península del Alacrán, Caleta Vítor, Caleta Camarones and the mouth of the Lluta River, with binoculars (10×42) and telescopes (15–60×).

To estimate the number of pairs within each colony (and sub-colonies in Arica), we covered 76 transects (between 16 and 38 per colony or sub-colony, in proportion to the colony surface area) 10 m wide and of variable length (between 100 and 2640 m, depending on terrain conditions) within the area with cavities, identifying all the active nests (with an adult, chick or egg, odour and/or tracks at the entrance of the cavity), from which an average nest density was obtained for each colony. To estimate population size from these densities, we extrapolated linearly to the total area of the colony. For calculating the area of the colony, we used satellite photos in Google Earth Pro to delimit the borders of the colony. Considering that cavities occur heterogeneously within the salt flats, we performed five to ten transects of 1–20 km in each colony to be able to accurately extrapolate. In these transects, we assessed whether each 100 m point was suitable for a colony, which enabled us to calculate the proportion of the appropriate substrate within each site (Bullock 1996).

Finally, we identified the current and potential threats at each site by observations in the study areas and by consulting residents and local authorities. Considering that the impact of artificial lights on fledglings may be a critical threat, we searched for fledglings that were grounded using a systematic count in two areas with public artificial lights in Salar Grande, in March 2017. These areas were surrounding the Kainita and Tenardita salt mines. The area surrounding Kainita

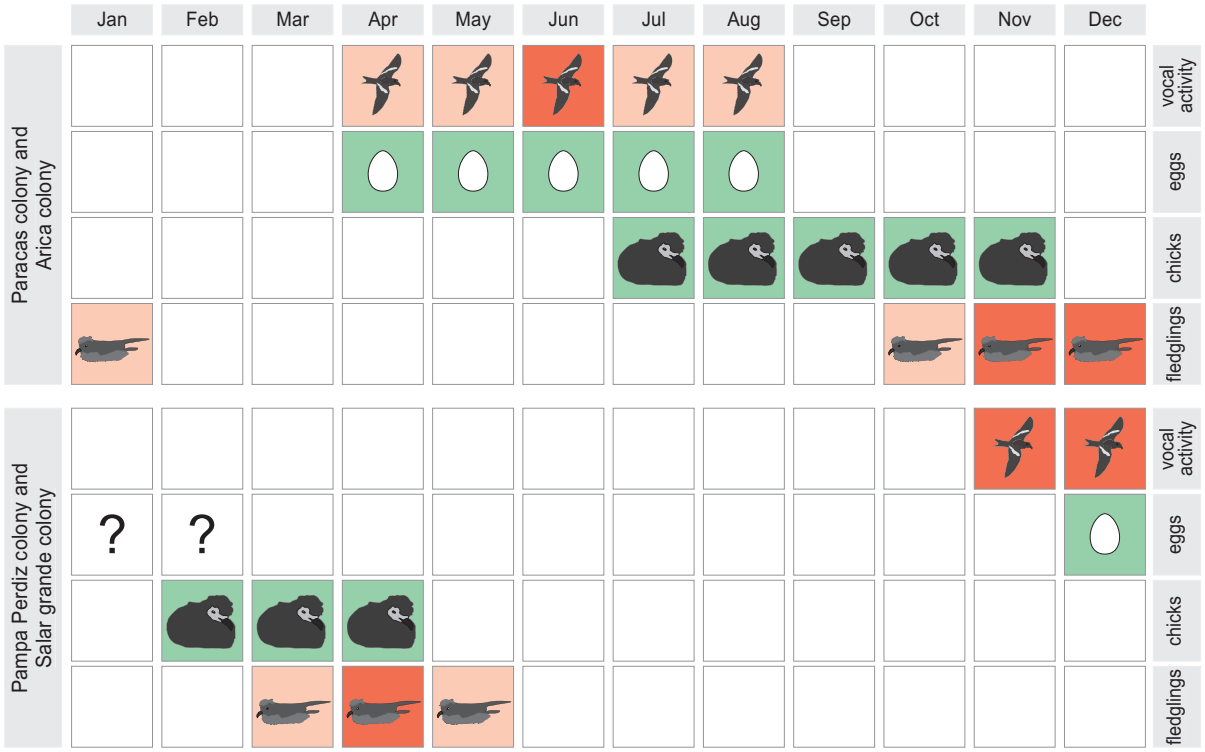

Figure 2. Breeding phenology of the Paracas (based on Jahncke 1994) and Arica colonies (top) and of the Pampa la Perdiz and Salar Grande colonies (bottom). The brightest red indicates the peak occurrence of the breeding stages throughout the year, while a paler red indicates a low frequency of the breeding stage. Green indicates that the peak in occurrence of that breeding stage is not known.

