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Status and reproductive success of striated caracara at Sea Lion Island, Falkland Islands

15/06/2020

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Summary

The striated caracara (*Phalcoboenus australis*) is a near threatened bird of prey that has a geographic range limited to the southern part of South America, and to the Falkland Islands in particular. The current knowledge of the breeding biology of striated caracara is scarce, and it is based mostly on descriptive accounts that lack quantification. From 2013 we carried out regular surveys of striated caracara at Sea Lion Island, the southernmost inhabited island of the Falkland Islands. We collected data on striated caracara spatial distribution, nesting habitat and reproductive success. Moreover, we assembled information from previous irregular surveys carried out from 1998 to 2012, and anecdotal information about specific pairs collected from 1995.

Although our sample size was small (about 20 pairs per season), and we had data for just seven breeding seasons, we were able to estimate various measures of reproductive success and analyze their trends. We concluded that: 1) number of striated caracara pairs, proportion of trios, and total number of adults increased; 2) total number of chicks and productivity (chicks/pairs) decreased; 3) brood size, although high on average (2.0 chicks/breeding pair), decreased. Those patterns were the result of the establishment on new pairs that partially replaced old pairs and that were unsuccessful or produced less chicks than the average during their first breeding seasons. The increased competition between striated caracaras due to the increase in number of adults was possibly augmented by the breeding failure of some marine bird species that happened at Sea Lion Island in recent years.

Sea Lion Island is currently the only island of the Falklands where regular monitoring of all striated caracara nests has been carried out for a rather long string of years. Therefore, notwithstanding the rather small sample size, we suggest that nest monitoring should be carried out to provide an assessment of long term reproductive success patterns of this rarely studied species, which is a very important component of the Falklands food chain and biodiversity.

Introduction

The striated caracara (*Phalcoboenus australis*) is a rare medium-sized raptor with a rather limited geographic range, which includes the Falkland Islands and Tierra del Fuego. The species is classified as near threatened by IUCN (www.iucnredlist.org), was the target of an intensive human persecution (Strange 1996), and breeds mostly on outer islands of the Falklands (Woods and Smith 1999; Woods 2007). A recent survey of most potential breeding places in the Falklands (Reeves et al. 2018) found 354 confirmed breeding pairs and 477 likely breeding pairs. The distribution of striated caracaras was similar to the one observed in previous surveys, with high concentrations in islands with dense tussac grass (*Poa flabellata*) and large breeding colonies of marine birds.

The knowledge of the life history and breeding biology of the striated caracara is still limited. The early studies carried out by Falklands naturalist Ian Strange (1996) provided a very accurate description of many aspects of caracara biology, but lacked quantification. A study carried out at New Island (Catry et al. 2008) provided information on distribution, breeding success and diet, but was carried out over just two breeding seasons and, therefore, did not provide information on long term nesting and breeding success. Recent studies on specific aspects of striated caracara biology (Autilio et al. 2019; Harrington et al. 2018) greatly added to the knowledge of the species, but many details of caracara nesting and breeding are still missing.

Starting in 2013 and during the past seven seasons we monitored striated caracaras at Sea Lion Island, the southernmost inhabited island of the Falkland Islands. Sea Lion is a small island (992 hectares) and shelters a small population of caracara (about 20 pairs) but it is the only place in which all nests were regularly monitored for more than a few consecutive seasons. In this report we presented results about spatial distribution of caracara nests, breeding habitat and nest characteristics, and nesting and breeding success. We also attempted to assemble in a coherent way the data obtained during past striated caracara surveys of the island. The result provided in our report may be a useful foundation for the long term monitoring of striated caracaras of Sea Lion Island.

