Does Tagging and Handling Affect the Growth of Northern Fur Seal Pups (*Callorhinus ursinus*)?

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From 1957 to 1966, samples of tagged and marked northern fur seal pups (*Callorhinus ursinus*) consistently weighed less than untagged and unmarked pups on the Pribilof Islands, Alaska. At the time, it was concluded that tagging and handling had caused a loss of weight and had slowed the normal rate of pup growth. In re-evaluating the data from this time period, it seems that tagged pups grew at the same rate as untagged pups, but were smaller at the time of tagging than average size pups. The growth curve for tagged pups appears to lag behind that of untagged pups, suggesting that tagged pups were born later in the breeding season and were more susceptible to being captured and tagged than older and heavier pups.

De 1957 à 1966, des échantillons de jeunes otaries à fourrure (*Callorhinus ursinus*) des îles Pribilof, Alaska, révélaient que le poids des animaux étiquetés et marqués était constamment inférieur au poids des animaux sans marque ni étiquette. On avait alors conclu que l'étiquetage et la manipulation des jeunes otaries avaient causé une perte de poids et un ralentissement de leur croissance. Une nouvelle analyse des données semble toutefois indiquer que le taux de croissance était le même pour les animaux, qu'ils soient étiquetés ou non; cependant, les animaux étiquetés avaient une taille inférieure à la moyenne au moment de l'étiquetage. En effet, la courbe de croissance des animaux étiquetés est décalée par rapport à celle des animaux non étiquetés, ce qui laisse croire que les animaux étiquetés sont nés plus tard au cours de la période de reproduction; ils étaient de ce fait plus faciles à capturer et à étiqueter que leurs congénères plus âgés et plus lourds.

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In 1957, northern fur seal pups (*Callorhinus ursinus*) were weighed a few weeks after tagging and found to be lighter than untagged pups (Abegglen et al. 1957). Over the next 9 yr, biologists continued to report that untagged pups outweighed tagged pups on the Pribilof Islands, Alaska (Roppel 1984). Their conclusion was "tagging, marking, and handling, individually or combined, causes a loss of weight or slows the normal rate of weight gain. Loss of weight may cause tagged or marked pups to die at a greater rate than untagged and unmarked pups during their first winter at sea, thus inflating later estimates of the population based on recoveries of tagged and marked seals" (Marine Mammal Biological Laboratory 1969, p. 13).

Research into the effect of tagging and handling on the growth of northern fur seal pups ended in 1966 as interest in tagging seals waned. Biologists began expressing renewed interest in tagging in the mid-1980s (see Fowler 1986) and have been applying tags to samples of pups on the Pribilof Islands since 1987 to evaluate early survival, tagging procedures, and the longevity of different types of tags (G. A. Antonelis, (National Marine Mammal Laboratory (NMML), Seattle, WA, pers. comm.). The possibility that handling pups might slow growth and reduce future survival has implications for pinniped studies that rely on marking individuals for future identification. It also has bearing upon the interpretation of historical data collected from tagged northern fur seals and is relevant to understanding whether the mark–recapture method for estimating the number of pups born is detrimental to the survival of the Pribilof population. Could the shearing of thousands of pup heads (see York and Kozloff 1987) be reducing the young animals' growth rates and future survival?

The goal of my study is to reassess the data collected on tagged and untagged pups from 1957 to 1965 to determine whether tagging affects pup growth. A second goal is to reexamine data collected during 1965–66 from pups that were marked but not tagged to see whether the type of marking is related to pup growth. I begin by reviewing the methods used to tag and, later, to weigh the pups. I then compare the weights of tagged and marked pups and test whether tagged pups actually grew at a slower rate than untagged pups.

Materials and Methods

Tagging, Marking, and Weighing

Fur seal pups are born between the last week of June and the end of July (Bartholomew and Hoel 1953; Peterson 1968). The number of births over time is positively skewed, with over 50% occurring during the first 2 wk of July (Bartholomew and Hoel 1953; Peterson 1968; Trites 1992). By early August, the pups from large aggregations, gathering in areas where they are least likely to be trampled by the bulls. As the month progresses the pups being to play in and near the water's edge. On average, pups were about 5–6 wk old when tagged in mid-August and 7–8 wk old when weighed from August 29 to September 3.

