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RESEARCH ARTICLES

Population Dynamics of Pedigree Leopards, *Panthera pardus* ssp, in Captivity

Alan H. Shoemaker

Riverbanks Zoological Park, Columbia, South Carolina

The demographic history of 4 races or subspecies of leopard, *Panthera pardus*, was reviewed from international studbook records dating back to 1953. The Chinese leopard has been the most common pedigree race maintained in captivity, a factor linked to the length of time (29 years) this subspecies has been in captivity. The relative youth of the wild-born founders also helped them to adjust to captivity as well as live long reproductive lives. Today, however, this race is suffering from the ill effects of inbreeding due to the small founder size. This condition appears to be correctable now that additional specimens have been located.

Persian leopards have a larger founder size than the former race, but some of their ancestors were older animals at the time of acquisition. Because of this, their potential fecundity was probably depressed from psychological problems related to adjustment and a shorter life span in captivity. Two founding females experienced pelvic deformities while young, and few of their cubs survived because they all had to be delivered via caesarian section. This procedure also shortened the reproductive life of the females involved because the owning zoos refrained from breeding the animals in the leopards' later years.

Captive leopards appear to live longer than their wild counterparts, although precise data on wild populations is not available. In captivity many reach 12–15 years old, and exceptional individuals of several races have lived 20 years. Most captive-born leopards begin breeding when they are 3 years old and continue until they are 8–10 years old. Reproduction in females usually ceases at 12–14 years, although males have a longer reproductive life, with several successfully breeding when 19–20 years old.

Key words: Amur, Chinese, Persian, Ceylon, leopard, maturity, fecundity, subspecies, reproduction, fertility

INTRODUCTION

Since 1974 four subspecies or races of leopards, *Panthera pardus*, which are rare in captivity, have been organized into international studbooks [Shoemaker, 1977, 1980]. These include the Amur leopard, *P p orietalis*; Chinese leopard, *P p japonen-*

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Address reprint requests to Alan H. Shoemaker, Riverbanks Zoological Park, 500 Wildlife Parkway, Columbia, SC 29210.

sis; Persian leopard, *P p saxicolor*; and Ceylon leopard, *P p kotiya*. Individuals qualifying for registration in the studbook must be able to trace their ancestry back to the wild in an unbroken chain possessing no other races of leopards within it. Three of these races are derived from a very limited gene pool of wild-born ancestors, however, and the ill effects of inbreeding have been noted in two lineages [Shoemaker, in press].

HISTORY

The information collected in the leopard studbooks begins as early as 1953 when the first Chinese leopards were imported to the Leipzig Zoological Park [Shoemaker, 1978]. Since then some races have been very prolific in captivity, with the Chinese subspecies now possessing over 330 individuals within its pedigree. This large number is partially related to the great length of time this race has been in captivity as well as its somewhat larger founder size and popularity within zoological parks. Coincidentally, however, this race has probably been more prolific than others because its founders arrived in captivity as young animals rather than adults. Some founders for the Amur and Persian leopards were fully adult upon arrival, a situation which retarded their races' propagation.

In establishing managment plans for any species, the accumulation of demographic data on a number of different individuals over prolonged periods of time is very useful in planning for future exhibits and management programs [Foose, 1981]. The following information not only provides census data on all four races of pedigree leopards, a factor which by itself may be misleading, but also gives insight into the reproductive potential of the species as a whole and some of the management problems confronting it. While husbandry techniques and expertise vary widely among the owners and span several continents and many countries, the large sample size does present some good averages as well as exceptional cases.

CENSUS

The Amur leopard has been in captivity since 1960, and in the case of Russian zoos, for even longer. A number of males have been taken from the wild and exhibited within the USSR but only one female has ever been paired with these males and no young were ever reared. Most specimens in European and North American zoos are derived from the Russian part of their range but today (1982) the seemingly large population (Fig. 1) is actually derived from a founder size of only five wild ancestors. Nearly all captive-born animals derive the bulk of their ancestry from a single pair of animals imported by the Frankfurt Zoo, although some animals also contain founders from Leipzip or Center Hill, Florida, importations.

