Southern elephant seals of Sea Lion Island

A long-term research project

Instructions

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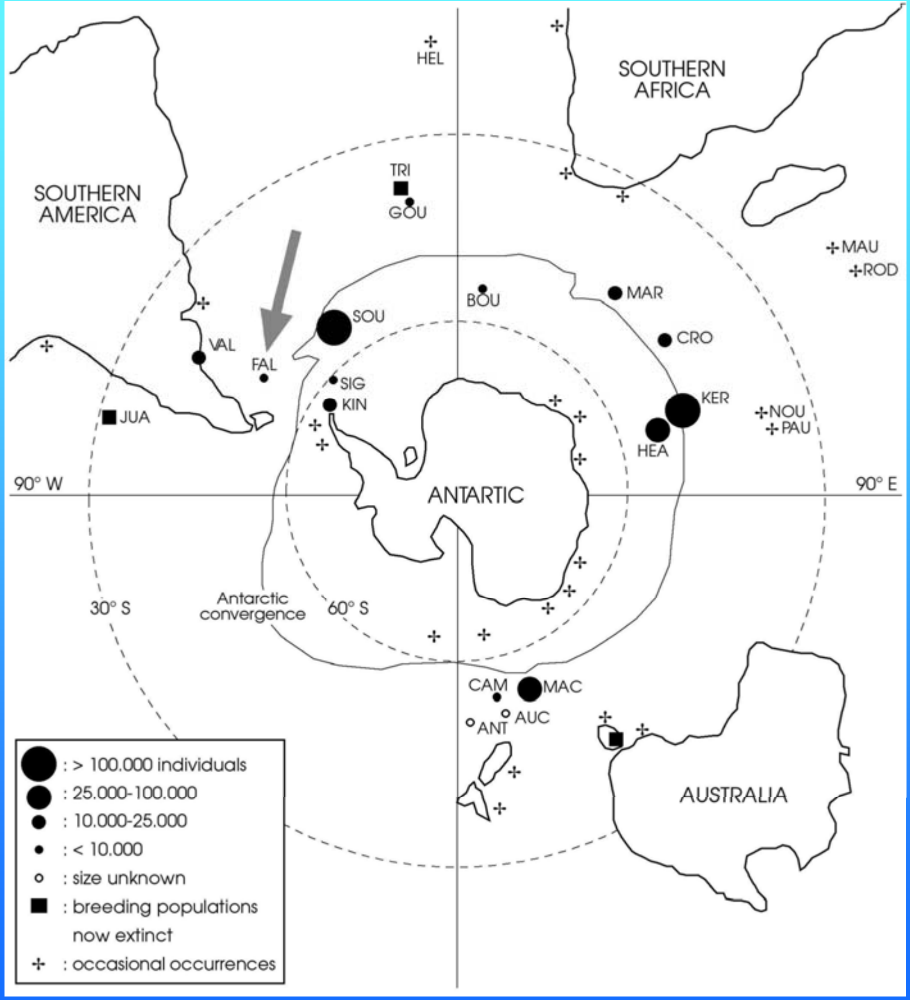
Southern elephant seal stocks



- South Georgia stock

  (South Georgia, Valdés Peninsula, Falkland Islands, South Orkneys, South Shetlands)

- Kerguelen stock

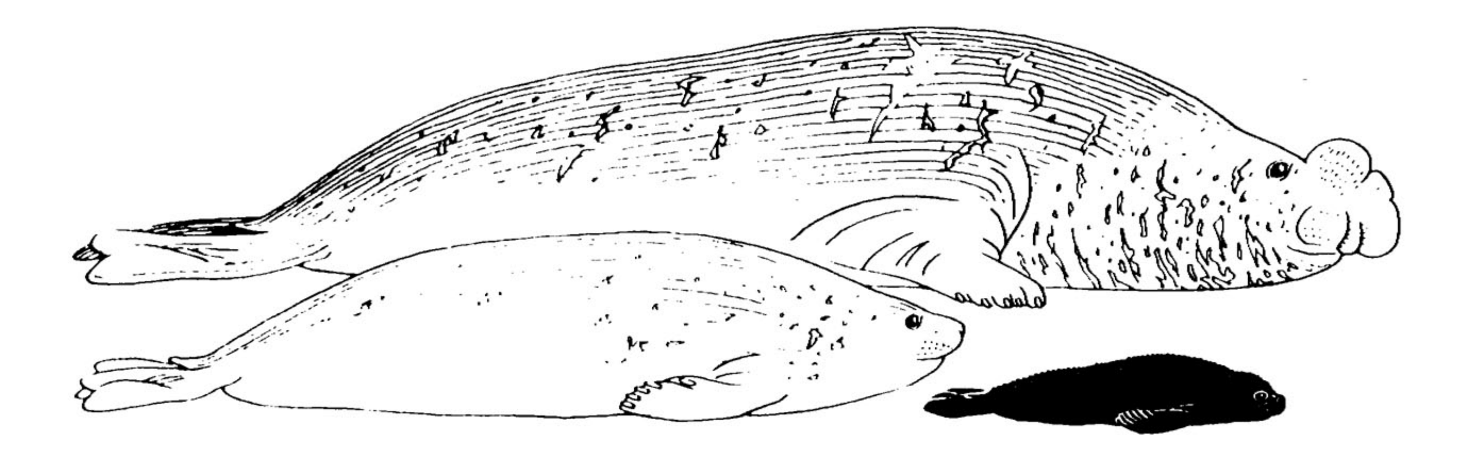
  (Isles Kerguelen, Heard Is., Marion Is., Prince Edward Is., Isles Crozet)

- Macquarie stock

  (Macquarie Is., Campbell Is., Antipodes Is.)

Southern elephant seals biology

- Mixed yearly life cycle: 2 aquatic and 2 land phases
- Large body size (males up to more than 5 m, female 2.6 m)
- Extreme sexual dimorphism (males up 8 times heavier than females)

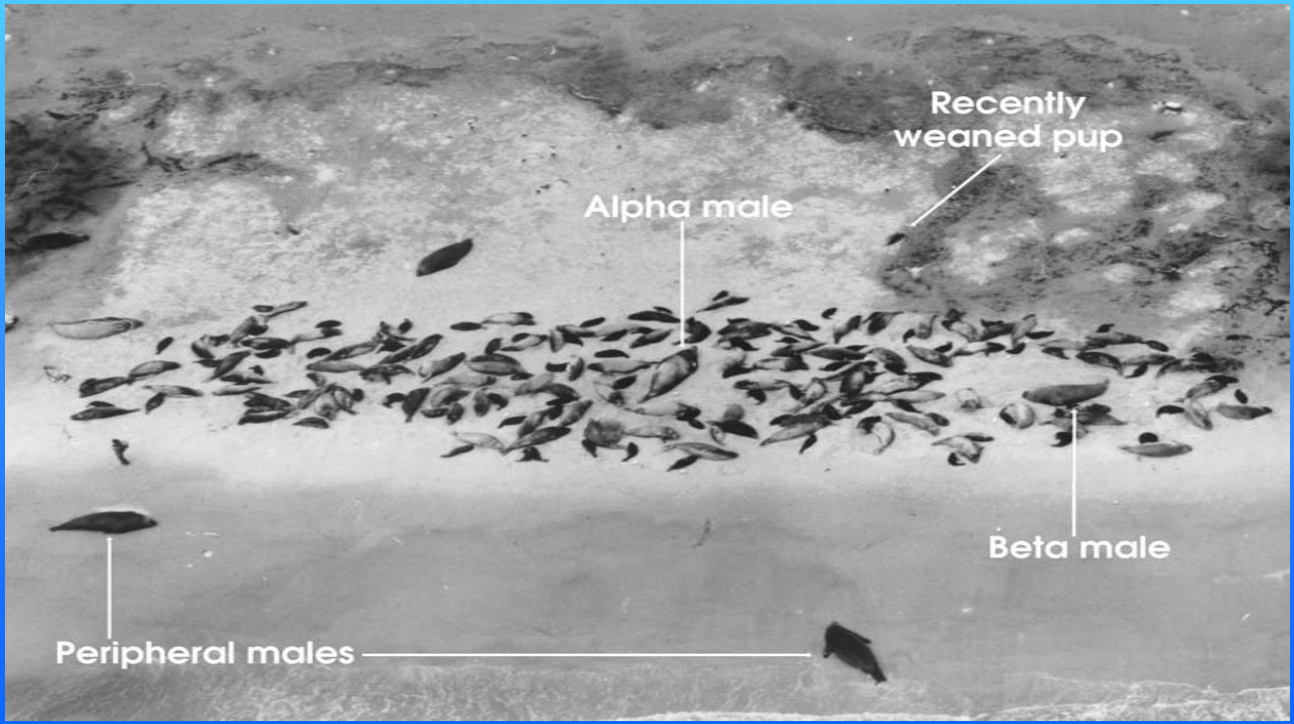


- Gregarious social system during the land phases, solitary life style during the aquatic phases

More on the *Mirounga* genus

The breeding system

- Tendency to aggregate and colonial breeding
- Concentrated breeding season (about 3 months)
- Purest form of harem defence polygyny
- Harems of up to a few hundreds of females



The female breeding cycle

Each female:

- Arrives on land, and join other females, forming *harems*
- Gives birth to a single pup after about 5 days
- Suckles the pup for a mean of 23 days (fasting)
- Comes into oestrus at day 21 and mates for 2 days
- Weans the pup and return to sea for feeding

