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# Recent population change of the southern elephant seal at Îles Crozet and Îles Kerguelen: the end of the decrease?

**CHRISTOPHE GUINET*, PIERRE JOUVENTIN and HENRI WEIMERSKIRCH**

*Centre d'Etudes Biologiques de Chizé, Centre National de la Recherche Scientifique, F-79360 Villiers en Bois, France*
**guinet@cebc.cnrs.fr*

**Abstract:** The elephant seal populations breeding on the Îles Crozet and Kerguelen were regularly surveyed over the last three decades. At Îles Kerguelen the number of breeding females decreased at an annual rate of 3.6% between 1970 and 1987, then increased at an annual rate of 1.1% to 1997. At Îles Crozet, the population was reported to decrease at a rate of 5.35 % between 1970 and 1990 but no change in numbers was found between 1990 and 1997. These results indicate that the rapid decline observed both at Îles Crozet and Îles Kerguelen has ended, and these populations are now either stable or slightly increasing. We suggest that broad scale change in environmental factors affecting the food availability for elephant seals may be responsible for the change in numbers of these marine predators. The higher rate of decrease, the longer period of decline, and the absence of any significant change between 1990 and 1997 observed on the Îles Crozet may be explained by additional factors such as killer whale predation.

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**Key words:** Îles Crozet, Îles Kerguelen, *Mirounga leonina*, population size, southern elephant seal

## Introduction

The southern elephant seal populations are divided into four main breeding stocks: (1) South Georgia, (2) Marion Island and Îles Crozet (3) Îles Kerguelen and Heard Island and (4) Macquarie Island. Monitoring studies of elephant seal populations have reported different population trends according to the breeding localities over the last four decades. South Georgia was the only breeding location where elephant seal numbers were reported to be stable (McCann & Rothery 1988, Boyd *et al.* 1996) while the other three populations, breeding in the Indian and Pacific sectors of the Southern Ocean, were reported to decline over the same period (Marion and Îles Crozet: Wilkinson & Bester 1988, Barrat & Mougin 1978, Guinet *et al.* 1992, Kerguelen-Heard: Pascal 1981, Burton 1986, Guinet *et al.* 1992, Slip & Burton 1999, Macquarie: Hindell & Burton 1987, Hindell *et al.* 1994). The highest rate of decline (5.7 % per year) was reported at Îles Crozet (Barrat & Mougin 1978, Guinet *et al.* 1992) and Marion Island (Bester & Wilkinson 1994). Elephant seal were reported to have declined to a lesser extent at Îles Kerguelen and Heard Island (Pascal 1981, Guinet *et al.* 1992) and at Macquarie Island (Hindell & Burton 1987). At Îles Kerguelen the decline stopped in the mid eighties and the elephant seal population was reported to be stable between 1984 and 1989 (Guinet *et al.* 1992).

The aim of the present study is to present the latest data for elephant seal numbers at Possession Island (Îles Crozet ) and at Îles Kerguelen and to discuss the recent population trends of elephant seal numbers within the Indian and Pacific sector of the Southern Ocean.

## Methods

Both at Possession Island and Îles Kerguelen adult females present ashore were counted by observers on foot. Counts of breeding females were corrected using a normal distribution model proposed by Pascal (1981). Pascal (1981) has shown that the Gaussian curve fits well the representation of the percentage of females ashore in relation to the total number of females coming on shore to breed. Other empirical haulout normal distribution models were later used by Rothery & McCann (1987) and Hindel & Burton (1988). All these models are sensitive to (1) the date of maximum haulout and (2) the percentage of females present ashore at peak haulout. The percentage of females present ashore at peak haulout is directly related to the arrival distribution and the average duration of period ashore for the female (Boyd *et al.* 1996).

For both Îles Crozet and Kerguelen, the average date of maximum haulout is 15 October (see Barrat & Mougin 1978, Pascal 1981, Guinet *et al.* 1992) which is similar to the dates of maximum haulout in other localities of the Indian sector of the Southern Ocean: Marion: 15 October (Condy 1979, Wilkinson 1991), Heard Island: 16 October, with no trends in changing dates of maximum haul out (Slip & Burton 1999). Furthermore, despite some small interannual differences in the date of maximum haulout for a given location, there is no evidence of a drift of the date of maximum haulout with time either for Îles Crozet (Barrat & Mougin 1978, Guinet *et al.* 1992) or Heard Island – same elephant seal stock as on Îles Kerguelen – (Slip &Burton 1999).

