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Elephant seals of Sea Lion Island: status of the population Update 2019-2020

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Summary

Background. Sea Lion Island (SLI hereafter) is the main breeding colony of southern elephant seals (*Mirounga leonina*) in the Falkland Islands. Therefore, the colony is an important component of the Falklands' wildlife diversity. We monitored the population during the past 25 years. Here, we present updated estimates of the number of breeding females, the total number of seals and the population trend. Moreover, we highlight some aspects of the future monitoring of the SLI population, and the Falklands elephant seals at large, that might be particularly important.
Methods. We carried out counts of females hauled out during each breeding season. We applied a mathematical model of the female haul out process to calculate the total number of breeding females and the pups production. We estimated the total population size by applying to the pups production a multiplication factor obtained from a life table estimated from serial records of marked individuals.
Results. The number of females at peak haul out (605) was the maximum ever recorded, and was 4.49% greater than in 2018. The estimate of the total size of the population (all sex and age classes, excluding pups) was greater than the one of the previous year (2424 seals in 2019 versus 2232 in 2018, +8.60%). The population trend showed a clear turning point in 2003. The population was steady from 1995 to 2002, with fluctuations around a mean size of 1903 seals, while in the period 2003-2019 the population increased at an average rate of 31.7 seals/year.
Discussion. The population appears to be healthy, and the time series is now long enough to conclude that the population is increasing, albeit at a rather low rate. Simulations using reasonable demographic and life history parameters indicate that the population should be increasing at a faster rate, but there seems to be no environmental factor with a clearly negative impact on SLI elephant seals, either during the land or the aquatic phases of the annual cycle. The role of killer whales (*Orcinus orca*) in regulating the elephant seal demography, a potential source of reduction of the population growth rate, has been shown to be modest.
Conclusion. Monitoring of the SLI population should be continued, and the presence of a regular increase trend should be confirmed. Moreover, a) regular surveys of other actual or potential breeding sites should be carried out; b) a revised estimate of the whole islands elephant seal population should be produced; c) the demography of elephant seals during the moulting season should be studied. We are currently: 1) assembling data collected during opportunistic surveys of other islands carried out during the breeding and moulting season; 2) modelling the haul out of Sea Lion Island moulters by sex and age class; 3) using the Sea Lion Island haul out data to establish

habitat preferences during the moult. All together, we should be able to obtain an approximate estimate of the total size of the elephant seal breeding population of the Falkland Islands, and of the number of alien individuals visiting the islands for the moult, that might be the most important aspect of the elephant seal demography from a conservation point of view.

Background

Sea Lion Island (SLI hereafter) is the main breeding colony of southern elephant seals (*Mirounga leonina*) in the Falkland Islands (Galimberti et al. 2001). SES breeding happens also on other islands of the archipelago, but is limited to few locations and small groups of females, with the only exception of the Carcass Island colony, that has an estimated size of about 160-180 breeding females (unpublished data), but which net productivity is currently unknown due to the lack of regular monitoring and marking. The SES population of SLI is an important component of the Falklands wildlife diversity, a potentially important conduit for gene flow, both within and between breeding stocks (Fabiani et al. 2003), and a main asset for the wildlife tourism business (J. Luxton, pers. comm.).

In 1995, the Elephant Seal Research Group (ESRG, www.eleseal.org) begun a long term research project on SLI elephant seals, that includes various aspects relevant to the assessment of the population status, including: 1) accurate counts of females hauled out during the breeding season; 2) tagging of the whole cohort of pups produced every year; 3) estimation of timing of breeding, pup mortality, weanling sex ratio, parental investment, and breeding effort; 4) calculation of vital statistics (age at first breeding, survival, fecundity) from long term records of marked individuals. Starting from 2013 we extended our presence in the field to be able to monitor also the elephant seal moulting season. Counts and tagging of moulters are now routinely carried out from November to April. Here, we present an updated estimate of the population size and trend during the last 25 years.

