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Elephant seals of Sea Lion Island: a long term research project

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Summary

In 1995 we began a research project on the southern elephant seals of Sea Lion Island. The project started as a small scale, short-term, pilot study but gradually developed into a long-term, full scale project that was carried on in the past 23 years, and that is producing information on many aspects of southern elephant seals biology, including demography, ecology, behaviour, physiology and genetics. The first goal of the project was to study the survival and breeding strategies of individual seals, to determine which phenotypic traits and aspects of the social and physical environment determine the lifetime reproductive success of individuals. Along the years we gradually expanded the goals of the projects to improve the understanding of the biology of southern elephant seals at large, and to provide a constant monitoring of the population, that can be useful to orient conservation and management policies.

The study of individual survival and breeding strategies requires the seals to be followed along their lifetime, which can be more than 20 years for the longest living females. Sea Lion Island is an ideal place for this kind of study, because the population is small and almost isolated during the breeding season and, therefore, a small field team can intensively monitor all the seals in consecutive years. We have now marked 23 cohorts of pups, we have a database of more than 20000 individually recognized seals, and are gradually building up a very large database of individual histories that will permit to investigate survival and breeding with a very high detail. Although we have a specific interest in the behavioural components of breeding strategies, we are

considering all aspects of the seals phenotype, the social and mating system characteristics, and the effect of the physical environment.

Long-term studies of wild animals in their natural environment are producing a quantum leap in our understanding of behaviour, ecology and evolution, and are increasingly driving conservation and management policies. All together, we think that our project is a valuable part of the environmental research that is carried out in the Falkland Islands, and it is producing data and results that are useful not only to improve the knowledge of elephant seals biology and evolutionary theory, but also to help the conservation of the species in the islands.

In the following project description we provide a brief summary of the project rationale, information of some basic aspects of elephant seals biology that are crucial to understand the project, a detailed description of the methods used in the field, an ethical statement, and a summary of the impact of the research on Sea Lion Island environment and our mitigation actions.

Introduction

Our research project on southern elephant seals (*Mirounga leonina*) of Sea Lion Island (SLI, hereafter) was started in 1995, and has been carried on during the last 23 year. Our goal is to study the population demography and dynamics, the breeding strategies of males and females, and the effects of genetics, socionomy and environmental constraints on individual behaviour. This kind of study requires the lifetime follow up of individuals (Festa-Bianchet et al. 2017). Therefore, a pre-requisite of our research is to be able to recognize the seals and monitor them for their lifetime, i.e., more than 20 years in case the longest living females (unpublished re-sight data). SLI was chosen to carry out our study because the island shelters a small and localized population of elephant seals, where almost all individuals can be marked and followed along their whole lifetime, due to the almost null emigration and immigration of breeders (Galimberti and Boitani 1999; unpublished mark-resight data).

SLI is the main breeding colony of southern elephant seals in the Falkland Islands (Galimberti et al. 2001; unpublished survey data). Although many alien elephant seals haul out at SLI during the moult, the population is almost isolated from other populations during the breeding, and immigration of breeding individuals is rare (Fabiani et al. 2003). The Falkland Island southern elephant seals population is just a small fraction of the world population of the species, and of the South Georgia stock (Laws 1994). However, the Falklands population can provide a link for gene flow between the two main populations of the stock, South Georgia and the Valdés Peninsula (Fabiani 2002), is a main component of the Falklands biodiversity (Augé et al. 2017), has an important function within the Falklands oceanic ecosystem (Rita et al. 2017), and plays an important role in the wildlife tourism business (J. Luxton, pers. comm.). Moreover, SLI is a moulting hotspot for many thousands of elephant seals coming from almost all populations of the South Georgia stock (unpublished data). Being small, the population of SLI presents specific problems for status assessment, forecasting and conservation (Forcada 2000; Galimberti 2002) and, therefore, requires an intensive monitoring. From a conservation point of view, much of our research fulfils the actions suggested in the Falkland Islands Species Action Plan for Seals and Sea Lions 2008 - 2018 (Otley 2008) and in the Sea Lion Island National Nature Reserve Management Plan 2010-2109 (Falklands Conservation 2011), including population surveys, estimation of vital statistics and investigations of breeding and foraging strategies, to determine potential threats.

Objectives of the research project for the next five years, 2018 to 2023

We have three main general objectives: 1) the monitoring of the demography, dynamics and health of the population; 2) the long term study of the behavioural components of the survival and breeding strategies of individuals, with a specific focus on male mating tactics and female parental investment; 3) the study of phenotypic selection and quantitative genetics.

1) Monitoring of the population

Monitoring of marine mammal populations is useful not only because the information is required for a proper management and conservation of each species, but also because marine mammals, being top predators, are valuables proxies of the general health of the oceans (More 2008) and can be used as environmental samplers to collect valuable oceanographic and climatic data (Boehlert et al. 2001; Fedak 2013).

From the beginning of the project we carried out a regular monitoring of the population during the breeding season, and we established a long term mark-recapture project. For the previous 23 years, we collected data about the number of females on land, the adult sex ratio, the gross and net productivity, and many other demographic parameters. Our estimates are very accurate, because are based on a large number of counts carried out by trained observers, with cross-validation by the PIs. Those counts permitted us to develop a very good model of female haul out (Galimberti and Sanvito 2001), than can be applied to other colonies and populations, and to other sex and age classes (e.g., to moulters, unpublished data). This information permits to analyze in great details the trends in the population demography and dynamics, and to relate them to changes in environmental quality at local and regional level. Demographic information is also essential to understand social behaviour, organization and structure (Eberhart-Phillips, et al. 2018). Moreover, the intensive tagging and tag re-sighting are permitting us to obtain very accurate estimates of survival and breeding statistics of both males and females. Studies on marine mammals, and mammals at large, that show the same level accuracy in the information collected on individually recognized individuals of our project are still quite rare (Festa-Bianchet et al. 2017; Kappeler and Watts 2012). Moreover, most long-term studies on pinniped species are focused on ecological aspects (Rotella et al. 2009), and long-term studies of pinnipeds individual behaviour are very rare (Meise et al. 2013). The study of marine mammals' behaviour can not only improve our understanding of the evolution of individual behaviour in complex social systems, but can be useful for an applied and conservation point of view (Brakes and Dall 2016).

Long-term studies are a very valuable tool to understand the effect of environmental variability on the biology of animal species (Clutton-Brock and Sheldon 2010). In our project we are using weight of pups at weaning as a general index of the status and health of the population, and we plan to assess the effect of local and general environmental variability using the long-term time series of weights. Weaning weight is a very good index of mother access to resources (Burton et al. 1997). Mother access to resources should be, in turn, related to resources availability. Therefore, weight at weaning is a cheap and effective index of the environmental health of elephant seals foraging areas.

More recently, starting in 2013, we extended the monitoring to the moult phase of the elephant seals annual cycle, discovering that a very large number of seals, most of them not born/breeding on Sea Lion Island, are using the island as a moulting site. Brief surveys carried out in other places of the Falklands (Carcass Island, Saunders Island, Pebble Island and Islet, Kelp Point) confirmed that the Falklands are a moulting hotspot for a very large number of elephant seals, and the re-sight of our tags showed that individuals coming from all populations of the South Georgia stock are in fact coming to the Falklands for the moult (unpublished data).

2) Survival and breeding strategies

The study of individual breeding strategies is the core of our long term project. The final goal is to get good estimates of lifetime reproductive success, and to relate them to various aspects of the individual phenotype, behaviour in particular, but also size (Galimberti et al. 2007), age (Sanvito et al. 2008), morphology (Sanvito et al. 2007c), physiology (Sanvito et al. 2004), kinship (Fabiani et al. 2006), and genetics at large (Fabiani et al. 2003, 2004). Long term studies of long living mammals are rare, due to the effort they require, but are having an enormous impact on our understanding of evolutionary processes (Clutton-Brock and Sheldon 2010; Coltman et al 2005) and are becoming increasingly important in orienting conservation policies (Durant et al. 2007; Festa-Bianchet et al. 2017; Kappeler and Watts 2012). Moreover, these studies are showing that short term research not only has a rather limited value, but can lead to erroneous conclusions due to the fluctuation in time of selection pressures, and the ubiquitous presence of reaction norms that depend on age and growth (Altmann and Alberts 2003), including behavioural reaction norms (Dingemanse et al. 2010). Although our focus is on male mating tactics and parental investment (e.g., Galimberti et al. 2007), we are studying various aspects of behaviour and phenotype that are related to breeding, including male dominance (Galimberti et al. 2002 b), vocal communication (Sanvito et al. 2007 b) and secondary sexual traits (Sanvito et al. 2007 c).