was illuminated by 12 low-intensity yellow lights, with a light radius of 1.3 ha. The Tenardita area was illuminated by two halogen white lights, with a light radius of 0.7 ha. To avoid recounts, all remains and old carcasses were removed. Subsequently, for six consecutive nights, live and dead individuals were counted. The survey was done two hours before sunrise, thus controlling for removal by Turkey Vultures *Cathartes aura*, which we identified as the main source of removal of carcasses. With this information we used a linear extrapolation to estimate the number of fledglings in the inaccessible private area (375 ha), for the two days before and the two days after the new moon in April, when numbers of grounded birds peak. This gave us a rough number of grounded birds in Salar Grande. Birds that were found alive were captured and released on the same night, in coastal areas away from artificial sources of light, under permit from Servicio Agricola y Ganadero. In Arica we did not do a systematic search for fledglings, but instead we searched for fledglings in the main artificial light sources within the city of Arica between 21 and 29 November 2017.

RESULTS

We identified three colonies of Markham's Storm-Petrel in Chile: (1) Arica Colony, which incorporates the colony described by Torres-Mura & Lemus (2013), significantly expanding the earlier estimate of its size and population, (2) Pampa de la Perdiz Colony, and (3) Salar Grande Colony. Pampa de la Perdiz was not previously identified. The colonies are all located in saline deposit areas, whose rough substrate generates natural cavities, which are used by the species to nest. The disposition of the patches of salt is variable, with areas where only isolated patches of salt are found and others where the salt occurs in extensions of tens of kilometres (Figure 1). The colonies are located immediately to the east of the mountain range Cordillera de la Costa running parallel to the coast, at 5–18 km from the coastline at 600–800 m.a.s.l.

In all colonies, a pair's reproductive season spans c. 5 months, from the arrival at the territories until the departure of the fledglings, matching Jahncke's (1994) description from Peru. However, the pairs within each

colony do not reproduce synchronously, so that the reproductive activity in a single colony can span ten months (Figure 2). Another feature common to all colonies is that adults arrive at the breeding sites at least 45 min after sunset, as is typical for most Procellariiformes populations. As with most storm-petrel species, adults vocalize both in flight and from inside the cavities.

Site-specific features

Arica colony

With a total length of 85 km (north-south) and being 8 km at its widest point (east-west), the Arica colony is composed of five sub-colonies: Pampa Chuño, located immediately east of the city of Arica (18.535°S, 70.106°W), Pampa La Higuera, located southeast of Arica (18.600°S, 70.198°W) between the Azapa and Acha valleys, Pampa Chaca, located south of the city of Arica (18.700°S, 70.240°W), Pampa Camarones, located between the valleys of Chaca and Camarones (18.937°S, 70.171°W) and Pampa Tana, the southernmost sub-colony (19.236°S, 70.101°W). The reasoning behind considering this extensive area to constitute only one colony, even though the valleys of Azapa, Acha, Chaca and Camarones run through it, is that it is likely that most of the individuals of the sub-colonies fly inland from the sea exclusively through Caleta Vítor (Chaca Creek). This was determined in two ways: first, when seawatching at the potential access points, between 6000 and 10,000 individuals were recorded approaching and entering through Caleta Vítor (3 August 2016), while no individuals were observed in Caleta Camarones (5 August 2016), Peninsula El Alacrán (6 August 2016) or the mouth of the Lluta River (8 August 2016), and, second, after twilight, we found that the individuals from the southern tip of Pampa Camarones reached their nests one hour later than individuals from the northern end of the pampa, which is closer to the entrance point at Caleta Vítor. Because both points are at equal distance from the coastline, it supports the hypothesis of a single entrance point. The characteristics and threats of each colony are described in the Table 1.

Adults' vocalizations were heard between April and August with a peak in June. Nests with eggs were found from the end of April until the beginning of August, when a female with an egg in the abdomen was captured. The departure of fledglings was recorded between the end of October and the beginning of January, with a peak between November and December (Figure 2).

There are numerous dangers threatening this colony, which may differ between sub-colony (Table 1): (1) roads (Route 5 and Route A-31) and secondary roads that cross the colony, which may damage areas with cavities, (2) litter from roads, mainly cans and

Table 1. Characteristics of Markham's Storm-Petrel colonies in Chile and current threats to these populations.