Persian leopards registered within the studbook include specimens from both northern Iran and Afghanistan. Recently this race has become one of the most popular subspecies of leopards in captivity. From a conservation standpoint, this is probably prudent since both Iran and Afghanistan have experienced political strife in recent years. Although the implementation of CITES (Convention in International Trade in Endangered Species of Flora and Fauna) has halted the international trade in skins, an overall reduction of ungulate and other prey populations in both countries, coupled with a lack of conservation practices, has almost certainly had a detrimental effect on wild populations.

Fig. 1. The number of Amur leopards, *P. p. orientalis,* in captivity, excluding those in the USSR.

The founder size of this race is the largest of any of the pedigree leopards. The fecundity of this race has been impaired nevertheless because some of the wild-born specimens were captured as adults and undoubtedly had adjustment problems as well as an obviously shorter life span in captivity. Two imported females also suffered from skeletal deformities presumably related to a calcium-deficient diet when young. Although several young were successfully delivered from these individuals via caesarian section, most young born to these females did not survive and their overall potential was not realized.

Until recently, captive populations of Persian leopards in North America and Europe have remained separate and have not benefitted from interchange between their respective gene pools (Fig. 2). Such a condition would have been harmful to both populations in time if it had been allowed to persist. In the last several years, however, specimens have been transferred among owners on both continents, and the isolation, particularly of the North American population, has been relieved.

The Chinese leopard is the most numerous of the four pedigree races maintained in captivity (Fig. 3), and 92 animals were alive in 1980. Although nearly all captive animals are derived from only three pairs of wild ancestors, all these individuals arrived from the wild as young and thus were able to initiate long reproductive lives and geneologies. It is also quite likely that some or perhaps even all of these three pairs were littermates. Although such a theory cannot be proven, the overall pattern of inbreeding has had an alarming effect on the survival of the young [Shoemaker, 1982]. A new collection in Omaha totaling nine (three males and six females) pure animals unrelated to any other captive specimens has now been verified and, it is hoped, will bring relief to the present situation.