3) Phenotypic selection and quantitative genetics

Until recently, studies of the action of natural and sexual selection in the wild were quite rare (Endler 1986). Development of new approaches to quantify phenotypic multivariate selection (Lawler and Blomquist 2010), applicable to field studies (Kinsolver et al. 2012), produced a spurt of studies of the fundamental mechanism of selection and micro-evolution in wild populations (Kingsolver et al. 2001). The study of quantitative genetics of wild populations is a hot area of evolutionary studies (Pemberton 2008), because it permits to study the core processes of evolutionary theory outside the lab and in the real world. The animal model approach (Milner et al. 2000; Thompson 2008; Wilson et al. 2010) permits the estimation of the parameters of natural selection, sexual selection, heritability, and evolutionary response to phenotypic selection. Quantitative genetic studies require large number of individuals (Postma and Charmantier 2008), accurate measurements of phenotype (Kruuk 2004), and the capability to control cohort effects (Kruuk et al. 2008). The SLI elephant seal project is an ideal setting for a quantitative genetic study: a large number of individuals is sampled at birth, full cohorts are followed up along their lifetime, accurate measures of natural and sexual selection pressure are available, and many traits of the structural and behavioural phenotype of individuals are routinely measured.

Methods

The project requires the collection of data with the same protocol for a large number of consecutive breeding seasons. Therefore, the methodology adopted in the field work is the year-after-year replication of a research protocol that was established at the beginning of the study, and that survived until now, with improvements mostly due to technological progress. Although we are very open to innovation, we also try to introduce in the protocol only changes that can significantly improve the quality of the collected data, because we need data that is comparable across the whole lifespan of each individual, and among individuals born in different cohorts. Therefore, most methods described in this section were applied before on the SLI population of elephant seals, with few exceptions that are noted.

Some important aspects of the elephant seals biology and behaviour

We would like to emphasize some aspects of elephant seals biology that are relevant for the evaluation of the methodology, and of our research licence application at large.

- Elephant seal yearly life cycle has two terrestrial phases, the breeding and the moult, and two aquatic phases, in which seals remain at sea without hauling out. The core part of our study on elephant seals is carried out during the two terrestrial phases (end of August – begin of April).

- Elephant seals breed in harems, i.e., groups of two or more females, with a dominant male who hold the harem, and 0-12 peripheral males. There is no continuous “colony”, just a series of harems irregularly scattered along the sand beaches. We study all harems of the population, to avoid sampling biases (Sharman and Dunbar 1982), but we work at the same time on one or a small number of close harems and, therefore, disturbance to each seal is limited in time and space.
- Most elephant seals have a very short reaction distance, i.e., they can be approached to a few meters without disturbing them. Moreover, the latency in time and space of elephant seals behavioural reaction is very short, i.e., it is enough to move away to have the seals resume their usual behavioural pattern. Therefore, we can apply research methodologies that require getting very close to harems and to individual animals with a modest impact on their welfare. This applies to the “average” seal, and specific individuals may be very aggressive towards humans. We know quite well how to interpret seals reactions, and we react accordingly. We spend a significant amount of time training our field helpers and, therefore, they are usually able to safely work with the seals without disturbing them too much.
- In southern elephant seals, and at SLI in particular, the mother-pup bond is very stable and, therefore, the likelihood of pup abandonment is almost null. In our many years of research at SLI we observed just one case of abandonment definitely produced by human disturbance (a group of visitors approached at very close distance a first time breeder right during parturition). All our handling of pups never produced a single case of abandonment. Therefore, we are almost sure that we can handle pups without any risk to affect their survival.
- At SLI, there are about 60/80 breeding males and about 630 breeding females. About 615 weanlings are produced every season. Breeding males begin to haul out in late August, and start leaving SLI at the end of November. Females begin to haul out during the second week of September. They stay on land for about 28 days, and suckle the pup for an average of 23 days. Peak haul out of breeding females is 19th or 20th October every year. Breeding is almost over in the third week of November, with just very few females (< 10) yet on land.
- The elephant seal moulting season is November to April. Young seals (1-3 years old) moult from early November to mid December; juvenile males moult mainly in December and early January; breeding females moult from late December to early February; sub-adult and adult

breeding males moult from early February to late April, with the biggest/oldest males moulting later.

- Most SLI moulters are not SLI born/breeders, they are alien seals coming from other places. We mark moulters and we currently have confirmed re-sights of them from various locations of the Valdés Peninsula, various locations of South Georgia, King George Island, Livingston Island, various islands of the Antarctic Peninsula and Gough Island. In most cases re-sights outside the Falklands regards males that come to the Falklands for the moult, and are then observed breeding in other places the following breeding season.

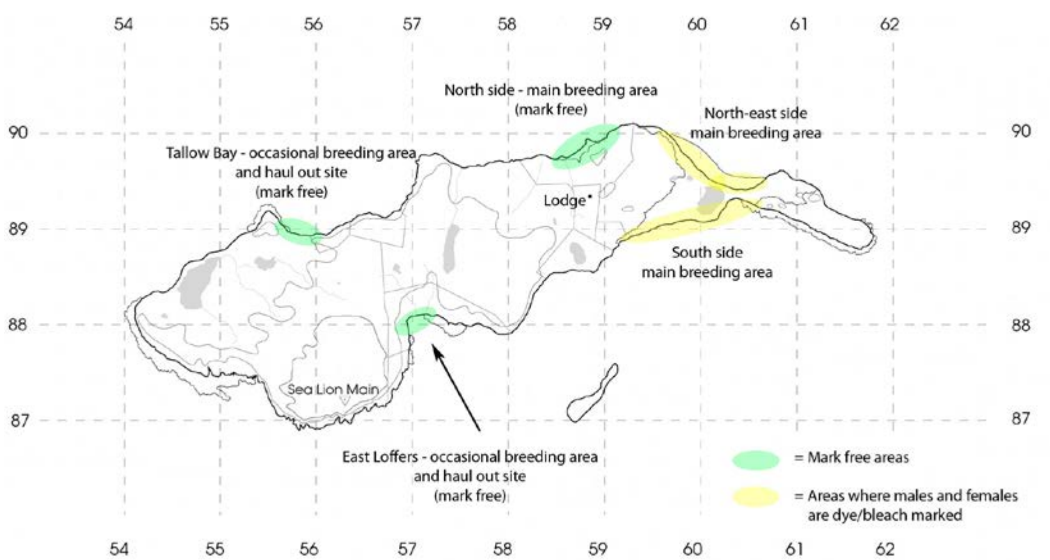

Figure 1 – Map of Sea Lion Island. The map shows the areas where elephant seals breed, and the areas where the most intensive research activity is carried out.

General research procedure

At SLI, elephant seals regularly breed only on the sandy beaches of the eastern part of the island (Figure 1). They occupy three main breeding areas, called South (about 280 breeding females at peak haul out), North-East (about 240 breeding females), and North (about 40 breeding females). Sometimes there are isolated females or small harems (< 10 females) in Tallow Bay and East Loafers. We use the full set of research methodologies described below, including dye marking, only in the South and North-East area. In the North area, which is the area closest to Sea Lion Lodge, we carry out daily counts, we deploy tags and we get skin samples. In the rest of the island we carry out weekly surveys, counting the animals and putting tags opportunistically. Dye marking is restricted to the yellow areas of the map (Figure 1) and to the breeding season only.