Methods

Field work was carried out at Sea Lion Island (Falkland Islands, 52° 26′ S 59° 05′ W) during seven striated caracara breeding seasons (November-March, 2013-2020). Each season we carried out searches of striated caracara nests looking for signs like presence of adults, head up displays, adult and chick vocalizations, attacks on observers and transportation of nesting materials. We checked all nests of the previous seasons for signs of usage. When we found a nest we recorded its geographic coordinates obtained by GPS (Garmin GPSmap), and we collected data on habitat and substrate, nest appearance, nest content, and number and behaviour of adults and chicks. GPS positions were taken as close as possible to the nest, but for some nests on cliffs direct access was not possible and, therefore, positions were taken from top of the cliffs. Moreover, commercial grade GPS are not very accurate (at SLI CEP ~

3 meters, unpublished data). Therefore, we calculated the mean position of all GPS fixes of each nest and we manually adjusted the nest position using high resolution aerial imagery and field notes. All together, nest positions actually used in the analysis should be accurate to a few meters.

Starting from the third season (2015/16) we recorded not only nest data but also striated caracara sightings obtained ad libitum during all the field work that we are doing at Sea Lion Island (see www.eleseal.org). All together, in the last five seasons we obtained 1187 striated caracara records (121-357 records per season).

From the field data of each season we obtained the following counts: total number of pairs/trios defending a territory ("pairs"), number and percentage of trios ("trios"), total number of adults, number and percentage of pairs attempting to nest (i.e., building the nest and laying at least one egg; "nesting pairs"), number and percentage of pairs producing at least one fledged chick ("breeding pairs"), number of eggs ("eggs") and fledged chicks ("chicks") produced by each pair. From these counts we calculated: breeding success (breeding pairs/pairs), laying success (eggs/pairs), hatching success (chicks/eggs), productivity (chicks/pairs), the brood size (chicks/breeding pairs; Balza et al. 2017). Please note that in our study all hatched chicks were able to fledge and, therefore "chicks" = hatched chicks = fledged chicks.

Two clusters of observations were initially identified as pairs (C20 and C23) but were then excluded from the analysis, because 1) we never observed chicks or nests associated to them, 2) they were in between the territories of other pairs, and 3) they were close to places were striated caracara chicks and juveniles were often observed to group at the end of the breeding season. We suspected that one pair that stopped breeding after three unsuccessful seasons (C03) actually moved to another area (C19) instead of disappearing, but lacking safe identification of individuals we considered those two pairs as different ones. The movement of chicks after fledging made difficult to attribute them to specific nests. Moreover, we sometimes saw fledged chicks in places that we were not able to access due to high density of tussac grass patches bordering steep and inaccessible cliffs. In particular, during the 2017/18 and 2018/19 we observed up to two fledged chicks in the area east of the Gulch, that we were not able to attribute to a specific pair/nest. These chicks were considered likely dispersed from other identified nests and were not included in the analysis. All together, the factors mentioned above render slightly conservative our estimate of pairs, nests, and chicks.

Various surveys of Sea Lion Island striated caracaras were carried out before the beginning of our study. Although those surveys were carried out over a short time span (usually 1-3 days), and although they likely missed a variable number of nesting pairs, they provided anyway useful information on long term nest/area occupancy. We assembled those survey data using sketch maps with coordinates, observer notes and reports found at Sea Lion Lodge, and files archived on the Sea Lion Lodge public computer. Maps of nest locations of the different surveys are provided in Appendix III. In the same appendix we provide a comparative table in which our own pair ID is matched with the IDs reported in the original source of the surveys. We considered the following five previous surveys:

- 20-23/11/1998, carried out by Mike Morrison and Robin Woods, original annotated map plus data and map reported in Woods and Smith 1999; coded "MW1998".

- December 2004, carried out by Kirsty Denley, unpublished report found at Sea Lion Lodge; coded "KD2004". The spatial distribution of pairs/nests and statements of the reports suggest that this survey did not provide a full coverage of the coastline.
- Summer 2005/2006, carried out by Lindsey Duncan, unpublished report, observer notes and maps found at Sea Lion Lodge; coded "LD2005".
- Summer 2006/2007, carried out by Morag Smart, unpublished report and Excel data file found on Sea Lion Lodge public computer; coded "MS2006".
- 23-25/01/2013, carried out by Micky Reeves and Sarah Crofts, unpublished report and map kindly provided by MR; coded "RC2012".

All surveys contained approximate coordinates of most or all the nests and pairs observed. The reporting quality and position accuracy of the first four surveys was rather low and, therefore, the maps should be considered tentative. On the contrary, the surveyors of RC2012 provided a detailed report, accurate coordinates, and map.