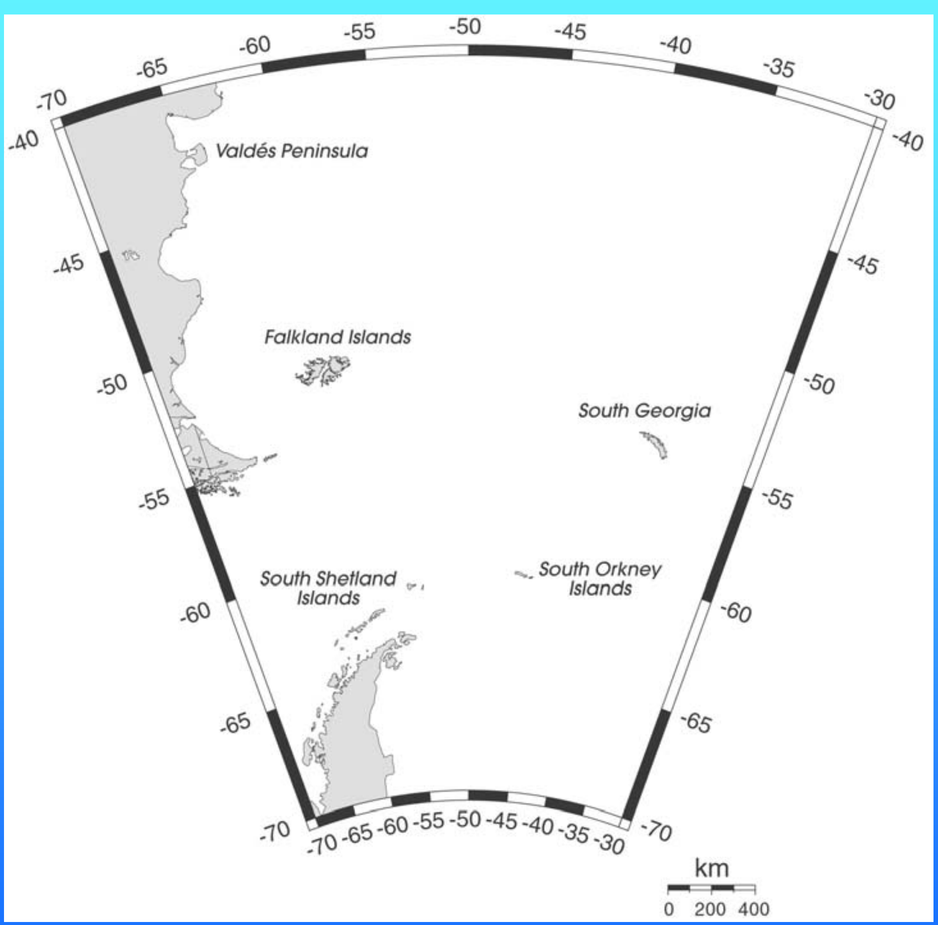
The male breeding cycle

Each male:

- Arrives on land in September, adult males before the first female
- Competes with other males to get an high rank and get control of harem
- Mates with harem females (if holder) or opportunistically
- Remains on land for up to 100 days and more (fasting)
- Goes back to sea at end of the season (late November)

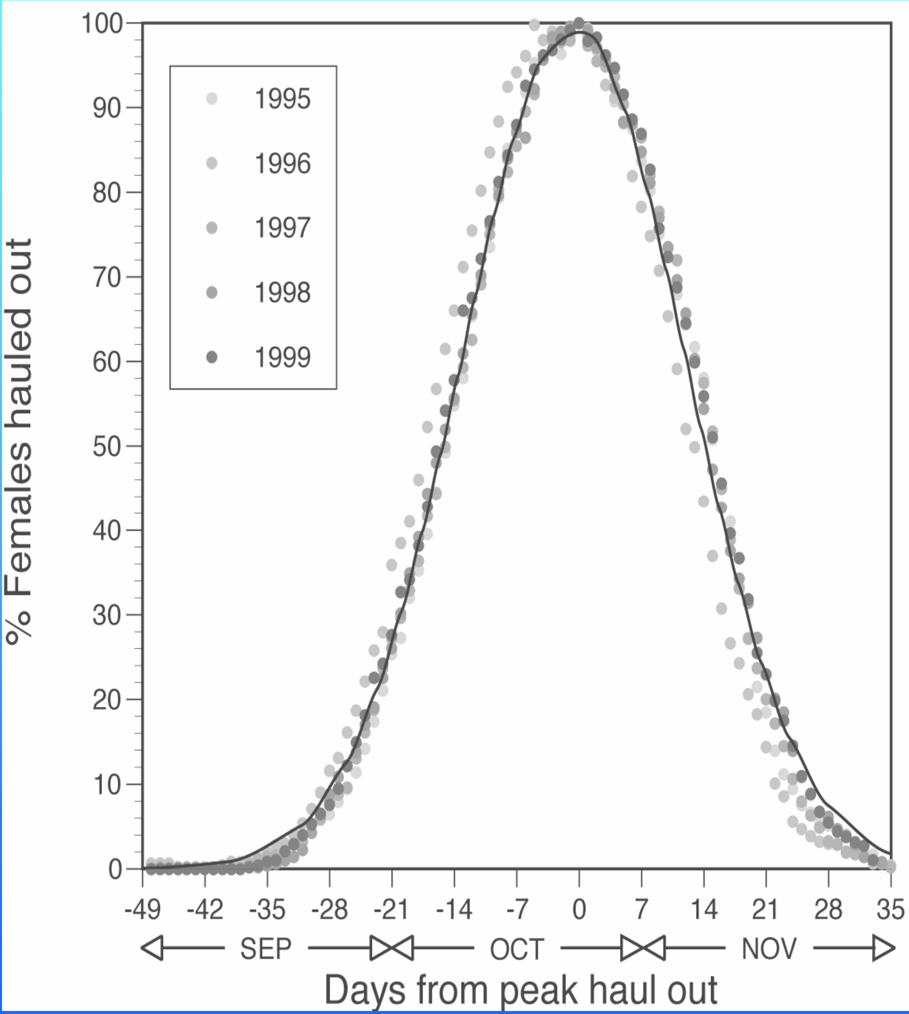
The Sea Lion Island Population

- Part of South Georgia stock
- Small and localized: a mean 550 breeding females
- About 95% of the whole Falklands population
- Harem size: 2-125 females (median 37)



Sea Lion Island Demography

- Females have a predictable pattern of presence on land
- Females haul out: 2nd week Sept - 3rd week Nov
- Peak haul out: 19-20th of Oct, approx. 480 females
- Mean productivity = 522 pups per year
- Very low pup mortality (about 3%)
- Estimated total population = 1820 animals in 1999
- Stable population size from 1989, with fluctuations



Rationale of the project

- *Small and localized population*
  - Easy tracking of individuals
  - Low or null immigration and emigration
- *Long-term duration*
  - Lifetime individual records
  - Data spanning full cohorts of individuals
- *Comprehensive approach to breeding biology*
  - Big effort put on simple field data-collection techniques
  - Use of advanced technologies when needed

Main goals of the project

- Sexual selection on males: from structural phenotype to communication
- Phenotypic and social correlates of maternal investment
- Individual breeding strategies and life history evolution
- Population genetics: from individuals to stocks

Specific research objectives

Male mating tactics

- Male agonistic behaviour and dominance
- Effect of male structural phenotype
- Hormonal correlates of dominance
- Role of male acoustic communication
- Mating and harassment of females
- Mating tactics and genetic paternity

Specific research objectives

Breeding strategies of males and females

- Long term study of individual life histories
- Age-specific variation of breeding effort
- Female parental investment
- Effect of female phenotype on investment
- Effect of local socionomy on investment
- Parental investment and pup survival

Specific research objectives

Population-level correlates of breeding

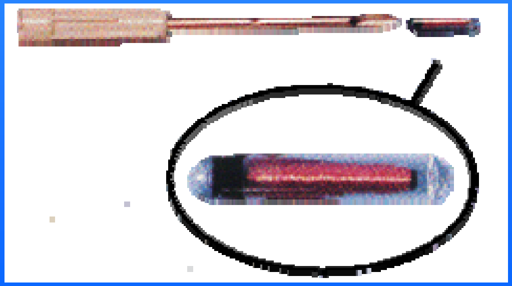
- Effects of variations in demography and population dynamics on breeding
- Movement at sea and feeding strategies of breeding individuals
- Genetics structure of the population, migration, and gene flow towards other populations of the stock
- Population viability and long-term forecasting

Study of individual life histories

- Individual recognition is essential to study ecology and behaviour at the individual level
- It is the only way to estimate demographic parameters for forecasting and viability analysis
- In large samples of animals requires artificial marking

Marking of animals

- Tagging: nylon cattle tags in the rear flippers
- Dye marking: hair dye marks on back and flanks
- Pellets: oil based paint pellets applied with a soft air gun or a slingshot
- Passive transponders: microchips implanted above the tail, and read with a “Star Trek-like” device



Daily counts: Demography

- Daily counts of the breeding beaches
- Collection of data on the social structures: count per sex and age and identification of individuals
- Weekly counts of the whole island

Spatial distribution on land

- GPS mapping of individual males and isolated females
- GPS mapping of harems throughout the breeding season
- GPS mapping of pups during the post-weaning dispersion

Some technical information on our GPS set up

Male breeding

Competition, dominance and mating tactics

- Very strong male competition for the access to females
- Only few successful males actually reproduce
- Competition through conventional contests and actual fights
- Observation of male agonistic behaviour (7154 hours from 1995 to 2000)

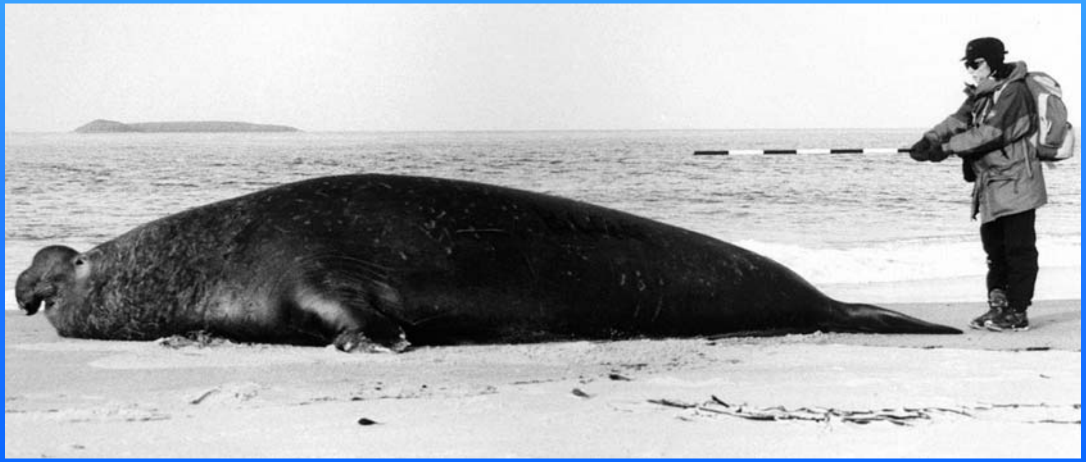
Male agonistic behaviour

Male size and shape

Photogrammetric techniques are used to obtain :

- Measures of standard body length
- Estimates of body weight from lateral area
- Measures of sexual traits (trunk and canines)
- Indices of asymmetry of hind and rear flippers

The goal is to study morphology and growth using non-invasive methods only.



