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Elephant seals of Sea Lion Island: status of the population
Update 2018-2019

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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 a very important component of the Falklands biodiversity. Monitoring of the population has been carried out for the past 24 years. Here, we present an updated estimate of population size and trend, and we highlight the most promising areas for future research and monitoring.
Methods. Daily counts of females hauled out were carried out during each breeding season. A mathematical model of female haul out was used to calculate the total number of breeding females and pups production. From these numbers, total population size was calculated by applying a multiplication factor obtained from a life table estimated from serial records of marked individuals.
Results. The number of females at peak haul out (572) was greater than in 2017, with a 4.00% increase that followed the decrease of the previous year (-3.51% from 2016 to 2017). The estimate of the total size of the populations (all sex and age classes, excluding pups) was greater than the one of the previous year (2232 seals in 2018 versus 2107 in 2017), with an increase of 5.95% that permitted a full recovery from the previous decrease (-3.82%). 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. In the period 2003-2018 the average rate of linear increase in population size was estimated at 28.52 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, and with fluctuations. 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 seal demography, either during the land or the aquatic phases of the yearly cycle. The role of killer whales in regulating the elephant seal demography, that was a potential source of depression 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 obtained, c) the demography of elephant seals during the moulting season should be studied. The ESRG is currently seeking funding to carry out a whole islands census during the 2019-2020 moulting season.

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 weaned pups marking. Therefore, the SES population of SLI is a very important component of the Falklands biodiversity, and can be an important conduit for gene flow, both within and between breeding stocks (Fabiani et al. 2003). Moreover, the elephant seals are an important resource for the wildlife tourism business of Sea Lion Lodge and the Falklands at large (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 population status: 1) accurate counts of females hauled out during the breeding; 2) tagging of the whole cohort of pups produced every year; 3) estimation of timing of breeding, female parental investment, breeding effort and pup mortality; 4) calculation of vital statistics from long term records of marked individuals. Starting from 2015 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 December to early April. Here, we present an updated estimate of population size and of its trend during the last 24 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 daily counts of hauled out females during the whole breeding season (see Galimberti and Boitani 1999 for detailed protocol).
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 22 years series) as day 0, to synchronize daily 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).
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 fecundity (0.995) and pre-weaning mortality (0.027) estimates calculated previously (Galimberti and Boitani 1999). These estimates were validated using individual records from the tagging of the whole cohorts of pups.

4) We used a life table, obtained from a very large number of individual mark-resight records (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. For these models we calculated robust errors that take into account the autocorrelation of yearly values, and confidence intervals. Data analyses and model fitting were carried out in STATA (version 15; Stata Corporation Inc.; www.stata.com).

Results

Summary statistics of the female haul out, and parameters of the Gaussian haul out models, for the 1995-2018 period, are presented in Table 1.

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	4.5	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	534.6	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	592.2	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

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

Counts = number of daily 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.

In 2018, the maximum number of hauled out females observed during a single day (20/10) was 572, a 4.0% increase from 2017, that followed a notable decrease in the previous breeding season (-3.5% from 2016 to 2017). The total number of breeding females estimated by the Gaussian haul out model was 641 females (95% confidence interval = 637-644). Females counted at peak were 89.3% of total females, a percentage slightly higher than the previous 23 years average of 88%, showing that breeding was less synchronized in 2018. The high number of counts carried out in 2018 (N = 84) guaranteed a low standard error and a very narrow confidence interval of the estimate. Current population size was estimated at 2232 seals one year old or older (95% confidence interval = 2218-2243), i.e., the maximum estimate of the 24 years period, a 6.0% increase from 2017, and a 1.9% increase from the previous maximum of 2016.

Observed gross productivity (= number of individually tagged pups) was 637 pups and pre-weaning mortality was 2.0%. The number of weaned pups as calculated from serial records of tagged pups was 624, very similar to the estimated number from the Gaussian model (621). Pup mortality was very low if compared to other populations (Galimberti and Boitani 1999), as in previous seasons. Post-weaning mortality due to killer whale predation was low (2.7%). Pup sex ratio at weaning was 1.13 (52.9% females), not significantly different from the expected balanced sex ratio (Binomial test: $p = 0.19$). All together, the overall 2018 demography was similar to the one observed in previous years.