Very little variation was found in the percentage of females present ashore at peak haulout between localities estimated



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either from a normal distribution model (86%, Pascal 1981; 87% Boyd *et al.* 1996 in fig. 1), on the regular monitoring of individually identified females (86%, Guinet *et al.* 1992) or on the regular serial counts of cows, weaned pups and dead pups (88%, Slip & Burton 1999). Furthermore, Pascal (1985) found *a posteriori* that the best fit was obtained with an average female shore bout duration of 27 days, while in Boyd *et al.* (1996) the average duration of the prepartum haulout and lactation haulout used *a priori* a 27-day female shore bout duration.

At Possession Island from 1980–97 a census was done every year on every beach. Censuses conducted on Possession Island from 1966–76 (Barrat & Mougin 1978) were restricted to the main breeding locations. The total number of elephant seal females breeding on Possession Island between 1966–76 were estimated from the censuses conducted at Baie du Marin, Baie Américaine and la Hébé. From 1980–97, we calculated the percentage of females breeding on these four beaches relative to the total number of elephant seal females breeding on Possession Island. In the present study, on Possession Island: Baie Américaine and La Petite Manchotière are equivalent to Baie Americaine in the study conducted by Barrat & Mougin (1978). The census dates for the data published by Barrat & Mougin (1978) are unknown. We decided to consider that the censuses took place on the day of maximum haulout. The estimates of breeding female numbers should thus be considered as minima. At Possession Island, the number of elephant seal females is small enough to allow the precise census of all seals present ashore.

At Îles Kerguelen, censuses were restricted to the beaches of the Courbet Peninsula, where most of the population is thought to be breeding and where censuses were done in previous study (Pascal 1979, van Aarde 1980). Counting error was estimated in 1994, when 44 counts were made by two people counting simultaneously and independently. At Kerguelen most of the censuses are conducted within one or two days of 15 October and according to the Pascal (1981) model thus a ± 2-day change in the date of peak haulout between years should result in a maximum 2% change in our estimation of the total number of breeding elephant females if censuses are conducted between 13 and 17 October.

All the rate of population changes, over a defined study period, were calculated using an exponential least square fit on the estimated total number of breeding females calculated each year for that given period of time with:

$$Y = k\, e^{r x},$$

where Y is the estimated number of elephant seal breeding during the year (x), k is a constant and r the exponential intrinsic rate of population change observed over the study period. The annual percentage change was calculated according to:

$$(e^{r}-1) \times 100$$

The statistical significance of the product moment correlation coefficient obtained with the exponential least square fit was set at $P \leq 0.05$.

## Results

The 44 counts which were made by two people counting independently at Îles Kerguelen in 1994 showed no tendency for either counter to have a positive or negative bias and the average difference on each count was ± 1.3% (range 0–4.5%).

Results of the censuses conducted at Possession Island and on the Courbet Peninsula at Îles Kerguelen from 1990–97 are presented in Tables I & II.

On Possession Island, from 1980–97 (see Guinet *et al.* 1992 for the census data from 1980–89) we calculated that 61 ± 3% of the total number of breeding females were censused at Baie du Marin, La Petite Manchotière, Baie Américaine and La Hébé. No changes in the proportion of females breeding in these four bays relative to the total number of breeding females censused on Possession Island could be detected from 1980–97 ($r^2 = 0.003$, $n = 15$, $P > 0.05$). Thus according to the data published by Barrat & Mougin (1978) and assuming that 86% of the females were present ashore on the day of maximum haul out (Pascal 1981, Guinet *et al.* 1992, Slip & Burton 1999) we estimated that respectively 2030, 1720 and 1373 elephant seal females were breeding on Possession Island in 1966, 1970 and 1973.

Both at Possession Island and Îles Kerguelen no significant change of the breeding female numbers was detected between 1990 and 1997 (Possession Island: $r^2 = 0.04$, $n = 8$, $P > 0.05$ and Îles Kerguelen: $r^2 = 0.01$, $n = 8$, $P > 0.05$).

Based on the census data presented in previous studies at Crozet (Barrat & Mougin 1978, Guinet *et al.* 1992) and Îles Kerguelen (Pascal 1981, Guinet *et al.* 1992) we have reported the population change in numbers since 1970, a year for which censuses were conducted both at Possession and Îles Kerguelen (Fig. 1).

