APPARENT RATES OF INCREASE FOR TWO FERAL HORSE HERDS

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Abstract: Rates of increase for 2 Oregon feral horse (*Equus caballus*) herds were estimated from direct aerial counts to be about 20% per year. These rates can be achieved only if survival rates are high, and reproduction exceeds that normally expected from horses. A population dynamics model suggests adult survival to be the key parameter in determining rates of increase, and there is some direct evidence of high adult survival rates. Management implications are discussed.

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Widespread interest in feral horses, combined with differing management priorities, has led to substantial controversy about abundance and rates of increase of free-ranging herds. Counts of several Oregon herds in recent years have indicated high rates. This paper documents observations of horses on 2 such areas in Oregon, and compares estimates with potential rates. We do not propose that the observed rates in these herds are necessarily typical of feral horses in general. Because the observed rates are appreciably higher than might be expected on the basis of other experience with large mammals, we used a simple model of population dynamics to explore the range of vital parameters likely to be required if such rates are to persist.

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OBSERVED RATES OF INCREASE

Beaty's Butte Herd

The Beaty's Butte herd management unit is 78 km east of Lakeview, Oregon, on the Nevada border. The unit totals 176,900 hectares, of which 160,470 hectares are managed by the Bureau of Land Management. Topography varies from gently rolling hills to steep hills and buttes with a number of broad valleys and shallow or dry lakes. Big sagebrush (*Artemisia tridentata*) dominates virtually the entire area with an understory of Sandberg bluegrass (*Poa sandbergii*), Thurber needlegrass (*Stipa thurberiana*), bottlebrush squirreltail (*Sitanion hystrix*), bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), and early season forbs. Livestock grazing and wildlife habitat are the primary public land values within the area.

Substantial numbers of horses have used the general area since the early 1900's. From the mid-1930's to the late 1940's there were approximately 2,500–3,000 horses present. By the mid-1950's numbers had been reduced to less than 50 head. The population increased slowly until the early 1970's, probably as a consequence of periodic removals. The first recorded aerial count was in 1969, and counts have continued to the present (Table 1). Fencing and natural barriers have limited ingress or egress of horses to and from the area. A fence to the south was down in 1972 (but repaired by November 1972), and the sharp increase in

Table 1. Feral horses censused on Beaty's Butte Management Unit, Oregon, 1969–80.

Date	"Adults"	Foals	Foals/ 100 "adults"	Totals
Oct 1969				142
Mar 1971				179
Oct 1971	190	44	23	234
Oct 1972	271	69	25	340
Apr 1973	279	25		365
Aug 1973	345	78	23	423
Jan 1974	328	85	26	413
Aug 1974	372	110	30	482
Aug 1975	494	117	24	611
Aug 1976	586	176	30	762
Aug 1977	690	189	27	879
Sep 1978	229	44	19	273
Sep 1979	251	54	22	305
Aug 1980	328	91	28	419

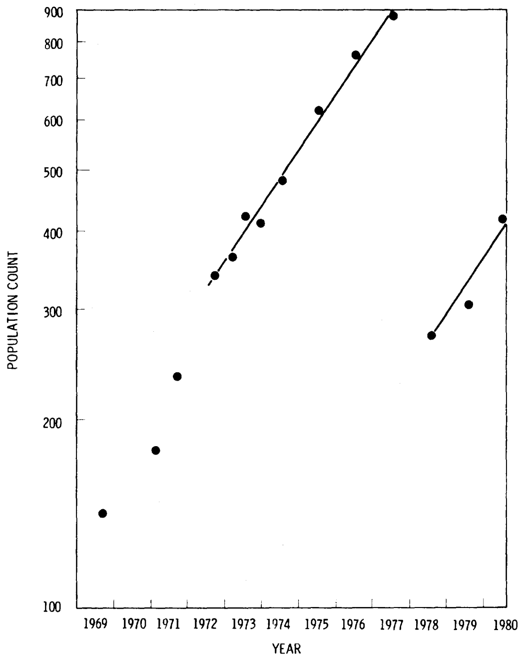

Fig. 1. Feral horse counts on the Beaty's Butte Management Unit. Regression line (log scale) calculated from 1972 to 1977 data, and projected to 1980.

numbers from 1971 to 1972 may have been associated with ingress from the adjacent Sheldon Game Range herd.