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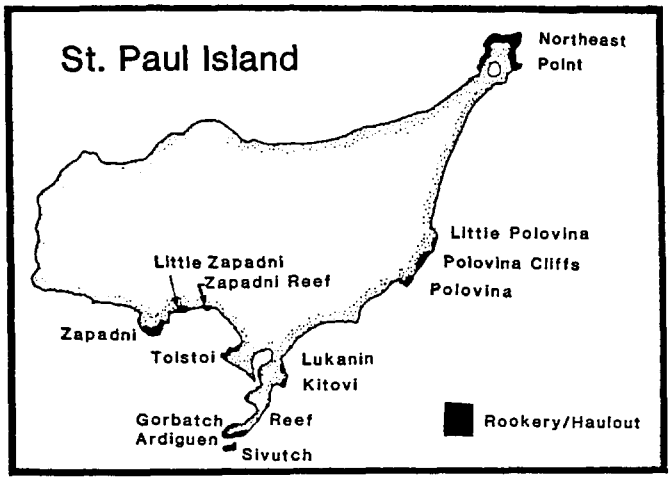

FIG. 1. Rookery sites on St. Paul Island, Alaska (adapted from Lander 1980).

Tagging and weighing were conducted between 1957 and 1966 on St. Paul Island, Alaska, by the United States Fish and Wildlife Service. Methods of data collection are contained in the annual "Fur Seal Investigations" reports (e.g. MMBL 1969) published by the United States Fish and Wildlife Service and are summarized as follows.

From 1957 to 1965, monel metal cattle-ear tags were applied at the hairline on the front flipper (1957–64) or between the fourth and the fifth digit (1964–65). Checkmarks, used to identify pups that lose the tag, were made by cutting a V-notch near the tip of a flipper or by slicing off a flipper tip. Tags were allotted to each rookery according to the proportion of harem bulls counted on that rookery. From 1957 to 1962, approximately 10 000 pups were annually tagged at each of Northeast Point and Reef rookeries (see Fig. 1 for locations). Fewer pups were tagged each year at Polovina (4400) and Zapadni Reef (3500). There was a further drop in the number of tags annually attached from 1963 to 1965 (2400 at Reef; 2500 Northeast Point; 1000 Polovina; 900 Zapadni Reef). In all, approximately 200 000 pups were tagged at these four rookeries on St. Paul Island between 1957 and 1966.

The aggregations of pups on the rookeries were approached from the inland side and herded towards barricades set up behind the rookery away from the water. The pups were lifted onto tables, tagged, and released seaward of the barricades. Some areas were covered more than once to achieve the desired number of tagged seals.

Information on the effect of handling as opposed to tagging was obtained in two years. In 1965, some untagged pups were marked by removing the tip of the first digit on the right hind flipper and were weighed 12–14 d later (Roppel et al. 1966). In 1966, 800 pups on Zapadni Reef and an equal number at Northeast Point were marked by shearing a patch of fur from the rump. They were weighed 13 d after marking (MMBL 1969).

Pups were weighed on a spring scale in the early years and later on a platform scale (Roppel et al. 1966). While the technique for weighing the pups was refined over the years, it remained consistent within years such that tagged and untagged pups were weighed under identical conditions in any given year.

For weighing, pups were rounded up and herded towards barricades. Pups were chosen for weighing from the "mob" that ensued and were released beyond the enclosure to prevent