Nest coordinates were mapped using QGIS 3.6 (/www.qgis.org). We used QGIS to calculate distances between nests and to carry out nearest neighbour analysis (Processing, Nearest neighbour analysis algorithm) and point pattern analysis (Processing, SAGA, Spatial point pattern analysis algorithm). Shapefiles of nest locations are available from the first author. Trends in breeding parameters were analyzed with OLS linear regression. All calculations were carried out in Stata 14 (www.stata.com).

A very important limitation of our study protocol was the lack of individual marking (see Discussion). Therefore, we collected our data without being able to safely recognize the individuals of each pair during consecutive seasons. We attributed IDs to pairs using nest usage and spatial clustering of GPS fixes. For nesting pairs, if a pair used the same nest of the previous season, or a nest close (< 50 m) to the previous one, we attributed to it the same ID of the previous season. If the pair was not nesting, we used the clustering of GPS locations of one season compared to the previous one to attribute the ID. Most pairs used just one nest in the same location across the seven seasons of the study, or two/three nests located at close distance (see Results). Nest usage in consecutive years and spatial clustering of GPS fixes are obviously relaxed criteria for identity attribution, and they do not guarantee that the pairs were in fact made up by the same individuals.

Results

Nesting and breeding success

Nesting and breeding success statistics are tabulated in Appendix I. The number of pairs observed during a single breeding season ranged from 18 to 23 (mean = 20.86, SD = 1.57). Trios ranged from zero to five (mean = 2.00, SD = 1.83), representing on average 9.32% of the pairs. There was an increase of trios in recent years, from 0 in 2014/15 and 2015/16 to 5 in 2019/20. The increase of pairs and trios produced an increase in the number of adults from 37 to 51 (37.8%; linear regression: b = 1.86, R^2 = 0.808). On average, 91.19% of the pairs attempted to nest, laying at least one egg, and 87.23% of pairs was able to breed, with at least

one fledged chick. Mean laying success was 2.25 eggs per pair, mean productivity was 2.00 chicks per pair, and mean brood size was 2.29 chicks per breeding pair.

Notwithstanding the small sample size (seven breeding seasons), some trends in breeding measures were apparent (Figure 1). The number of pairs increased along the breeding seasons from 18 to 23, but the total number of chicks produced dropped from 45 in 2013/14 to 37 in 2018/19 (Linear regression: b = -1.18, R^2 = 0.752). Laying success decreased from 2.61 eggs/pair in 2013/14 to 2.00 in 2018/19 (Linear regression: b = -0.09, R^2 = 0.855). Productivity decreased from 2.50 chicks/pair in 2013/14 to 1.65 in 2019/2020 (Linear regression: b = -0.11, R^2 = 0.717). Brood size went down and up until 2016/17, and then decreased from 2017/18 to 2019/20. The overall decrease was from 2.65 chicks/pair in 2013/14 to 1.90 in 2019/2020 (Linear regression: b = -0.08, R^2 = 0.587).