Methods

Estimation of pinniped population size is difficult, because individuals of different sex and age classes are never observed on land together at the same time (Eberhardt et al 1979). Therefore, the usual procedure is to carry out direct counts of a single class, and then calculate total population size from these counts using some kind of mathematical model. We used the following procedure (see also Galimberti et al. 2001):

1) We carried out accurate counts of hauled out females during the whole breeding season (see Galimberti and Boitani 1999 for detailed protocol). Counts were carried out at least weekly, but during most seasons they were carried out daily (Table 1).
2) We fit a Gaussian model of female haul out (Rothery and McCann 1987) to the counts of hauled out females, using the day of peak haul out (19th or 20th of October in the 25 years series) as day 0, to synchronize the time series of different years. This model provides a very good estimate of the total number of females breeding at SLI during the whole season (Galimberti and Sanvito 2001). Fitting was carried out by least squares and standard error of

parameters were calculated using a robust approach that takes into account the autocorrelation of daily counts (Newey-West heteroskedasticity and autocorrelation-consistent variance estimate, Newey and West 1987). During some seasons a small number of females (< 2%) breed at Tallow Bay, outside our many study area, where the counts were carried out. Those females were added to the numbers of the females estimated by the haul out model.

3) We obtained the number of pups born (gross productivity) and the number of pups weaned (net productivity) from the total number of breeding females, by applying estimates of average fecundity (0.995) and pre-weaning mortality (0.027) calculated previously (Galimberti and Boitani 1999). These estimates were validated using serial records of the whole cohorts of pups (that were all tagged).
4) We used a life table, obtained from a very large number of individual records of tagged seals (unpublished data), to calculate a conversion factor to estimate total population size from the number of pups. The number of individuals one year old or older was estimated to be 3.5 times the number of pups (see also McCann 1985).

To estimate the population trend, we fit various models, including a simple linear regression model, a piecewise regression model with change point determined by maximum likelihood, and a piecewise regression model with change point determined previously using a change point test. We used linear models because there were no clear nonlinearities in the data, as shown by data exploration using nonparametric smoothers (Cleveland and Devlin 1988). For these models we calculated robust standard errors and confidence intervals that take into account the autocorrelation of annual values (Newey and West 1987). Data analyses and model fitting were carried out in STATA (version 15; Stata Corporation Inc.; www.stata.com).

Results

Number of counts, date and number of female on land at peak haul out, and parameters of the Gaussian haul out models, are presented in Table 1. In 2019, the maximum number of hauled out females observed during a single day (October 20th) was 597. Eight females were breeding at Tallow Bay, outside our main study area, and, therefore the estimated total number of breeding females at peak haul out was 605, a 4.49% increase from 2018. The total number of breeding females estimated by the Gaussian haul out model was 688 females (95% confidence interval = 670-706). Females counted at peak were 86.8% of total females, a percentage slightly lower than the previous 24 years average of 88%, showing that breeding was somehow less synchronized in 2019. Notwithstanding the low number of counts carried out in 2019 due to the lack of personnel (N = 11) the standard error and confidence interval of the estimates were quite good. Current population size was estimated at 2424 seals one year old or older (95% confidence interval = 2361-2487), a 8.60% increase from 2018.

The number of weaned pups calculated from serial records of tagged individuals was 667, very similar to the estimated number from the Gaussian model (674), and well within its 95% confidence interval (656-691). Pup mortality (2.49%) was very low if compared to other populations (Galimberti and Boitani 1999), as in previous seasons. Pup sex ratio at weaning was 1.27 (55.9% females), and for the first time in 25 years it was very different from the expected balanced sex ratio (Binomial test: $p = 0.0039$). All together, the overall 2019 demography was quite similar to the one observed in previous years. The only notable difference was the presence of a very big harem, that included 191 females at peak haul out, the maximum harem size ever recorded in the Sea Lion Island population.

In the period 1995-2019, the population was almost steady until about 2002, with fluctuations around an average size of 1903 individuals, and then started to increase (Figure 1). The overall linear trend (1995-2019) showed a rather poor fit ($R^2 = 0.705$), with an increase of 17.9 seals per year, and a rather large robust standard error (2.59) and confidence interval (95% CI = 12.55-23.25). On the contrary, the period 2003-2019 showed a rather clear evidence of an increase trend, and the linear fit was good. Number of females at peak haul out increased by 9.44 females/year ($R^2 = 0.948$, robust se = 0.572, 95% CI = 8.22-10.66). Total number of breeding females increased by 9.09 females/year ($R^2 = 0.886$, robust se = 1.01, 95% CI = 6.93-11.24). Net productivity increased by 8.81 weaned pups/year ($R^2 = 0.887$, robust se = 0.975, 95% CI = 6.74-10.89). Total population size increased by 31.64 seals/year ($R^2 = 0.886$, robust se = 3.51, 95% CI = 24.15-39.13). Average rate of increase during the 2003-2019 period was 1.96% per year.

