Relative population sizes and trends, and hybridization of fur seals *Arctocephalus tropicalis* and *A. gazella* at the Prince Edward Islands, Southern Ocean

G.I.H. Kerley

Mammal Research Institute, University of Pretoria, Pretoria

Fur seals were counted at the Prince Edward Islands during the 1981/1982 austral summer. Classified counts, adjusted for pup undercounting and mortality, pregnancy rate and seasonal haul-out patterns, of *Arctocephalus tropicalis* and *A. gazella* are presented. These populations have entered a phase of rapid growth, as indicated by higher rates of population growth than previously found. The possible role of *A. gazella* immigration is unknown. There has been an increase in the number of breeding localities used by both species. At present the extent of hybridization between these two species appears limited, possibly by behavioural, ecological and genetic processes.

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Pelsrobbe is gedurende die 1981/1982 suidelike somer op die Prins Edward-eilande getel. Geklassifiseerde tellings van *Arctocephalus tropicalis* en *A. gazella*, aangepas vir onderskattings van welpiegetalle en sterftesyfers, dragtigheidstempo en seisoenale aankoms- en vertrekpatrone, word aangebied. Hierdie bevolkings het 'n tydperk van snelle groei, soos aangetoon deur die hoër tempos van bevolkingsgroei as voorheen gevind, betree. Die moontlike rol van immigrasie van *A. gazella* is nie bekend nie. Daar was 'n toename in die aantal teelkoloniegebiede wat deur albei spesies gebruik is. Tans is die mate van hibridisering tussen die twee spesies beperk, moontlik deur ekologiese, genetiese en gedragsprosesse.

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G.I.H. Kerley
Mammal Research Institute, University of Pretoria, Pretoria, 0002 Republic of South Africa

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The subantarctic and antarctic fur seals were considered conspecific by King (1959a, b) with *Arctocephalus tropicalis tropicalis* occurring on islands north of the Antarctic Convergence, and *A. tropicalis gazella* on islands south of the Convergence. They are now, however, accorded species status based on cranial and dental characteristics (Repenning, Peterson & Hubbs 1971) and show external features distinct from each other. Although exploited to the verge of extinction in the last century, their recovery subsequent to the cessation of sealing has been well documented (Budd 1970; Payne 1977; Condy 1978; Bester 1980; Jouventin, Stahl & Weimerskirch 1982; Hes & Roux 1983), with the largest populations of *A. gazella* and *A. tropicalis* occurring at South Georgia (Payne 1977) and Gough Island (Bester 1980) respectively. Concomitant with these population increases, an expansion of their breeding range took place, both species now co-existing on some islands situated near the Antarctic Convergence.

The first possible record of *A. gazella* at Marion Island was from a skull collected by Rand (1956) in 1951/52 which King (1959a) identified as resembling the southern population. In 1974 Condy (1978) recorded *A. gazella* breeding sympatrically with *A. tropicalis* on the Prince Edward Islands, as did Jouventin *et al.* (1982) for Possession Island, Iles Crozet during 1979.

As some adult fur seal males at Marion Island showed external characteristics of both species, and some breeding harems contained both *A. tropicalis* and *A. gazella*, Condy (1978) speculated that hybridization was occurring between the species, although there appeared to be a measure of ecological and behavioural separation.

The present study was initiated to investigate the relationship between these two species at the Prince Edward Islands. Information presented here deals with the assessment of population sizes and trends and the extent of hybridization. This information is complementary to recent work on the *A. tropicalis* populations on Gough Island (Bester 1980) and Amsterdam Island (Hes & Roux 1983) and furthermore contributes to the South African Scientific Council for Antarctic Research (SASCAR) programme dealing with the spatial and temporal distribution of pinnipeds in the Southern Ocean.

This study was carried out at Marion Island (Figure 1) and Prince Edward Island (Figure 2). The vegetation, climate and geology of the Islands has been summarized by Gremmen (1981). The habitats used by fur seals have been described by Condy (1978).