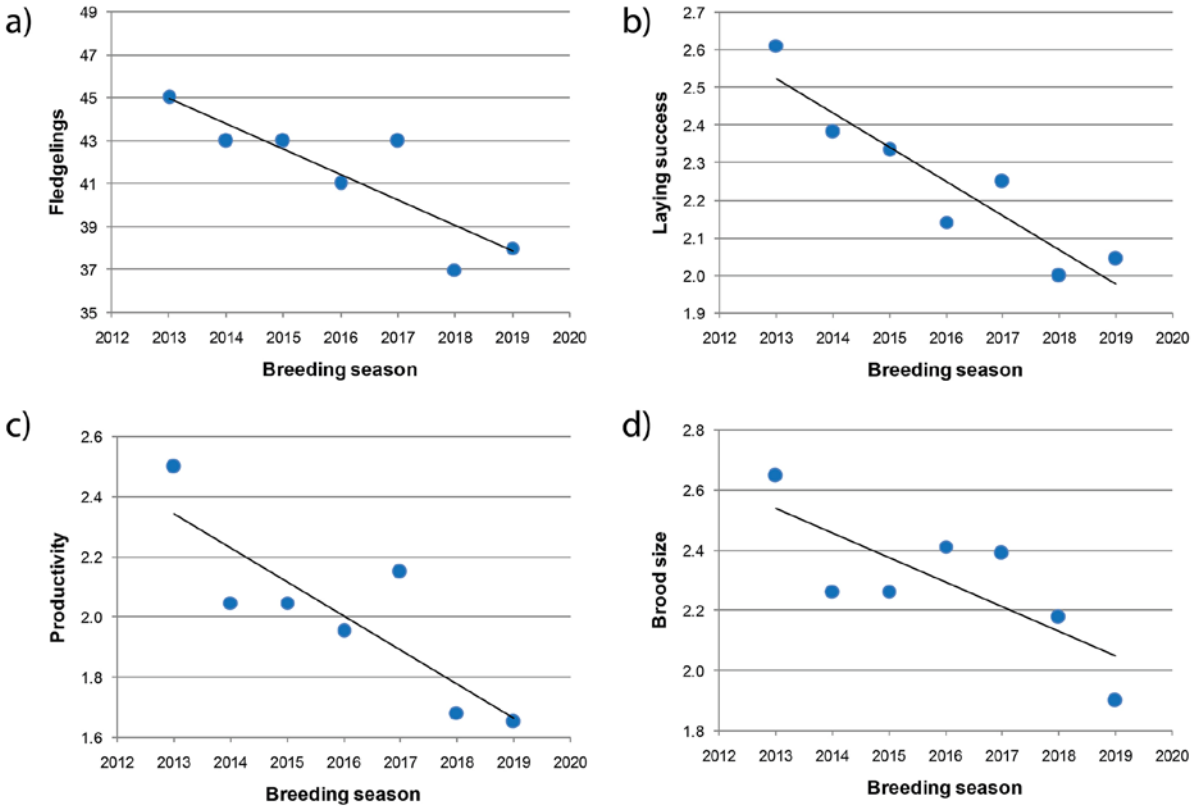

Figure 1 - Trend in reproductive success. a) Number of fledged chicks; b) Laying success (eggs/pairs); c) Productivity (chicks/pairs); d) Brood size (chicks/breeding pairs).

There was a large variation in breeding performance of the pairs. For the pairs that produced at least one chick during at least one season (N = 24), the total number of chicks produced during the study ranged from 1 to 19, and the mean number from 1 to 2.80. For the pairs that were present during the seven breeding seasons of the study (N = 14), the total number of chicks produced ranged from 8 to 19, and the mean number from 1.14 to 2.71. There was also a large variation in the distribution of the brood size during the seven seasons of the study. The percentage of pairs with three chicks was on average 35.83%, but ranged from 17.39% to 61.11%, showing a tendency toward a reduction in recent years.

Long term nest occupancy and breeding

The 27 pairs that were present on the island in one or more of the seven breeding seasons of the study were observed for an average of 5.41 seasons (SD = 2.10; Table 1). Fifteen pairs were present during all the seven seasons (55.56%), three pairs present at the beginning of the study disappeared at same stage (11.11%; they were present for three to five seasons), and nine new pairs appeared after the beginning of the study (33.33%; one of those pairs disappeared before the end of the study, after three seasons of presence).

Those 27 pairs had an average of 4.67 seasons in which they produced one or more chicks (SD = 2.65). Of the 27 pairs, 96.30% laid at least once, 92.59% generated at least one chick, 48.11% laid at least one egg in each of the seven breeding seasons, and 44.44% produced at least one chick in each of the seven breeding seasons.