	Arica colony						
	Pampa Chuño	Pampa La Higuera	Pampa Chaca	Pampa Camarones	Pampa Tana	Pampa La Perdiz colony	Salar Grande colony
Characteristics							
Distance at sea (km)	21.5–24.5	15.46	5.4–12.7	9.8–21	14.81–24.6	10	9–21.5
Maximum length (km)	0.51	–	14.17	19.6	–	0.9	49.2
Maximum width (km)	0.19	–	12.3	5.1	–	0.85	8.4
Altitude (m.a.s.l.)	770–970	656	600–700	640–1080	620–1000	900	650–750
Colony size (ha)	41	–	6100	2209	–	33	–
Average density (pairs/ha)	2.2	–	248.15	4.42	–	18.9	–
Number of pairs	90	5	24,815	9772	2	624	20,000
Threats							
Roads	–	–	X	–	–	X	X
Garbage	–	–	X	–	–	?	–
Military exercises	–	–	X	–	X	–	–
Power lines	X	–	X	–	–	X	–
Mining companies	–	–	–	X	–	–	X
Power plants	–	–	–	X	–	–	–
Artificial light pollution	X	?	–	–	–	X	X

Figure 3. Main threats affecting the Markham's Storm-Petrel: (A) Mining facilities, which directly destroy the colonies and create light pollution by night; (B) Light pollution, which triggers fledgling fall-out; (C) Litter from roads, which blocks the entrances of the cavities, and (D) military training exercises, which destroy the salt substrate and may cause the collapse of cavities.

plastic bottles, which can block the entrances of the cavities. This happens even at dozens of kilometres from the roads due to the wind (Figure 3), (3) military training exercises (tanks moving and testing of bombs), which destroy the salt substrate and may cause the collapse of cavities (Figure 3), (4) power lines that cross the colony, creating a potential collision threat, and (5) mining, energy plants and road works installations, which directly destroy the salt substrate (Figure 3).

There are also potential threats common to the entire colony: (1) the installation of new electric lines creating a collision hazard, (2) the introduction of new mines and/or power plants that destroy the salt substrate, and (3) the installation of artificial lights in areas surrounding the colonies and in the city of Arica that could cause fledglings fall-out. Regarding this last threat, no grounded fledglings were detected around the salt mining and energy facilities (electrical high voltage towers) that are adjacent to the sub-colonies of Pampa Chaca and Pampas Camarones. However, in the city of Arica, 86 grounded fledglings were recorded, with most of them being close to the Carlos Dittborn stadium and to street lights at the entrance to the Azapa road. Of grounded fledglings, 27 (31%) were found dead and 59 (69%) were captured and released. Some fledglings were predated by Peregrine Falcons *Falco peregrinus*, Turkey Vultures, Dogs *Canis lupus familiaris* or Ants *Pheidole chilensis*.

Pampa La Perdiz Colony

The Pampa La Perdiz colony is located northeast of the city of Iquique (20.104°S, 70.073°W; Figure 1). Charac-

teristics of the site can be found in the Table 1. In this colony, breeding started in November–December with the arrival of the adults to the nests and continued until March–May with the departure of the juveniles (Figure 2).

The colony is currently threatened by (1) the presence and expansion of route A-514, which directly destroys the salt deposits, (2) a high-voltage line, causing collision risks, and (3) light pollution in the fledglings' flightpath to the sea (the cities of Alto Hospicio and Iquique are probably along this flightpath). Potentially, there are several more threats: (1) the creation of new high-voltage lines, (2) the establishment or expansion of legal and illegal landfills in the vicinity of the colony, from which garbage can clog cavities and which may also attract predators, such as introduced rodents *Rattus* spp., Dogs and Turkey Vultures, and (3) establishment of solar energy parks or mining projects in the colony.

Salar Grande Colony

In Salar Grande (21.032°S, 69.987°W), north of the Loa River, there is a large colony where only 20 nests have currently been found (Figure 1). The nests were found on slopes at the edge of the salt flat. Since the number of known nests is small, we were not able to estimate the population size as done for the other colonies. Instead, we used the estimated number of fledglings that were grounded by artificial lights of the mines as a conservative size of this colony. We estimated that at least 20,875 pairs occur here (see below). The finding of a cavity with a strong odour (7 December 2015) and of an individual, probably juvenile, flying at noon (24 May 2014) in Salar de Llamara, located 30 km to the southeast, suggests that the colony could extend towards that area, or that it could be a separate colony. The finding of 20 nests corroborates the idea proposed by Brooke (2000), confirming Salar Grande as a nesting colony of Markham's Storm-Petrel. The location at the coast where individuals access the colony remains unknown.