Year	**Counts**	**Peak haul out date**	**N_p**	**R^2**	**N_h**	**se(N_h)**	**CI(N_h)**
1995	84	20th October	465	0.999	520.02	1.96	516.11-523.93
1996	84	20th October	465	0.999	531.22	2.16	526.93-535.51
1997	84	19th October	495	0.999	551.85	3.01	545.87-557.83
1998	83	19th October	493	0.999	558.47	0.86	556.76-560.17
1999	82	19th October	477	0.999	552.9	0.89	551.12-554.68
2000	84	19th October	480	0.999	548.01	1.13	545.77-550.25
2001	83	20th October	486	0.999	542.74	2.23	538.31-547.17
2002	84	20th October	492	0.999	565.56	2.73	560.14-570.98
2003	84	19th October	444	0.999	516.06	1.57	512.94-519.18
2004	84	20th October	451	0.999	521.82	1.57	518.70-524.94
2005	71	20th October	454	0.999	539.79	1.71	536.38-543.20
2006	19	19th October	464	0.999	535.35	4.50	525.80-544.90
2007	17	20th October	494	0.999	550.54	5.07	539.66-561.42
2008	10	19th October	468	0.995	534.60	10.11	510.70-558.50
2009	74	20th October	498	0.999	595.06	1.09	592.88-597.24
2010	79	19th October	514	0.999	583.77	0.76	582.25-585.29
2011	81	19th October	515	0.999	592.20	0.92	590.37-594.03
2012	31	19th October	539	0.999	595.16	4.68	585.56-604.75
2013	84	20th October	549	0.999	613.89	1.25	611.41-616.38
2014	84	20th October	544	0.999	609.34	1.79	605.77-612.91
2015	84	19th October	558	0.999	627.46	1.76	623.95-630.98
2016	84	19th October	570	0.999	628.98	1.17	626.66-631.31
2017	84	20th October	550	0.998	604.98	3.43	598.15-611.81
2018	84	20th October	572	0.999	640.78	1.71	637.38-644.18
2019	11	20th October	597	0.999	688.04	7.96	669.69-706.39

Table 1 – Summary statistics of female haul out and parameters of the haul out model

Counts = number of counts. Peak haul out date = date when the maximum number of females on land was counted. N_p = number of females counted at peak date. R^2 = coefficient of determination of the Gaussian haul out model. N_h = estimate of the total number of females that bred at SLI from the Gaussian haul out model. se(N_h) = robust standard error. CI(N_h) = robust 95% confidence interval.

Discussion

Small and isolated populations present practical problems for trend detection and forecasting, because of the intrinsic lack of statistical power of analyses carried out on small samples (Forcada 2000; Galimberti 2002). This problem is evident in the SLI data. All together, the whole dataset, 1995-2019, suggests that the population has been steady, with fluctuations. On the contrary, the analysis of the 2003-2019 period suggests that the population is, in fact, increasing. This last time series now comprises 17 years and clearly points toward an increase trend, although at a rather low rate.