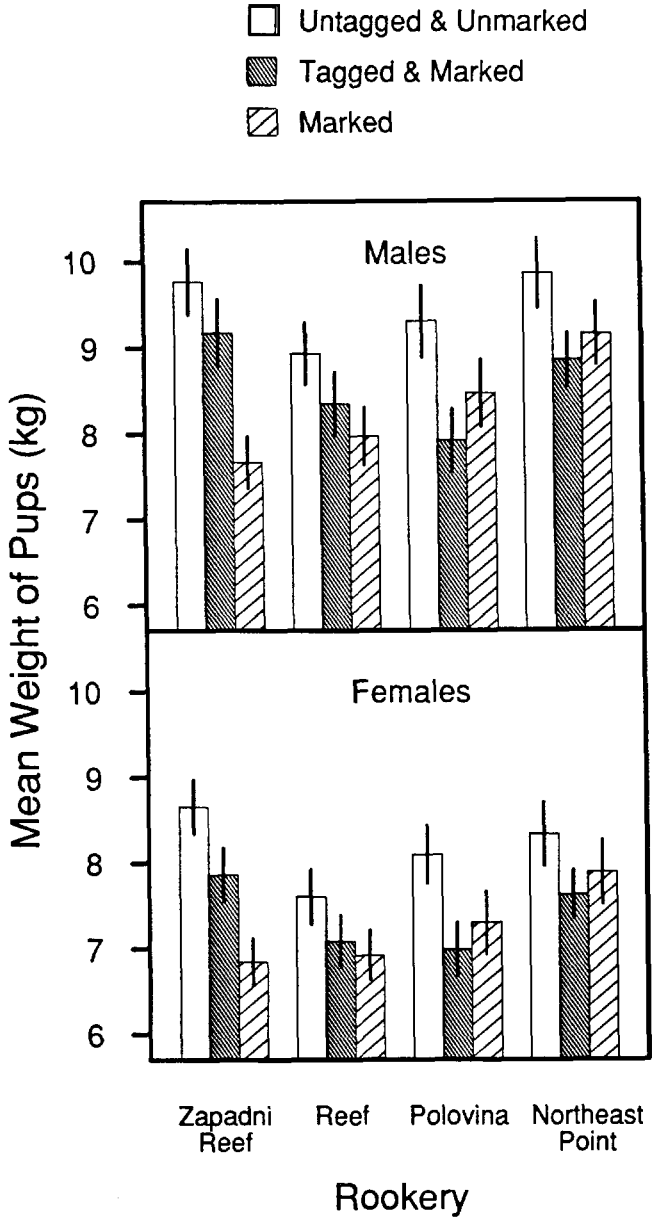

FIG. 2. Mean body weights of the tagged, marked, and untagged/unmarked pups weighed on four rookeries on September 2–3, 1965. Untagged pups were always heavier than those tagged and marked. Similarly, males weighed more than females. The solid lines show the 95% confidence intervals for the estimated mean weights.

reweighing. From 1957 to 1961, the annual number of tag-bearing pups weighed on a rookery varied between 1 and 111 of each sex and averaged about 50. The number of untagged pups also varied during the same period, averaging about 100 animals of each sex. From 1962 to 1966, biologists annually weighed 75 tagged and 75 untagged pups of each sex. In all, approximately 3500 tagged and 5500 untagged pups were weighed between 1957 and 1966.

The pup weight data are summarized in the annual "Fur Seal Investigation" reports and were obtained on magnetic tape from NMML, Seattle, WA.

Analysis of Growth Patterns

The mean weights of male and female pups (untagged, marked, and tagged) were estimated for each rookery and year

when more than 30 pups were weighed. Differences between the mean weights of tagged and untagged pups were then determined and 95% confidence intervals calculated. Weights of marked, tagged, and untagged pups recorded in 1965 were also reexamined and tested, by analysis of variance, to determine whether changes in weight were related to the type of mark applied.

The effect of tagging on growth was considered in three ways. First, the mean weights of tagged pups were compared with the mean weights of untagged pups. Next, the relative difference in weights ([untagged − tagged]/untagged × 100%) was plotted against the number of days elapsed since tagging to see whether or not a relationship could be attributed to the effects of tagging. Finally, growth curves were constructed for tagged and untagged pups and compared with one another.

Growth curves were drawn for two different time periods. The first was a reanalysis of three weighings of tagged and untagged pups made a month apart in 1962 that began 1 wk after tagging (Roppel et al. 1963). The second growth curve pooled the mean weights of pups recorded on each rookery from 1958 to 1966 and plotted them against the day they were made (between August 29 and September 3). Separate linear regressions were fit to the tagged and untagged data sets. The equality of the two population regression coefficients was determined with a Student t-test (Zar 1984). If the slopes (i.e. growth rates) were not statistically different, a second t-test was applied to determine whether the elevation (i.e. the vertical position) of the parallel growth curves differed significantly (Zar 1984).

Results and Discussion

Marked and tagged pups weighed in 1965 were lighter than previously unhandled pups (Fig. 2). But there does not appear to be a significant difference between the mean weights of marked pups and tagged pups. The weights of marked and tagged females were not significantly different on each of the four rookeries ($F_{1,588} = 1.767$, $p = 0.184$). For males, the difference in weight ($F_{1,588} = 4.039$, $p = 0.045$) is attributed to the Zapadni Reef sample. There was no significant difference in the mean weights of marked and tagged males among the other three rookeries ($F_{1,441} = 1.122$, $p = 0.290$). Thus, since the type of mark (either tagging or slicing the flipper tip) does not appear to be correlated with the weight of the pup, the remainder of this paper refers to all marked and tagged pups as being tagged.