Results of the aerial counts were plotted as a semi-logarithmic plot with a regression line fitted to the counts from 1972 to 1977 (Fig. 1). These counts, with 1 exception, were made by A. K. Majorowicz from a Cessna 182, using basically the same flight pattern during the first 4 or 5 hours of daylight. A total of 776 horses was removed from fall to spring 1977, and about 30 were moved into the area in "gathering" operations to the east. The regression estimate of the instantaneous annual rate of increase from 1972 to 1977 is 0.20 (95% CL = 0.18 to 0.23). Projecting this rate from 1978 to 1980 appears compatible with the observations for those years (Fig. 1).

Jackie's Butte Herd

The Jackie's Butte herd management unit is in southeastern Oregon, about 19 km southeast of Rome. The unit includes 31,600 hectares of which 98% is managed by the Bureau of Land Management. The topography is relatively flat, with gentle undulations. Jackie's Butte (1,340 m) is the only prominent landmark. Cover types are similar to those of the Beaty's Butte area, with big sagebrush, bluebunch wheatgrass and squirreltail as major vegetation types. Portions of the area have been seeded to crested wheatgrass (*Agropyron cristatum*), and the area is completely fenced.

This herd has been counted since 1969, with counts from 1974 to 1979 by J. A. Wilcox, who also participated in the 1969 and 1970 surveys (Table 2). A helicopter was used in 1970, and again from 1974 to 1980. Fixed-wing aircraft were used for counting in the other years. Three removals were made (Oct or Nov) from the area since 1969. These provide a check on the accuracy of the counts as the difference between the total count of 1 year and the "adult" category in the following year should equal the known removals plus any other losses.

For example, in 1970, 181 horses were removed as compared to the difference between 263 in September of 1970•and 78 "adults" in January of 1972, which was 185 horses. In 1976, 137 were removed while the corresponding difference was 135. A 1978 removal of 136 may be compared with a difference of 134. There thus is little reason to doubt the accuracy of the counts, although it is possible that a few early-season foals might have been classed as "adults", decreasing the apparent difference somewhat. The "adult" category includes all animals older than foals, due to the difficulties of classification from the air.

Table 2. Feral horses censused on Jackie's Butte Management Unit, Oregon, 1969–80.

Date	"Adults"	Foals	Foals/ 100 "adults"	Totals
Mar 1969	175	50	28	225
Sep 1970	208	55	26	263
Jan 1972	78	16	20	94
Jan 1973	86	27	31	113
Mar 1974	113	27	24	140
Oct 1974	125	30	25	150
Apr 1975	186	36	19	222
Aug 1976	208	72	35	280
Nov 1977	145	56	39	201
Aug 1978	198	37	19	235
Dec 1979	101	27	27	128
Nov 1980	119	34	28	153

Estimating the rate of increase for the Jackie's Butte area was complicated by the removals and it was necessary to pool rates from 3 different time intervals, using a weighting scheme (Snedecor and Cochran 1967:432–436). The resulting value was an 0.18 instantaneous annual rate of increase. Using only the data from 1972 to 1976 (the longest period with no removals) gave a rate of 0.19.

POTENTIAL RATES OF INCREASE

Biologists having extensive experience with large mammals are likely to view the above rates as improbable in terms of their experience. An important point, however, is that most such experience is with wild animals subject to mortality from a number of causes. In the horse herds considered here, few mortalities have been observed, and the likely sources of mortality are largely limited to disease (not yet observed) and an occasional accident (largely with fences). It is thus instructive to examine potential rates of increase with low mortality rates.

Any detailed appraisal of population dynamics requires a knowledge of both age-specific mortality rates and age-specific reproductive rates. Unfortunately neither of these requirements can be supplied for the herds considered here, beyond the little evidence of mortalities in the recent history of the areas, and the relatively high proportions of foals observed with the herds (Tables 1, 2). There are few suitable data on mortality rates for any feral horse herd, and surprisingly little data on reproduction for unconfined horses in comparable environments. Survival estimates for adult horses range from 70 to 80% per year (Wolfe 1980:Table 5) to 95% and higher (National Research Council 1980).

A number of foalings was observed in eastern Montana by Speelman et al. (1944) under range conditions. Their data yield a 60% foaling rate for 209 mares age 4 or older, observed over several breeding seasons. Peak rates were observed between 8 and 10 years of age, with a gradual reduction to age 20, and a sharp decline thereafter. Maximal reproductive rates for horses under good conditions are apparently not well established as domestic horses are rarely maintained in conditions permitting maximal possible foaling. We thus arbitrarily assume a maximal rate of 90% per year, to contrast with the data of Speelman et al. (1944). Boyd (1979) observed an 86% foaling rate in animals 4 years of age and older on a Wyoming area in 1978, but the rate dropped to 54% in 1979, after a severe winter. Several additional sets of data on foaling rates are tabulated in the National Research Council (1980) report.