Methods

The entire coastline of Marion Island, except for three small

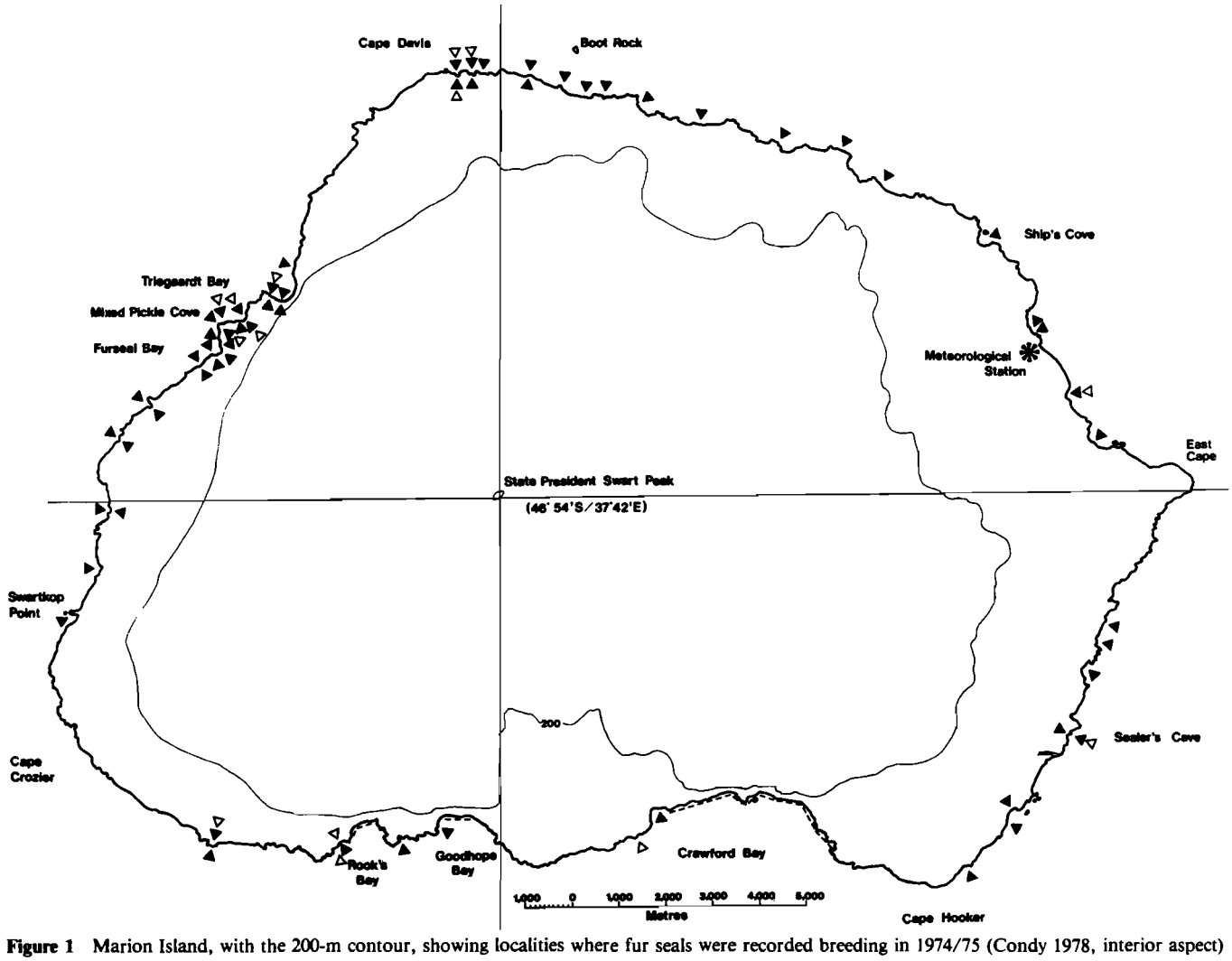

Figure 1 Marion Island, with the 200-m contour, showing localities where fur seals were recorded breeding in 1974/75 (Condy 1978, interior aspect) and 1980/81/82 (exterior aspect) (▲ = *A. tropicalis*, Δ = *A. gazella*, ----- = inaccessible sections of the coast).