Vocalizations were heard in November–December. Nests with eggs were found in December, and the departure of fledglings occurred between March–May, with a peak in April (based on data from grounded fledglings; Figure 2).

This colony is currently threatened by (1) light pollution from ports and mines, particularly mines located on the salt flat (Figure 3), (2) the destruction of the salt pan by salt mines, which directly destroy the nests (Figure 3), and (3) roads (A-750) and secondary roads that cross the colony, which may damage areas with cavities. Other potential threats include (1) the installation of new high-voltage power lines or wind farms that potentially could cause collisions, (2) the construction of new mines and/or power plants that destroy the habitat, and (3) the installation of more lights at existing mines.

Regarding the impact of artificial light sources, individuals were found at both survey points in the public areas during the six monitored days. In the days prior to the systematic count, Turkey Vultures were seen at both survey points (a maximum of 30 individuals in Ternardita), and we observed them feeding on the grounded storm-petrels immediately after dawn. In the Kainita area, 110 storm-petrels were collected, and 57 in Tenardita. All the individuals found were offspring of that breeding season – with down feathers –, which were collected alive (79%) or dead (21%); the latter killed mainly by vehicle collisions. Given that lights cover around 375 ha of the salt flat, and that most of the fledglings that are grounded die of starvation, predation or dehydration (as happens with other petrels; Rodríguez *et al.* 2017a), we estimated that in Salar Grande more than 20,875 fledglings might die each year.

DISCUSSION

Our results confirm that the Atacama Desert in northern Chile holds the largest known nesting colonies of Markham's Storm-Petrels. According to our results, in Chile we estimate at least 55,328 pairs, which, added to the minimum of 2305 pairs found in Peru by Jahncke (1994), would comprise a world population of at least 57,613 reproductive pairs and, therefore, a population in excess of 150,000 individuals (including immatures); a number that far exceeds what was previously postulated by Birdlife International (2017) and Carboneras *et al.* (2018), but that is below the estimate of Spear & Ainley (2007). However, our population estimate may still be too low because, in addition to the three colonies we describe here, there are at least two other areas in Chile that could hold colonies. Those sites are: (1) Santa Rosa-Chacalluta Coastal Customs area (18.314°S, 70.314°W), where hundreds of fledglings are grounded each season (November– December), attracted by artificial lights (Vizcarra pers. comm.). This area lies at the border between Chile and Peru and has restricted access due to landmines. (2) Interior areas of Mejillones (23.315°S, 70.046°W) and Antofagasta (23.754°S, 70.020°W), where there are records of grounded fledglings between March and May (Hernández pers. comm.).

If confirmed, these would be the southernmost colonies for the species. All the colonies are in areas of absolute desert (Luebert & Pliscoff 2006) that are practically devoid of other forms of life.

The reproductive phenology differs between the northernmost Arica colony and the colonies of Pampa la Perdiz and Salar Grande. While in the Arica colony the phenology (April–December) is like that described for the Paracas colony (Peru), located 800 km further north (Jahncke 1994), for the Pampa de la Perdiz and Salar Grande colonies, which are only 140 and 240 km south of the Arica colony, respectively, the phenology is totally different (November–May; see Figure 2). The existence of these two contrasting reproductive periods could be explained by the hypothesis of Perrins (1970), according to which the birds would time their reproductive season in such a way that hatching of chicks coincides with a peak in food abundance, in this case the spawning of the Peruvian Anchoveta *Engraulis ringes*, which is one of Markham's Storm-Petrel's main prey (García-Godos *et al.* 2002). The spawning has two peaks: one in September (Einarsson *et al.* 1966) and another in March (Csirke *et al.* 1996), which coincides with the hatching date of the offspring in the colonies. This type of phenomenon can lead to speciation, due to the temporal breeding segregation of populations, as occurred with the Monteiro Storm-Petrel *Oceanodroma monteiroi* and Madeiran Storm-Petrel *Oceanodroma castro*; Bolton *et al.* 2008). To study this process, genetic studies could be informative, together with behavioural studies and marking or tracking of individuals to study movements between colonies.