Acoustic communication

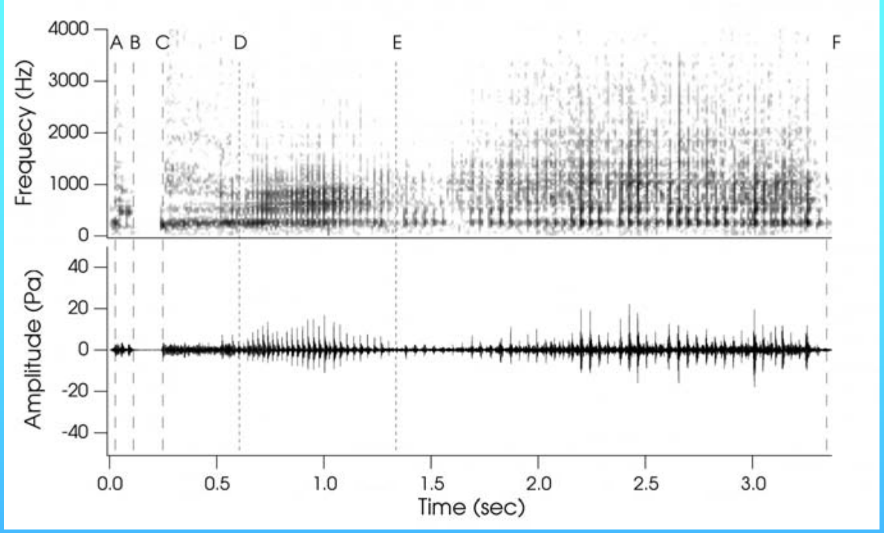
The role of vocal communication in male contests

Recording of male vocalizations in standard condition of stimulation: the male react to the researcher as he do toward another male

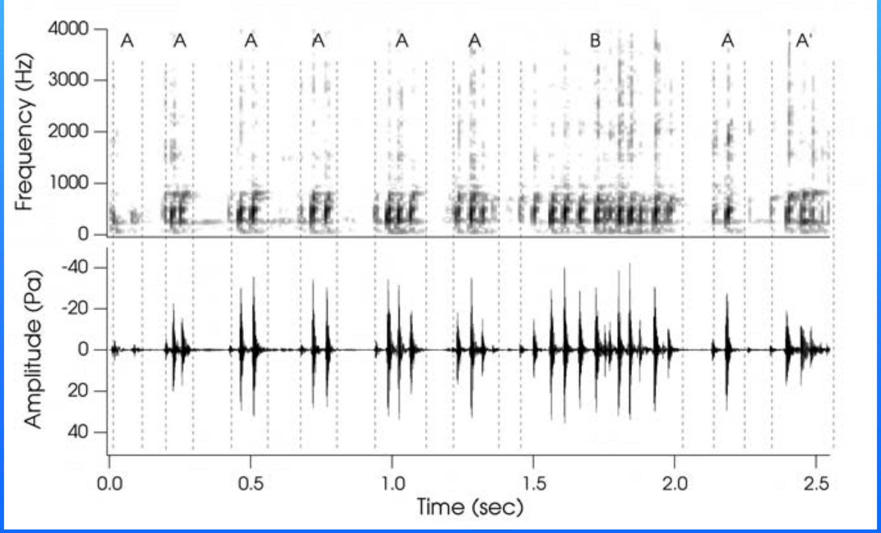
- To study the onthogenesis of vocalizations
- To evaluate the function of vocalizations
- To study the phenotypic correlates of vocalizations

Male aggressive sound kinds

Continuous vocalization

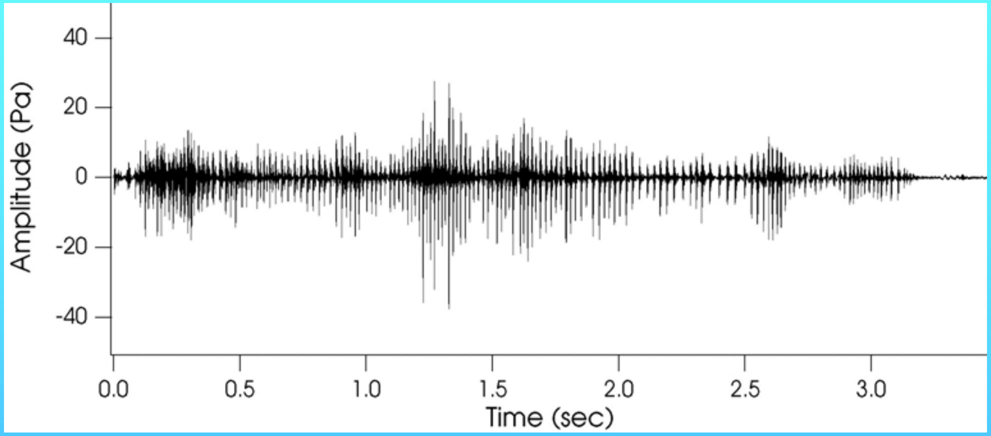


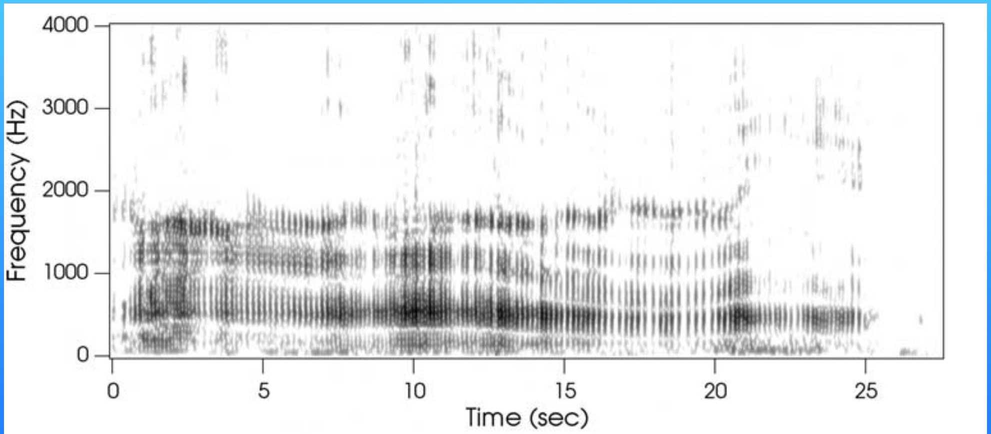
Drumming vocalization



Male submissive vocalization

- Produced by losing males at the end of a fights or interactions
- Higher pitch respect to aggressive vocalizations
- The changes in behavioural posture are mirrored by the changes in acoustic structure