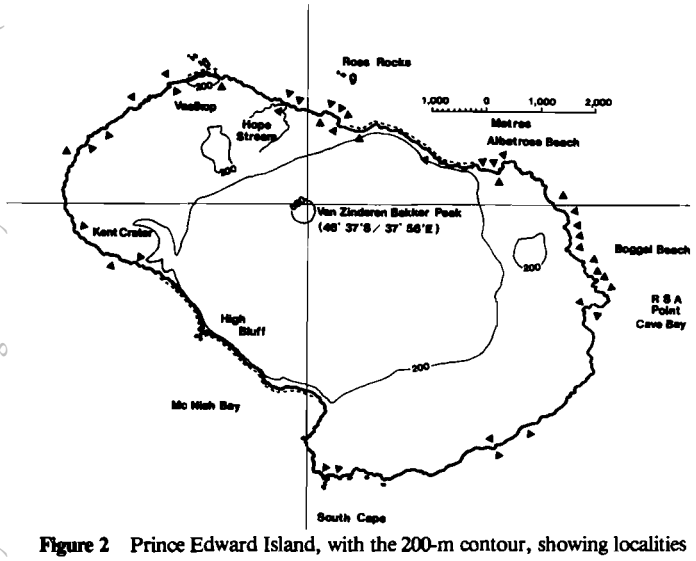

Figure 2 Prince Edward Island, with the 200-m contour, showing localities where *A. tropicalis* were recorded breeding in 1974/75 (Condy 1978, interior aspect) and 1980/81/82 (exterior aspect) (▲ = *A. tropicalis*, ----- = inaccessible sections of the coast).

inaccessible coastal sections (Figure 1) was censused by one observer on foot using direct methods from 26 January to 3 February 1982 when all pups have already been born. The accessible coastal sections of Prince Edward Island (Figure 2) could not be counted during a single summer and the combined results (5 – 7 May 1981; 28 April and 12 – 13 May 1982) are used.

Beaches were systematically searched and fur seals in the inshore surf zone were included and offshore pods ignored. All fur seals were allocated to one of the following classes: adult males (AM), adult females (AF), immatures (SAU) and pups, following Condy (1978) and Bester (1982). Species recognition followed Condy's (1978) description of the two species and the assumed hybrid.

The following adjustments were made to the counts (*vide* Payne 1977; Condy 1978; Bester 1980; Laws 1980):

(a) The corrections for undercounting caused by the irregular terrain and the secretiveness of the pups were based on mark-recapture experiments at Sealer's and Cliff Beaches, Cape Davis, using Bailey's estimate (Caughley 1977). Pups were marked with enamel paint or monel-metal tags (Condy & Bester 1975). The mean correction factor of 16% (five trials) was expressed as a percentage of the estimated number of pups present.

(b) A pup mortality figure prior to the date of the census was based on regular searches of the Cape Davis (*A. tropicalis*) and Rook's Bay (*A. gazella*) breeding colonies for dead pups. The pup counts were further adjusted by these figures to yield an estimate of the total number of births.

(c) As the number of females counted was lower than the number of pups and each female normally bears only one pup (Payne 1977), the estimated number of births [adjustment (b) above] and the number of females were equated. The derived female numbers were further adjusted by assuming a pregnancy rate of 86%, found for *A. gazella* at South Georgia (Payne 1977), as applied to the Marion

Island (Condy 1978) and Gough Island (Bester 1980) *A. tropicalis* populations.