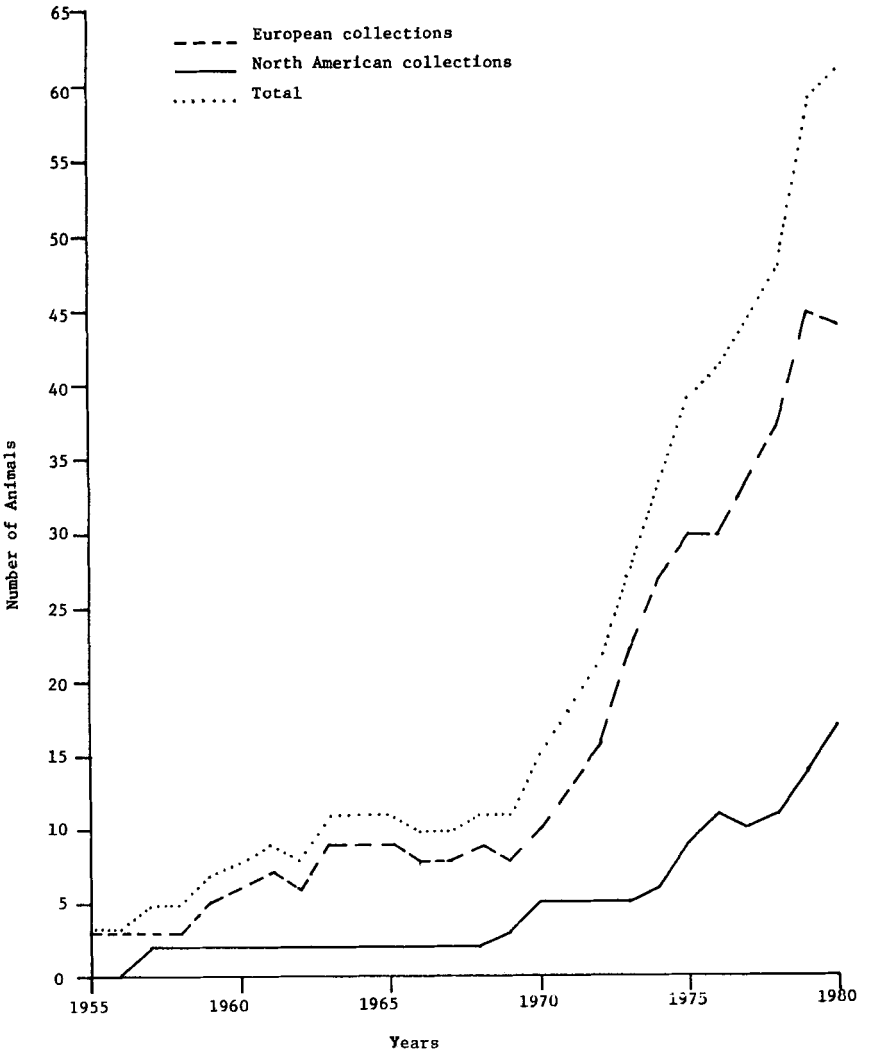

Fig. 2. The number of Persian leopards, *P. p. saxicolor,* in captivity.

Chinese leopards in Europe have remained isolated from North American specimens. The numerically significant animals are those which have remained within the sphere of European ownership. This race was quite popular there during the mid-1960s and early 1970s. Several notable breeding centers produced numerous young, which were dispersed to zoos and private owners in nearly every country of that continent. More recently, however, after the main breeders died or ceased breeding because of advancing age, there has been a reduction in both captive propagation and in overall numbers. Replacement breeders have frequently been difficult to locate and many of the apparently compatible pairs have unusually high levels of inbreeding, a factor suspected of repressing reproduction during the last five years.

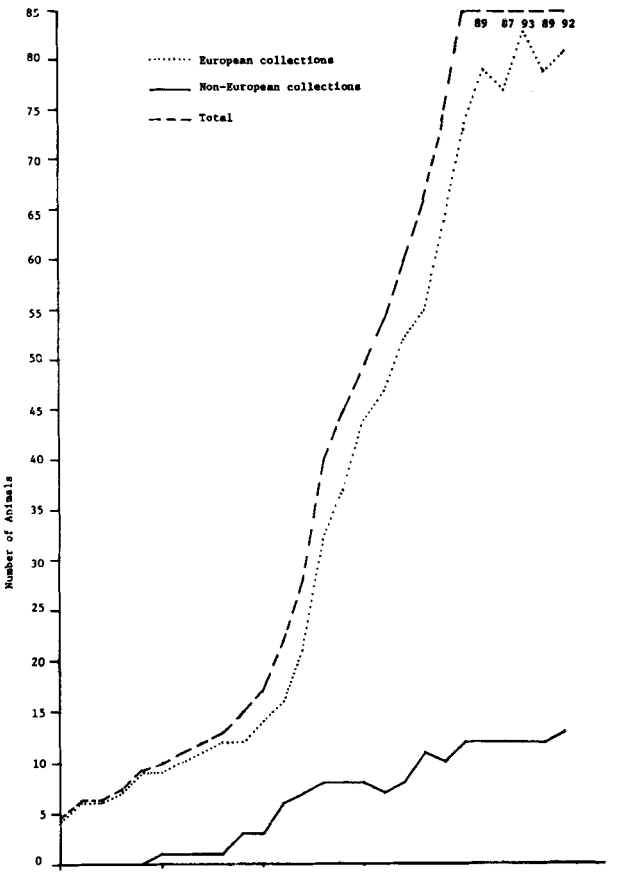

Fig. 3. The number of Chinese leopards, *P. p. japonensis,* in captivity.