Please note that we are describing here only the methods that we regularly apply every field work season. In the past we used methods non covered in this project description, like blood sampling, deployment of satellite tags, and deployment of TDR (time depth recorders). Those methods were included in separate research licenses for specific sub-projects that were carried out just during one or a small number of field work seasons.

Details on the specific research methods

Counts

PROS: provide estimates of population parameters and give information on status of individuals, i.e., the basic data for the long term breeding strategies studies; counts are non invasive, and observers move rapidly around harems, because dye marked animals are easy to recognize
CONS: none, very low invasiveness, but requires tagging, to permit long-term identification, and dye marking, to permit identification from the distance and to reduce seals disturbance and stress

Counts of the main breeding areas are carried out daily, to estimate numbers and collect data on marked individuals. Full counts of the whole island coast are carried out weekly during the breeding season, and every 1-3 days during the moulting season. Details on the count protocol can be found elsewhere (Galimberti and Boitani 1999). Briefly, two observers carry out the census of the study area at low tide, identifying and mapping with GPS the males (see below), counting females and pups, identifying females and weaned pups, and taking notes of observed and suspected females arrivals, new births, females departures, and pup deaths. Mapping is done using commercial grade GPS, and data is recorded on palmtop computers (iPaq, HP) using a custom programmed relational database system, that was devised to simplify data entry and reduce typing errors thanks to the extensive use of entry screens, popup menus, and item lists (HanDBase, http://www.ddhsoftware.com/handbase.html; Figure 2).

Figure 2 – Data collection system. Left: an operator is inputting data on a palmtop computer; right: a sample database input screen.

<u>Tagging</u>

PROS: permits safe long term recognition of individuals, a pre-requisite for the long term study
CONS: approaching the animals at close distance, short term pain. Please note: tagging does not require physical or chemical restraint of the animals and, to our best knowledge, has no detrimental effect on animal welfare, except from a short term pain

We permanently mark seals with numbered cattle tags (length ≈ 45 mm; weight ≈ 2 grams). Along the years we used different models of tags, but all were about the same size (Jumbo Rototags or Supertags, Dalton Supplies Ltd; Primaflex 0, Caisely; Cheviflex Small). To increase the number of combinations we changed colour and printing pattern along the years. A sample of used tags is presented in Figure 3. The change in the tag model was due to a decrease in the quality of the Jumbo Rototag, and the suboptimal long term performance of the Caisley model. In the first part of the study we used tags with hot foil prints, while recently we moved to laser printing. We are currently using preferentially the Cheviflex model because it is small and non intrusive, and the laser printing seems to be deeper. Tags are deployed mostly by surprise by approaching the seal from the back and placing the tag using an applicator in the inter-digital membrane of rear flippers (Figure 4, see also Figure 9; Galimberti and Boitani 1999).

Figure 3 – A sample of tags used in the project

All tagging of adults is carried out without restrain, by approaching the animals from their back, and placing tags by surprise. Tagging of pups is carried out either without restrain, or during weighing operations. Most breeding individuals, males and females, already have tags deployed during the previous breeding seasons. We replace lost tags, such as to have at least two tags on each adult individual. Tag loss rate at SLI is low (likelihood to lose two tags = 0.36% for females, 0.37% for males, unpublished data; see also Wilkinson and Bester 1997), so the number of new tags deployed on breeders is small. We double tag all pups, placing the first tag as soon as possible after birth, and the second after weaning. Until now, we have tagged 23 full cohorts of SLI pups. Tagging of moulters is carried opportunistically along the whole moulting phase. Tagging by surprise of unrestrained seals is carried out only by the PIs, and field helpers are allowed to tag only weaned pups during handling operations and under the supervision of one of the PI.

In most animals, tagging produces a brief reaction (a few seconds) and an apparently small pain, although animal pain is obviously difficult to assess (Bateson 1991). Tagging may produce a wound in the inter-digital membrane and a local infection, but this rarely happens in our population, as showed by the very low tag loss rate (a bad tag, that produces local infection, tends to pass through the hole and get lost). After many years of continuous tagging, we have no indication of any adverse effect of the procedure. Tagging of elephant seals seems to have no effect on their survival rate (Pistorius et al 2000). Much more invasive marking methods also have very small effects on elephant seals welfare (branding: McMahon et al. 2006).

Figure 4 – Tagging by surprise of a weaned pup. An operator is deploying by surprise a Jumbo Rototag in the inter-digital membrane of the right rear flipper of a weanling, using a tag applicator. The right top insert shows the position of the tag and applicator. Ideally, the tag should be deployed such as about 1/3 of the tag body protrude from the border of the flipper membrane.

<u>Dye marking</u>

PROS: permits safe short term recognition of individuals from the distance, a pre-requisite for the study of behaviour; reduces the need to get close to the seals to read tags, reducing disturbance of the subjects and stress

CONS: approaching the animals at close distance; visual impact on tourists. Please note: marking does not require any physical or chemical restraint of the animals, and has no detrimental effect on animal welfare

Figure 5 – Dye marking of breeding females and males. Top: marking of a breeding female, that is unaware of the presence of the operator. Bottom: marking of a male that is seeing the operator but shows no adverse reaction to the marking procedure.

Dye marking is carried out using commercial hair dye (Professional Black Hair Dye 1N, Kosmodaf) activated with 20 volumes (6%) peroxide. The products are safe for use on humans and, therefore, we assume that are also safe for use on seals. Dye marking is carried out with no restraint of seals, by approaching them from the back and placing the mark (Figure 5, top). Most males can be marked also when they are awake, and show no reaction to the marking procedure (Figure 5, bottom). A good mark requires the seal to be fully unaware of the presence of the operator and, therefore, dye marking is fully non invasive. Field helpers do dye marking after a period of training in which they dye mark under the supervision of a PI.

We mark breeding individuals, males and females on the South and North East breeding areas only (see map of Figure 1). We do not dye mark seals on the North area. Obviously, we cannot guarantee that animals marked outside the North area will not move there, because we have no control on seals movements, but we do our best to respect the mark free area. Dye marks last for the breeding season only, and are completely lost during the following moult. Many females are not returning to SLI for moulting, and so they just appear again on the island without marks the next breeding season. About 70% of the breeding males return to SLI to moult in late January to early April. In many cases dye marks put in place during the breeding season fade away when animals are at sea, but some marks are easy to spot on ex-breeders during the moult. Those marks are usually lost within the first week of the moulting period. Counts carried out in the period December-April show that less than 20% of the moulting animals have a recognizable dye mark. We usually do not dye mark pups. In the past, we have marked pups only when doing a specific subproject on parental investment. We also do not dye mark the seals that come to SLI to moult.

For our marks, we use names (usually between 3 and 6 letters) instead of codes because they are much easier to read from the distance, and to remember. We dye mark seals opportunistically on their flanks, back and belly. Maximum letter size is usually kept within a 20 cm height per 10 cm width limit, with the average mark usually not wider than 60 cm. The size of the mark is somehow proportional to the size of the animal, with larger marks on males. Male elephant seals at SLI are 3.5 to 4.5 m long (trunk base to tail), and females are 2.5-3.0 m long (nose tip to tail). We cannot guarantee that all marks will be within these limits, but we try to do our best to avoid large marks. Figure 6 below is a good example of an average dye mark put on a large sub-adult male. The mark is rather small, but it was well done and, therefore, is clear to read. On the contrary, Figure 7 shows a bad mark, one of the worst ever put at SLI. It is big, placed in a bad position, and not well done. Therefore, it is intrusive without being effective. This sort of marks is a minority of the marks (< 5%), and are usually the first tries of our field helpers. Figure 8 is an example of a small mark. Marks smaller than this cannot be easily recognized from the distance. Figure 9 is an example of an average female mark. Although marks can be pretty visible on individual animals their overall appearance in harems is not very intrusive. We are showing below a sample of pictures of harems of different size (Figure 10, 11, 12), taken from different distances. Although most animals actually bear marks, it is difficult to see them in the pictures.

