# PUP MORTALITY OF THE NEW ZEALAND FUR SEAL (*ARCTOECEPHALUS FORSTERI* LESSON)

R. H. MATTLIN

*Department of Zoology, University of Canterbury,*

*Christchurch*

SUMMARY: Mortality of New Zealand fur seal pups from birth until approximately 300 days was investigated on Taumaka, Open Bay Islands, Westland, New Zealand (43° 52' S, 168° 53' E) between December 1974 and August 1976. In both 1974-75 and 1975-76 there was an approximate mean mortality rate of 20 percent from birth to 50 days, and 40 percent from birth to 300 days. Starvation was the greatest cause of mortality, accounting for 70 percent of the deaths to 50 days. Other deaths were a consequence of stillbirths, suffocation, drowning, trampling and predation. First year mortality could have been as high as 50 percent of the total pup crop. Human disturbance killed pups indirectly by causing panic on the rookery. Tagging with monel metal cattle ear tags on the posterior edge of the foreflipper may have increased mortality.

## INTRODUCTION

Little is known about the population structure and dynamics of the New Zealand fur seal *(Arctocephalus forsteri)* in the New Zealand region, although there is a growing literature on the behaviour, activity and general biology of the species, e.g., Crawley *et al*. (1977), Crawley and Wilson (1976), Miller (1974). This paper presents data on mortality rates of pups from birth to about 300 days and discusses suspected causes of death, both natural and those caused by human disturbance.

The causes of mortality and the mortality rates are compared with those of other fur seal species, e.g., the Kerguelen fur seal *(A. gazella),* the Amsterdam Island fur seal *(A. tropicalis),* and the northern fur seal *(Callorhinus ursinus),* and with selected phocid seal species, e.g., the southern elephant seal *(Mirounga leonina)*.

This study forms part of an investigation of fur seal population structure carried out from October 1974 to February 1977 on Taumaka, the larger of the two Open Bay Islands, located 4.8 km northwest of the mouth of the Okuru River, Westland (43° 52' S, 168° 53' E). Taumaka previously has been described by Burrows (1972).

## METHODS

Quantitative mortality data were collected in two ways:

1. For the period from birth to 50 days, the number of dead pups in the two study areas, one of 655 $m^2$ and the other of 525 $m^2$, was counted. These two study areas were chosen because they best represented the types of terrain occupied by seals on Taumaka. Together, they comprised about six percent of the total rookery area and contained between five and six percent of the breeding population. When weather conditions permitted, several censuses were made daily on one or the other of the study areas, and the locations of living and dead seals were mapped. The pup mortality rates (= cumulative mortality loss over a defined period of time) calculated were considered to apply to the entire pup population.
2. Calculation of pup mortality rates (up to 300 days) was based on estimates of the decline in numbers of living pups on the entire rookery. Pup mortality beyond 300 days could not be determined as pups began to leave the island at that age.

   For each study area, an estimate of the total number of pups born was calculated as follows:

   total pups born = (total number of dead pups seen) + (maximum number of live pups seen at anyone time) - (number of dead pups seen after maximum live pup count).

Estimates of pup mortality to 50 days (until the end of January, when observations on the study area ceased) were calculated by:

$$\text{pup mortality to 50 days} = \frac{\text{total number of dead pups}}{\text{total number of pups born}}$$

It is probable that more pups were born than were counted, but it is also probable that more pups died than were counted, so these estimates were accepted as representative of the true values for each of the two study areas.

During February 1975, 253 male and 262 female pups of average age 55 days (mean birth date 10 December; 90 percent of births occurred before 31 December) were tagged on the posterior edge of either the left (male) or right (female) foreflipper with numbered monel metal cattle ear tags (Stockbrands Co. pty Ltd., Mt. Hawthorn, Western Australia). In February 1976, 429 male and 393 female pups were given a year-mark only, by removing the cartilaginous tip of the second digit of the left hind flipper.