With few exceptions, the mean weights of pups not previously handled or tagged consistently exceeded the mean weights of tagged individuals on all rookeries (Fig. 3 and 4). In some years the difference in weights between the two groups was as much as 1.7 kg, but there was no consistent pattern among the

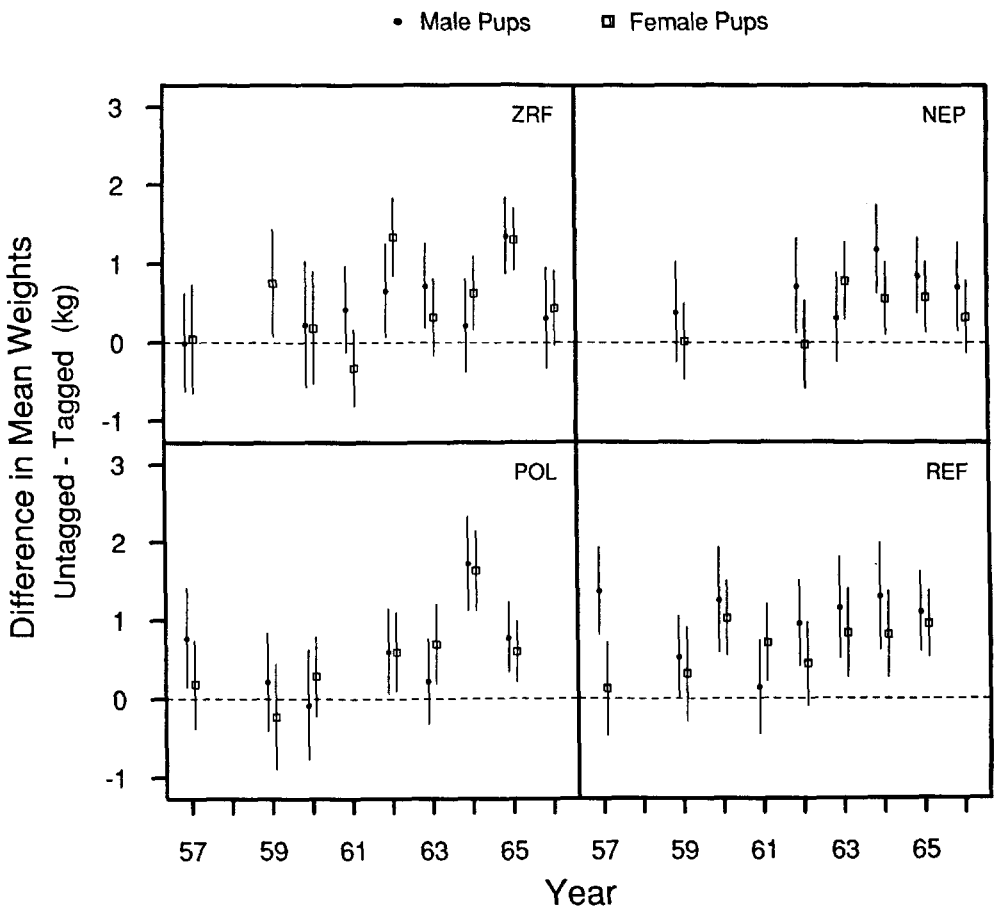

FIG. 3. Annual differences in the mean body weights of tagged and untagged male and female pups weighed on four rookeries: Zapadni Reef (ZRF), Northeast Point (NEP), Polovina (POL), and Reef (REF). Most of the points lie above the broken line of no difference, indicating that untagged pups weighed more than tagged pups. Solid lines are 95% confidence intervals for the estimated difference in mean weights.