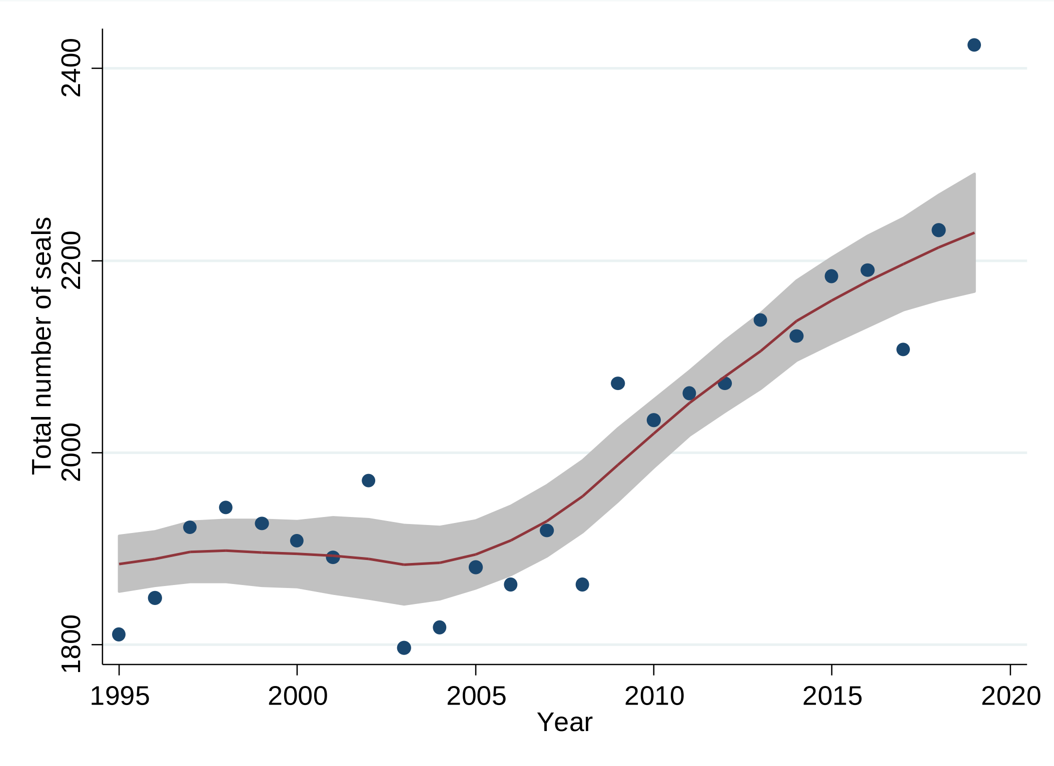

Figure 1 – Variation of the population size over the period 1995-2019

Population size is number of seals one year old or older. Red line is a local polynomial smoother. Grey area is 95% confidence band of the smoother.

The lack of a more sustained increase in the SLI population of elephant seals is somehow puzzling. In the past, we carried out a population viability analysis (PVA) using a deterministic and a stochastic approach (Galimberti et al 2001), and both suggested that the population should be increasing at a faster rate. The PVA was based on an approximate life table, but the results were shown to be robust to moderate changes in the vital statistics. The mark-recapture data that has been accumulated in the meanwhile confirmed that those vital statistic estimates were accurate (unpublished data). A revised population viability analysis, including updated vital statistics and a provision for the (small) effect of killer whale predation of weaned pups, is in preparation.

There seems to be no clear constraint that may limit the population growth rate of SLI elephant seals. Breeding space is not constrained, female density is low, harems are small, and there is a low level of aggression among females. Therefore, a density-dependent constraint during the land phase is unlikely. SLI pre-weaning mortality is low if compared to other populations of the stock (Galimberti and Boitani 1999), and much lower than the mortality that we observed in the northern elephant seal (up to 40%, Salogni et al. 2016), a species that is showing a sustained increase in population size (Lowry et al. 2014). Elephant seals are tolerant to humans, and human disturbance is a rather unlikely cause of population decline (Wilkinson and Bester 1988). The largest decrease in the number of females was observed in 2003, and during that breeding season there was an increase in female mobility and harem instability (unpublished data). These facts may have been related to the increase in human disturbance (e.g., a great increase in the number of helicopters landing at SLI) observed during that breeding season, but a causal link is uncertain, and the effect was anyway limited to that specific season. The decrease observed during some other breeding seasons happened without any evidence of increased human disturbance, and when the research-induced disturbance was at the lowest level. We are currently investigating the impact of human disturbance at large, and research disturbance in particular, on SLI elephant seals, but we think that disturbance is an unlikely candidate for the low population growth rate. The paucity-of-males hypothesis (Wilkinson and Van Aarde 1999) does not hold at SLI, because genetic data shows that harem holders are able to fertilize the vast majority of females (Fabiani et al. 2004). Altogether, it seems very unlikely that the current low increase rate depends on some factors related to the land phases of the annual cycle.