In North America, this race has suffered from a scarcity of males and unintentional subspecific hybridization. One collection unwittingly produced over 20 such hybrids and therefore lost the breeding potential of two females, one of which is wild born. The breeding group in Omaha, coupled with existing individuals and new potential animals from China, should change the situation in North America.

Ceylon leopards were added to the international studbooks three years after the project was initiated [Shoemaker, 1979]. Historically this subspecies was included within the Indian subspecies, *P p fusca*, but was separated from that race by Deraniyagala in 1956. Leopards of Ceylon (Sri Lanka) are smaller than mainland forms, as would be expected of an insular subspecies, have closer spaced rosettes, and proportionately longer tails. Many of the specimens imported from Ceylon were juveniles at the time of their capture and have reproduced for all their reproductively mature lives (Fig. 4); some are still alive and breeding. Efforts are now being made to mix the several lineages and thus avoid excessive inbreeding. In the wild, this race is fairly common because of its protected status, secretive nature, and the presence of

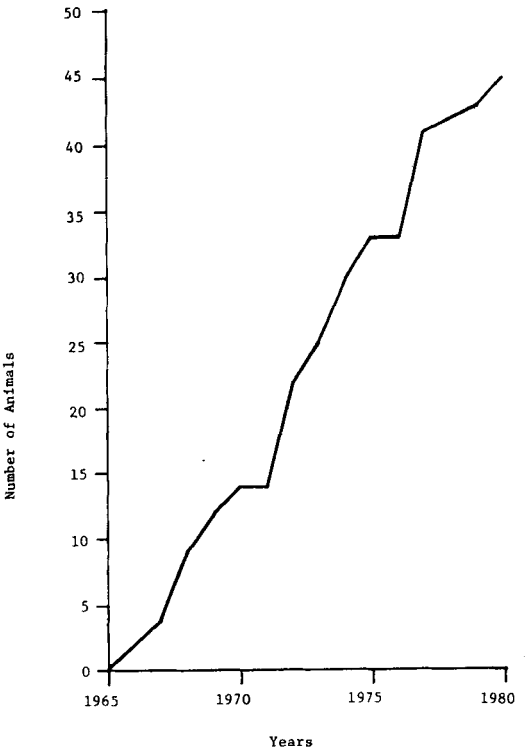

Fig. 4. Number of Ceylon leopards *(P. p. kotiya)* in captivity.

several large parks designated for elephants and other land-intensive species [Eisenburg, personal communication].

AGE STRUCTURE

The maximum ages reached by large felids in captivity are presumably greater than those of their wild counterparts. African lions in Kruger National Park seldom reach their tenth year and all die by age 12 [Smuts et al, 1976, and personal communication]; in captivity they are known to exceed 20 years. Field studies involving African leopards are just now being developed and information on their normal life span in the wild is still forthcoming. In captivity leopards of several races have lived on occasion for over 20 years, although this is far longer than the norm.

Until the 1960s, Amur leopards were found primarily in Russian zoos. Because there have never been any breeding groups in that country, the captive population continues to be small. None have been captured in recent years because of increased protection from the government and a declining population in the wild, and most of the older (10–15 years) animals in captivity are housed in zoos in that country. The marked increase in young animals in captive collections (Fig. 5) is linked to increased propagation in European and North American collections, although there appears to be an abnormally large number of males being born in recent years. Nearly all