After the pups were marked at 55 days, a census was taken of pups over the entire rookery. Assuming that we could have captured all marked and non-marked pups that we were able to touch, and knowing how many pups were originally marked, an estimate of the total pup population at the time of marking was calculated by using the Peterson estimate:

$$N = \frac{M(n+1)}{m+l}$$

where N is an estimate of the total population size, M is the total number of marked pups, n is the sample size, and m is the number of marked pups in the sample.

The standard error of the estimate was calculated by:

$$S.E. = \sqrt{\frac{M^2(n+1)(n-m)}{(m+l)^2(m+2)}}$$

The Peterson estimate assumes that there was no differential mortality between marked and non-marked pups from the time marking began until the census was completed; that no immigration or emigration took place for that time; and that marked pups were as easy to catch as non-marked pups. The three assumptions are probably correct, as mortality was probably minimal over such a short period (about five days); young pups avoid the open sea, so no immigration or emigration could occur; and all pups fled when approached, so it is unlikely that marked pups were any easier or harder to "capture" than non-marked pups. Therefore, these population estimates are thought to be realistic.

By assuming that the mean mortality rate to 50 days for the two study areas was true for the whole rookery, and having estimated the pup population at 55 days, the total number of births on Taumaka was calculated.

During subsequent trips to Taumaka (at mean pup ages of 140 and 235 days in 1975 and 1976, and also 290 days in 1976 only), pups were counted while the observer walked the length of the rookery. Because of the extreme disturbance it would have caused, no effort was made to climb into deep gullies or look under rocks for pups. Various other factors also affected census accuracy. For example, on warm, clear days, fewer pups were out in the open than on cooler, more overcast days; and as pups grew older, they spent more time by the sea or in tidal pools, where the irregular terrain of the rookery obscured them from view. Consequently, it was difficult to estimate accurately the total pup population. Crawley and Brown (1971), when using the same census technique, suggested a 20 percent under-count, but this most certainly was an under-estimate of the error. During February 1975, approximately 50 percent of all pups were tagged. By greatly increasing search efforts, 64 percent were marked during February 1976. This indicates that one could expect an under-count of as high as 50 percent during subsequent pup censuses. Therefore, estimates of the total number of pups were made by doubling the total pup count for each census. The high census count in August 1976 (at 235 days) was due in part to the rough seas present at the time of the census which forced pups away from the sea to where they were more easily seen. It was assumed that more than 50 percent of the pups were counted during the August 1976 census but, for consistency, the total count was doubled when calculating the total population estimate.

## RESULTS

The collection of mortality data during the breeding season was difficult. Movement onto the rookery was curtailed because of the disturbance it caused, and because of the danger of attack from territorial bulls; most dead pups could therefore not be marked or retrieved. Consequently, specific results are given only for overall mortality rates, and for those mortality factors for which quantifiable data were collected. Other, non-quantifiable, causes of mortality are reviewed in the discussion.

### *Mortality rate estimates to 50 days*

In 1975, proportionally more pups died on Area I than on Area II (26 *versus* 15 percent), but the following summer the reverse was true (24 percent for Area II *versus* 20 percent for Area I). For the two years together, there was no significant difference in pup mortality between the two areas ( $\chi^2 = 1.63$, $p > 0.05$) so the data were combined for further analysis. The estimated pup mortality up to 50 days was 21 percent, which for convenience was rounded to 20 percent (Table 1).

*Causes of mortality*

1. Starvation

Two dead pups, both with umbilical cords still attached, had, respectively, 6 mm and 4 mm of blubber across the sternum, suggesting that pups have about 5 mm of blubber either at, or shortly after, birth.