Killer whales are regularly present at SLI during the elephant seals breeding and moulting seasons and attempts of predation on elephant seals are frequent, although they seem to be often unsuccessful (Yates et al. 2007). In recent years, we observed an increase in evidences of killer whales attacks toward adult individuals, males and females, although the total number of individuals killed was very small (unpublished data). The satellite tracking study that we have carried out (Galimberti and Sanvito 2012) gave a preliminary estimate of the predation on adult females when they return to sea after breeding. Of 24 females instrumented, just one disappeared immediately after departure due to killer whale predation. A large database of careful observations of female returns to sea confirm the low killer whale predation pressure on breeding females (unpublished data). In the period September 2013 to March 2019 we collected data on killer whales predation of elephant seals, and the results point toward a scarce impact of killer whales on SLI pinnipeds (report in preparation). During the current season, killer whale presence at SLI was lower and more irregular than usual, and few predations were observed. It is worth nothing that this low predation rate, in particular on weaned pups, is at variance with the much higher predation impact often mentioned in anecdotal reports and in the media. All together, we think that the impact of killer whales predation on elephant seals is low, and cannot explain the low population growth rate.

A recent study using satellite linked devices provided the first information about movements at sea and feeding areas of SLI seals (Galimberti and Sanvito 2012). Although there was some variability among the tracked individuals, the data collected suggests that SLI breeding females have good access to food resources, because most females forage in small areas rather close to the breeding colony, a somehow unusual pattern for elephant seals. A recent study using stable isotope analysis (Rita et al. 2017) showed that Sea Lion Island females have unusually diverse individual foraging strategies, that may reduce intra-population competition, and permit better access to food resources. Weaning weight is a reliable and easy to measure index of female access to resources, and general population health (Burton et al. 1997). At SLI, weaning weight is on the high side of the range observed in southern elephant seals (Galimberti and Boitani 1999), and this confirms that SLI breeding females should have easy access to good food resources. Moreover, both sex ratio and weight at weaning show no relationship with indices of climatic and oceanographic change (unpublished data) and, therefore, the SLI population seems to be resilient to gross environmental variations. All together, the SLI population of elephant seals seems to be in good condition and not constrained by food resources, but the reason of the lack of a more sustained increase in population size is still unknown, and deserves further investigation.

Conclusions and perspectives

SLI shelters a small population of southern elephant seals, with a very limited exchange of breeding individuals with other populations of the stock (Galimberti and Boitani 1999). Although we showed, using molecular markers, that long range migration of male breeders is possible (Fabiani et al 2003), the intensive mark-recapture study carried out during the past 25 years showed that immigration of breeders to SLI is a very rare phenomenon. Most foreign individuals observed at SLI are seals (mainly males) coming from all populations of the South Georgia stock, which haul out at SLI for the moult (unpublished data). Hence, SLI presents the specific forecasting and conservation problems of small and isolated populations, and should be carefully monitored. Therefore, we suggest that:

- The monitoring of population size should be carried on; regular counts around the date of peak haul out of breeding females (19/20 October), combined with our haul out model (see Methods), will permit to get a good estimate of the total number of females, total population size, and trend.
- The mark-recapture study started in 1995 should also be carried on, to improve the estimates of vital statistics and life tables; better estimates of age specific female survival and fecundity rates will improve the effectiveness of population viability analysis and forecasting.
- The study on the regulating effect of killer whales by weanling predation should be finalized, to produce an accurate estimate of the predation rate, and its variability in time.
- The study of movements at sea carried out during the 2009-2011 breeding seasons should be expanded to a larger scale study, that should include not only movement patterns but also diving profiles; the deployment of time-depth recorders carried out in 2016 should be expanded to a greater sample of seals.
- The assessment of the feeding niche and diet using stable isotope analysis carried out on breeding females should be expanded to other sex and age classes.
- The current study of the demography of moulting elephant seals should be finalized. We know that many alien seals, not born at SLI, come to the islands to moult, and it is of paramount importance to estimate their number, sex and age class, and likely population of origin. The temporal and spatial distribution of moulters, native and alien from other populations, is probably the most important aspect of the Falklands' elephant seals from the point of view of wildlife diversity, conservation, and management policies.
- A whole island census should be carried out, to update our knowledge of the distribution elephant seals in the archipelago, that is currently quite limited.

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