Pair ID	2013	2014	2015	2016	2017	2018	2019	N	Total	Mean
C01	3	3	3	2	3			5	14	2.80
C02	3	3	3	2	3	2	1	7	17	2.43
C03		0	0	0				3	0	0.00
C04	3	3	3	3	2	2	1	7	17	2.43
C05	3	3	2	3	3	3	2	7	19	2.71
C06	3	3	2	2	3	2	2	7	17	2.43
C07	3	2	2	3	3	2	2	7	17	2.43
C08	3	3	2	2	3	0	1	7	14	2.00
C09	2	2	2	2	3	3	3	7	17	2.43
C10	2	2	3	2	2	2	1	7	14	2.00
C11	3	3	3	2	2	3	3	7	19	2.71
C12	3	3	2	0	0	0	0	7	8	1.14
C13	2	2	2	3	2	1	2	7	14	2.00
C14	3	2	2	3	2	3	2	7	17	2.43
C15	2	1	2	3	2	2	2	7	14	2.00
C16	2	2	2	2				4	8	2.00
C17	2	1	2	2	1	2	2	7	12	1.71
C18		2	2	3	2	3	2	6	14	2.33
C19				2	3	1	3	4	9	2.25
C21	0	0	0	0	0	0	0	7	0	0.00
C22		0	2	0	3	2	3	6	10	1.67
C24					1	1	1	3	3	1.00
C25						3	2	2	5	2.50
C26						0	0	2	0	0.00
C27							1	1	1	1.00
C28	3	3	2					3	8	2.67
C29						0	2	2	2	1.00

Table 1 - Summary of the presence and chick production of the striated caracara pairs present at Sea Lion Island from 2013/14 to 2019/20. Empty cell: the pair was not present. Zeros (i.e., pair present but produced no chick) are shown in red; the most successful pair/season, with three chicks, are shown in blue. N = number of breeding seasons, Total = total number of chick produced; Mean = mean number of chicks produced.

One of the pairs (C12) was present, territorial and showed courting/mating behaviour for seven seasons, but actually bred for just the first three. One pair (C21) was observed and showed territorial behaviour during all seven seasons but was never observed nesting and/or with chicks.

Data collected opportunistically from 1995 and irregular surveys carried out from 1998 to 2012 showed that some of Sea Lion Island caracara nests have been in use for up to 25 years (C02, C08A, C15; see Figure 2). The first survey, MW1998 (November 1998), which identified only six potentially nesting pairs, is dubious, because: 1) Strange (1996; p. 51) reported ten observed nests and 14 estimated nests in the late 1980s, and 2) the survey missed two of the three very obvious nests that were surely in use from 1995 (C08A, C15); the survey counted four active nests, plus two territorial pairs. The second survey, KD2004 (December 2004), which written report is somehow confusing in the wording, counted four nesting pairs and three territorial pairs potentially nesting, but observed only one chick. This survey likely underestimated the number of pairs/nests/chicks due to the incomplete coverage of the coastline. The third survey, LD2005 (2005/06 breeding season), reported a total of ten nests (six confirmed and four potential nests), and the confirmed nesting pairs raised a total of 12 chicks. The fourth survey, MS2006 (2006/07 breeding season), reported one nest more than LD2005 (total 11 confirmed or possible nests), confirming the location of most nests of the previous survey. This survey reported the number of chicks only for few nests (total number of chicks = 8). The last survey, RC2012 (January 2013), which was carried out the year before the start of our study, reported nine pairs that raised a total of 14 chicks, one pair with nest but without chicks, and one territorial pair potentially nesting. This last survey probably missed two nests (C11, C12) that were known to be occupied by the Authors, but is anyway the most complete and accurate of all previous surveys.

Figure 2 - Map of caracara nest locations. This is a summary of the position of all 35 caracara nests observed during the seven seasons of the study. Each of the 27 pairs observed during the study occupied one to three nests.

Spatial distribution of nests

The spatial distribution of nests is shown in Figure 2. Season specific maps are presented in Appendix I. Twenty six pairs nested one or more seasons, occupying a total of 35 different nests (1.35 nests per pair; nests occupied for more than one season counted for one). Of the 24 pairs that nested more than one season, 58.33% used always the same nest, 37.5% used up to three different nests, and one pair switched multiple times between two nests at about 36 meters one from the other.

Nests were denser toward the East Point than toward the west end of the island, and the disappearance of old pairs and appearance of new pairs during the seven seasons of the study did not change the nest distribution (see maps, Appendix II). Mean pair density was 2.10 pairs/km^2 (SD = 0.16), and showed a slight increase along the study (1.81 to 2.32). On average each pair potentially had 47.8 ha of available space to occupy. Mean nest distance from the closest other nest was 540.6 m on the whole study period, with a slight reduction in recent years (Table 2). Nearest neighbour analyses showed that nests had a distribution compatible with a random distribution or a slight over dispersion (mean nearest neighbour index = 1.09; Table 2).