TABLE 1. *Pup mortality to age 50 days, as a percentage of total births.*

| | 1974-75 AREA I | 1974-75 AREA II | 1974-75 AREA I+II | 1975-76 AREA I | 1975-76 AREA II | 1975-76 AREA I+II | Years and areas combined |
|---|---|---|---|---|---|---|---|
| A. Maximum number of pups counted alive at anyone time | 53 | 57 | 110 | 57 | 54 | 111 | 221 |
| B. Total number of dead pups counted | 17 | 9 | 26 | 14 | 15 | 29 | 55 |
| C. Total number of dead pups counted before maximum count of live pups | 13 | 4 | 17 | 13 | 9 | 22 | 39 |
| D. Total number of pups born (A+C) | 66 | 61 | 127 | 70 | 63 | 133 | 260 |
| E. Percent mortality $\frac{B}{(A+C)}$ | 25.8 | 14.8 | 20.5 | 20.0 | 23.8 | 21.8 | 21.2 |

*Mortality rate estimates to 300 days*

For 1975, pup population estimates were: total born, 1319; at 55 days, 1055 (± S.E. = 83)[1]; at 140 days, 716; at 235 days, 758. The 1976 pup population estimates were: total born, 1628; at 55 days, 1273 (± S.E. = 57); at 140 days, 892; at 235 days, 1242; at 290 days, 984. These data suggest that there was little pup mortality after 140 days. This conclusion is supported by the number of dead pups counted during each visit to Taumaka. In 1975, 36 dead pups were counted at 140 days and 9 were counted at 235 days. In 1976, only three badly decomposed pups were found at 140 days, two dead pups were found at 235 days, and three at 290 days.

The population estimates given above indicate that in 1975 there was a 42 percent mortality rate to 235 days, and in 1976 there was a 40 percent mortality rate to 290 days (the maximum pup ages for which data were collected).

[1] It was possible to calculate the standard error for capture/recapture data only.

Two males and one female accidentally killed by us when they were approximately 50 days old had an average blubber thickness across the sternum of 17.1 mm (range: 17-18 mm). They appeared to be average to slightly above average in size, suggesting that at 50 days pups of either sex with at least 15 mm of blubber across the sternum are in good condition.

Twenty fresh, dead pups were collected during January and early February for weighing and measuring. None had milk in its stomach. Eleven (55 percent) had no measurable blubber across the sternum, three (15 percent) had 5 mm or less, and the remaining six (30 percent) had between 5 mm and 10 mm of blubber. Assuming that blubber acts as a food reserve (Young, 1976), this suggests that the 11 pups with no blubber had starved to death. Whether starvation was the sole cause of death for the remaining 9 pups is unknown, but it is probable that it was a contributing factor.

Assuming that pups with 5 mm or less of blubber had starved to death, then starvation accounted for 70 percent of the mortality to 50 days.

For the above analysis, data from three dead pups collected in December were not used. They were probably all very young, and two still retained umbilical cords.

2. Mortality caused by human disturbance

a. Pup handling

There is evidence from studies of the northern fur seal that handling pups can have an adverse effect on their growth; in 1966 handled pups were significantly lighter ($p < 0.05$) 13 days after handling than non-handled pups (Marine Mammal Biological Laboratory, 1969). To see if handling affected New Zealand fur seal pups in a similar manner, the weights of marked and non-marked pups were compared. Apparently it did not, as there was no significant difference between the weights of marked and non-marked pups at 140 days (85 days after marking) in 1975 and 1976 ($p > 0.05$; Mann-Whitney U test; Siegel, 1956).

b. Tagging

In February 1975, pups on Taumaka were tagged with monel metal cattle ear tags. Although every effort was made to apply the tags in such a way that they would cause the least harm and discomfort, it was seen in May 1975, during the first return trip to Taumaka, that the tags were working in the wounds, preventing proper healing. Seventy-seven percent (43 of 56) of the tagged pups recaptured showed some indication of either suppuration or incomplete heal ing at the tag site. In August of the same year (180 days after the pups had been originally tagged), 75 percent (46 of 61) of the pups had incompletely-healed tag wounds.