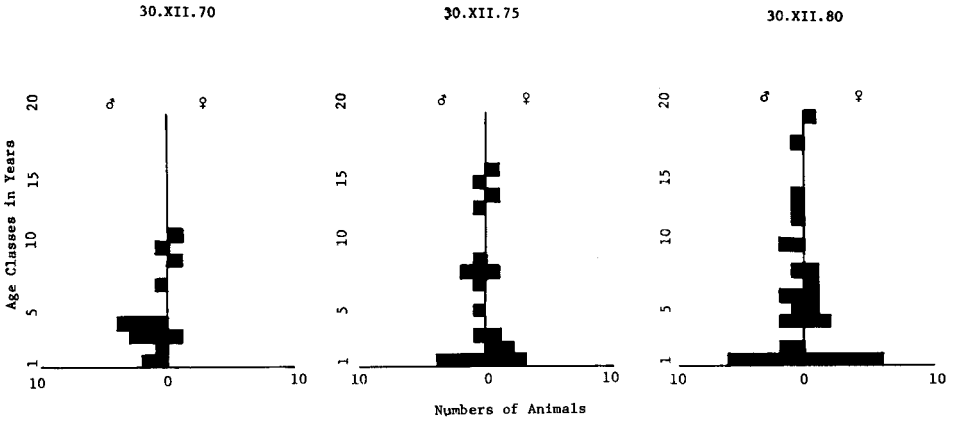

Fig. 5. Age structure of Amur leopards *(P. p. orientalis)* in captivity since 1970.

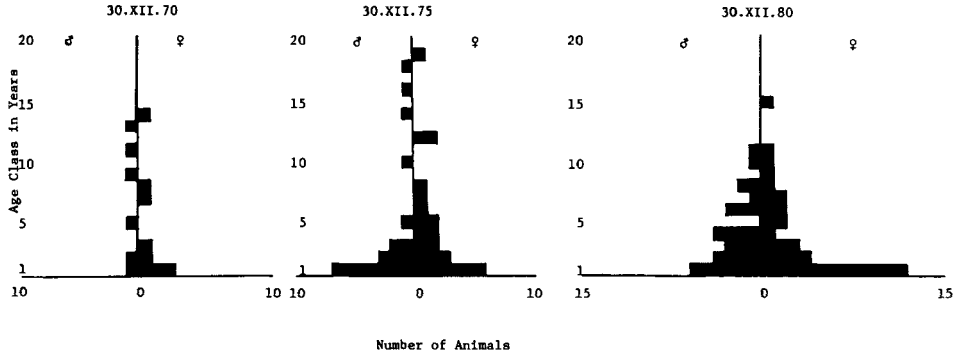

Fig. 6. Age structure of Persian leopards *(P. p. saxicolor)* in captivity since 1970.

animals breeding in various collections are related to a pair imported to the Frankfurt Zoo and new specimens are vitally needed for prolonged maintenance of this race in captivity.

The founding size of Persian leopards is larger and more diverse than that of any other races. Although propagation got off to a slow start because of the advanced age of some founders and the reproductive difficulties experienced by some founding females, this situation had changed by Dec 31, 1980 (Fig. 6). The oldest animals alive on Dec 31, 1975, were often wild-born founders of the middle-age adults (7–12 years old) alive five years later.

Historically the Chinese leopard has been the most numerous captive subspecies of pedigree leopard. Although the founding stock is nearly as large as that of the Persian leopard, all specimens of the three pairs of main Chinese leopard breeders arrived in captivity while still juveniles and adapted well. The early progeny did equally well, as can be seen the progressively greater number of young animals in captivity on Dec 31, 1970, and Dec 31, 1975 (Fig. 7).