At Îles Kerguelen a steady decrease took place from 1970 until the mid eighties. From 1970–87 (year of minimum number of breeding females counted on the Courbet Peninsula) the number of breeding females decreased at an annual rate of 3.6%. However, from 1987–97 the number of breeding females increased significantly at an annual rate of 1.1% ($r^2 = 0.38$, $n = 11$, $P < 0.05$) and, if the adjustment is calculated between 1984 and 1997, we found that the number of breeding females increased significantly at an annual rate of 1.2% ($r^2 = 0.54$, $n = 13$, $P < 0.01$).

At Possession Island the elephant seal population decreased at an annual rate of 5.35% from 1970–90 ($r^2 = 0.95$, $n = 10$, $P < 0.001$) and as indicated above no significant change in number of breeding females can be detected since them.

## Discussion

The recent censuses conducted both at Îles Kerguelen and Îles Crozet tends to confirm that the rapid decline of both

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**Table I.** Results -raw (N) and calculated (Nc)- of the censuses of elephant seal females on land during the breeding period on Possession Island, Îles Crozet. All the counts were done in October and census dates are given in brackets.

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|
| Baie du Marin | N | 17 (16) | 31 (14) | 28 (15) | 32 (18) | 26 | | | |
| | Nc | 20 | 36 | 33 | 39 | 31 | 20 | 17 | 22 |
| Sphinx | N | 0 (16) | 2 (14) | 8 (13) | 0 (16) | 3 (13) | 0 (17) | 6 (9) | 0 (11) |
| | Nc | 0 | 2 | 10 | 0 | 4 | 0 | 8 | 0 |
| Chaloupe | N | 2 (16) | 0 (14) | 4 (13) | 4 (16) | 0 (13) | 4 (17) | 0 (22) | 3 (11) |
| | Nc | 2 | 0 | 5 | 4 | 0 | 5 | 0 | 4 |
| Petite Manchotière | N | 75 (15) | 105 (14) | 75 (17) | 72 (15) | 61 (13) | 79 (16) | 79 (20) | 68 (16) |
| | Nc | 87 | 123 | 89 | 84 | 72 | 92 | 101 | 80 |
| Baie Américaine | N | 88 (15) | 80 (14) | 93 (17) | 90 (15) | 83 (13) | 93 (16) | 66 (20) | 113 (16) |
| | Nc | 102 | 94 | 111 | 105 | 99 | 109 | 84 | 132 |
| Baie Hébé | N | 71 (18) | 83 (14) | 89 (16) | 106 (18) | 112 (15) | 100 (16) | 93 (18) | 90 (20) |
| | Nc | 86 | 97 | 104 | 129 | 130 | 117 | 113 | 115 |
| Petit Caporal | N | 13 (18) | 24 (15) | 16 (16) | 17 (6) | 14 (16) | 21 (16) | 15 (19) | 12 (20) |
| | Nc | 16 | 28 | 19 | 26 | 16 | 24 | 19 | 15 |
| Jardin Japonais | N | 53 (19) | 51 (19) | 57 (14) | 85 10) | 45 (18) | 42 (12) | 48 (14) | 74 (16) |
| | Nc | 66 | 63 | 67 | 109 | 55 | 51 | 56 | 87 |
| Mare aux Elephants | N | 82 (12) | 78 (18) | 71 (13) | 55 (12) | 61 (10) | 53 (11) | 91 (15) | 62 (18) |
| | Nc | 99 | 95 | 84 | 67 | 78 | 66 | 106 | 75 |
| Baie Lapérouse | N | 27 (23) | 38 (16) | 43 (11) | 31 (14) | 30 (15) | 32 (13) | 27 (10) | 34 (13) |
| | Nc | 39 | 44 | 53 | 36 | 35 | 38 | 35 | 40 |
| Total females | Nctot | 517 | 582 | 575 | 599 | 520 | 522 | 539 | 570 |

**Table II.** Results of females counts on Courbet Peninsula, Îles Kerguelen according to those reported by Pascal (1981) and Guinet *et al.* (1992). Raw (N) and calculated (Nc) of the census of elephant seal females during the breeding period.