(d) The counts were not conducted during the peak haul-out of seals, therefore counts of adult males and immatures (older than one year) were adjusted by 83% and 29% respectively to compensate for known decreases to the date of the census.

(e) Yearling seals were not present at the Islands during the censuses and were estimated from the previous year's pup production, using an estimated mortality to one year of age of 23,9% found for *A. gazella* at South Georgia (Payne 1977). The previous year's *A. gazella* pup production was estimated from the calculated rate of population increase (Bester 1980) determined in the present study (see Results). The previous year's *A. tropicalis* pup production was obtained from censuses during 1980/1981 (unpublished).

(f) The counts at Prince Edward Island were carried out after the summer peak in *A. tropicalis* numbers, and the population was estimated from the pup : total numbers ratio determined for Marion Island.

(g) More *A. gazella* pups and males were identified on Marion Island outside the census period than were counted during the census. Therefore the number of counted *A. gazella* was adjusted by the number of known individuals. Pups were marked with monel-metal tags and individual adult *A. gazella* males were recognized by distinctive scars, wounds and colouration.

(h) Only adult male hybrids could be identified (Condy 1978), therefore the population size of hybrids was estimated from the proportion of males to the total numbers calculated for *A. tropicalis* on Marion Island.

The annual intrinsic rates of population increase (r) were calculated using data in Rand (1956), Condy (1978), and the present results and the exponential function

$$N_t = N_o e^{rt}$$

(Caughley 1977), where

N_o = population numbers at the start of observations,
N_t = population numbers after time t,
e = base of natural logarithms.

Results

Numbers of *A. tropicalis* on Marion Island

Numbers of *A. tropicalis* counted on Marion Island are presented in Table 1. These figures were adjusted [(a) – (e) in Methods]. The 1981/1982 number of live pups is 3 813 (a) with 4 101 births [7,0% (b)] to yield an estimate of 4 768 adult females (c). The estimates of adult males and immatures are 5 244 and 3 554 respectively (d). The 1980/81 pup production [2 535 pups counted, adjusted by (a) and (b)] was 3 256 births, with 2 478 yearlings surviving to 1981/82 (e). The total *A. tropicalis* population on Marion Island is estimated to be 19 857 seals.

Numbers of *A. tropicalis* on Prince Edward Island

Numbers of *A. tropicalis* counted on Prince Edward Island are presented in Table 2. The 2 300 pups counted were adjusted for undercounting (a) and the higher mortality figure [9,4% (b)] to the later census date to yield an estimate of 3 030 births. The total population of *A. tropicalis* on Prince Edward of 14 761 is calculated from the ratio of births : total numbers (1 : 4,8) found on Marion Island.

The total population of *A. tropicalis* on Marion and Prince Edward Islands was therefore estimated at 34 528 seals.

Table 1 Numbers of *A. tropicalis* counted on Marion Island from 26/1/82 to 2/2/82 with adjusted totals

Locality	AM	AF	Pups	SAU
Cliff Beach, Cape Davis	9	66	52	18
Sealer's Beach, Cape Davis	88	122	114	343
Cape Davis to Triegaardt Bay	42	64	6	36
Triegaardt Bay, South Section	63	247	397	187
Mixed Pickle Cove	62	147	292	205
Fur Seal Peninsula	292	1281	1984	490
Fur Seal Bay	62	210	238	73
Fur Seal Bay to Swartkop Point	51	95	22	199
Swartkop Point Beach	37	48	1	103
Swartkop Point to Rook's Bay West	54	17	8	161
Rook's Bay West	11	2	8	89
Rook's Bay to Sealer's Cave	37	9	4	210
Sealer's Cave	2	11	18	15
Sealer's Cave to Ship's Cove	17	16	21	173
Ship's Cove to Cape Davis	38	49	28	214
Unadjusted totals	865	2384	3193	2516
Adjusted totals	5244[a]	4768[b]	3813[c]	3554[a]

[a]adjustment (d). [b]adjustment (b) & (c). [c]adjustment (a).
(See text for legends.)