Pup recapture data were tested to see if tagging had increased pup mortality. The ratio of tagged to non-tagged pups was calculated by taking a pup census within one day after tagging. As all pups ran when approached, it was unlikely that tagged pups were any more wary of our presence than non-tagged pups.

In 1975, the expected ratio was calculated by averaging the separate counts made at the same time by two different observers (85 tagged, 87 non-tagged; 76 tagged, 83 non-tagged). There was no significant difference between the two censuses ($\chi^2 = 0.09$, $P > 0.05$), so the expected ratio was accepted as representative of the true ratio. From this, it was determined that 49 percent of the pups were tagged.

In 1975, there was a significant difference in a goodness-of-fit test between the actual and expected ratios of tagged to non-tagged pups (number tagged: number non-tagged) at 140 days (72:102; $\chi^2 = 4.044$, $P < 0.05$) and at 235 days (67: 108; $\chi^2 = 8.039$, $P < 0.01$) such that there were fewer tagged pups than expected, there was no significant difference between the actual and expected ratios of marked (64 percent) to non-marked (36 percent) pups at 140 days (96:64; $\chi^2 = 1.111$, $P > 0.05$), 235 days (92:65; $\chi^2 = 1.988$, $P > 0.05$) and 290 days (114: 53; X2 = 1.318, $P > 0.05$). The only difference in pup handling between the two years was that pups in 1976 were permanently marked by digit clipping rather than by tagging.

## Discussion

The mortality rate estimates and factors which contributed to, or were thought to have contributed to, pup mortality are discussed below. The mortality factors are divided into two major groups, *viz.,* natural mortality, which includes starvation, still-births, suffocation in the amnion, drowning, trampling and predation; and mortality caused by human disturbance, which includes pup handling, human presence and tagging.

*Mortality rate estimates*

As the two study areas were thought to be representative of the rookery, the 20 percent mortality to 50 days of pups in the study areas should apply to the total pup population of Taumaka. The mortality rate to 300 days of 40 percent is more speculative. It is based on population estimates of the remaining pups at specific times, and is therefore directly dependent on the accuracy of these estimates. Nevertheless, the estimated 40 percent mortality to 300 days probably approximated the actual mortality.

There was no apparent pattern as to when most pup deaths occurred during the first 50 days, but the mortality rate was greatest during this period. Of the remaining 20 percent mortality, most probably took place before 140 days. The first 15 days are the most critical for Amsterdam Island fur seals (Paulian, 1964), and northern fur seal pup mortality is greatest during the first few weeks of life (Kenyon *et al.,* 1954).

With a 40 percent mortality to 300 days, the first year mortality could be in the vicinity of 50 percent. If this is correct, then deaths on land made the greatest contribution to first year mortality. Many other seal species have a similar first year mortality, but the deaths on land can be of considerably less significance. For example, the northern fur seal in recent years has had a first year mortality of 31.9 to

61.9 percent, but an on-land mortality of 4.8 to 11.1 percent (North Pacific Fur Seal Commission, 1975). These pups leave for the sea after about four months (Baker *et al.,* 1970). The southern elephant seal on Macquarie Island has a first year mortality of 40-50 percent, and a birth-to-weaning mortality of 2 to 16 percent (Carrick *et al.,* 1962). They are weaned in about 23 days (King, 1964). This does not mean that New Zealand fur seal pups survive better than those of other species at sea, but only that they are at sea for a relatively short period of time during their first year of life.

First year mortality of the Kerguelen fur seal on South Georgia is 23.9 percent (Payne, 1977); slightly less than half of the estimate for the New Zealand fur seal. However, the South Georgia population is increasing rapidly, whereas the New Zealand fur seal population on Taumaka is either stable or increasing very slowly.