In the past, marking has been a recurring source of conflict between our research and visitors, and photographers in particular. On the other hand, in recent years there were rather few complaints. This is in part due to the excellent job done by Sea Lion Lodge managers (Jenny Luxton, Carol Peck and Micky Reeves) that greatly helped to minimize the conflict between our research activities and the lodge tourism business. We are confident that with a good collaboration between us and SLI staff, conflicts can be kept to a minimum, and the research work can easily get along together with nature tourism. Moreover, in recent years, possibly thanks to our effort to promote out research and explain its rationale to visitors, the dye marking has been in fact taken in a positive way by many visitors of the island, because it permits to follow up each seals and understand more their individual behaviour.

Figure 6 – An average mark placed on a large sub-adult male.

Figure 7 – A very bad mark.

Figure 8 – A small mark on an adult male.

Figure 9 – An average female dye mark.

Figure 10 – A medium sized harem from the distance.

Figure 11 – A small harem where all seals are dye marked.

Figure 12 - Close up of harem females.

To improve the experience of daily helicopter visitors and lodge guests, we adopted a series of actions including:

1) leaving the North breeding area, and the coastline outside the main study area, without dye marks (this policy was started in 1996)
2) providing a leaflet to explain the dye marking rationale, that includes a sketch map of the island with the mark free area
3) providing general information about the rationale of the research project, accessible to lay people, including a small poster in the lodge conservatory, a large poster in the lodge TV lounge, and booklets placed in all lodge rooms and in the main lounge
4) providing a poster placed at MPA, in the helicopter departure lounge

Mapping and study of spatial structure of the population

PROS: GPS mapping provides fundamental information on both population structure and individual movements; laser telemetry permits to get positional data from the distance, during observation of behaviour, and without disturbing the animals; pictures taken from a drone permit to collect spatial information on all harems in a brief time
CONS: for GPS mapping, approaching the animals at close distance for a very short time; for laser telemetry none, very low invasiveness (laser is safe for human use); for drone flights, we did not observe any effect on elephant seal behaviour when the drone was flown at an altitude suitable for mapping of whole harems (20-50 meters)

Commercial grade GPS receivers (GPS 60 and GPSMap 60, Garmin), survey grade GPS receivers (Pro Mark 3, Thales), a laser telemetry system (Laser Locator, Leica Geosystems), and semi-professional drones (Phantom III and Mavic Pro, DJI, www.dji.com) are used to collect spatial data, including position and movements of individuals, and structure of harems and moulter groups. There is an increasing awareness of the fact that fine scale spatial information has a paramount importance in the study of behaviour and evolution (Twiss et al. 2006). We already showed the effect of gross spatial structure on male behaviour and reproduction

(Galimberti et al. 2002 a, 2003) and we are now collecting data at a much higher resolution, also thanks to technological improvements of laser telemetry and drones.

Mapping of males and females outside harems is carried out by approaching seals from the back and taking a fix with a commercial grade GPS, possibly without the seal to became aware of the observer (Figure 13). Mapping of seals within harems, including breeding females and pups, is carried out by combining survey grade GPS receivers (to obtain the harem outline) and laser telemetry, that permits safe mapping of core harem individuals.

Figure 13 – Using a GPS receiver to obtain the position of a male. The insert show a commercial grade GPS (Garmin GPS 60) that in the open areas of SLI permits to obtain locations with a good precision (circular error probable, CEP = ~ 3 m, unpublished data).

Laser telemetry is also used to map position and movements during behavioural observation, to relate behaviour to the spatial structure of the individuals. The telemetry system includes a laser to determine distance and a very accurate three-axis digital compass, and permits to obtain 3D positions of individual seals from 20-100 meters distance, without disturbing their behaviour. The telemetry system is connected to a laptop running a custom developed software that permits mapping and real time field validation of the positions collected (Figure 14).

Figure 14 – Use of laser telemetry to map the seals of a harem. The insert shows the Laser Locator mounted on a tripod.

Figure 15 – An elephant seal harem from the drone. The picture was taken from 55 m of altitude.

More recently, we started using drones to get pictures of harems, to determine the relative position of seals. The drone is normally flown at altitudes between 20 and 50 meters. To reduce disturbance to the seals, the harem is approached at higher altitude, and then the drone is lowered to the maximum altitude suitable to take the pictures. The pictures are calibrated using a combination of the altitude reported by the drone, the altitude reported by a custom pressure-based data logger attached to the drone, and reference scales placed on the ground and included in the picture frame.

Handling and weighing of pups

PROS: crucial in monitoring the health of the population, and fundamental to study individual breeding strategies and maternal investment
CONS: physical handling (no chemical anaesthesia), modest short term disturbance (but no long term effect); use of a vehicle to transport the weighing equipment

Figure 16 – Weighing of a pup after birth. The pup is being freed by the weighing bag after the weighing, and will be returned to the mother.

Pups are weighed within 24 hours from birth using a canvas weighing bag attached to a digital dynamometer, and lifted by hand by two operators (Figure 16). As soon as the weight is obtained the pup is returned to the mother. Pups are taken from the mother by surprise, and mother movements are controlled by one of the PI using a blue canvas cloth. We would like to emphasize that we are not using sticks or touching the seals to control them, because the blue canvas is exceptionally effective at stopping elephant seals, including large males. Pups are restrained by hand, with no chemical anaesthesia. Mean handling time for pups is 2’ 30”, from the separation from the mother to the return to her. Weighing of pups at birth never produced abandonment, and all pups weighed at birth were successfully weaned.

Weanlings are weighed as soon as possible after weaning using a weighing bag, i.e., a canvas sheet with straps cut out to fully enfold the weanling, held up by two horizontal aluminium poles. The weighing bag is connected by steel chains and springs to a digital dynamometer and a 500 kg hoist, that is in turn connected to an aluminium tripod (Figure 17; Galimberti and Boitani 1999). The use of the tripod is required due to the heavy weight of the weanlings (mean weight about 135 kg, but up to more than 200 kg). Mean handling time for weaned pups is 3’ 30” (single measure) or 5’ 30” (three consecutive measures, to calculate weighing error). The weighing equipment is heavy, so we move it using a vehicle.

Figure 17 – Weighing of a weaned pup. The canvas bag is connected to the tripod and lifted using a hoist. We usually wait 10 to 30 seconds to let the dynamometer reading stabilize.

Every year, we weigh a sample of weanlings to study: 1) females parental investment; 2) effects of global environmental changes on the population (weaning weight is a very good proxy for resource availability, see Burton et al. 1997). We weighed pups at birth only in 1998, 1999 and 2001. We currently have no plan to weigh pups at birth the coming breeding season, although we may need to weight pups in the following breeding seasons, to improve our studies on parental investment. We require a sample of 120 weaned pups of each sex to accurately determine trends in weight.

Observation of behaviour

PROS: provides data on individual behavioural tactics of males and females; permits the accurate estimation of the timing of breeding, that is, in turn, critical in understanding fine-scale population dynamics; permits to study behaviour of moulters, that is currently unknown in southern elephant seals; operators observe harems and moulting groups from the distance
CONS: very low invasiveness, but requires dye marking to recognize animals from the distance; seals should be undisturbed for their behaviour to be natural, so we sometimes may need to kindly ask people that come very close to the animals to keep their distance from the seals, or move to a nearby, not observed, harem

We carry out two kinds of observations of behaviour: observations focused on males (called male observation periods) and observations focused on female-pup pairs (called female observation periods). During male periods, behaviour is observed during a 2-hours period from a distance of 10-100 m from the seals (Figure 18).

We are using a standard data collection protocol described in detail elsewhere (Galimberti et al. 2000). Briefly, we collect general environmental information and data about the local demography and harem structure; during male observation periods we keep a serial record of all interactions among males and between males and females (all occurrence sampling; Altman 1974); we take notes about breeding events (arrivals on land of females, births, weaning, departure to sea of females); we record the frequency and context of male vocalizations, and we record the time budget of the observed individuals at 5 min interval. This data permit to estimate male dominance rank and fighting success, male mating success, and harassment rate on females.