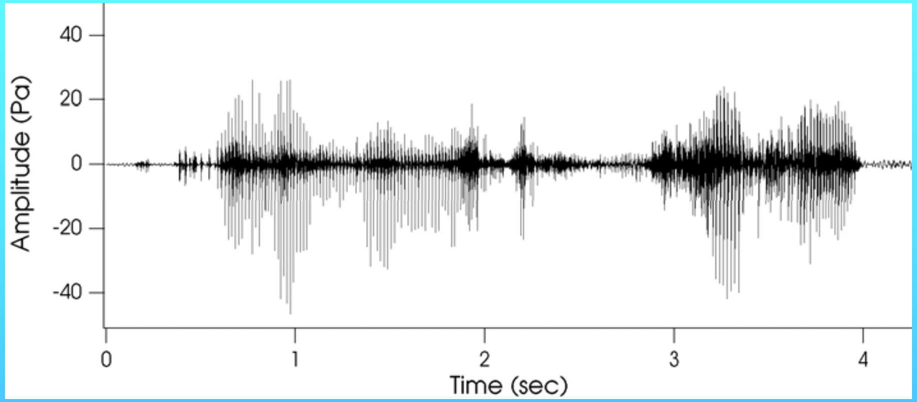


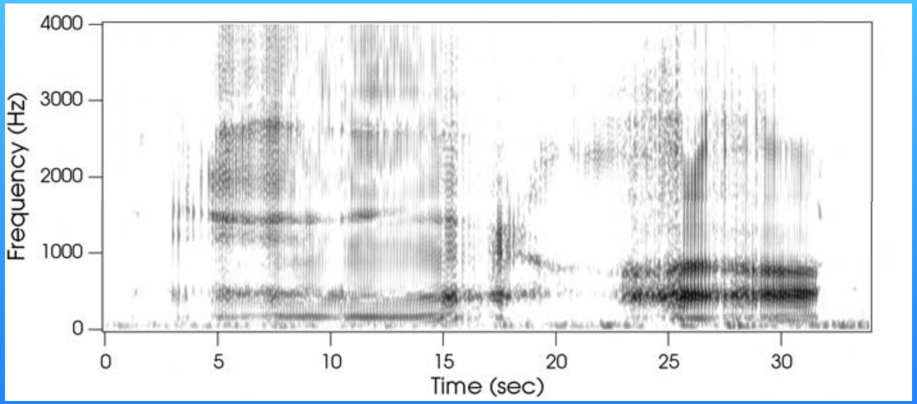


Submissive

Aggressive

Female aggressive vocalizations

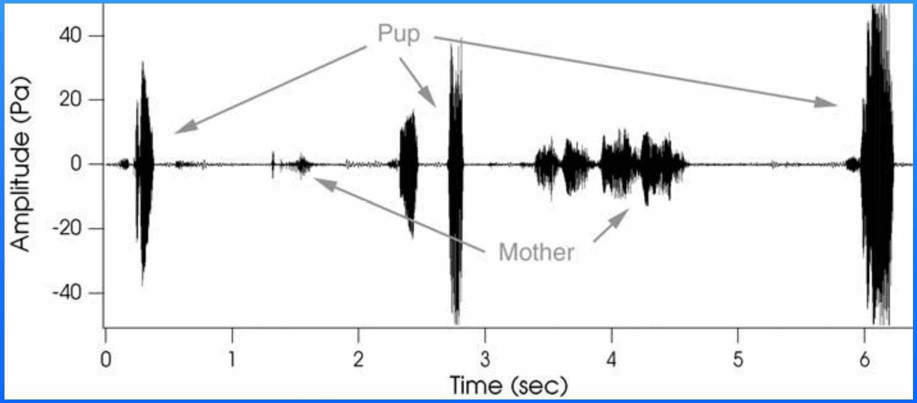


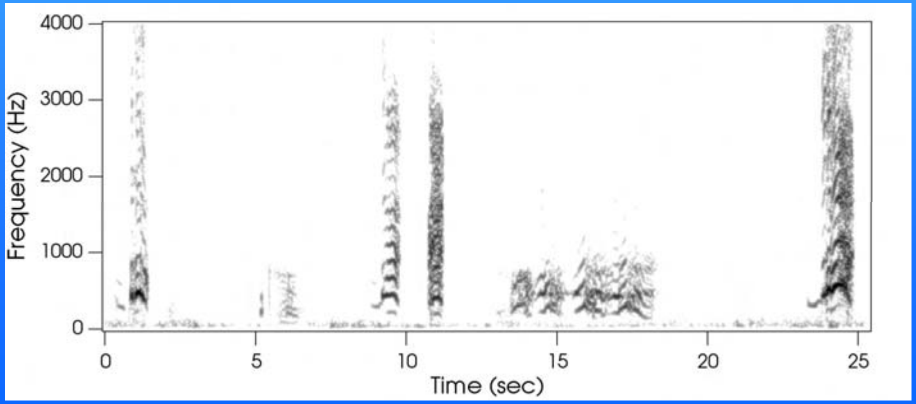


Produced towards other females to keep them away from the pup, or towards approaching males

Mother -pup vocalizations

- Produced by mothers and pups towards each other
- Used for individual recognition, to maintain contact
- To induce mother to take the right position for suckling



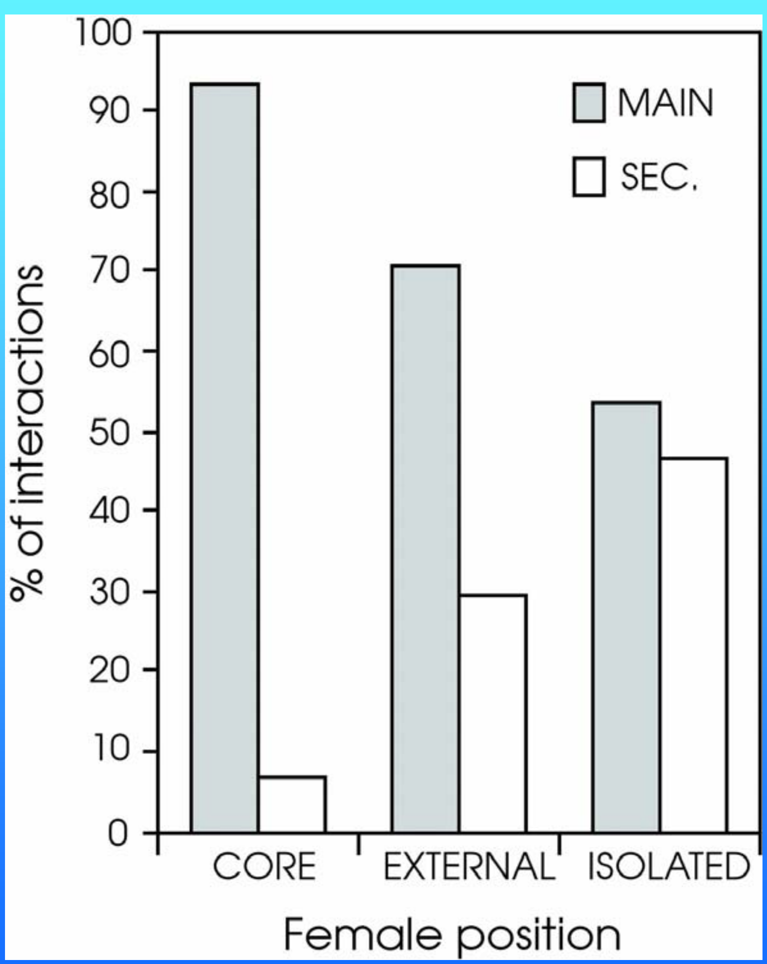


Harassment: costs for females

Harassment:

- Produces a disruption of female time budget and suckling schedule
- Has a slight effect on weaning weight, evident only in very large versus small harems
- Almost never results in pup abandonment
- Almost never results in physical damage of females, and reduction of survival

Harassment: female strategies



- Synchronized breeding to reduce harassment (risk dilution)
- Avoidance of solitary breeding (reduced rate of encounter with sub-adult males)
- Preference for larger harems (lower per-capita harassment rate)
- Tactics to avoid interception during departures to sea

Parental investment

- Pup measurements as indices of maternal investment
- Weight at birth and at weaning
- Structural size and shape
- Total pre-weaning growth, and pre-weaning growth rate
- *Weighing without any chemical restrain, and very short handling time*

Some weighing results…

Hormones and physiology

Collection of blood samples for hormones analysis

- To study the correlation between male testosterone levels and breeding and agonistic performance
- To determine the potential physiological stress on weaned pups due to handling and humane disturbance
- Development of a non invasive method for blood collection

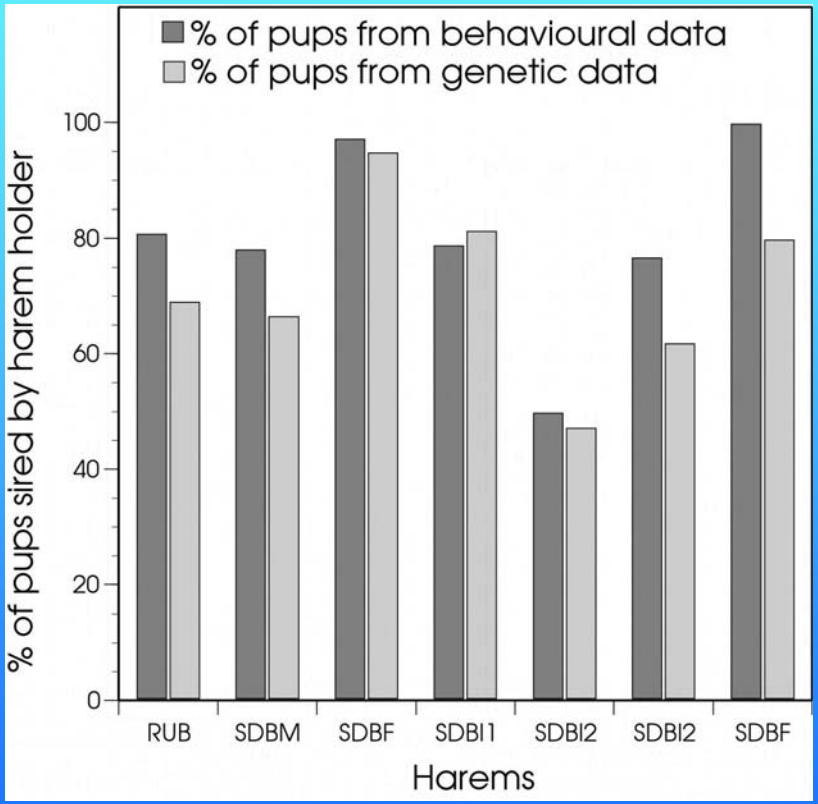
Genetic studies: rationale

- To determine genetic paternity of individual males and compare it with behavioural measures of mating and fertilization success
- To discover undetected cases of pup-mother mismatches and adoptions
- To analyse the genetic structure of the Sea Lion Island population (relatedness, genetic sub-structuring)
- To compare the genetic structure of Sea Lion Island population to the other populations of the South Georgia stock

Genetic studies: methods

- Collection of skin samples (few grams) using ear-notchers and biopsy heads mounted on a pole
- DNA extraction and amplification using PCR (polymerase chain reaction)
- Genotyping using microsatellite markers and fluorescent dye labelling
- Statistical analysis of paternity, and intra- and inter-population genetic structure