*Natural mortality*

1. Starvation

There is little doubt that starvation is a major cause of pup deaths, but without detailed studies of other causes of mortality, it is extremely difficult to quantify. Nevertheless, it is reasonable to assume that the 11 pups with no blubber over the sternum starved to death. Considering that the three apparently healthy and robust pups accidentally killed had 17-18 mm of blubber over the sternum, it is likewise reasonable to assume that pups with 5 mm or less of blubber were at least weakened by lack of food.

Starvation is probably the greatest cause of pup deaths in many seal species, including the New Zealand sea lion *(Phocarctos hookeri;* Marlow, 1975), southern elephant seal (Carrick *et al.,* 1962; Carrick and Ingham, 1962), Tasmanian fur seal *(A. pusillus doriferus;* Warneke, 1975) and Kerguelen fur seal (Bonner, 1968).

Starving New Zealand fur seal pups often attempt to suckle surreptitiously from any available female, but females will knowingly suckle only their own pups. Adoptive suckling is never common in phocids, and is rare in otariids. It has never been reported in the Arctocephalinae.

2. Stillbirths

On 29 and 30 September 1976, one dead male and two dead female pups were collected on the rookery. Each weighed less than 2 kg and had very little hair. Although they were not dissected to see whether or not they had ever breathed, it is probable that they were stillborn. Because few dead pups similar in appearance were seen, stillbirths probably made only a small contribution to the overall mortality. On St Paul Island, in the Pribilof group, five of the 379 (1.3 percent) dead northern fur seal pups collected in 1968 were stillborn (Marine Mammal Biological Laboratory, 1970).

3. Suffocation in the amnion

New Zealand fur seals make no attempt to clean their pups immediately after birth *(pers. obs.;* Stirling, 1971b), but despite this, death by suffocation in the amnion appears to be rare. None was observed during this study, but two instances were reported from Taumaka during the 1973-74 summer (McNab and Crawley, 1975). Amsterdam Island fur seals (Paulian, 1964) and Kerguelen fur seals (Bonner, 1968) occasionally do attempt to clean their pups, but, in the latter species at least, deaths due to suffocation still result.

4. Drowning

Even pups less than three weeks old are remarkably adroit at scrambling out of the wash of high seas, but they are nevertheless in danger of being swept off the rookery during stormy weather. There is no hope for those washed out to sea, and little hope for those washed back ashore unless they are quickly reunited with their mothers. Drowning no doubt accounts for pup mortality on Taumaka, but the nature of the terrain is such that most pups are born out of the reach of high seas. Also, females will remove their young pups from the sea's wash.

In some seal species, drowning can account for a high percentage of pup mortality. At Amsterdam Island in 1955-56, 58 percent of the Amsterdam Island fur seal pups on the Plateau de la Recherche rookery were drowned (Paulian, 1964). This mortality rate was exceptionally high, and occurred because the females pupped closer than usual to the sea's edge during a period of fine weather and calm seas.

5. Trampling

An obvious disadvantage of the gregarious breeding found in the otariids is that pups may be trampled on by larger seals. New Zealand fur seal bulls are indifferent to pups *(pers. obs.;* Stirling, 1971a), to the extent that they make no attempt to avoid them when moving about the rookery. However, pups learn to take evasive action even when as young as one to two weeks old.

Early in the season, pups avoid trampling by sheltering amongst rocks or by congregating in open areas *(pers. obs.;* Crawley and Wilson, 1976), but later they escape by running away, foregoing any cover offered by the terrain. Pups usually do not appear to be harmed by being trampled, but they risk receiving internal injuries which may not be immediately apparent, and some pups are fatally crushed (Stark, *pers. comm.* 1975). Older pups will often bite bulls which trample on them.