During female periods we carry out focal observations (Altmann 1974) on two or more mother-pup pairs (average 6-7 pairs). We record the time budget of mothers and pups at 1 min interval, and we keep a serial record of all females dominance interactions, all aggressions toward pups, and all rare events like pups separation, abandonment, allo-suckling and adoption. These data permit to estimate dominance rank of females, time dedicated to suckling, and intensity of maternal care.

Figure 18 – Observation of elephant seals behaviour. A male observation period is carried by two operators from a vantage point over a small harem. The second operator is in charge of taking positions using the laser telemetry system (see above), to obtain combined behavioural and spatial data.

During the moult we carry out observation periods of 30 minutes length using a scan sampling protocol (Altmann 1974), with a 1 minute scan interval. We are using this protocol with moulters because they are not dye marked and, therefore, can be recognized by reading the tags only at the beginning of the observation period. This protocol is definitely not optimal, but permits to avoid the dye marking, that can have an adverse effect on the tourism business because the moulting months overlap with the peak tourist season. During the scan we record individual behaviour using a simplified ethogram, and we collect data about group size, number of individuals touching each other, and movements between groups. Data on social behaviour is processed using standard techniques (Whitehead and Van Parijs 2010), including social network analysis (Farine and Whitehead 2015).

Audio recordings of vocalizations

PROS: very valuable information to understand the evolution of animal signals and communication; mother-pup recording is carried out from the distance and is totally non invasive
CONS: researchers approaching seals at close distance to record males and females aggressive vocalizations

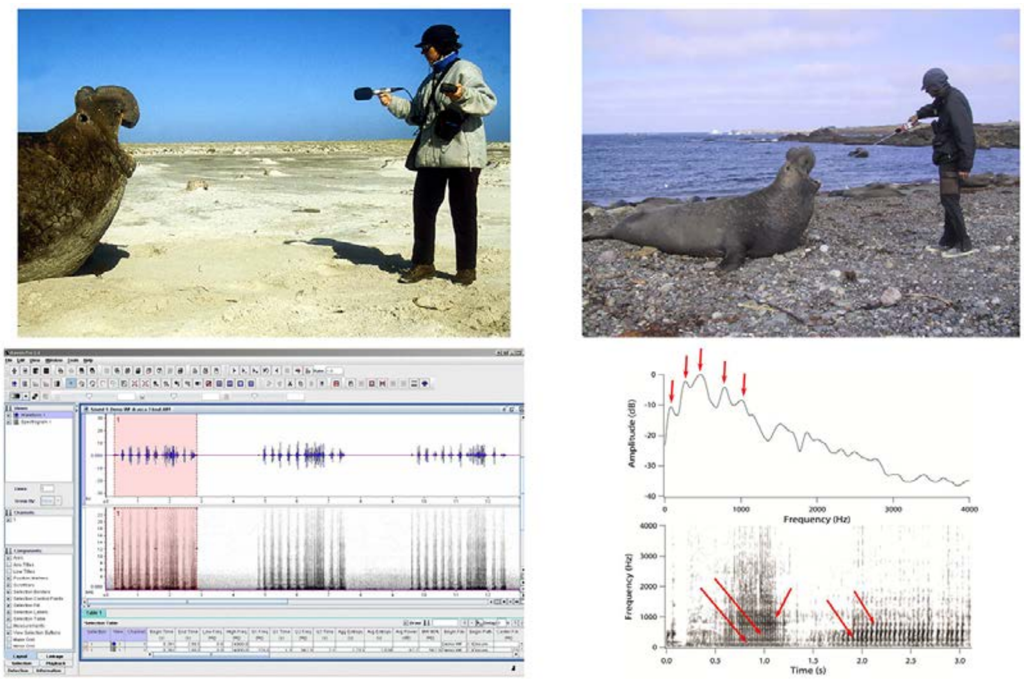

Figure 19 – Audio recording and processing of male vocalizations. Top left: recording of a male vocalization. Top right: measurement of vocalization power using a sound level meter. Bottom left: visualization of waveform, spectrogram and acoustic parameters in bioacoustics software. Bottom right: average power spectra and spectrogram showing frequency formants, i.e., the components of the sound frequency structure that should convey honest information on male size and phenotype at large.

We obtained interesting results by recording and analyzing males vocalizations, including the demonstration of the presence of vocal learning by imitation of harem holders (Sanvito et al.

2007a), honesty of vocal signals and their role to reduce the risk of direct fights (Sanvito et al. 2007b), and the role of the proboscis in sound emission (Sanvito et al. 2007b). More recently we had MSc students working on female aggressive communication, mother-pup contact calls, and the role of frequency formants in honesty of aggressive vocalizations of both males and females.

To study male acoustic communication we use two different methods, recording of vocalizations in natural contest, and standardized recording with artificial stimulation. During natural contests, we record males from the distance using a dynamic microphone (MD-441, Sennheiser) and a high quality digital recorder (PMD 660, Marantz), adding vocal notes to discriminate males. During standardized recording, one of the PIs approaches the subject to a few meters of distance to elicit a vocal display (Figure 19). This method proved very successful (Sanvito et al. 2007 b), and permitted us to collect a large amount of recordings of most of the breeding males when the recording conditions were optimal, something that rarely happens at SLI due to very windy weather, and the lack of cover on the sandy beaches. Although with this stimulation we modify the time budget of the subjects, the low frequency of stimulation of each individual (maximum once per week) make us confident that no long-term effect will result.

Figure 20 – Audio recording of female and pup contact calls. An operator is waiting for a mother-pup pair to produce contact calls and record them.

To study mother-pup communication, only natural recordings are carried out, with no stimulation. The operator just sits down at 5-15 m of distance from the target mother-pup pair, and waits (Figure 20). We have a long term experience in recording mother-pup pairs in both species of elephant seals, southern and northern, and we observed no adverse effects on the seals. Even in the northern species, that is much more sensitive to human disturbance than SLI seals, we never observed any case of pup separation or abandonment due to the presence of an operator carrying out audio recordings.

Video recording of behaviour

PROS: permits to obtain detailed information about complex social interactions
CONS: none, video recording is carried out without disturbing the seals

Figure 21 – Video recording of a males fight. An operator is video recording a males fight. The video will then be processed using custom software to extract data on behavioural sequence.

Complex social interactions, like male fights, juvenile sparring-fights, and mother-pup interactions after birth are difficult to observe and describe while they happen. Video recording of those interaction permits to obtain a permanent record that can be viewed more than one time and from which very detailed information about the behavioural sequence can be extracted (MacDonald et al. 2000). Video are recorded in high definition using digital cameras (Olympus E-M10 Mark II-IV) and zoom lenses, at variable distance, but always avoiding disturbance to the seals and alteration of their natural behaviour. Video are then processed using custom software to extract the behavioural information.

Measurement of size

PROS: provides very good information on body size, which can be used to estimate growth and to study the pervasive effect of size on biological phenomena; the photogrammetric methods we use are much less invasive than any direct estimation
CONS: none, very low invasiveness; the photogrammetric approach requires the subject to be completely unaware of the presence of the operator handling the scale; the trigonometric approach is carried out from the distance, without any interaction with the seals

Until now we used two non invasive methods to estimate size. The first one is based on short-range 2D photogrammetry and requires two operators, one taking a picture, and one holding a scale. Photogrammetry is increasingly used to obtain non-invasive estimates of size in field conditions and on wild subjects (Berger 2012), in accordance to the general tendency to reduce the invasiveness of field research at large (Pauli et al. 2010). Digital pictures are taken from the side and the front of animals using a high resolution digital camera (Olympus E-M10 II-IV), with a calibrated surveying pole in the frame as reference. The operator holding the pole needs to be at very close distance from the animal, but the animal should not be aware of his presence for the picture to be taken. Measurements are then obtained with image analysis software using the pole as scale (Sanvito et al. 2007 c; Figure 22, bottom). The photogrammetric length (L, Figure 22) is then converted to the standard body length (American Society of Mammalogists 1967) using conversion equations obtained from tape measures of seals resting on the side (Figure 22, top). This method permits to obtain estimates of body weight with high repeatability (Galimberti et al. 2007), by measuring the side area and applying conversion equations obtained for the northern elephant seal (Haley et al. 1991).