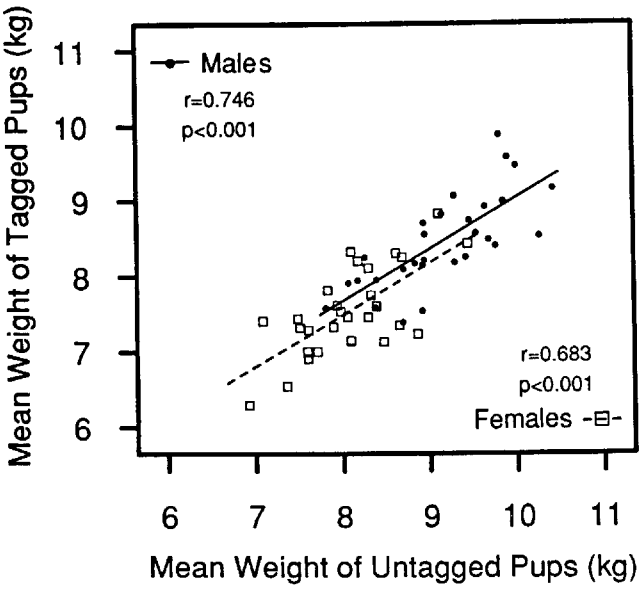

FIG. 4. Mean weights of tagged pups versus those without tags. Each point represents one rookery and one year (mean weights were calculated for samples sizes greater than 30 pups). The significance of the linear regressions is shown at the top and bottom of the panel for males and females, respectively. The different elevation of the parallel regressions shows the size difference between males and females.

different rookeries (cf. York and Antonelis 1990a, 1990b). Considerable variability existed among sexes. In some years, and on some rookeries, the difference between the weights of tagged and untagged pups was the same for both males and females. At other times and places (e.g. Reef, 1957, Fig. 3) there was a marked difference between the apparent effect of tagging on males and females.

Growth Rates

In 1962, tagged and untagged pups were weighed on three occasions: September 2–3, October 2–3, and October 24–25 (Fig. 5). Roppel et al. (1963) applied a *t*-test to each pair of observations according to date and rookery. They concluded that weight differences within rookeries were significant at the first weighing but were insignificant at the third weighing. In other words, they concluded that the immediate weight loss caused by tagging was partially overcome after 2 mo.

The lack of significance between the weights of tagged and untagged pups at the third weighing is partly explained by the small sample sizes and by the large variation in body weight attributable to growth. Pooled estimates of the standard deviation of male weights increased between the successive weighing periods from 2.00 to 2.46 to 2.98 kg. The standard deviations of female weight on the three occasions were 1.64, 2.12, and 2.41 kg. Sample sizes of 75 were sufficient on the first day of weighing to detect differences as small as 0.75 kg between the weights of tagged and untagged females, but should have been increased to 112 and 144 on the second and third weighings to maintain the power of the *t*-test (when $\alpha = 0.05$, $\beta = 0.25$). The sample size necessary to detect the same weight difference among tagged and untagged males should have been 95, 150, and 220 pups for each successive weighing. Thus it cannot be concluded with assurance that tagged pups regained their weight loss 2 mo after tagging because the probability of