6. Predation

With the exception of humans, seals in the New Zealand region have no natural terrestrial predators and no aerial predators. Once they go to sea, they may be preyed upon by sharks, killer whales and other seal species. Such predation is unquantifiable, but probably accounts for a large portion of the mortality of immature fur seals. For example, a great white shark *(Carcharodon carcharias)* caught in a fisherman's net off the Fiordland coast had two small fur seals in its stomach (W. McIvor, *pers. comm.,* 1975), and two seven-gill sharks *(Heptranchias cepedianus)* caught in a fisherman's trawl both contained fur seal parts (P. Eggling, *pers. comm.,* 1976). Whether these fur seal parts were from individuals killed or scavenged is unknown, but sharks are undoubtedly capable of catching fur seals. A small female fur seal with a series of three very severe gashes across her pelvis was observed pulling her way up the rocks at Taumaka during the austral summer of 1975-76. Such wounds could easily have been shark inflicted.

Adult fur seals were seen swimming in the same vicinity as seven-gill sharks, and while they were obviously aware of the sharks and alert to their presence, they showed no signs of flight. Conversely, the sharks paid no obvious attention to the fur seals. Perhaps it is the small, immature, or incapacitated fur seals which tend to be attacked. If so, then pups first venturing into the sea would be subject to more intense shark predation than other age classes. Sharks are known to prey upon other fur seal species, e.g., the Tasmanian fur seal (Warneke, 1975) and the South American fur seal *(A. australis;* King, 1964).

Killer whales *(Orcinus orca)* generally are not found in the vicinity of Open Bay Islands, but are commonly seen further south. Because severe wounds are rarely seen on New Zealand fur seals, Csordas and Ingham (1965) suggested that either killer whales do not prey upon them or else fur seals seldom escape if attacked. It is unlikely that killer whales would forego fur seals as food. Rather, a fur seal injured by an attack would stand little chance of escape.

Fur seal parts, including one small pup, have been identified in the regurgitation of New Zealand sea lions from the Snares Islands (M. W. Cawthorne and D. S. Horning, *pers. comm.,* 1977). The leopard seal *(Hydrurga leptonyx)* also probably preys upon fur seals, but because there is very little overlap in their ranges such predation is undoubtedly low.

*Mortality caused by disturbance*

Even if handling did not affect pup growth adversely, human presence was itself enough to cause pup deaths. When startled, adults and pups alike will panic and run, often precipitating a general stampede. Because of this, three pups were inadvertently killed during weighing and tagging operations. Two suffocated when trapped beneath a pile of pups under a large rock and the other was killed when a fleeing female leapt on it. On another occasion, a pup was killed when it ran off the edge of a 10 m high cliff onto rocks below. Such deaths can be minimized by not disturbing fur seals on the rookeries unless absolutely necessary during the first two months following pupping. After February, the immediate effect of human disturbance is not as critical, as by then the pups are more able to fend for themselves.

The capture of fewer tagged pups than expected at age 110 and 235 days in 1975 suggests that one or more of three things may have happened. Either tagged pups became more difficult to catch; or they suffered a greater mortality than non-tagged pups; or the original censuses from which the calculated ratio was obtained were inaccurate. The first possibility is highly unlikely because pups always run when approached. The third possibility also is unlikely, as there was no significant difference between the two independent counts, though more counts would have been desirable. Based on these limited data, the second alternative appears to be the most likely, although a count of dead pups made in May 1975 does not support it. Of 36 dead pups counted, 19 were tagged and 17 were not, which was not significantly different from the expected ratio of 49 percent tagged to 51 percent non-tagged ($\chi^2 = 0.21, P > 0.05$).

Although the evidence is not conclusive, the inference from the recapture data that tagging did increase pup mortality was considered sufficient to warrant the discontinuation of the use of monel metal cattle ear tags. In the northern fur seal these tags have been found to interfere with circulation and to damage an important muscle in swimming, the flexor carpi ulnaris (Keyes, 1966); they have also been shown to increase mortality (Chapman and Johnston, 1968). The tags are no longer used on northern fur seal pups (G. Y. Harry Jnr., *pers. comm.,* 1975).

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