Undoubtedly both reproductive and survival rates decrease sharply in older animals. We assume that a decrease probably occurs at about 20 years of age, from experience with domestic horses and the observations of Speelman et al. (1944). The effects of old age probably are minimal for 2 reasons. One is that the herds have increased dramatically in a relatively short span of time (Tables 1, 2). The other is that the several reductions probably removed the oldest horses. This circumstance probably prevails in many managed areas, as the oldest animals are usually readily caught and are customarily not returned, if any animals are released back into the area.

The remaining issue in estimating potential rates of increase is age structure. The highest rates can be expected if the population is concentrated in the "prime" age classes, where reproductive rates are highest and mortality is minimal. Unfortunately, little is known about the age structure of the herds considered. However, the relatively short periods in which larger numbers of horses were present make it clear that the age structure has few old animals. This is supported by observations of the vigor of individuals in the annual surveys. For lack of a useful alternative, we assume that the age structure follows a "stable" age distribution, i.e., that established after a substantial period at a constant rate of change.

Although it seems clear that mortality was low in the herds concerned, it is a generally accepted principle that the youngest animals in most populations will show appreciably higher mortality than fully mature individuals. We have considered that a lower rate of survival needs to be incorporated for the younger animals, specifically from birth to 2 years of age. We thus used 2 survival rates, a single reproductive rate, and assumed a stable age distribution. The model is essentially that used by Leslie (1966), and seems to be the simplest practical approach in the absence of knowledge of the actual age-specific rates (as is often true in unconfined populations).

In Leslie's example, adult survival was such that the expected decrease in old age was not particularly important as relatively few animals survived to reach senescence. In the present situation, survival rates are quite high. However, animals in age classes beyond 20 are not likely to be present in any numbers, so we have simply truncated the age-structure at age 20. This can be thought of as either implying zero survival after age 20, or an effective cessation of reproduction at that age.

With the exception of the above truncation at age 20, the balance of our model follows that of Leslie, as adopted by Eberhardt and Siniff (1977). We assume the Lotka equation for a steady-state population:

$$1 = \sum_{0}^{\infty} \lambda^{-x} \ell_x m_x$$

$$= \lambda^{-a} P_0 P_1 P^{a-2} F \left[\frac{1 - (P/\lambda)^{w-a+1}}{1 - P/\lambda} \right],$$

where a = age of first reproduction, w = maximum age, ℓ_x = survival to age x (replaced in the 2nd equation by products of P_0, P_1, and P, which represent respectively survival in the 1st, 2nd, and subsequent years of life). Also m_x denotes the age-specific reproductive rate, expressed as female births per female which is replaced by a single rate, F, in the 2nd equation, and lambda denotes the finite population multiplier. Lambda is a multiplier denoting the size of the population 1 year after the current time. We assume an equal sex ratio at birth, so that F is one-half of the rates proposed above ($F = 0.3$ or $F = 0.45$).

Although the above model is greatly simplified from the Lotka equation, or the often-used Leslie matrix formulation, it nonetheless still contains several variables, making it difficult to evaluate potential rates of increase without making an explicit choice of values of these several variables. A convenient way to depict the possible solutions was used by Eberhardt and Siniff (1977). The equation is rearranged so that the ratio of the first 2 years' survival to adult survival can be denoted by K, that is:

$$K = \frac{P_0 P_1}{P^2}.$$

We can then plot K for various values of P and a choice of the age (a) of first reproduction. For present purposes we use $a = 3$ and $a = 4$. It should be noted that a denotes the age of the female when the first foal is born, and that available data indicate that relatively few females give birth at the earliest observed reproductive age. Consequently, the age assumed here is presumed to be that of the 2nd year, i.e., when $a = 4$ there will normally be a small proportion of females producing their first foal at age 3 (but this is neglected in the model). It is evident (Fig. 2) that the age of first breeding has a minor effect compared to that of adult survival rate, unless rates of increase are relatively high and juvenile survival is also high, as in the 2 herds considered here. The right-hand margins give values of lambda, the finite population multiplier.