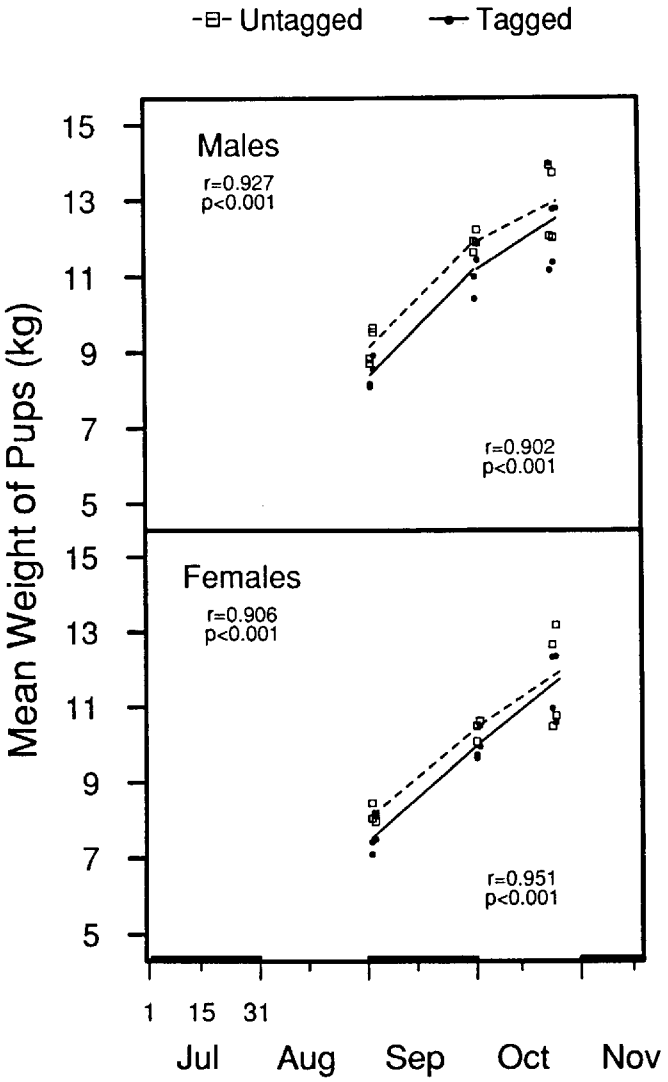

FIG. 5. Mean body weights of male and female pups weighed on four rookeries from September to October 1962. Linear regression describe two periods of growth for tagged and untagged pups. The significance of the separate regressions are contained in Table 1, while the significance of a single regression of the weight of pups over the three time periods is shown in the top and bottom of each panel, respectively.

detecting a true difference among the mean weights of tagged and untagged pups on the third weighings was too small (i.e. β, the probability of not rejecting the null hypothesis when it was in fact false was greater than 0.80).

Fitting linear regression to the 1962 data, pooled from all four rookeries, suggests that tagged pups grew at the same rate as untagged pups over the periods September 2 to October 3 and October 2–24, but were smaller than average when tagged (Fig. 5; Table 1). The same conclusion is drawn from growth curves constructed for the 6-d period August 29 to September 3 (Fig. 6; Table 1). It seems that both groups of pups started out in time at different sizes.

Unlike the weights of tagged males, tagged females, and untagged females shown in Fig. 6, the linear regression of untagged male weights from August 29 to September 3 was not significant because of the large variance associated with the larger male body weights. A significant relationship occurs when the number of data points is increased by including untagged males weighed in 1967–71, 1984, and 1987 ($F_{1,55}$ =

TABLE 1. Linear regression coefficients (growth rates) estimated for tagged and untagged pups weighed in 1962 and 1957–66. The equality of the two population regression coefficients was tested with a Student t-test (t_{slope}). A second t-test was used to test whether the elevations of the two population regressions were the same ($t_{elevation}$). The probabilities associated with the sample statistics are enclosed in parentheses. The rate of growth from 1957 to 1966 was determined using the annual mean estimates of body weights from each rookery where at least 30 pups were weighed.

Time period			Growth rate ($kg \cdot d^{-1}$)				
Year(s)	Days	Sex	Tagged	Untagged	t_{slope} (p)	$t_{elevation}$ (p)	Sample size
1957–66	Aug. 29 – Sept. 3	M	0.179	0.131	0.432 (0.334)	−4.307 (<0.001)	56
		F	0.180	0.160	0.214 (0.416)	−4.005 (<0.001)	58
1962	Sept. 2 – Oct. 3	M	0.093	0.092	0.120 (0.452)	−5.768 (<0.001)	1191
		F	0.081	0.077	0.544 (0.293)	−4.864 (<0.001)	1194
1962	Oct. 2–25	M	0.057	0.046	0.742 (0.229)	−3.547 (<0.001)	1191
		F	0.073	0.061	0.952 (0.171)	−2.517 (0.006)	1196