Our work shows that the three colonies are strongly threatened by current and future mining and development of energy projects (wind farms, power lines; see Table 1). The lack of knowledge of the existence of breeding colonies and the difficulty in locating the nests meant that the impact on these colonies was not included in the environmental impact assessments of multiple development projects under the Chilean legislation. For this reason, we believe it is a priority to consider the potential impact of existing development projects and to carry out the necessary mitigation and compensation measures to avoid the local extinction of the species. Furthermore, currently none of the colonies in Chile are protected, making it of utmost importance to generate measures that prevent further destruction of these environments and their natural cavities, which would lead to irreplaceable loss of nesting habitat. All the above testifies to the need for all these colonies to be declared as protected areas, prohibiting the construction of new projects (e.g. mines, roads, power lines) and of destructive recreational activities, such as off-road driving (e.g. Dakar Rally). In addition to protecting the breeding sites, it is also important to ensure that important points along the flightpaths, such as Caleta Vítor, are kept free of threats, such as wind energy parks, coastal electric transmission lines or significant artificial light sources. Just one threat could have a significant negative impact on the largest known colony of this species, namely Arica.

Regarding the impact of artificial lights, this study likely underestimates the number of fledglings that die every year from being grounded, because, in the case of Arica, only some areas of the city were surveyed, and extrapolation to the total area was not possible, as proposed by Rodríguez *et al.* (2017b) and because in the case of the Iquique colonies, the impact of the city lights and most of the coastal industries on the fledglings has not been quantified. We only sampled accessible areas in Salar Grande, even though these have a relatively low light intensity compared to other sites inside the mines. To reduce the impact of artificial lights, the most effective measures would be to turn-off or reduce lights during the breeding season, to schedule large cultural events during the day instead of at night, to modify the direction of some lights so they do not point to the sky, and if possible, change the colours of the lights, as suggested by Rodríguez *et al.* (2017a,b). These measures should be complemented (but never replaced) by rescue and release programs for grounded fledglings (Rodríguez *et al.* 2017a). Although these programs exist in mines in Salar Grande, their design and implementation make their effect on mitigating the impact marginal, causing most individuals to be depredated by Turkey Vultures after dawn; to increase the success rates of these campaigns, the rescue of grounded birds should be conducted before dawn. For both the cities of Arica and Iquique, measures to avoid grounding of fledglings are difficult to implement because that would imply a major change of the light of the whole city. However, the reduction of light pollution should be on the political agenda in the short term, leading to legislation. On the other hand, rescue and release programs seem to be easier to implement in the cities, where groups of volunteers are participating every year.

Our results are a first step in understanding how and where to protect the Markham's Storm-Petrel. Nevertheless, it is necessary to make advances in management, to search for new colonies, to improve the estimate of fledgling numbers grounded by artificial lights, and to implement programs that effectively protect this species.

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SAMENVATTING

Het Humboldts Stormvogeltje *Oceanodroma markhami* is een van 's werelds minst bekende zeevogels. Tussen 2013 en 2017 hebben wij in de Atacama-woestijn in het noorden van Chili een uitgebreide inventarisatie uitgevoerd naar het voorkomen van dit stormvogeltje en getracht de broedfenologie van de soort te onderzoeken. De inventarisatie bestreek het gebied tussen Arica (18.240°ZB, 70.509°WL) en Taltal (25.050°ZB, 70.486°WL). Er werden drie kolonies gevonden, waarvan twee nieuwe, met in totaal 55.308 nesten (Arica 34.684 nesten, Pampa La Perdiz 634 nesten en Salar Grande 20.000 nesten). Het gevonden aantal nesten in Arica betekende een zesvoudige toename van een eerdere schatting van de broedpopulatie daar. Vóór het huidige onderzoek waren slechts twee kolonies met in totaal 9362 broedparen bekend. Het totaal aantal van 55.308 nesten omvat bijna 95% van de wereldpopulatie. We ontdekten dat de kolonie in Arica een andere voortplantingsfenologie heeft dan de kolonies in Pampa Perdiz en Salar Grande, wat het gevolg kan zijn van een verschil in de fenologie van de aangevoerde prooien op die plaatsen. Geen van de kolonies ligt binnen aangewezen beschermde gebieden. Ze liggen bovendien in gebieden met huidige en geplande mijnbouwactiviteiten, windmolenparken en energiecentrales. Afgezien van de vernietiging van leefgebieden en nesten vormen deze ontwikkelingen ook belangrijke bronnen van lichtvervuiling, waardoor jongen 's nachts naar de grond komen en vele van hen waarschijnlijk doodgaan als gevolg van de botsing met de grond en predatie. Het is van vitaal belang voor het behoud van de soort om hun broedgebieden te beschermen en de lichtvervuiling niet alleen in de kolonies, maar ook op de toegangspunten tot de kolonies en in de nabijgelegen grote steden te minimaliseren.

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