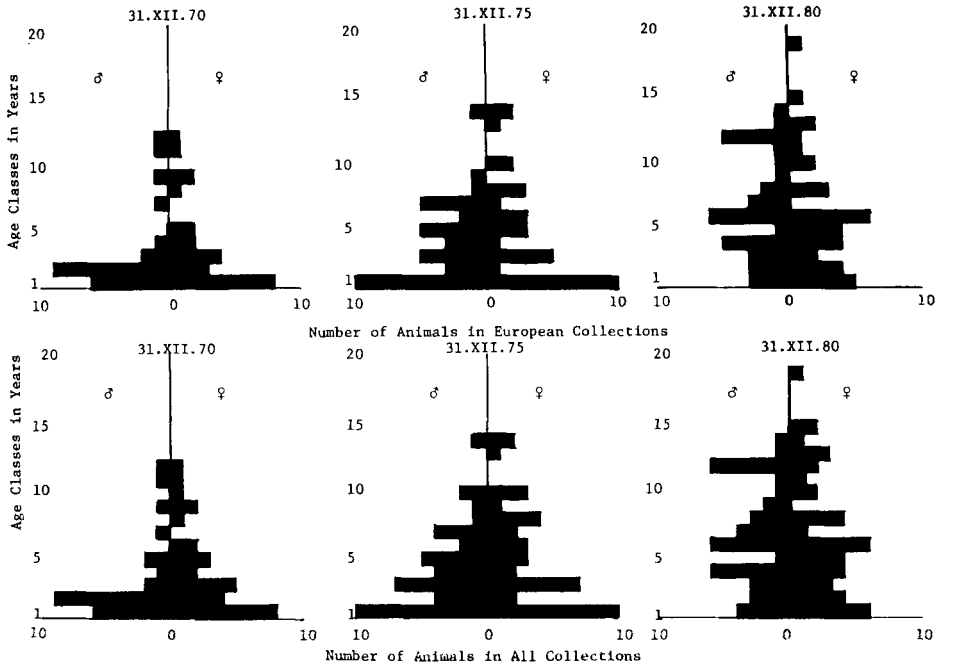

Fig. 7. Age structure of Chinese leopards *(P. p. japonensis)* in captivity since 1970.

The subspecies has been highly sought after by zoos in Europe and elsewhere. Young were distributed to a wide variety of zoos, but many of the initial breeding centers failed to retain sufficient young in preparation for the time when their existing specimens would cease breeding. The collections of some newer owners have suffered from the effects of inbreeding or other undetermined factors and have failed to rear many offspring. Space for leopards and similar-sized felids is limited and disposal of young Chinese leopards has at times presented problems to several European owners, causing them to restrict propagation efforts. Because of these factors, reproduction has been curtailed, particularly in Europe, although it is quite likely that numbers of Chinese leopards within North American collections will increase in the near future because of newly located specimens.

The Ceylon leopard has been maintained in captivity for a relatively short time, with most animals having been imported from the wild after 1965. The studbook was also initiated after the others [Shoemaker, 1979]. Figure 8 demonstrates the rather rapid growth of this race in captivity, with the older imported animals still alive and breeding on Dec 31, 1980. One unfortunate aspect of this race is the number of animals that have been sold to private owners. Such animals have had no later contact with the captive population and their owners have rarely participated in studbook programs, a situation which should be rectified.

FECUNDITY

Little is published on the fertility of leopards, although most authors consider leopards and similar-sized felids to be sexually mature when 3 years old [Asdell,

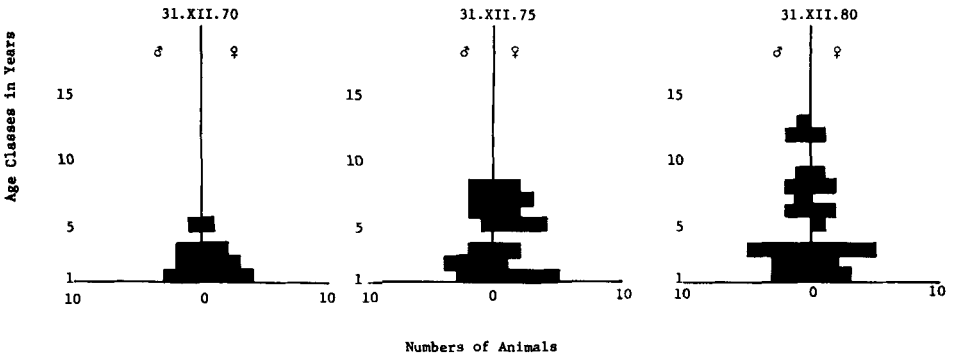

Fig. 8. Age structure of Ceylon leopards *(P. p. kotiya)* in captivity since 1970.