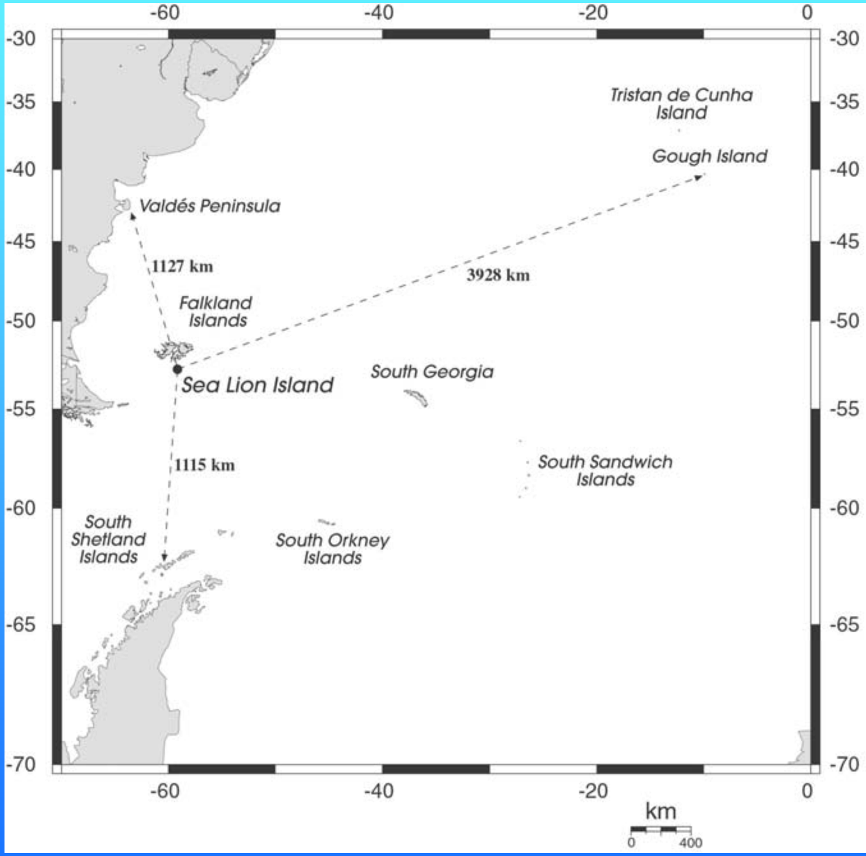
Genetic studies: results



- Behavioural measures of mating success agree with genetic paternity
- Reproductive success is strongly skewed: only few males sire most pups
- Harem holders monopolize fertilizations in their harems
- Genetic structure of the population is intermediate among South Georgia and Valdés Peninsula

Movement at sea

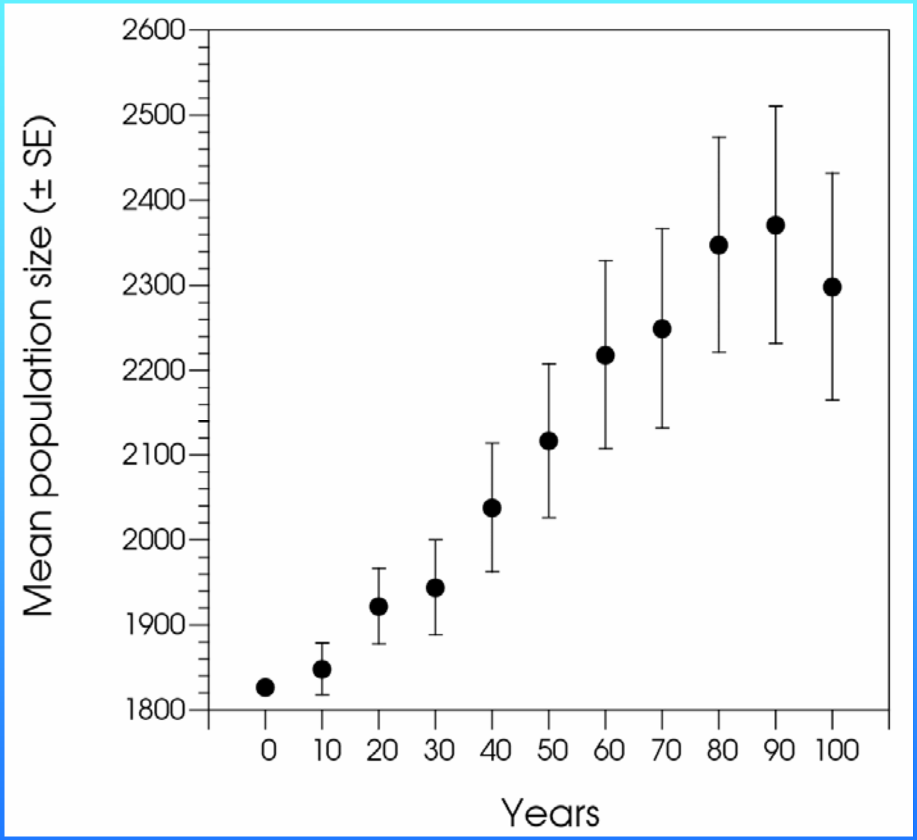
Information on the aquatic phase of the cycle



Deployment of satellite tags:

- To determine the location of the feeding areas
- To explore the differences in feeding locations among sex and age classes
- To evaluate the interaction among seals and fishing activities
- To study the migration patterns in relation to genetic studies

Population viability



- The population appears healthy, although not increasing
- Notwithstanding the small size the likelihood of extinction in the medium term is small
- The crucial component of the population dynamics is survival of mature females during the first breeding years
- Information on feeding areas and movements are badly needed

Sources of seal information

Additional information on elephant seals, and seals in general, is available on the Internet:

- ESRG web page
- Literature on elephant seals
- Seal Conservation Society
- Sea Mammal Research Unit

Inquires on the ESRG and the Sea Lion Island project should be directed to Dr. Filippo Galimberti by e-mail (fgalimbe@libero.it)

The end

Thank you for your kind attention

Press the ‘Esc’ key on you keyboard to exit

More: Male agonistic behaviour

Male agonistic behaviour in southern elephant seals comprises two components, conventional assessment and direct aggression: both are very important in establishment and maintenance of dominance relationships. Assessment through visual and acoustic threats is more frequent than direct aggression and it is used to settle the most of the contests, especially between males with large differences in resource holding potential. Aggression through direct interaction with physical contact and long all out fight, although less frequent, is of crucial importance in the initial phase of settlement of dominance relationships between males with almost equal RHP. Specific tactics and strategies of competition adopted by individual males are well correlated with both structural and behavioural phenotype. Variance in behavioural performance between males is very large, and larger than the one measured for simple structural traits. The specific breeding situation has a significant effect on the relationship between performance in competition and breeding success, but the same basic trend is apparent in all places. Results of agonistic interactions set up dominance hierarchies, and these hierarchies are long lasting and strongly linear, both at local and population level. Excellent performance in competition between males is a fundamental requisite to high breeding success, however the local variation of parameters like breeding sex ratio and density of competitors moulds the strength of this link: stochastic factors, and factors with a deterministic nature but almost unpredictable by individual males, change the rewards of effective competition tactics in different areas.

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More: Male structural phenotype

The most amazing fact about elephant seals is the huge difference in size and morphology between males and females. Males may weight up to four tons while maximum recorded weight for females is around 700 kg, and the most of them are notably lighter. Males are provided by a proboscis, enlarged canine teeth and a stiff dermal shield in the chest. All these characters may be the result of evolution by sexual selection, driven by the role of these traits in competition among males for access to breeding females.

Body size is an important component of both fighting behaviour and fasting endurance. The larger males frequently win the agonistic contests, although most evidences on the role of body size in determining dominance rank are anecdotal, and even males which are small for the age and status class may occasionally be very successful. Moreover, we expect larger males to be able to fast during the breeding season for longer periods. Canines are used to bite during contests, and the dermal shield is an effective defence against bite, although the most exposed to bites part of the body is the the trunk.

The trunk seems to have the footprint of a sexually selected trait, i.e., it is an extreme exaggeration of the nose, it seems useless in everyday life (and frequently represent an obstacle), and it is kept retracted when the male is not in the breeding phase. It has been suggested that the trunk could be a target of female choice: males with larger trunk may be selected by breeding females as mating partner, although this seems somehow unlikely due to the scarce opportunities for females to effectively choose their mate.

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More: Hormones and dominance

Mammalian behaviour regulated by hormones. In particular, male aggressive behaviours are related to testosterone. Although there are many evidences of this regulation from experimental and laboratory studies, the testosterone control of male behaviour has been not explored in details in natural populations, where the hormonal status of an individual interacts with a full array of social stimuli. This is particularly true for seals and sea lions. In both northern and southern elephant seals, the beginning of the breeding season is characterized by both an increase in the level of aggression among males and in the level of circulating testosterone. Different males arrive on land during the breeding season at different times. Each male usually requires a variable span to fully come into breeding condition, and start to actually compete for females. Our hypothesis is that the day-by-day behaviour of breeding males is not moulded only by the social context but also by his hormonal status.

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More: Competition and communication

Acoustic communication is a fundamental aspect of elephant seals social behaviour. Most of the studies concentrated on the northern species, while scarce information is available for the southern species. The most striking aspect of acoustic communication in southern elephant seals is male use of vocalizations to establish and maintain dominance. Agonistic contests have a stereotyped structure and almost invariably involve the emission of sounds by the contestants. The study of male vocalizations on Sea Lion Island revealed an high repeatability in the structure of sounds emitted by each individual, along with a very large variation of sound structure between individuals. This pattern of intra-individual constancy is evident both from in the macrostructure of the sound (i.e., its composition in syllables and part of syllable) and in the acoustic parameters (e.g., the fundamental frequency). Notwithstanding this general constancy, there is also a substantial variation in acoustic parameters of the sounds emitted by a male in different moment of the breeding season. Evolutionary theory predicts that only signals that are good and honest indicators of phenotype quality may be maintained in steady state in natural populations. Hence, we expect elephant seals aggressive vocalizations to be correlated to male structural phenotype and his physiological state. All these traits are prone to substantial variation during the breeding season: vocal performance may be affected by the variation in hormonal levels and breeding status, or by variation in weight due to fasting.

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More: Harassment of females

Sexual harassment is the use by males of aggressive behavioural modules (like herding, pushing, biting, chasing) when approaching females during the breeding season. Male harassment of females is probably an important factor in evolution of mammals mating systems. In most mating systems, males compete for females and are usually more eager to mate with any partner and at any time than females, and this conflict between sexes about when and how much to mate lead to sexual harassment.