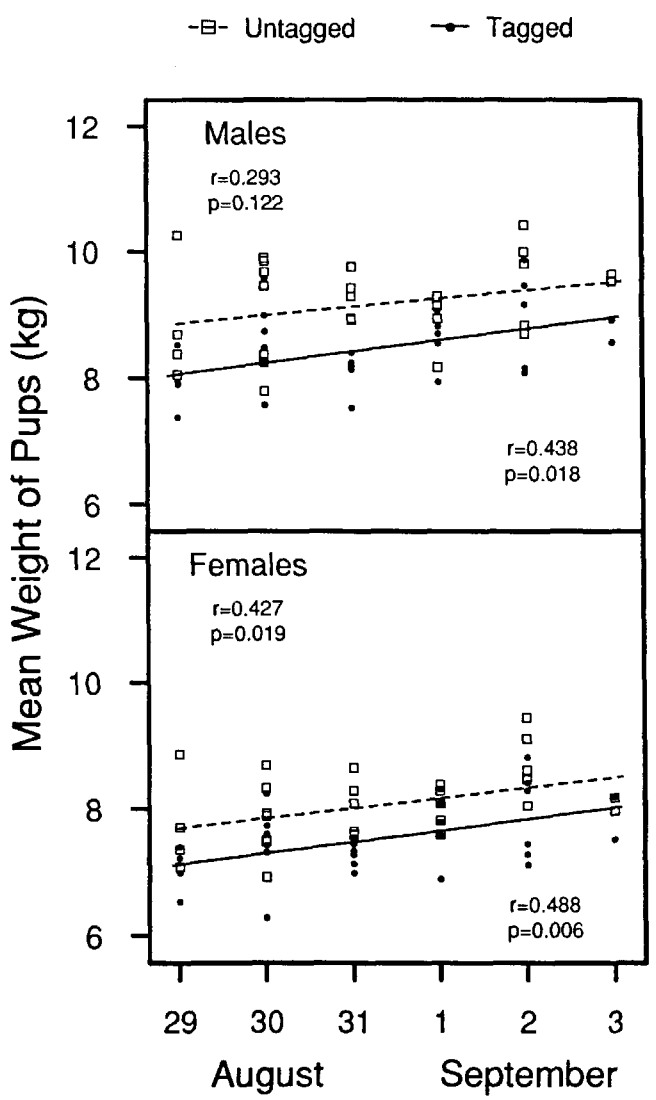

FIG. 6. Mean body weights of tagged and untagged pups weighed from August 29 to September 3. Each point represents one rookery and one year from 1957 to 1966 where the sample size was greater than 30. The linear regressions were fit to the mean data points rather than the raw values to reduce the combined effect of annual differences in body weights and sample sizes. The significance of the regressions is shown in the top and bottom of each panel.

4.97, $p = 0.030$; unpubl. data from the files of NMML, Seattle, WA). The slope of this regression (the growth rate) was not significantly different from the slope for tagged pups ($t_{83} = 0.486$, $p = 0.314$), but the regression elevations did differ ($t_{83} = -5.974$, $p < 0.001$).

The growth rate of males and females slows from August to November during the moulting period. For untagged males, the growth rate decreased from 0.131 to 0.092 to 0.046 $kg \cdot d^{-1}$ as the season progressed (Table 1). This reduced growth rate may reflect a decline in the amount of energy that a mother can transfer through her milk to her growing pup, or it may be that the metabolism of pups increases more rapidly with body size than does feeding rate. The duration of female feeding trips at sea (absence from the rookery) is known to increase over the breeding season and is believed to reflect the nutritional needs of the pup (Gentry and Holt 1986) Presumably, milk cannot meet the needs of a growing pup for more than about 4 mo, and it becomes necessary for the pup to increase its energy intake with solid foods.

Curiously, the growth rates of tagged pups, although not statistically different, always exceeded the growth rate of untagged pups (Table 1). If there was no difference in the growth rate, there should be an even distribution of the slopes, half (on the average) being greater for one group compared with the other. But all six cases fall in the same pattern which, from a binomial view of the probability, would occur with a chance of only 0.016. Some might therefore conclude that tagging increases the growth rate. A more likely explanation, however, is that tagged pups were born later than untagged pups and hence were in a different growth phase, or that the growth curve of tagged pups lagged behind that of untagged pups, or both.

If tagging had a persistent effect on growth, then there should be a relationship between the size of the pup and the number of days elapsed since tagging (Fig. 7), but there is none. It therefore appears, based on this and the above evidence, that tagging and handling did not affect pup growth, but that the pups selected for tagging were smaller than average and hence were not representative of the whole population. Conceivably, the pups rounded up for tagging were born late in the season. Perhaps many pups born earlier were in the surf and tide pools at the time of tagging and could not be rounded up. Or perhaps pregnant females that returned to land later in the breeding season were forced to give birth in the low-density peripheral regions of the rookery, such that their pups were more susceptible to being captured. Furthermore, taggers may not have chosen pups at random from the numbers they rounded up. Pups tend to pile up (and even smother) when surrounded. Perhaps