Table 2 Numbers of *A. tropicalis* counted on Prince Edward Island during 1981 and 1982

Date	Locality	AM	AF	Pups	SAU
28/4/82	Vaalkoppie West to Kent Crater Bay	22	5	5	40
12/5/82	McNish Bay to Cave Bay	21	2	2	57
6/5/81	Cave Bay	7	9	7	113
13/5/82	RSA Point to Boggel Beach	7	32	90	11
13/5/82	Boggel Beaches	20	113	561	81
13/5/82	Boggel Beach to Albatross Beach	31	213	559	71
13/5/82	Albatross Beach	7	27	125	17
7/5/81	Ross Rocks Beach	31	158	412	115
7/5/81	Ross Rocks to Hope Stream	11	39	36	9
7/5/81	Hope Stream Beach	46	144	503	338
Unadjusted totals		203	742	2300	852

(See text for legends and adjusted totals.)

Table 3 Numbers of *A. gazella* counted on the Prince Edward Islands during the census periods and the numbers of recognized individuals on Marion Island

Locality	AM	AF	Pups	SAU
Marion Island unadjusted counts	4	23	33	14
Marion Island recognized individuals	20	–	43	–
Prince Edward Island unadjusted counts	6	21	8	26

(See text for legends and dates of the censuses.)

Numbers of *A. gazella*

A total of 43 pups and 20 *A. gazella* adult males were individually identified, in addition to 14 immatures counted on Marion Island (Table 3). The pup numbers yield an estimate

of 55 adult females [8,7% (b) and (c)] and 30 yearlings (e) and a total population estimate of 162 *A. gazella* on Marion Island.

The censuses of Prince Edward Island were conducted after the post-weaning dispersal of *A. gazella* pups (unpublished data). Therefore these counts can not be used to estimate the Prince Edward Island population, although the 61 *A. gazella* counted on Prince Edward Island (Table 3: combined counts for 1980/81 and 1981/82) indicate there are approximately as many *A. gazella* on Prince Edward Island as there are on Marion Island. The total population of *A. gazella* on both Islands is thought to be in the order of 300 – 400 seals.

Numbers of *Arctocephalus* spp. hybrids

During the 1980/81 austral summer 11 assumed hybrid adult males, of which five were culled, and during 1981/82 four assumed hybrid males, were identified on both islands. Assuming that the ratio of adult males : total population is the same as for *A. tropicalis* on Marion Island (1 : 3,8) then the 1980/81 total number of hybrids is estimated at 37 seals.

Population increases

Comparable counts for 1974/75 (Condy 1978) and 1981/82 (Table 4) for Marion Island (N_0 = 1 115, N_t = 3 193, t = 7 years) indicate a mean intrinsic rate of increase for unadjusted *A. tropicalis* pup numbers of 15,0% per year on Marion Island and the increase in pup numbers at the major breeding colonies is shown in Table 4. The annual rate of increase of the total estimated *A. tropicalis* population was 14,9% (N_0 = 7 000, N_t = 19 857) over the same period and 11,9% from 1951/52 (N_0 = 500; Rand 1956) to 1981/82 (t = 31 years). The mean rate of increase in *A. gazella* pup numbers on Marion Island from 1974/75 (N_0 = 15; Condy 1978) to 1981/82 (N_t = 43, t = 7 years) was 15,1% per year.