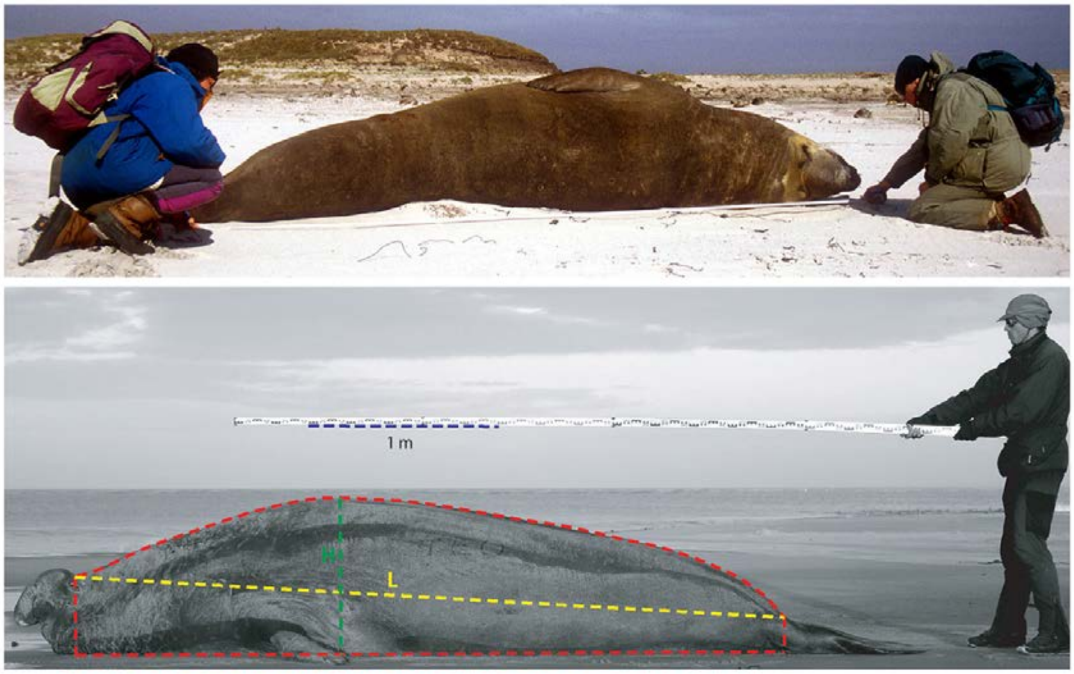

Figure 22 – Photogrammetric measurement of an adult male. Top: direct measurement of the standard body length of a male using a measuring tape. Bottom: photogrammetric measurement of body size and weight; the red dotted line is the side area, that is a very good proxy of body weight.

The second method requires just one operator and is based on the measurement of angles, using a digital protractor (GAM 220, Bosh) and distances, using a high accuracy laser telemeter (Disto 8, Leica). To estimate size, one angle and two distances needs to be measured (Figure 23, top); body length is then obtained by applying simple trigonometry. The advantage of this method is that measurements can be carried out from the distance, by just one operator, and without the need to approach the animal. Moreover, no post-processing is required, as happens with photogrammetry, and size estimates are obtained and validated in the field. This method is the best option to measure females, which are more difficult to approach from the back, in particular when they are inside large harems. A trial study using both experimental measurements of known size objects and actual measurements of seals showed that this method has a high repeatability and is very effective, permitting to obtain a large number of size measurements in a short time and directly in the field (Sanvito et al. 2018). Recently, we acquired a new laser telemetry system (Disto S910, Leica) that includes in the same instrument the capability to measure both distances and angles, without requiring an external digital protractor. With this new system the measurement is even easier and faster than with old laser plus protractor assembly (Figure 23, bottom).

Figure 23 – Trigonometric measurement adult females and weaners. Top: the measuring system based on laser rangefinder plus digital protractor. Bottom: the new system based on a single instrument capable to measure both distances and angles.

We plan to add a third method to measure seals size, i.e., the measurement of size on calibrated pictures taken from the air using a drone. Basically, the procedure will be the same explained above to map seals (see section on mapping), but the drone will be flown at a lower altitude, to permit to better see the individual seals. During the breeding season most seals bear dye marks and, therefore, can be identified in drone pictures. The advantage of using drone pictures is that pictures of many seals can be obtained in a short time. Pictures will be taken at 10-20 meters of altitude. Test flights at variable altitude showed that elephant seals have a brief reaction when the drone altitude is around 5 meters, but show no change in behaviour when the altitude is 10 meters or higher (unpublished data). Moreover, even when the drone is flown at very low altitude the reaction is brief, and seals usually resume resting, showing no tendency to move or run away.

Figure 24 – Drone picture suitable for measurement of size. The dye marks of some females are clearly readable in a picture taken at 10 meters of altitude.

Measurement of morphology

PROS: provides very good information on morphology that can be used to study the evolution of secondary sexual traits and vocal communication
CONS: requires close approach to seals as stimulus to elicit proboscis inflation and vocalization (see the audio recording section)

The measurement of morphometry can greatly help in the study of phenomena as diverse as the evolution of secondary sexual traits and honest communication. The non invasive measurement of morphometry in field conditions is usually carried out using photogrammetric methods (Bergeron 2007). We are using the stimulation of males, using the same protocol described above for the audio recording of male vocalizations, to study the structure, ontogeny and function of the proboscis, and the anatomical constraints of the vocal tract, that provides the basis for honest vocal communication.

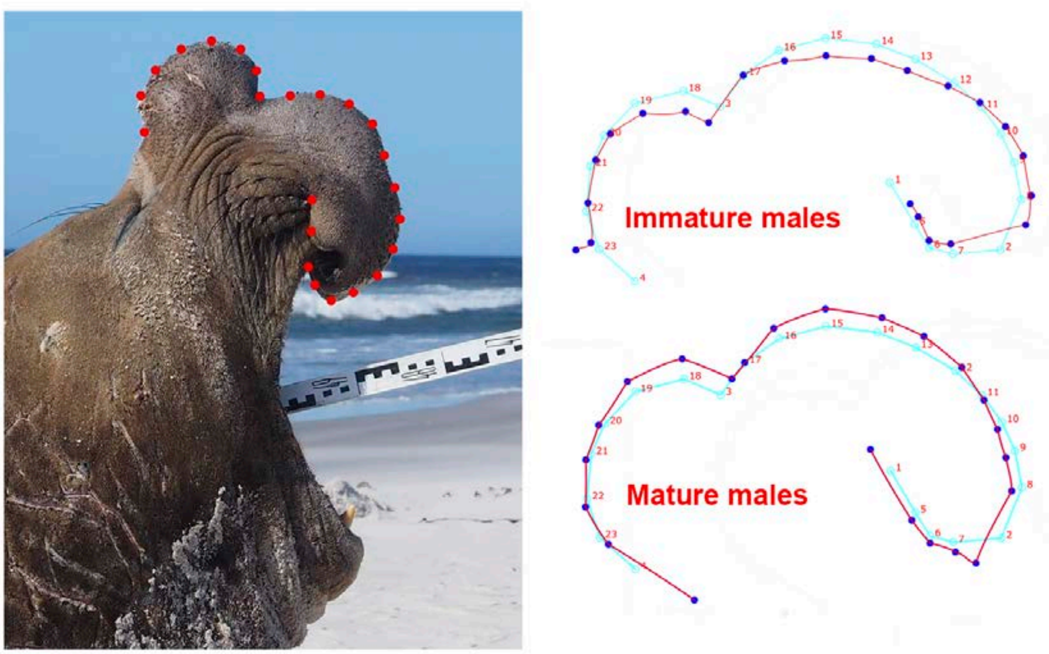

Figure 25 – 2D photogrammetry and geometric morphometry to study the proboscis development. Left: the 2D photogrammetry approach, and the landmarks defining the proboscis shape. Right: comparison of the size-removed shape of the proboscis between immature and mature male elephant seals.