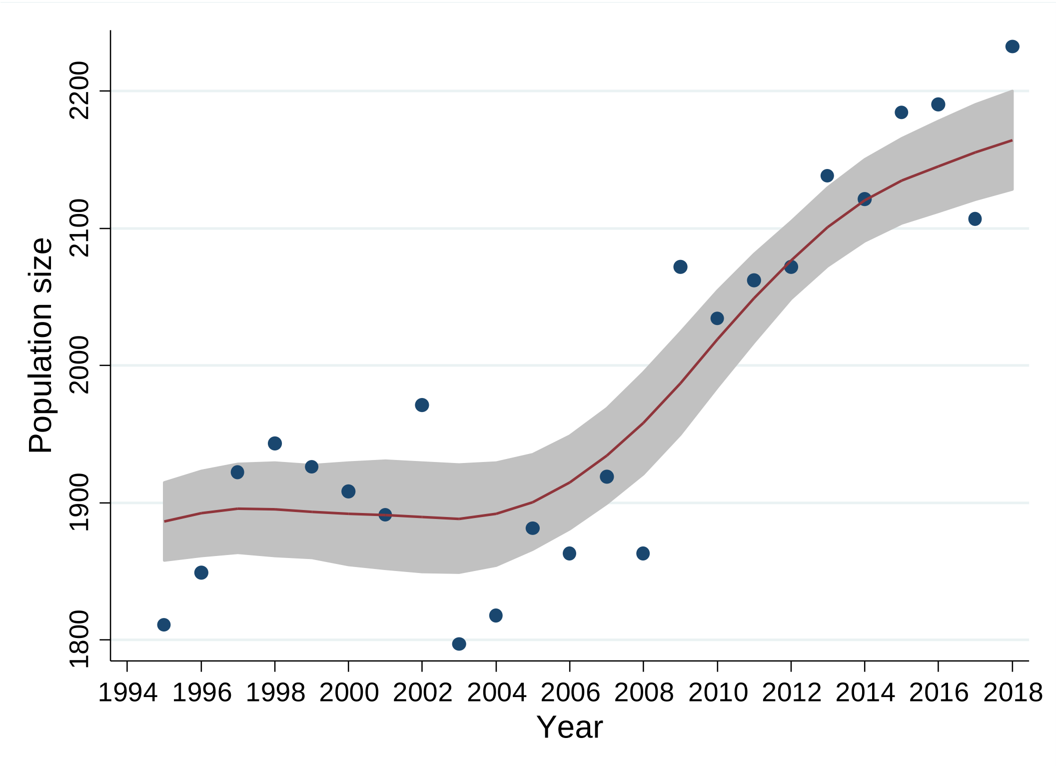

Figure 1 – Variation of the population size over the period 1995-2018

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.

If taken all together, the period 1995-2018 suggests that the population was almost steady, with fluctuations around an average size of 1982 individuals (Figure 1). The overall linear trend showed a rather poor fit ($R^2 = 0.696$), with an increase of 15.63 seals per year, a rather large robust standard error (1.76) and confidence interval (95% CI = 11.97-19.29). On the contrary, the period 2003-2018 showed a rather clear evidence of an increase trend, and the linear fit was a good description of the data. Number of females at peak haul out increased by 9.12 females/year (R^2 = 0.941, robust se = 0.581 95% CI = 7.88-10.38). Total number of breeding females increased by 8.19 females/year (R^2 = 0.894, robust se = 0.689, 95% CI = 6.71-9.67). Net productivity increased by 7.94 weaned pups/year (R^2 = 0.896, robust se = 0.663, 95% CI = 6.52-9.36). Total population size increased by 28.51 seals/year (R^2 = 0.894, robust se = 2.40, 95% CI = 23.36-33.66). Average rate of increase on the 2003-2018 period was 1.5% per year.

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 Sea Lion Island data. All together, the whole dataset, 1995-2018, suggests that the population has been steady, with fluctuations. On the contrary, the analysis of the 2003-2018 period suggests that the population is, in fact, increasing. This last time series now comprises 16 years and, albeit still quite short, clearly points toward an increase trend, although at a rather low rate.

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 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%, unpublished data), a species that is showing a sustained increase in population size (Lowry et al. 2014). Elephant seals are rather tolerant to humans, but may be affected by heavy disturbance, mostly due to the disruption of time budget of suckling females. 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 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 effect of human disturbance at large, and research disturbance in particular, on physiological and behavioural stress, 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 lack of increase depends on some factors related to the land phase.

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, so predation rate on adult females should be low. A large database of careful observations of female return to sea confirm this hypothesis (unpublished data). In the period September 2013 to March 2018 we collected data on killer whales predation of elephant seals, and the results point toward a scarce impact of killer whales on SLI pinnipeds (unpublished data). During the current season, killer whale presence at SLI was lower, and more irregular, than usual, and very few predations were observed notwithstanding a very large observational effort (22 successful predations, 17 on weaned pups, 4 on departing breeding females). It is worth nothing that this low predation rate, in particular on weaned pups, is much at variance with the much higher predation impact often mentioned in anecdotal reports and in the media. All together, 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 almost no relationship with global 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.

Conclusions and perspectives

SLI shelters a small population of elephant seals, with a very limited exchange of breeding individuals with other populations of the stock. 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 24 years showed that immigration of breeders to SLI is a very rare phenomenon. Most foreign individuals observed at SLI are 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 daily 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 pilot 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 Sea Lion Island, come to the islands to moult, and it is of paramount importance to estimate their number, class and population of origin; the distribution of moulters, native and in particular alien from other populations, is probably the most important aspect of the Falklands elephant seals from the point of view of biodiversity, 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 very limited.

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