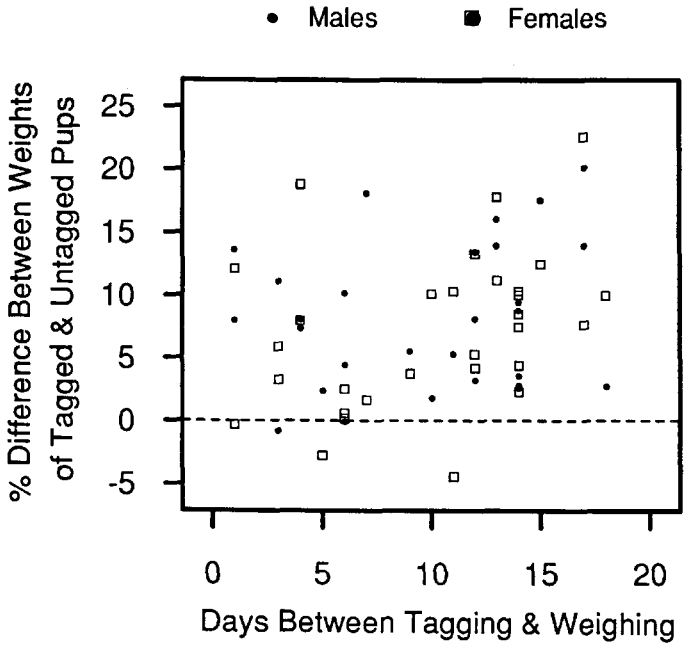

FIG. 7. Relative differences between the mean body weights of tagged and untagged pups subsequent to tagging. Each data point shows how much heavier untagged pups were compared with tagged individuals (expressed as a percent of tagged body weight). Each value represents the mean relative difference in body weights for one rookery and one year from 1958 to 1966. Dates of tagging were not available for 1957. There appears to be no relationship between the effect of tagging and the number of days elapsed since tags were attached.

smaller pups were taken from the top of the piles, leaving the heavier pups at the bottom.

There are a number of cases reported in which tagged (or marked) pups have been found to be lighter that the remaining seals at the time of marking. In one study, Roppel et al. (1981) followed a shearing crew that moved through the breeding beach to mark pups by shearing a patch of fur from the top of the pups' heads. The authors found that pups selected for shearing were lighter than unsheared pups and concluded that smaller pups were easier to handle. Another study by Gentry and Francis (1981) of known-aged animals concluded that pups captured for shearing were younger than noncaptured pups. Further evidence of this sampling bias is contained in Fig. 3 which shows a larger weight difference for males than females in 20 of 29 comparisons (binomial probability $P(X \geq 20) = 0.012$). This observation is again consistent with a sampling bias for selecting small pups at the time of tagging, given that males are on average heavier than females.

Other Species

Tagging pinnipeds facilitates studies of life history, population biology, behaviour, growth and development, dispersal from rookeries, and fidelity to birth sites. It also permits validation of aging techniques based on teeth (Condy and Bester 1975; Summers and Witthames 1978). Despite the tagging of many species of fur seals (e.g. Rand 1950, 1959; Csordas and Ingham 1965; Bonner 1968; Crawley and Brown 1971; Stirling 1971; Laws 1973; Condy and Bester 1975; Payne 1979; Mattlin 1981; Kerley 1985), there is little or no information about the possible effect that tagging might have on pup growth. Observations of Antarctic fur seals (*Arctocephalus gazella*) led Payne (1979) to suggest that pups tagged within 1 mo of birth grew slower than untagged pups, although no data were presented. Further studies of Antarctic fur seal pups, tagged when 2 mo old, showed no abnormal growth rates (Kerley 1985), not did tagged New Zealand fur seal pups (*A. forsteri*) (Mattlin 1978, 1981). Possibly the tags did not alter growth because they were attached at a less critical time in the development of the pup (Kerley 1985). On the other hand, it should be noted that none of the authors presented their data and that their conclusions appear to be based on small sample sizes. Thus it is doubtful that differences between the mean size of tagged and untagged pups could have been detected had they actually been present.

Results from reassessing pup weight data from northern fur seals suggest that tagging too early does not alter growth rates, but results in selecting individuals that are smaller than average. Possibly, pups of different ages are not randomly distributed on the rookery during the first month of pupping, but are segregated by size, such that small pups are more easily accessible for tagging and weighing than are larger ones.

While I do not believe that the weight differences between tagged and untagged pups are due to the tag, they are clearly nonetheless real and associated with tagging. This may well affect the relative survival of tagged pups in their first winter (or at any other time) and hence the validity of the assumptions of mark–recapture analysis. Thus the conclusions quoted from MMBL (1969) in the opening paragraph may be quite valid, if for the wrong reasons.

The conclusion that tagging and handling do not significantly affect pup growth can be strengthened or weakened by weighing pups at the time of tagging, recording their tag numbers, and then resampling at later dates to compare changes in body weight. This would undoubtedly reveal some of the possible biases inherent in the sampling design and shed light on the biological factors that cause differences in average weight. Researchers must be aware of the large variances in body weight and the difficulty of recapturing marked animals and therefore take statistically large samples to detect any changes in body size. This kind of research should be done before committing resources to long-term tagging programs.

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