| | | Area 1 | | Area 2 | | Area 3 | Area 4 | Area 5 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | Date | 10 Oct | | 11 Oct | | 12 Oct | 12 Oct | 14 Oct | |
| | N | 5266 | | 6042 | | 2148 | 10145 | 11702 | |
| | NC | 6738 | | 7488 | | 2605 | 12305 | 13696 | 42832 |
| 1991 | Date | 16 Oct | 11 Oct | 11 Oct | 12 Oct | 13 Oct | 14 Oct | 16 Jan | |
| | N | 1635 | 1357 | 2279 | 5002 | 2472 | 13984 | 7366 | |
| | NC | 1979 | 1681 | 2824 | 6067 | 2938 | 16367 | 8621 | 40477 |
| 1992 | Date | 10 Oct | 12 Oct | 13 Oct | 14 Oct | 14 Oct | 15 Oct | 16 Oct | |
| | N | 1744 | 1569 | 3828 | 4549 | 2087 | 9548 | 13206 | |
| | NC | 2232 | 1903 | 4549 | 5324 | 2443 | 11119 | 15456 | 43026 |
| 1993 | Date | 14/10/98 (Area 1 & 2) | | 17 Oct | | 13 Oct | 14 Oct | 14 Oct | |
| | N | 3502 | | 8637 | | 3689 | 11305 | 12503 | |
| | NC | 4099 | | 10161 | | 4384 | 13231 | 14634 | 46509 |
| 1994 | Date | 11/10/98 (Area 1 & 2) | | 12 Oct | | 13 Oct | 14 Oct | 14 Oct | |
| | N | 3613 | | 7409 | | 3012 | 11186 | 11578 | |
| | NC | 4477 | | 8987 | | 3579 | 13092 | 13551 | 43686 |
| 1995 | Date | 15 Oct | | 13 Oct | | 14 Oct | 14 Oct | 15 Oct | |
| | N | 3693 | | 7106 | | 2993 | 11748 | 11770 | |
| | NC | 4300 | | 8444 | | 3503 | 13750 | 13706 | 43703 |
| 1996 | Date | 19 Oct | | 16 Oct | | 16 Oct | 16 Oct | 15 Oct | |
| | N | 4109 | | 5659 | | 3098 | 10737 | 10767 | |
| | NC | 5091 | | 6623 | | 3638 | 12567 | 12602 | 40521 |
| 1997 | Date | 16 Oct | | 16 Oct | | 16 Oct | 15 Oct | 14 Oct | |
| | N | 3747 | | 7323 | | 3225 | 7958 | 15195 | |
| | NC | 4386 | | 8571 | | 3774 | 9267 | 17784 | 43782 |

The different areas correspond to: Area 1. Pointe Molloy-Pointe Guite, Area 2. Pointe de l'Etoile-Pointe Morne, Area 3. Pointe Morne-Pointe Charlotte, Area 4. Pointe Charlotte-Cap Ratmanoff, Area 5. Cap Ratmanoff-Cap Digby.

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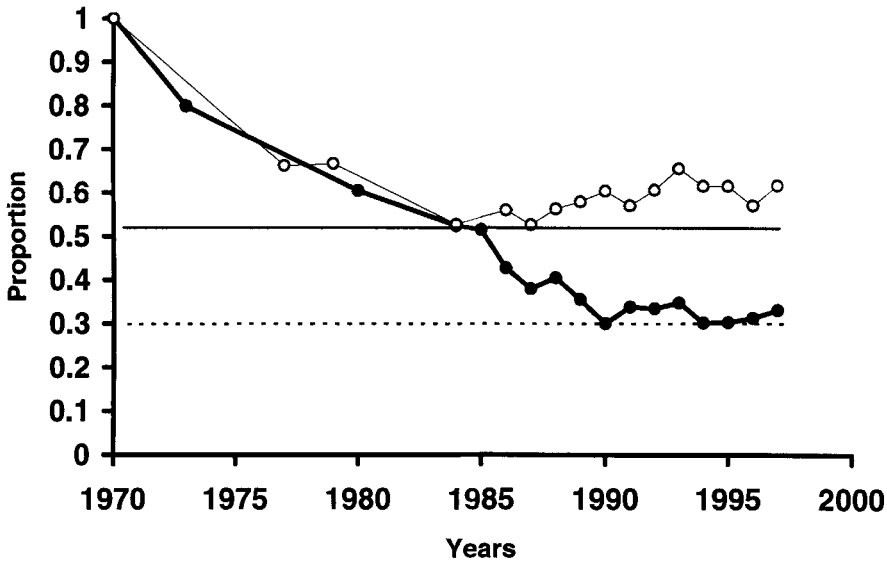