Extension of breeding colony sites

Localities where *A. tropicalis* and *A. gazella* were recorded breeding during the 1974/75 (Condy 1978), and 1980/81 and 1981/82 austral summers are presented in Figure 1. Both species have increased the number of breeding localities utilized. The increase in *A. tropicalis* pup numbers has resulted in an increase in the number of pups born within established breeding colonies (Table 4) on the west coast and an increase in the number of breeding localities on the east coast. The increase in the number of *A. gazella* pups is reflected in the establishment of five new breeding localities, including a relatively large colony at Crawford Bay, as well as the tenfold increase in *A. gazella* pups at Rook's Bay since 1974/75. There are no comparable data for Prince Edward Island before 1980/81, although an increase in the number of *A. tropicalis* breeding localities has occurred, and the position of *A. gazella* breeding localities is uncertain as the censuses were carried out after post-weaning dispersal of the pups had occurred.

Discussion

Circumstances prevented carrying out sequential counts over a period of time or multiple counts in a near-instantaneous time frame which would have allowed the calculation of confidence limits around the population estimates.

The estimates of the *Arctocephalus* populations presented here are considered to be accurate as the censusing techniques and adjustments to the counts are valid. The application of pregnancy and mortality rates from the South Georgia *A. gazella* population to these populations is thought to be justified as these populations have similar histories and growth rates and the population growth rate is a function of fecundity and mortality. Although parts of Marion Island were inaccessible, this does not detract from the accuracy of the census as these sections were searched from the air by helicopter during April 1982. No seals were observed and these exposed narrow beaches did not appear to be suitable for fur seals. Similarly, the inability to count the inaccessible sections on Prince Edward Island which appeared to have similar topography, does not affect the accuracy of the Prince Edward Island census.

Although 1 500 *A. tropicalis* pups were tagged on Marion Island (representing 39,3% of the pups) no tagged pups were found on Prince Edward Island during April/May 1982. A significant inter-island movement of pups, which would decrease the accuracy of the Prince Edward Island census is therefore unlikely to the date of census. The census of Prince Edward Island was carried out during post-weaning dispersal of *A. gazella*, illustrating the importance of complementary studies on the seasonal cycle of censused seal populations (Laws 1980), as a count of pups during the post-weaning dispersal would yield a serious underestimate.

The pup undercount correction factor obtained here (16%) is lower than correction factors of 34% estimated for *A. tropicalis* on Marion Island (Condy 1978), 33% for *A. tropicalis* on Gough Island (Bester 1980) and 54% for *A. gazella* on South Georgia (Payne 1977). Although this factor is dependent on censusing techniques, population density and topography (Payne 1977) the seal numbers extrapolated from pup counts should be considered a minimum. The relatively

Table 4 Unadjusted *A. tropicalis* pup numbers, mean annual percentage increase ($r \times 100$), proportion of pups and change in the proportion of pups on the main breeding beaches on Marion Island for the period 1974/75 to 1981/82

Locality	Unadjusted[a] pup numbers 1974/1975	Unadjusted pup numbers 1981/1982	$r \times 100$	Proportion of pups 1974/1975	Proportion of pups 1981/1982	Changes in the proportion of pups 1974/1975 – 1981/1982
Cliff Beach, Cape Davis	12	52	20,95	1,08	1,63	+0,55
Sealer's Beach, Cape Davis[b]	52	114	11,21	4,66	3,57	−1,09
Triegaardt Bay	59	397	27,23	5,29	12,43	+7,14
Mixed Pickle Cove[b]	118	292	12,94	10,58	9,15	−1,43
Fur Seal Peninsula[b]	720	1984	14,48	64,57	62,14	−2,43
Fur Seal Bay[b]	125	238	9,20	11,21	7,45	−3,76
Remainder of Island	25	116	21,92	2,24	3,63	+1,39
Total Marion Island	1115	3193	15,03	100	100	

[a]Data from Condy (1978). [b]Historically recorded fur seal beaches (Rand 1956).

high proportion of adults in the *A. tropicalis* population is due to early recruitment and longevity of adults.

The *A. gazella* pup numbers were not adjusted for undercounting as this figure is from individually identified pups. This figure is possibly an underestimate due to the difficulties of identifying isolated *A. gazella* pups in the crowded *A. tropicalis* colonies but is considered a better estimate of *A. gazella* pup numbers than the census data.