Photogrammetry of the proboscis is carried out by two operators. One of them approaches the male, elicits a proboscis inflation and vocalization response, and keeps a one meter long surveying pole close to the mouth of the subject, and aligned to its sagittal plane (Figure 25, left). The second operator takes digital pictures (same camera as above) of the side of the subject, including in the frame the head, the proboscis and a segment of the surveying pole. The pictures are then processed to place landmark defining the shape of the proboscis (Figure 25, left), and the landmarks are analyzed using the standard methods of geometric morphometry, that permits to separate size and shape (Webster and Sheets 2010). We already obtained interesting results on the development of the proboscis shape (Figure 25, right; Galimberti et al. 2018), and we plan to use this method intensively in the future to obtain measurement of large sample of male proboscis. This is one of the few successful applications of geometric morphometry to a soft tissue trait measured in the wild on naturally behaving subjects.

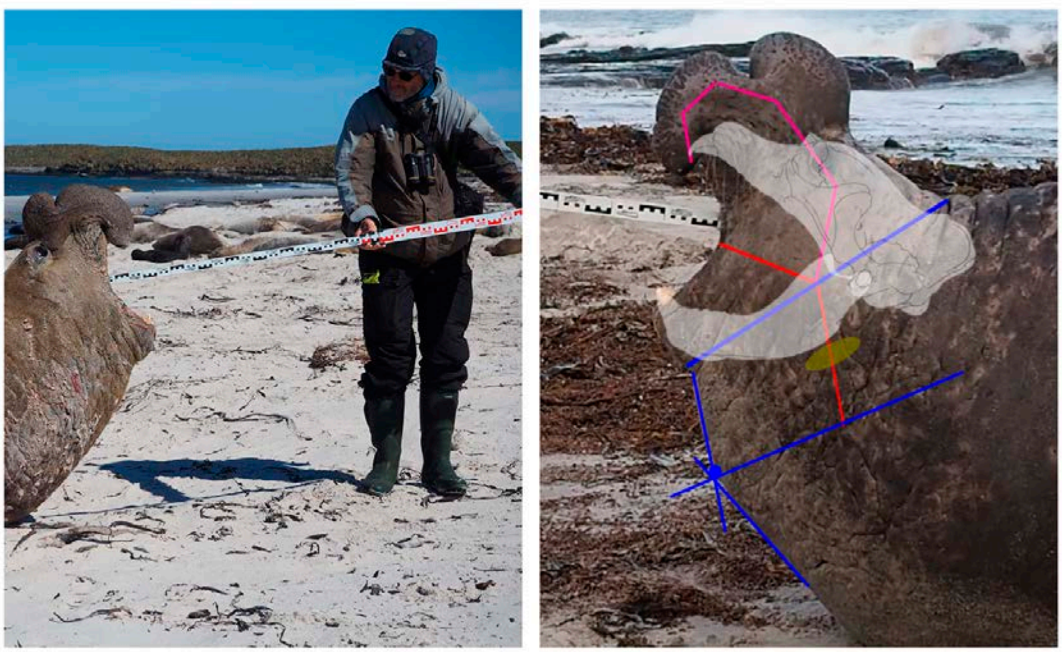

Figure 26 – Measurement of vocal tract length. Left: stimulation to elicit male vocalization; right: measurement of the components of the vocal tract using the surveying pole as scale.

The second area in which we are using the field photogrammetry is the measurement of the vocal tract, which is of paramount importance in the study of vocal communication, because the anatomical constraint between body size and vocal tract provides the basis for the evolution of honest vocal signals (Fitch and Hauser 2002). To obtain estimates of the total vocal tract length, and of the length of its parts, we are using an approach similar to the one described above for the proboscis, but using 2D videogrammetry instead of photogrammetry (Figure 26, left). Briefly, videos are taken instead of pictures. Those videos are then processed in a video editing software (Premiere Pro, Adobe) to extract the best video frames to measure the vocal tract. Those frames are saved as high resolution pictures, and are then measured using the ObjectJ plugin of the ImageJ software (Vischer 2017). A scheme of the measurements taken is shown in Figure 26, right. We have already obtained interesting results that demonstrate that the vocal tract is in fact constrained by size and age (Redaelli et al. 2018), and we plan to intensively use the method to increase the sample size and relate the vocal tract development to the development of the acoustic structure of vocalizations (Sanvito et al. 2008). The same methodology is used to estimate vocal tract of females. The only difference is that we are using a smaller surveying pole.

<u>Collection of environmental data</u>

PROS: detailed and accurate environmental data; no effect on the seals
CONS: deployed on the beaches, but barely visible

Figure 27 – A datalogger with the rain/sun cover. The logger data (air temperature and humidity) is being downloaded using a dedicated shuttle. Please note the nearby resting elephant seal female.

Elephant seals behaviour is affected by environmental conditions, including weather, microclimate, and tides. To collect data about weather and microclimate we use meteorological station data and we deploy dataloggers in the areas used by elephant seals. Until now we used three types of commercial data loggers: various models of Hobo Pro loggers (Onset Computers, www.onsetcomp.com), various models of Thermochron loggers (Maxim Integrated, www.maximintegrated.com), and the RC-5 logger (Elitech, www.elitech.uk.com). Thermochron are very small (diameter = 1.6 cm; height = 0.63 cm) and are not intrusive at all, being barely visible when deployed on the beaches. Hobo Pro are bigger, having a plastic rain/sun cover of 10 cm of diameter, but are also not visually intrusive. RC-5 dataloggers are small but we deploy them with the same cover of the Hobo loggers (Figure 27). Up to 50 dataloggers will be deployed each season.

Commercial dataloggers are expensive and have rather limited capabilities. Therefore, we are now experimenting custom made data loggers based on open source microcontrollers (Baker 2014, Hund et al. 2016). These loggers can be fitted with a large array of sensors (Larios et al. 2013) and can be custom programmed, providing a level of flexibility that cannot be achieved with commercial loggers (Beddows and Mallow 2018).

Apart from the loggers data, we are obtaining the following environmental data: 1) data on SLI weather from the SLI weather station managed by the British Meteorological Office; 2) data on the general Falkland Island weather from the GFS model of the NOAA; 3) data on tides, that can greatly affect seal behaviour, from the UK National Oceanography Centre; 4) data on sea conditions, including surf and swell average and maximum height from the FNMOC WW3 global model.

Skin sampling

PROS: fundamental for the quantitative genetics study; permits to study the genetic relationship between individuals, populations and stocks, and to assess genetic paternity; genetic markers are currently the most powerful tool of conservation biology

CONS: short and modest pain; the scars left by the ear-puncher or biopsy heads are barely recognizable after few hours, and we have never observed any sign of infection due to skin sampling

The use of genetic information is permitting a quantum leap in the study of behaviour and evolution (Selkoe and Toonen 2006). We have already produced results for the SLI population in three key areas: male paternity success (Fabiani et al 2004), kinship and its effects on behaviour (Fabiani et al. 2006), role of SLI in the South Georgia stock, and long range migration of breeders (Fabiani et al. 2003). Our plan for the future is to concentrate on the quantitative genetics study, with the goal of obtaining genotypes of all individuals of all cohorts. We carried out a great effort to develop an effective microsatellite markers panel for northern elephant seals (Sanvito et al. 2012), and we are using the results of this study in the southern species.

Figure 28 – Collection of skin samples with ear-notchers.

Almost all adults now coming to SLI for breeding were born there and were, therefore, already sampled in the past. For the next breeding seasons, we plan to sample the few adults for which we still have no samples, and all the weanlings of the each new cohort, as we did in the past seasons. This will permit us to reconstruct full pedigrees of all individuals born at SLI. DNA is extracted from skin samples, taken from the inter-digital web of the hind flippers of each animal using Dalton ear-notchers (Figure 28), or from the back using a biopsy head (ø = 4 mm) mounted on a pole. The sampling by biopsy head is used only when ear-notchers are impractical, mostly to reach core females of large harems. Ear-notchers and biopsy heads are carefully cleaned after each sample is taken, to minimize the risk of infection. The samples are about 8-10 cube millimetres in size and 1-2 grams in weight. The scars left by the ear-puncher and the small holes produced by the biopsy head are barely recognizable after few hours. We never observed any sign of infection due to skin sampling. This technique is widely used in seals, and implies a very small and short term disturbance to the animals. The skin sample usually contains enough fur to permit stable isotope analysis (see following section) and, in fact, we have used fur from skin samples to study trophic specialization of SLI females (Rita et al. 2017).