Female southern elephant seals gather in large groups during the breeding season. Each group has one or more associated males, and one of them has usually a more or less complete control of the harem. Hence, the mating system is very despotic, and just few males have free access to breeding females. This shortage in mating opportunities is coupled with a very high level of libido of all males. Males may attempt to mate with dead females, weanlings, yearlings and small juveniles, and even with individuals of other species (in the northern species inter-specific sexual harassment is frequent). Moreover, males are larger than females, they have enlarged canines, and they constantly show behavioural patterns of herding and biting while interacting with females. Hence, males could be a significant source of harassment for females, and sexual coercion could be an important component of male mating tactics. Preliminaries are short in southern elephant seal mating behaviour, and males are often able to overpower females; cases of forced copulation happen regularly, although not frequently. Hence, male-female interactions are potentially a very risky business for the female. For a female one or few copulations should be all the needed breeding activity: extra copulations and non mating interactions with males have no functional value for the female and may represent a significant cost. Hence, most male-female interactions may be considered a form of sexual harassment from the point of view of the female.

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More: Genetic paternities

The final goal of breeding strategies is to sire offsprings. Therefore, the complexity and variability of mating tactics should, in principle, be related to the optimisation of genetic paternities. All populations of elephant seals studied until now have an harem mating system, with few males that seems to monopolize copulations. On SLI, most harems tend be larger than fifty females, and every season there are at least two harems with more than one hundred. In most cases, harem holders are able to mate with all their females as soon as they come into oestrus. Even holders of large harems (> 110 females at peak) are able to maintain almost exclusive mating access, doing more than 95% of all copulations observed in the harem. Notwithstanding this, females usually mate with more than one male, and they are frequently intercepted by peripheral males when they leave harems to come back to sea. The result is that also non-holding males are usually able to mate, and many females copulate with other males apart from their harem holder. Therefore, the problem is to verify the relationship between mating success and genetic success, a relationship that may be complicated by timing of mating, mating order among males, sperm competition and post-mating female selection (e.g., by differential use of sperms of different males).

The preliminary results of an ongoing study of genetic paternity point towards a very good agreement among observed mating success and paternities in the Sea Lion Island population. Both the variability in mating success of different males, and the variability in the number of pups they sired, seem much higher on Sea Lion Island than in other populations of both southern and northern elephant seals.

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More: Individual life histories

The final goal of our project is to estimate lifetime breeding success of both males and females, and to relate it to the specific lifetime record of each individual. The study of long-term breeding strategies of individuals in long living species requires very long-term research projects. In these species, each individual has a chance to breed during many different seasons. Therefore, the effectiveness of a particular strategy of allocation of breeding effort may change from year to year, and what really matters is the net lifetime payoff. Studies of individual breeding strategies of long living species are rare. The main reason is the low productivity of the work, and the long delay required before getting results. On the other hand, long term longitudinal studies of marked individuals are the only way to solve the drawbacks associated to cross-sectional design. There are obvious advantages in concentrating on small and localized population for a long-term longitudinal study:

• it is feasible to mark and recognize across years all the breeding individuals, permitting the build up of a very accurate longitudinal database

• the risk of loss of marked individuals due to emigration is very small, because of the lack of alternative breeding sites close to the main population

• the likelihood of undetected mixing of different cohorts, due to immigration of non marked individuals, is also small because of the isolation from other populations

• the estimation of selection parameters is improved, the risks of sampling bias is reduced, and the effects of variation in local demography and age structure may be controlled.

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More: Age and breeding effort

Breeding effort is the sum of all expenditure of a breeding individuals, evaluated in term of time, energy, physical damage, reduction of expectation of survival. Life-histories theories predict a variation on breeding effort at different ages for species that breed more than one time in their life.

In elephant seal we expect a different age-specific variation of breeding effort among the sexes. Females start breeding at mean age of 4 years, and they may then carry on for up to 17-18 years, producing almost every year a single pup. On the contrary, males, although physiologically mature at 4-5 years, usually are not able to get control of an harem until much later. Moreover, a male usually breed for one or few seasons, during which he may even achieve a seasonal breeding success hundreds of times higher than a female.

Therefore, we expect females to adopt a strategy of gradual allocation of their resources to breeding, that will permit to maximize their reproductive output over the whole span of a long breeding lifetime. On the contrary, males should contain their breeding effort, and optimize the resources invest on growth, until they reach an age, size, and experience, suitable to effectively compete for control of an harem.

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More: Female parental investment

A core aspect of the study of breeding strategies is parental investment, which in elephant seals is almost completely on the side of the mother. Although female investment was studied in various elephant seals populations nothing nothing was known about the Falklands population before the beginning of our research. Moreover, some of the possible factors affecting parental investment received little attention in the literature. For example, no study has yet examined the role of harem structure, that may heavily affect the risk of molestation for females, and, therefore, their capability to suckle the pup.

To characterize female investment we are collecting data at individual level on:

- the timing of investment (day of arrival on land, length of permanence on land, length of the lactation)
- the time budgets (proportion of active time, proportion of time spent interacting with the pup, suckling time)
- spatial aspects related to investment (movements between arrival and parturition, changes of breeding units, position inside the harem)
- various behavioural measures of parental investment (number of suckling bouts, duration of suckling bouts, suckling efficiency)
- various structural measures of gestational investment (size and weight of pups at birth)
- various structural measures of post-birth investment (size and weight of pups at weaning, growth rate during suckling, weight loss of pups after weaning)

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More: Female phenotype and investment

In principle, the phenotype of the female may greatly affect her capability to invest in the pup. A bigger mother may be able to produce a bigger pup both at birth and weaning. An older and more experienced mother may be able to invest more efficiently, and, therefore, produce a bigger pup than a less experienced mother of the same size class.The effect of experience may be related to a better choice of the pupping harem, or to an higher efficiency in suckling.

A preliminary analysis of a large database of weights, collected on Sea Lion Island both at birth and at weaning, revealed that bigger mothers are in fact able to produce bigger pups at weaning. This effect holds both for male and female pups. Moreover, even after the removal of the effect of size, more experienced mothers, i.e., mothers that were recorded breeding on Sea Lion Island for longer, produced bigger pups.

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More: Socionomy and investment

Apart from depending on the female phenotype, investment could also be moulded by the local demography and socionomy of the harem where the female breed. The level of molestation by peripheral males that a female suffers, changes among harems, and is related to both the harem size and the number of males associated to it. The level of molestation, in turn, affects the time budget of females, reducing the resting time, and, hence, increasing the energy expenditure. Moreover, molestation may disrupt the suckling schedule, result in mother-pup separation, and even affect the physical condition and health of the female, although these phenomena are quite rare, al least in the Sea Lion Island population. Different females experience different levels of molestation, depending on the position they occupy in the harem and their propensity to react to approaching males. Marginal females are more exposed to peripheral males and suffer an higher level of molestation. We expect, therefore, a variation in parental investment related to the level of molestation, and, in turn, to the local breeding situation. The per-capita level of molestation is lower in larger harems, in part because of a dilution effect (molestation is shared by an higher number of females) and in part because larger harems are controlled by better holders, that are more capable to keep peripheral males away. A comparison among smaller and larger harems gave a preliminary confirmation of the affect of the local socionomy on investment. After controlling the effect of size and experience of mothers, we discovered that pups born in large harems are heavier than pups born in small ones, although the difference is quite small.

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More: Investment and pup survival

Parental investment should be related to the likelihood of survival of the pup. Pre-weaning mortality in elephant seals of Sea Lion Island is very low. The same holds for the post-weaning phase in which pups remain on land. Therefore, to be effective, parental investment should improve survival during the first aquatic phase of the life cycle, when pups go to sea for their first feeding trip. Pups fast while on land after weaning, and, therefore, start their first search of a feeding area after having lost a significant percentage of their weight. In principle, a pup which is heavier at weaning, should be also heavier when leaving the island for feeding, and, hence, should have a better chance to survive until reaching the food. Therefore, we expected heavier pup to have an higher chance to survive to their first feeding trip. Evidences on this aspect are unfortunately scanty, because it's not easy to accurately estimate survival during the first year of life.

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More: Demography and breeding

The variation in the local demography of the population may greatly affect mating tactics and breeding strategies. The opportunity to mate of a male elephant seal depends on the number of females, their density and distribution in the various harems, the number of competitors, and the ratio among breeding males and females. On the female side, the breeding success will depend on the density of harems, and the resulting rate of aggressive interaction with other females, and on the number of males associated to the harem, that affect molestation level.

Most behavioural studies concentrate on a small number of breeding units, and this may produce a notable bias in the results if the social behaviour depends on the demography and socionomy of the unit. This effect was clearly demonstrated in studies of social primates, but has been almost ignored in study of seals, and elephant seals in particular. During a previous, short-term, study of southern elephant seals of the Valdés Peninsula (Argentina), we found clear evidences of a large variation of the demography and socionomy of harems and breeding areas. This variation was related to a variation of the frequency of alternative mating tactics and of the mating success of harem holders and peripheral males. Therefore, we expect both inter- and intra-population variation of demography to strongly affect mating and breeding.

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More: Feeding and breeding

Both male and females elephant seals fast during the breeding season. Their breeding effort is therefore strictly related to their energy reserves, and, in turn, to their capability to get food during the aquatic phases of the life cycle. Bigger reserves mean bigger capability to invest in the pup for females, and to stay longer and compete harder for males. Although we have detailed breeding records of most Sea Lion Island seals, we have almost no information about what they do when they are at sea. The study of sea mammals at sea is now much easier due to the wide availability of technologies that permit accurate 3D tracking of individuals at sea. There are clear indications that individuals of different populations of elephant seals have different at-sea moving and feeding styles, although pretty similar diet. Moreover, also different individuals of the same population seem to adopt different moving and feeding strategies. This variation is probably adaptive and could be well related to variation in breeding success. Unfortunately, now research until now has been able to effectively related feeding at sea to breeding on land for specific individuals. Apart from the importance for our breeding strategies study, a good knowledge of the feeding areas and strategies has an obvious applied value. The status of the population will depend in the end to the opportunities for its individuals to access food resources. The Sea Lion Island population is currently steady, and the reason of this lack of increase, notwithstanding the low density and pup mortality, is probably related to some limiting factor during the aquatic phases.