**Fig. 1.** The change in the proportion of elephant seal females relative to the total number of elephant seal females census at Possession Island, Îles Crozet (●), and on the Courbet Peninsula, Îles Kerguelen (○), in 1970. In 1970, 1720 females were estimated to be present on Possession Island (see text for details and Barrat & Mougin (1978)) while 71 000 females were calculated to be present on the Courbet Peninsula (Pascal 1979).

populations has ended. However, the kinetic differ according to the locality and as reported in previous studies (Guinet *et al.* 1992, Bester & Wilkinson 1994). The elephant seal population was declining at a higher annual rate and over a longer period at Possession Island compared to Îles Kerguelen. This resulted in the lost of about 48% of elephant seal numbers at Îles Kerguelen between 1970 and 1987, compared to 70% of their numbers between 1970 and 1990 at Possession Island. Furthermore, after the decline ended at Îles Kerguelen, the number of breeding females increased significantly at an annual rate of 1.1% from 1987–97 or 1.2% if calculated from 1984–97, while no change in numbers could be detected at Possession Island between 1990 and 1997.

The check on counting accuracy at Kerguelen give an average difference of ± 1.3% (range 0–4.5%). These values are within the range of those reported by Boyd *et al.* (1996) at South Georgia: ± 0.9%, and Slip & Burton (1999) at Heard Island: ± 1.2% (range 0–5.5%). The exponential least square fit from 1987–97 indicates that the overall increase was about 12% and about 16% when calculated between 1984 and 1997. These overall increases are much larger than the usual inter-counter average difference reported above (± 0.9% and ± 1.3%) in different studies and to the maximum inter-count difference of 5.5% reported for Heard Island. Thus, according to these levels of error in counts, the significant exponential least square fits we found between 1987 and 1997 or 1984 and 1997 are very likely to be indicative of a real increase in elephant seal female numbers over that period of time.

On Heard Island, the elephant seal population, which is part of the Kerguelen–Heard stock, declined by 47% between 1949 and 1985 but very little change in numbers was detected from 1985–92 (Slip & Burton 1999). This suggests that the trend observed at Îles Kerguelen and Heard Island are similar and that this stock is now stable or may possibly be slowly increasing.

The trend observed at Possession Island tends to be similar to the trend observed at Marion Island over the same period. Bester & Wilkinson (1994) reported an annual rate of decrease of 4.8 % from 1974–89 but the rate of decrease had slowed to 1.9 % per annum between 1983 and 1989. We recalculated that from 1974–83 the annual rate of decrease was 5.4% which is similar to the 5.8 % annual rate of decrease observed on Possession Island from 1966–76 (Barrat & Mougin 1978) and the 5.7 % annual rate of decrease reported from 1966–89 (Guinet *et al.* 1992). Pistorius *et al.* (unpublished data) reported a rate of decline of 2.5% per year from 1991–96 indicating that the recent trend observed at Possession Island and Marion Island differed which suggests that other factors may be in action at Marion Island to explain the present decrease in comparison with the now stable elephant seal population at Possession Island.

At Macquarie Island the elephant seal population declined at an average rate of 2.1 % per annum between 1949 and 1984 (Hindell & Burton 1987) and was reported to decline at about 1.2 % per year since 1985 (cited in Slip & Burton 1999).

The combination of the data collected from the main breeding localities of the Indian and Pacific sectors of the Southern Ocean, indicate that the period of rapid decline has ended for all the breeding localities and that the populations are either decreasing at a lower rate, stable or slightly increasing. The concomitant changes in the population trends of elephant seals in both the Indian and Pacific sectors of the Southern Ocean suggests that these populations are likely to be responding to the same broad scale factors affecting the availability of food for these marine predators (Guinet *et al.* 1992, Slip & Burton 1999). Smaller inter-stock differences may be possibly related to local factors. Slip & Burton (1999) related the decline in elephant seals to the major change in pack ice condition which took place between the mid 1950s and 1973 (de la Mare 1997). These changes in sea-ice condition could have deeply affected the productivity of the Southern Ocean and may be a possible reason for the change

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in elephant seal numbers (Slip & Burton 1999). Added factors such as changes in killer whale predation at Îles Crozet (Guinet 1992, Guinet *et al.* 1992, ) may explain the higher rate of decrease, the longer period of decrease and the absence of any significant increase in numbers of elephant seals at Îles Crozet compared to Îles Kerguelen.

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