Year	N	Mean	SD	CV	Min	Max	Expected	NNI
2013	18	564.43	247.21	0.4380	287.65	1003.61	544.99	1.04
2014	21	561.28	255.47	0.4552	287.48	1129.91	504.44	1.11
2015	21	553.90	258.07	0.4659	287.21	1126.14	502.12	1.10
2016	21	564.38	373.16	0.6612	210.39	1663.05	504.49	1.12
2017	20	551.20	321.95	0.5841	214.05	1390.14	483.76	1.14
2018	22	508.39	268.78	0.5287	211.97	1146.97	474.12	1.07
2019	23	480.64	244.93	0.5096	176.48	1147.50	463.66	1.04

Table 2 - Summary statistics of the distance between neighbour nests. N = number of nests; SD = standard deviation; CV = coefficient of variation; Expected = expected mean distance between neighbour nests in case of uniform distribution; NNI = nearest neighbour index (observed mean distance/expected mean distance from a completely random distribution).

Nesting habitat

Of the 35 nests observed during the seven breeding seasons, 25.71% of the nests were located on the ground. The remaining 26 nests were located at an average height of 3.5 m (0.5-10). 57.14% of the nests were located close to the coast and 20.00% were located close to a permanent pond.

The main nesting habitat were prairie (28.57%), cliffs (28.57%) and the upper limit of pebble beaches (20.00%). These three habitats made up 77.14% of the nesting sites. 17.14% of nesting sites were located in dense tussac grass patches. The main nesting substrate was tussac grass (68.57%); nests built on steep cliffs were often built directly on the rock (11.43%); nests built on the ground on prairie were usually built on high grass (11.43%). 40.00% of the nests were located close to haul out sites of large pinniped groups (southern sea lion *Otaria byronia* breeding colony, southern elephant seal *Mirounga leonina* harems

and moulting groups); 17.14% of the nests were located close to gentoo penguin (*Pygoscelis papua*) breeding colonies; none of the nests was located close to the rockhopper penguin (*Eudyptes chrysocome*) colonies of the Sheffield Memorial area (this area was within the territory of pair C21 that never bred); most pairs (90.63%) nested close to areas of very high density of Magellanic penguin (*Spheniscus magellanicus*) burrows (please note that Magellanic burrows are present on most areas of the island excluding the diddledee patches of the interior); only one pair nested close to the main imperial shag (*Leucocarbo atriceps*) breeding colony; 80.00% of the nests were close to cliffs with a high density of rock shag (*Phalacrocorax magellanicus*) nests. A sample of nests located in different habitats is shown in Figure 3.

Figure 3 - A sample of caracara nests. a) Nest on top of tussac grass overlooking a pond; b) Nest on a steep cliff without tussac grass cover ; c) Nest on the ground with tussac grass cover (note the trio of displaying striated caracaras); d) Nest on the ground without tussac grass and with no cover.

Discussion

The first obvious limitation of our study was the lack of individual recognition. Sea Lion Island is a National Nature Reserve, and bird banding is discouraged. Moreover, Sea Lion Island is a premiere destination for wildlife tourism and photography, and previous bird banding programmes had negative effects on the tourism business (Jenny Luxton, pers.

comm.). Therefore, we avoided bird banding and resorted to nest location and spatial clustering of striated caracara records to identify pairs. In that, we were helped by striated caracara strong territorial behaviour and usage of the same nest across breeding seasons (Strange 1996). Our nest searching effort was quite balanced along the study, but it should be noted that in 2013/14 and 2014/15 we carried only nests searching sessions while in the following seasons we also recorded caracara opportunistically whenever there was a chance. Moreover, the lower number of pairs of 2013/14 can be in part the result of a less successful search, because it was our first field work season, and we were less experienced in locating nests. On the other hand, we think that the observed trends in the different measures of breeding performance are real, and not the result of a reduced effort and detection capability during the first two seasons of the field work.