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More: Genetic structure

The recent advances in molecular biology techniques permit to directly tackle problems of genetic structure at intra-population an inter-population level. In elephant seals, the high breeding site fidelity, the social sub-structuring in harems, and the high level of polygyny, point towards some degree of genetic structuring of local populations. On Sea Lion Island, females tend to return to same breeding area, or even harem, of the previous breeding season. Most females give birth within 500 metres from the location of their previous parturition. Therefore, we expect the genetic differentiation of the local population is sub-units that should correspond to social sub-units. We are currently working on this aspects using microsatellite DNA markers on samples of breeding females of various harems.

Regarding inter-population structure, preliminary evidences from mark-recapture data indicates that migration of breeding individuals to and from other breeding populations is currently low. On the other, the migration of just a few individuals may produce a notable gene flow among populations, in particular if the migrating individual is a successful male. The Falkland Islands may in principle represent, due their geographical position, a conduit for gene flow among the two main populations of the stock, South Georgia and Valdés Peninsula. We are currently testing this hypothesis using mithocondrial DNA markers.

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More: Viability and forecasting

Although our research project is focused on theoretical aspects of evolutionary biology, we are also working on more applied aspects. In particular, we are using our large and accurate database on demography of the population to estimate viability and forecast the future population dynamics. The modelling of natural populations of species with complex life cycle is complicated because of the many parameters involved, many of which are difficult to estimate. Age-specific survival rates of males and females, and female fecundity rates, require long-term data series to be accurately calculated. Unfortunately, practical conservation and management problems require to forecast the status of the population before actual data on demographic parameters are available. The most popular solution is to use the available data to estimate as much parameters as possible, and to use computer simulations to explore the effect of the variability of unknown parameters, an approach that is called “population viability analysis” through “Monte-Carlo simulation”. We recently employed this approach to Sea Lion Island population with a good success. We have very good estimates of the current size of the population, and of various demographic parameters (including fecundity, sex ratio at birth, mating sex ratio), but our time series are too short to provide good estimates of age-specific survival rates. By simulating a range of values for these parameters that we know only approximately, we were able to conclude that the population is currently steady, that there is no risk of extinction in the medium term (we predicted a small increase for the following 100 years), and that the crucial class of the population are adult females during the first 3-4 years of their breeding life.

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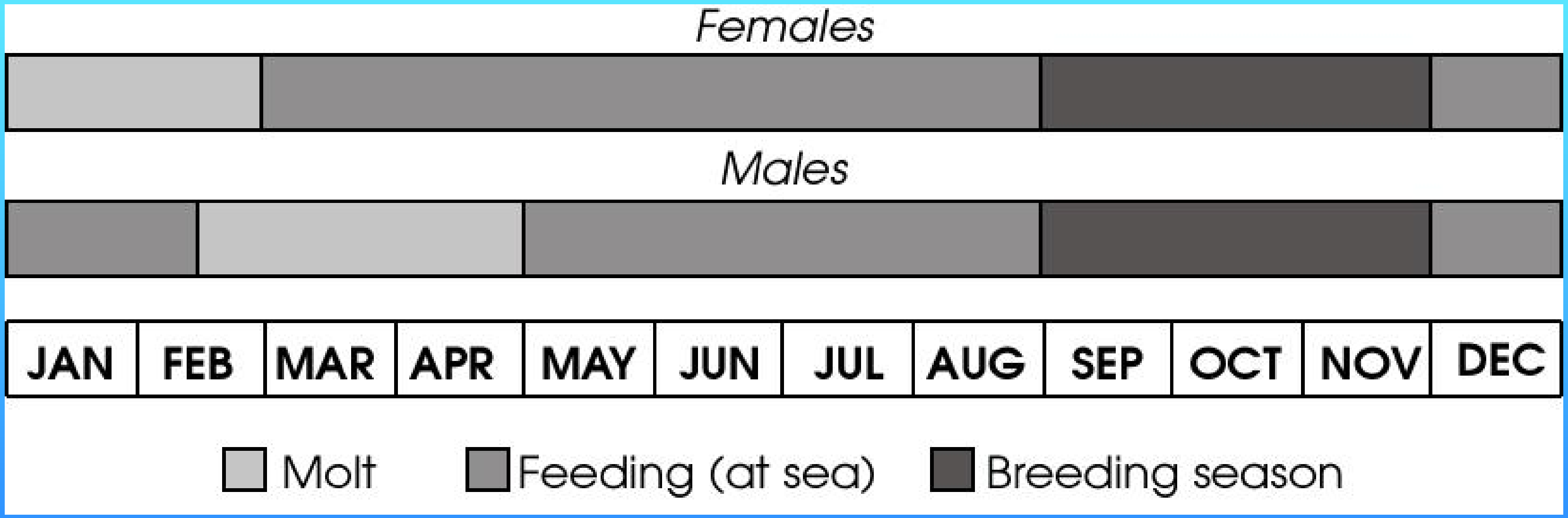
The elephant seal life cycle



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The Mirounga genus

The genus Mirounga comprises two species, the southern elephant seal (*M. leonina*) and the northern (*M. angustirostris*). Northern elephant seals breed in California and Baja California, mostly on offshore islands but also on the mainland (in particular , in the Ano Nuevo Reserve near Santa Cruz). Distribution of feeding grounds at sea is much wider, with some individuals reaching the Gulf of Alaska. Northern elephant seals were hunted almost to extinction during the 19th century, but after the introduction of protection laws in the United States and Mexico the species recovered at fast rate, and expanded outside its previous breeding range.

For many aspects, the two species of the genus Mirounga are very similar: external appearance, behaviour at sea, movement on land, gross traits of mating system and reproductive behaviour. The first difference is size, with the southern species much larger. In northern elephant seals maximum weight is about 2300 kg for males versus 3700 kg for southern, while females are more similar. On the contrary, secondary sexual traits are more developed in the northern species: the trunk is longer, and the neck and chest shield is more developed.

The two species have similar breeding cycle, but they breed at different time of the year (January-February in the northern species, September-November in the southern), and present differences in breeding strategies: in particular, length of lactation is longer in northern elephant seals (24-28 days) than in southern (22-23), and also post-weaning fast is longer (56-74 days versus 37).

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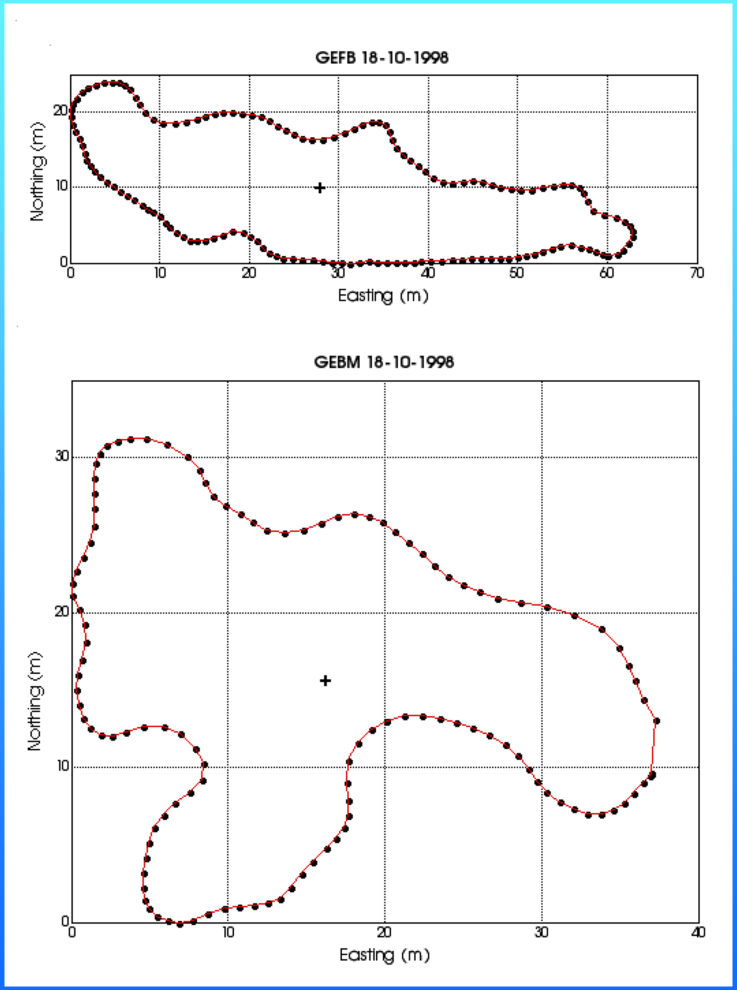
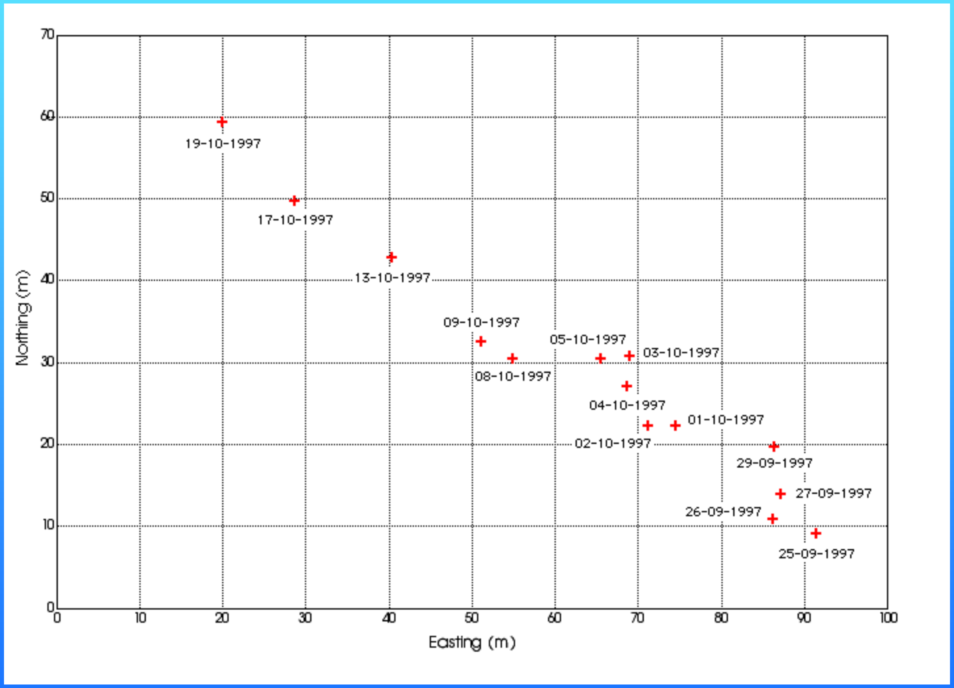
Mapping of harems