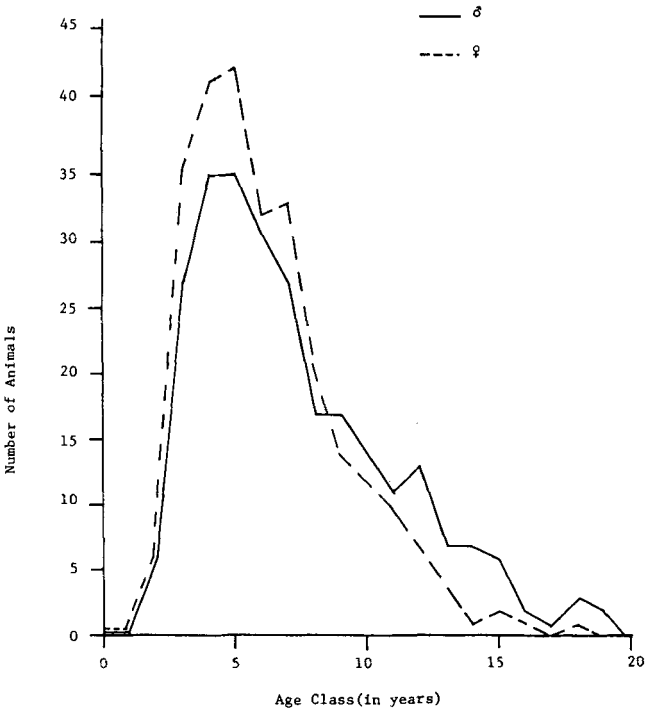

Fig. 9. Fertility of all 4 races of pedigree leopards combined since 1954.

1964]. It is also difficult to compare first breedings of wild versus captive leopard populations, although the age of the female at first conception is probably similar for either situation. In captivity a few pedigree females bred when 2 years old, but this was rare (six occurrences) and is probably equally uncommon in the wild (Fig. 9). In captivity males are able to sire offspring when 2 years old and could probably have sired more offspring at this precocious age if their partners, frequently a like-

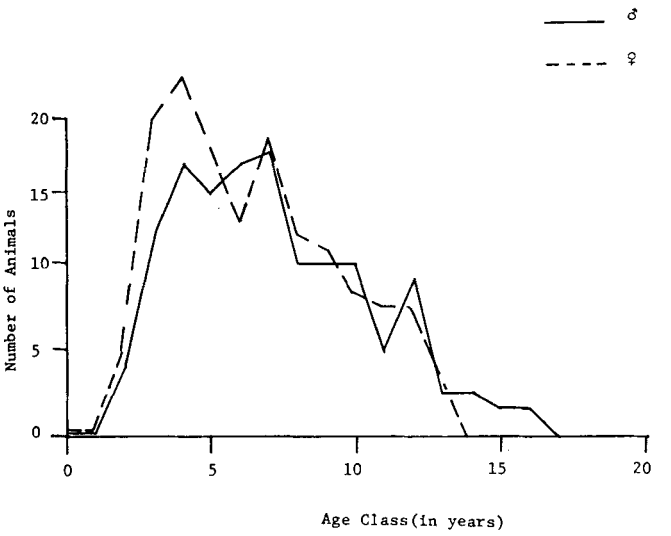

Fig. 10. Fertility of Amur leopards *(P. p. orientalis)* in captivity since 1967.

aged female, had been older. Instances of breeding by 2-year-old males are rather rare occurrences, and in the wild, such an event would be unlikely. Competition from older resident males would probably delay reproduction by young males until at least their third year, and perhaps even longer in areas possessing large populations.

Most animals of both sexes were sexually active through their eighth year, with reproduction decreasing rapidly thereafter. Only a few females bred after age 12 and only one continued breeding after age 15. Males have a longer potentially reproductive life, and some individuals bred beyond their seventeenth year. More older specimens would probably have bred if their mates had been able, but many of these males probably ceased breeding due to cessation of estrous cycling in the female. Most leopards in the wild probably survive for only 8–10 years, and these superannuated captive breeders are not realistically comparable to their wild counterparts. Such data is primarily of use in predicting management needs for various races.