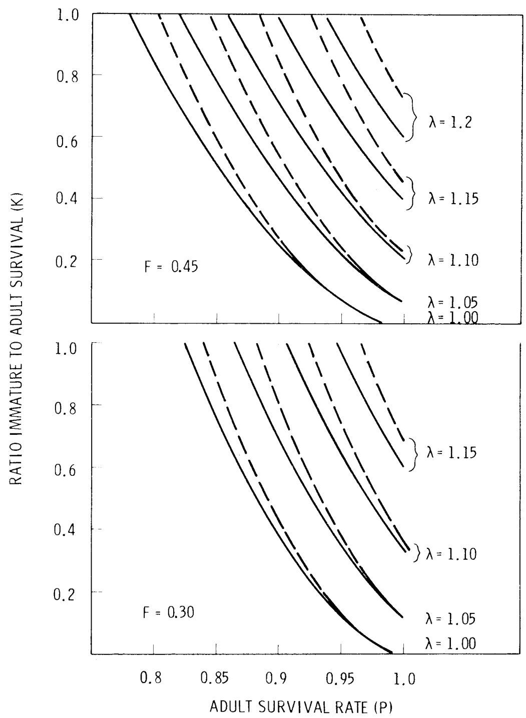

Fig. 2. Ratio of immature to adult survival (K) of feral horses plotted against adult survival (P) for various rates of population change (λ). Upper panel gives rates for annual reproductive rate (female births per female) of $F = 0.45$, lower panel for $F = 0.30$. First reproduction at age 3 (———); first reproduction at age 4 (— — —).

It can thus be seen that the values observed in the Oregon areas are rather improbable for $F = 0.3$, but are achievable at the higher reproductive rate ($F = 0.45$), providing adult survival exceeds 95% and survival for the first 2 years of life is 60–80% of adult survival. Conley (1979) gives results that are roughly comparable to ours (Fig. 2) but does not incorporate a separate survival rate for the first year, and truncates survival at age 14.

BIRTH AND SURVIVAL RATES

The data presently available on reproductive rates on the 2 areas are numbers of foals per 100 adults (Tables 1, 2). If there were no mortality of either adults or foals, then the ratio of foals to adults would necessarily be equal to the observed rate of increase. However, we believe there is presently some small rate of adult mortality, and that the rate of foal mortality is necessarily higher than that for adults. Consequently, the reproductive rate must be higher than the rate of increase if the increase is to be maintained with some mortality. An estimate of the birth rate thus required can be obtained from eq. (2) of Eberhardt and Siniff (1977), using the same modification for truncation at age 20 as discussed above. It is also necessary to provide values of P_0 and P_0P_1. These were obtained by supposing that $P_1 = P$, and writing $P_0 = PK$ and $P_0P_1 = P^2K$ in the equation for birth rate. With these modifications, the parameters of Fig. 2 can be used to calculate birth rates corresponding to adult survival rates. This gives values in the range of 0.20–0.25, in general accord with the observed foal/adult ratios (Tables 1, 2). We have assumed an even sex ratio in the calculations, which may not be the situation in reality.

Survival rates have been calculated from wild horse age data (National Research Council 1980, Wolfe 1980). The method frequently used is that of Chapman and Robson (1960). This method assumes a constant survival rate exists over the age classes actually used in the calculations, and an unchanging population level. This then makes the age structure a geometric series, with parameter equal to the survival rate. However, if the population is increasing, the estimates will be biased, to a degree that may not be adequately appreciated by many users of the methods. In the present instance, age structure can be calculated from eq. (3) of Eberhardt and Siniff (1977):

$$c_x = \beta\lambda^{-x}P_0P_1P^{x-2} \qquad (\text{for } 2 \leq x < 20),$$

where β = birth rate per head (assumed constant). If $\lambda = 1$, this then gives the geometric series referred to above.

Various methods are used to estimate survival from age distributions, depending on the assumptions made about sampling error in the data. For examination of the bias, we can use the simplest method, i.e., the ratio of 1 class to the next youngest. This gives:

$$c_{x+1}/c_x = P/\lambda.$$

Hence when $\lambda = 1$, the true survival rate is estimated. However, if the population is increasing, survival is underestimated. For example, if $P = 0.98$ and $\lambda = 1.15$, the estimated rate is 0.85. Given such a biased estimate, one might erroneously conclude that the population would be unable to attain the rates of increase observed in this study. The logical conclusion, using the results displayed in Fig. 2, would be to expect little or no increase in the population under study, but that conclusion would be an artifact of the bias in the estimated rate.

Wolfe (1980) recognized this problem, but did not attempt corrections. Multiplying his estimates of survival (Wolfe 1980:Table 5) by estimates of λ from his Table 1 gives adjusted survival estimates for 4 areas. The average rate thus obtained is 0.94 annual survival for adult females (1 of the 4 samples is a composite of males and females).