Outlines of two harems with a similar number of females



Seasonal variation (“migration”) of the centroid position of a large harem



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GPS technical info

GPS is now a well established method to collect wildlife positional data. Our GPS system was set up to achieve metric-level precision before suppression of Selective Availability. We used a meter-precision GPS system composed by two Magellan ProMarkX receivers one to be used as base station and the other as rover, and dedicated software for differential post- processing of data (MSTAR, Magellan Systems Corp.). To map position of individuals, we simply approached the resting individuals from the back and gathered 90 seconds of position at 1 position per second rate. To map harems we used mobile differential and walked around the harem trying to stay as much close to the peripheral females as possible (distance always < 1 meter), collecting a few minutes of positions at 1 position per second. We mapped every 3-4 days all the harems of the population, while one harem was mapped one or more times per day. This set up guaranteed a precision close to the practical limit of the system, i.e., < 3 m RMS.

More recently, we continued the mapping of harems using differential GPS, but, at the same time, we tested commercial, non corrected GPS, that, after the suppression of SA, could be suitable for positioning work that requires a lower precision. In particular, we were interested in mapping weaned pups position to study dispersion from harems after weaning. We discovered that plain commercial-grade, 12 satellites receiver, may guarantee, at least in our quite small study area, an excellent performance, with circular error always below 10 meters. Therefore, we used these receivers to map position of all weanlings every day of the breeding season. This positional information will now be imported in GIS software, to develop a model of weanling dispersion during the post weaning land phase.

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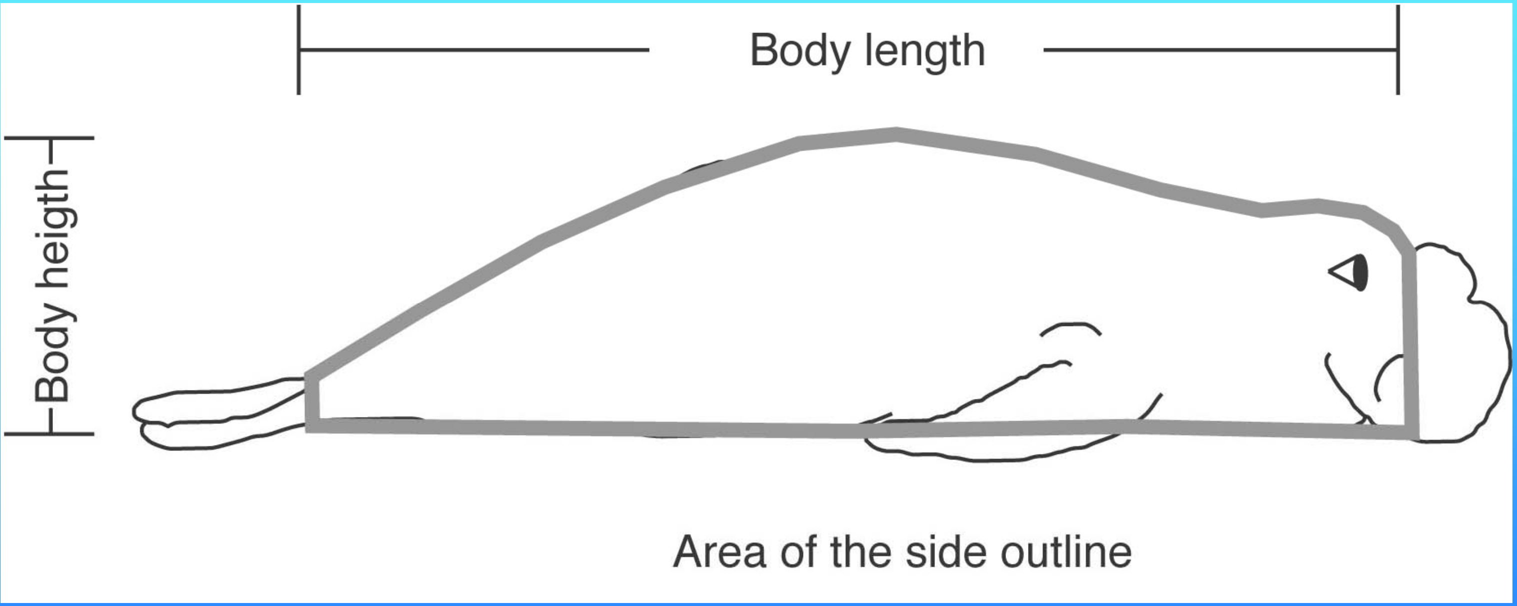
Body size measurement scheme



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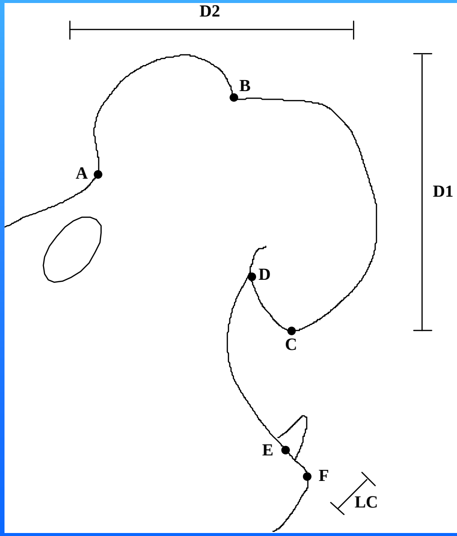
Measurement of the trunk and canines



The measurement of the trunk is a particularly complex task. To evaluate the social and behavioural role of the trunk, it should be measured when inflated. The advantages of using a photogrammetric method are in this case obvious. The measurement protocol is simple. A calibrated pole is put in front of the subject, roughly in line with the middle of the body. Then the usual vocal and visual threat display is elicited by one of the researcher, which tries to keep the middle of the male head in line with the pole. A second person takes a series of pictures from the side of the animal's head. A third person, if available, checks the alignment of the head with the pole. The photos are digitized and measured using a image analysis software, following the measurement scheme of the graph.

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Preliminary weighing results

The preliminary analysis of weighing data lead us to the conclusion that:

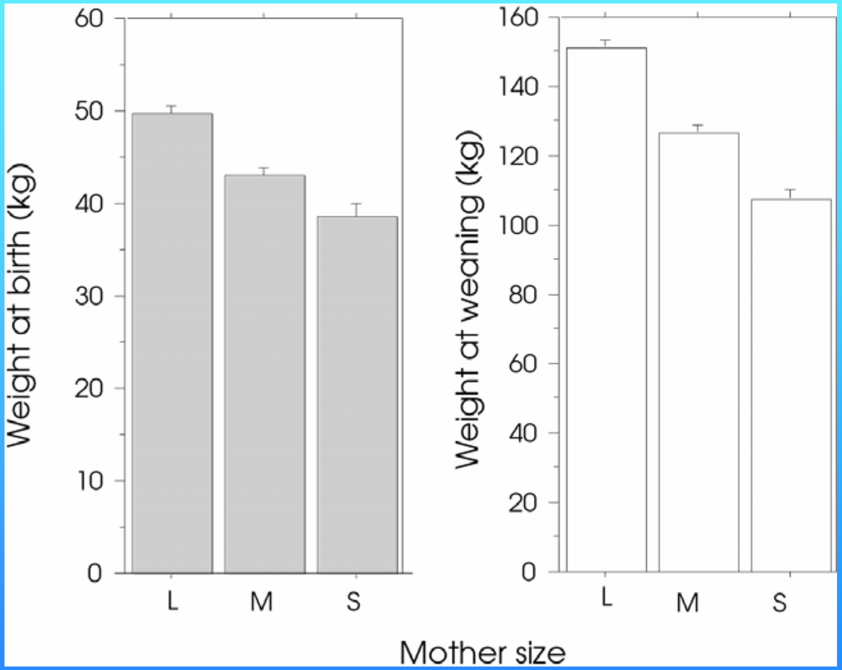
• mean weight at birth is about 46 kg, with males significantly heavier (49 vs 43 kg) and slightly longer (132 vs 128 cm) than females

• the difference between the sexes almost disappear by weaning, when females weigh about 133 kg and males about 139

• there is a huge individual variability of weaning weight, from 65 to 210 kg

• pups of bigger mothers are heavier and longer at birth, and they are also heavier at weaning (see graph); weaned pups of small mother weigh a mean of 107 kg at weaning, versus 151 kg for pups of large mothers

• mother size is the single most significant correlate of parental investment, and there is also a smaller effect of the mother experience, with older females being better able to suckle the pup



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