The rate of increase of *A. tropicalis* for the period 1974/75 to 1981/82 is higher than the 11% per year previously recorded for the period 1951/52 to 1974/75 on Marion Island (Condy 1978). The present growth rate of 14,9% per year is similar to rates found in other *Arctocephalus* populations after the initial slow recovery from sealing operations. On South Georgia, Payne (1977) recorded the *A. gazella* population to be increasing at an annual rate of 16,8% for the period 1958/59 to 1972/73, based on adjusted counts. On Gough Island, unadjusted *A. tropicalis* pup numbers showed a 15,9% annual increase between 1955/56 and 1977/78, while the total estimated population increased by 13,9% per year over the same period (Bester 1980). On Amsterdam Island the *A. tropicalis* population showed similar trends, increasing at 7,8% and 16,5% annually from 1955/56 to 1970/71 and 1970/71 to 1981/82 respectively (Hes & Roux 1983).

It would appear that all of the abovementioned fur seal populations have been following the classic sigmoid growth pattern since the cessation of the indiscriminate sealing of the last century. The Marion Island *A. tropicalis* population has completed the initial slow establishment phase characterized by slow growth and entered the period of exponential population growth (Bester 1980; Hes & Roux 1983). This high rate of population increase will continue until density dependent factors such as breeding space and food resources (specifically the availability of food to lactating cows) will become limiting.

As on Gough Island (Bester 1980) and Amsterdam Island (Hes & Roux 1983), the increase in the Marion Island *A. tropicalis* population has resulted in an increase in pup numbers within established breeding colonies as well as an increase in the number of breeding localities (Figure 1, Table 4). The annual rates of increase on beaches historically recorded as centres of fur seal activity on Marion Island (Rand 1956) are below the average rate of increase for the whole island. These beaches have presumably acted as foci for the recolonization of Marion Island and as on Amsterdam Island (Hes & Roux 1983), have become overcrowded with a resultant decrease in the rates of increase, probably through emigration of seals to neighbouring, less crowded beaches. This is also reflected in the decrease in the proportions of pups found on these beaches in relation to the total pup population of Marion Island (Table 4). Conversely, the more recently colonized beaches have above average rates of increase and the proportion of pups on these beaches in relation to the total Marion Island pup population has increased (Table 4). The high rate of increase found for the Triegaardt Bay colonies (27,2%) is similar to that found for recently colonized sections of Amsterdam Island (Hes & Roux 1983), indicating that breeding space at these localities is as yet not limiting.

The high rate of increase in *A. gazella* pup numbers (15,1% per year) since 1974/75 is similar to that for the Marion Island *A. tropicalis* population and indicates that this population has completed the unstable colonizing phase (MacArthur & Wilson 1967) which would have relied on immigration from other populations, possibly South Georgia, which is the location of about 90% of the world population of *A. gazella* (Payne 1977). However, this rate of increase is higher than would be expected at the present low population levels with the population in the establishment phase characterized by slow growth rates (Odum 1971; Hes & Roux 1983). This indicates that immigration of *A. gazella* is still occurring at Marion Island, in addition to the population growth through endogenous pup production.

The estimate of the number of hybrids presented here is the first quantitative assessment of the extent of hybridization between *A. tropicalis* and *A. gazella*. The method used to estimate the numbers of hybrids indicates the order of magnitude of the hybrid population. In terms of population sizes, the hybrids represent 9,3% of the *A. gazella* population and 0,1% of the *A. tropicalis* population. It would appear that hybridization is limited and the species identity of *A. gazella* and *A. tropicalis* is being maintained through behavioural, ecological or genetic processes (Condy 1978), although the possible role of *A. gazella* immigration is uncertain. With no previous data on the extent of hybridization it is not possible to predict any trends for the continued interbreeding of these two species.

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