A referee suggested calculating an approximate survival rate for the areas studied here by taking the ratio of the number of "adults" in 1 census to the number of "adults" plus foals in the previous year. For Jackie's Butte this procedure gives an average rate of 0.935, with individual rates ranging from 0.89 to 0.99. The Beaty's Butte data are rather more variable, but average 0.926. The rate thus estimated is a composite of "adult" and foal survivals. Using the total numbers of horses tallied in the years suitable for estimates (excluding removals) for weights gives (Jackie's Butte):

$$798P + 212P_0 = 944.$$

This can be rearranged into an expression in K ($=P_0/P$) and P. The resulting curve is nearly coincident with that for $\lambda = 1.20$ and reproduction at age 3 in the upper panel of Fig. 2. We conclude that these survival estimates are compatible with the assumption that $F = 0.45$ and that reproduction occurs at age 3 on the areas studied.

DISCUSSION

It appears that the rates observed in the 2 Oregon areas may be compatible with the usual results of population dynamics models. When lambda is defined as e^r, where r is the rate of increase, an observed rate of, for example, 0.18 must be transformed to 1.20 for comparison with Fig. 2.

Some biologists with experience in studying large mammals may doubt the rates of increase documented here. The difficulty may be that wild mammals are rarely encountered in situations where mortality is greatly reduced and reproductive rates achieve maximal values. For example, Eberhardt and Siniff (1977) noted that marine mammals are unlikely to be able to achieve rates of growth in excess of 10% a year, although a number of pinniped species do show reproductive rates of about 90% per year. However, Payne (1977) documented a rate of increase for the Southern fur seal (*Halichoerus grypus*) exceeding 15% per year. The likely conclusion is that these seals were temporarily in a position of abundant food supplies, lacked crowding, disease, and appreciable predation. This is the situation with some feral horse herds.

There has been a generally skeptical attitude as to the reality of rates of increase of 20%/year in recent literature on feral horse herds (Frei et al. 1979, National Research Council 1980, Wolfe 1980), although the reports do cite data yielding such rates. One difficulty is that these reports use data collected by different methods and observers, on areas of sometimes uncertain boundaries, with topography or cover that may be unsuited for aerial surveys. As the present study is largely free of these problems and arrives at similarly high rates, there is clearly a need for a much more detailed assessment of the underlying population parameters. Data on age-specific pregnancy and survival rates needs to be obtained on herds having different range conditions.

While a year's difference in age at first reproduction can make an appreciable change in the first year survival required to achieve high rates of population increase, that difference is only equivalent to 2 or 3 percentage points in adult survival (Fig. 2). Adult survival is thus a key parameter, and needs to be determined accurately. Radiotelemetry may provide the most cost-effective method for that purpose. Foal survival is known to vary with annual weather conditions, and evidently (Fig. 2) is not as narrowly controlling as is adult survival.

MANAGEMENT IMPLICATIONS

It is important to stress that the herds studied should not be regarded as typical of all feral horse herds. There are situations in which the rates of increase are appreciably smaller than those reported here and herds in the same management districts as those reported here appear to have lower rates, but are unfortunately not as well documented as those described above. Generalizations about all herds should not be made from the observed data, but research and management should be conducted in awareness that such rates are feasible and have been observed.

The management problem is basically that a herd with an annual rate of increase of 0.20 will more than double in size in 4 years. Substantial and continuing removals of feral horses must thus be made to sustain other uses of the affected rangelands, including cattle-grazing and wildlife uses. Under prevailing legislation, horses removed from Federal lands administered by the Bureau of Land Management cannot be sold, so that the bulk of the removals have been transferred to private ownership under an "Adopt a Horse" program. A "fact sheet" issued by BLM in June of 1981 reported that over 29,000 horses and burros (*Equus asinus*) have been removed and placed in private hands at an average cost of $300 per animal. Starting 1 October 1981, a flat fee of $200 per horse adopted will be charged, replacing a nominal fee in the past. The effect of this fee on adoption rates is as yet unknown. Current population estimates were reported as 56,000 feral horses and 17,000 burros on public lands.

Costs and numbers to be dealt with thus dictate a need for an efficient management scheme. Topography and cover conditions on many of the areas make censusing more difficult than on the 2 areas described here. Improvements in census methodology will at best provide better estimates of the numbers to be removed. Reduction of the total removals required can essentially be accomplished in 2 ways. One is to maintain the overall population at a low level. The other is to manipulate 1 or more of the parameters controlling rate of population growth. An approximate appraisal of the relative impacts of changes in the various parameters can be obtained from the model used here. Selective removals will change age structures, so a somewhat more complex analysis will ultimately be needed. Effective management requires both understanding of the processes resulting in population growth, and active use of that knowledge.

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