Fur sampling

PROS: estimation of feeding niche, feeding areas, and diet; long-term trends
CONS: none, the sampling is carried out on resting animals and produce no pain

Figure 29 – Collection of a fur sample from an adult male. Inserts are showing a detail of the placement of the pliers and scissors used for sampling, and a detail of the tools used. Sampling produced no pain or disturbance to the resting subject.

The collection of fur samples permits to apply stable isotope analysis (SIA; Ben-David and Flaherty 2012 a,b) and obtain estimates of feeding niche, feeding areas, and diet. SIA is a very powerful technique, because if samples from multiple years are available, long-term trends in feeding parameters can be estimated, and correlated to trends in climate and oceanography. Fur samples can be easily obtained from resting seals by grabbing a small amount of fur using long nosed pliers and cutting it using scissors. The procedure is low invasive because a very small amount of fur is removed, the sampling is carried out on resting seals with no needing of restraints, and there is no pain at all. We already used fur, obtained from skin samples (see previous section) to study feeding habits of SLI females (Rita et al. 2017), but the direct collection of fur will permit to extend our database of individuals. Another totally non invasive source of fur is the moulted skin that can be collected from the ground or removed from the seals by hand and without any pain or disturbance.

Ethics and research guidelines

Our imperative is to devise theoretical and practical solutions to get the best balance between the value of scientific results obtained and the cost for animal welfare. We have a specific interest in devising non-invasive methods to obtain data (e.g., to estimate size; Galimberti et al. 2007; Sanvito et al. 2007 b; Sanvito et al. 2018) or to reduce the invasiveness of existing methods (Sanvito et al. 2004; Sanvito et al. 2005).

The whole protocol of our research project was previously audited and approved by the Animal Care Committee of the Memorial University of Newfoundland (St. John's, Canada). Along the years, parts of the project protocol were approved by the Università degli Studi di Roma "La Sapienza" (Roma, Italy), the Università degli Studi di Milano (Milano, Italy) and the Universidad Autónoma de Baja California (Ensenada, Baja California, México). All the procedures were previously approved by the Environmental Committee of the Falkland Islands Government (1995-2018). The last five years research licences were R11/2007 (2007-2012) and R13/2013 (2013-2018). We are applying the following professional guidelines:

- Association for the Study of Animal Behaviour (2012). Guidelines for the treatment of animals in behavioural research and teaching. Animal Behaviour 83: 301-309, doi: 10.1016/j.anbehav.2011.10.031.

- Gales, N. J., W. D. Bowen, D. W. Johnston, K. M. Kovacs, C. L. Littnan, W. F. Perrin, J. E. Reynolds and P. M. Thompson (2009). Guidelines for the treatment of marine mammals in field research. Marine Mammal Science 25(3): 725-736, doi: 10.1111/j.1748-7692.2008.00279.x.
- Hodgson, J. C. and L. P. Koh (2016). Best practice for minimising unmanned aerial vehicle disturbance to wildlife in biological field research. Current Biology 26(10): R404-R405, doi: 10.1016/j.cub.2016.04.001.
- SCAR's Code of Conduct for the Use of Animals for Scientific Purposes in Antarctica, www.scar.org/policy/scar-codes-of-conduct/
- Sikes, R. S. and W. L. Gannon (2011). Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92(1): 235-253, doi: doi:10.1644/10-MAMM-F-355.1.

Environmental impact of the research

Impact of the research on elephant seals

We have no evidence of adverse effects of our research on the study population. Population size has been almost steady during 1989-2003, and then started growing. The maximum growth rate between seasons was observed after a season of very intense field research activity. Moreover, we have three direct indications of the good health of the population:
- female fecundity is close to 100%, which is equal to or higher than other southern elephant seal populations
- pup mortality is very low (average 2-3%), possibly among the lowest for any southern elephant seal population
- weight at weaning is on the high side of the range observed in southern elephant seals (compare Galimberti and Boitani 1999 with Burton et al. 1997). Despite these evidences, we are continuing our effort to reduce the invasiveness of our research, by devising new methods and exploiting technological advances. For example, we moved to laser telemetry to be able to get positions of animals from the distance.

Impact of the research on the SLI ecosystem

Our field work may in principle have a general adverse effect on the local ecosystem. This seems unlikely because the work is limited in space and time. Our main study areas are the sandy beaches of the eastern tip of the island, where elephant seals breed. Our presence in the rest of the island is spotty and not invasive at all, we just carry out counts of seals on the full island perimeter. Therefore, the most of our activity is carried out far away from the nesting sites of most bird species. Unfortunately, a full evaluation of the impact of the research on the local ecosystem requires time series on abundance and productivity of other species, which are rather scarce for SLI populations. In recent years we started a pilot environmental monitoring programme for SLI, which is helping us to understand the potential adverse effects of our elephant seal research on other species, but we are far from a full understanding of the human-wildlife interactions that happens on the island. Only the set up of regular monitoring of SLI wildlife may permit a full understanding of the impact of our research and of other sources of human disturbance, including nature-oriented tourism and wildlife photography.

Presence in the field and impact on other visitors

Our research team is small (2-8 people), well below the mean size of analogous operations carried out in other populations. We occupy at any time a very small area of the island, therefore our presence should not cause relevant disturbance to other visitors. At any time, there is plenty of room for everybody on the island. A specific problem is represented by the use of cars. We have one vehicle on the island, that is used to transport materials during weighing operation and, mostly, as shelter for behavioural observations. The vehicle is fitted with large tyres to reduce soil wearing.

We sometimes need to ask people to not get too close to the seals while we are doing behavioural observations. To collect good behavioural data the animals should be undisturbed. We are observing just one or few harems at the same time, so people have just to move a few hundred meters away to find another “free” harem. We also may ask people to keep a good distance (> 5 metres) from seals when we are handling them or doing specific jobs (e.g., sound recording). This is to avoid any interference with our work that will eventually slow down operations and increase disturbance. Moreover, we need to protect the welfare of the study animals, the researchers, and the visitors during handling operations.Due to the Falklands weather, we need to use shelters to protect ourselves during behavioural observations, and to put water-proof containers on the beaches to store instruments. We are trying to use our car as shelter as much as possible, because it can be moved away from the beach when not needed. Unfortunately, the car alone is not enough to cover all our observation work. Therefore, in the past years, we have gradually built up small stone shelters in various points of our study areas. They are made by stones found in place, they are temporary (and frequently destroyed in the winter), and they look well integrated with the landscape, and are frequently used as shelters also by SLI visitors.

Timeline, composition of the research team, and funding

The field work is carried out every year during the breeding season, late August to early December, and during the moulting season, mid December to early April. The fieldwork team will include the two PIs, Filippo Galimberti and Simona Sanvito, and 2 to 6 field helpers. At least one of the PI will be in the field at all times. After a period of training the field helpers will carry out alone the basic daily work (census, identification, observation of behaviour), but they will be supervised at all times by at least one of the PIs during invasive operations, like pups handling and weighing. Full funding is available to cover the logistics cost of the project.

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We thank Carla and Alberto Galimberti, and Maria Luisa and Roberto Sanvito, for their long-lasting support of our research on Sea Lion Island elephant seals; the Falkland Islands Government for granting the license to conduct research at Sea Lion Island; the Falkland Islands Development Corporation for permission to conduct field work on Sea Lion Island; Sea Lion Island Ltd and Wild Falklands Ltd for help with the field logistics; the Sea Lion Lodge managers Jenny Luxton, Carol Peck and Micky Reeves for their kind help and support of our research project; our field helpers, too numerous to be named; the Sea Lion Lodge staff. A special thanks goes to the elephant seals. Our research at Sea Lion Island is dedicated to our beloved son Leonardo.

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