The main result obtained from our data was the presence of a decrease trend in various breeding measures along the seven seasons of the study. Although the sample size was very small, we observed: 1) an increase in the number of pairs, including pairs that were starting to breed and were not successful during the first season(s); 2) an increase in the number of trios and adults at large; 3) a reduction in the total number of fledglings; 4) a pronounced reduction of the productivity and brood size. Altogether, the small increase in the number of pairs and the replacement of mature pairs with new ones not yet fully capable of breeding seems to have produced an increase in competition for food resources and a reduction in brooding efficiency that, in turn, produced a decrease in both population productivity and pair reproductive success.

The decrease in breeding performance described above is probably the result of the increased number of competitors amplified by factors affecting food availability. For example, the pairs nesting toward the west end of the island may have been affected by the breeding failure of imperial shags in their main Sea Lion breeding colony. While up to 2016/2017 imperial shags had about 1300 nesting pairs, during the last three seasons of the study they failed completely. On the other hand, pairs nesting around the lodge area may have been affected by reduction in availability of food leftovers. While until 2017/2018 feeding of caracara by human beings was common, starting in 2018/19 the island owners begun enforcing a ban of striated caracara feeding. This ban was more strictly enforced in 2019/20, and will likely be enforced in the future.

The comparison of previous surveys, anecdotal information, our own observations of the years before the beginning of this study, and the results of our own study showed that short term surveys likely produce a low estimate of the actual number of nesting pairs and a very low estimate of the number of chicks produced. This is probably because not all striated caracara pairs show a strong territorial behaviour, and some of them can be particularly shy and inconspicuous, making the identification of nesting pairs and actual nests very difficult. The problem is amplified by the preference to nest in tussac grass standing and in dense tussac grass areas. Therefore, it could be useful to produce correction factors for short term surveys based on intensive repeated surveys.

The published information about striated caracara nesting and breeding is scarce, and is summarized in Table 3. Mean breeding success at Sea Lion island (0.87) was higher than the values reported for both Beauchene Island and Staten Island, although the Beauchene value is dubious due to the limited field effort. Mean productivity (2.00) was greater than the

values reported for all other places. Mean brood size (2.29) was smaller only than the one reported for New Island, although the sample of nests of the Catry et al. (2008) study was probably biased toward successful nests. All together, Sea Lion Island striated caracaras showed a very good breeding performance. This result could be related to the low density (2.10 pairs/km^2), the lowest ever reported, and large mean distance from the closest nest (541 m), that likely reduce competition between nesting pairs.

Place	Year	Pairs	Density	Successful pairs	Breeding success	Productivity	Brood size	Ref.
Bauchene Is.	1979/80	64	35.83	27	0.45	0.88	2.07	1
Bauchene Is.	1983/85			16		1.30	1.30	2
New Island	2005/07		4.31	54			2.41	3
Staten Island	2014/15	11	4.34	8	0.73	1.27	1.75	4

Table 3 - Published information about nesting striated caracara nesting and breeding. Places: Bauchene Island is the southernmost island of the Falklands; New Island is in the west of the Falklands; Staten Island is off the southern tip of Argentinean Patagonia. See Methods for definitions. References: 1: Lewis Smith and Prince 1985; 2: Strange 1996; 3: Catry et al. 2008; 4: Balza et al. 2017.

The striated caracara population of Sea Lion Island is small and, therefore, is probably not very representative of striated caracara demography in the Falklands at large. Moreover, being small, it provides only a small sample of pairs and nests for data analysis. Finally, the lack of birds banding definitely constraints the results that can be achieved. On the other end, the breeding biology of striated caracaras is still rather poorly known, and Sea Lion Island is the only island of the Falklands in which regular monitoring of all striated caracara nests has been carried out for a good number of seasons. All together, we think that Sea Lion Island nest monitoring is worth to be carried on, because it may provide an assessment of long term striated caracara breeding success, and of its ecological determinants.

Acknowledgments

We would like to thank: Denise Blake, the Environmental Committee and the Environmental Department of the Falkland Islands Government for approving our research licence; the Falkland Islands Development Corporation for permitting us to carry out field work at Sea Lion Island; Wildlife Falklands Ltd. for providing accommodation for the research team at discounted rate and for logistic support; the past Sea Lion Lodge managers, Jenny Luxton and Carol Peck, and the current Sea Lion Lodge owners, Micky Reeves and Sarah Crofts, for their kind help, and their positive attitude towards our research; the Sea Lion Lodge staff for their great friendship. A special thanks goes to Micky Reeves for sharing with us his great knowledge of striated caracaras and birds at large. The data from past surveys were obtained from various sources including unpublished documents, maps and reports found at Sea Lion Lodge and files archived on the Sea Lion Lodge public computer.

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Appendix I - Nesting and breeding statistics

Season	Pairs	Trios	Nesting	Breeding	Eggs	Chicks	% Trios	% Nesting	% Breeding
2013/14	18	1	17	17	47	45	5.56	94.44	94.44
2014/15	21	0	20	19	50	43	0.00	95.24	90.48
2015/16	21	0	20	19	49	43	0.00	95.24	90.48
2016/17	21	3	18	17	45	41	14.29	85.71	80.95
2017/18	20	2	18	18	45	43	10.00	90.00	90.00
2018/19	22	3	19	17	44	37	13.64	86.36	77.27
2019/20	23	5	21	20	47	38	21.74	91.30	86.96
Total	146	14	133	127	327	290			
Mean	20.86	2.00	19.00	18.14	46.71	41.43	9.32	91.19	87.23
SD	1.57	1.83	1.41	1.21	2.21	2.94	8.02	4.04	6.05
CV	0.08	0.91	0.07	0.07	0.05	0.07	0.86	0.04	0.07

Season	Breeding success	Laying success	Hatching success	Productivity	Brood size
2013/14	0.94	2.61	0.96	2.50	2.65
2014/15	0.90	2.38	0.86	2.05	2.26
2015/16	0.90	2.33	0.88	2.05	2.26
2016/17	0.81	2.14	0.91	1.95	2.41
2017/18	0.90	2.25	0.96	2.15	2.39
2018/19	0.77	2.00	0.84	1.68	2.18
2019/20	0.87	2.04	0.81	1.65	1.90
Mean	0.87	2.25	0.89	2.00	2.29
SD	0.06	0.21	0.06	0.29	0.23
CV	0.07	0.09	0.06	0.14	0.10

Appendix II - Maps of nests locations

2013

2014

2015

2016

2017

2018

2019


C02
C27
C22
C25
C07
C04
C28
C26
C05
C08
C06
C18
C10
C09
C19
C12
C11
C13
C14
C15
C23

Appendix III - Maps of previous surveys

Conversion table of IDs of the different surveys

ESRG	MW1998	KD2004	LD2005	MS2006	RC2012
C01					JR1
C02	290	6	H	8	JR2
C03					
C04					JR3
C05				11	JR4
C06	291				JR5
C07			J		POSJR
C08		1	A	1	JR6 (JR6 SLI)
C09				10	JR13
C10	(288)	(2)	(B)	(2)	POSJR2
C11	(289)	4	D	4	
C12					
C13					JR8 (JR8 SLI)
C14		3	C	3	JR7 (JR7 SLI)
C15					POS JR3 SLI
C16	(288a)				JR10 (JR9 SLI)
C17		7	I	9	
C18					
C19					
C21					JR9
C22					
C24					
C25		(5)	(G)	(7)	
C26					
C27					
C28	(287a)				JR12 (POSJR4)
C29					

Please note that in the above table there are two missing pairs identified in LD2005 and MS 2006 that have no ESRG equivalent (E_LD2005 = 5_MS2006 and F_LD2005 = 6_MS2006). See Methods for survey codes. IDs of surveys MW1998 to MS2006 that are in brackets are tentative. IDs of RC2012 surveys that are in brackets are alternative IDs used by the surveyors.

Maps of the different surveys

In the following maps red dots are active nests (adult incubating, eggs or chicks) while blue dots are territorial pairs that were possibly, but not surely, nesting.

Morrison Woods 1998

Kirsty Denley 2004

Lindsay Duncan 2005

Morag Smart 2006

Reeves Crofts 2012