Amur leopards have never been numerous in captivity and the number of breeding pairs has been minimal. In spite of this, at least one pair which was originally imported by the Frankfurt Zoo has been both long-lived and extremely fecund (Fig. 10). The female's age can only be approximated since she was imported from the wild, but she certainly was over 20 years old at her death. Moreover, she successfully bred until the last year of her life, although the length of her estrous cycle was considerbly shortened [R. Baudy, personal communication]. The male of this pair was slightly younger but successfully bred when 19 years old, and at the time of this writing (1982), is still alive. Both of these case histories are obviously exceptional, with both animals appearing noticeably aged in their later years, but it does demonstrate the potential of some individuals. Equally important, these instances demonstrate the profound effect that prolonged reproductive lives of a few individuals can have on the overall captive gene pool.

Fig. 11. Fertility of Chinese leopards *(P. p. japonensis)* in captivity since 1954.

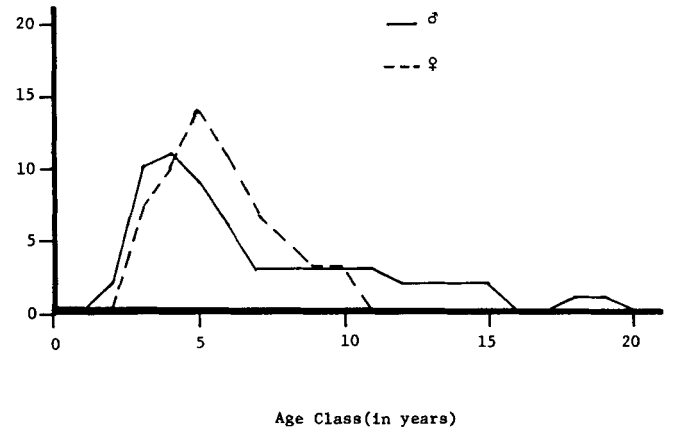

Fig. 12. Fertility of Persian leopards *(P. p. saxicolor)* in captivity since 1959.

Chinese leopards have been in captivity the longest of all pedigree races and provide the best picture of the leopard's fecundity because of the relatively large sample size. In this race, the curve of fecundity for both sexes is surprisingly similar, with only a few males breeding past age 15 (Fig. 11); none of the females bred after age 14. The delay in breeding by young males, with fewer males than females breeding when 3 years old, can partially be attributed to a surplus of males. This situation has kept many potentially reproductive males out of breeding situations until their fourth year.

Persian leopards are well represented in captivity, although the fecundity of several females has been reduced because of pelvic deformities, presumably caused by improper diet while young (Fig. 12). As a result owners of such females have been forced to curtail breeding programs at an otherwise early age rather than repeatedly breed them and possible cripple or lose them during the resultant caesarian

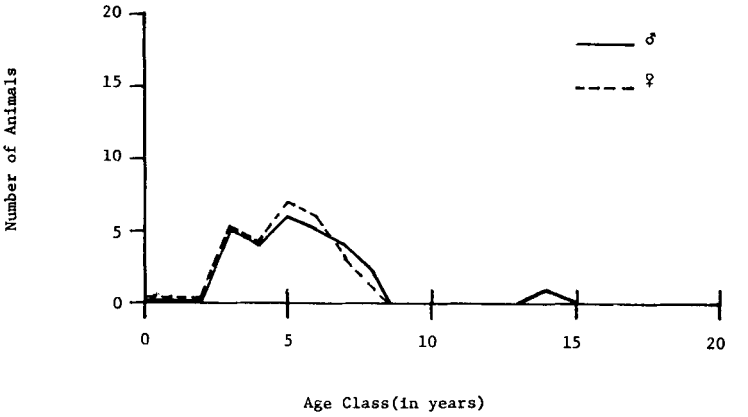

Fig. 13. Fertility of Ceylon leopards *(P. p. kotiya)* in captivity since 1968.

procedures. Some males ceased breeding at an earlier age than others, a factor sometimes linked to being paired with the afore-mentioned females; several other males arrived in captivity as adults and had obviously shorter life spans. A few notable exceptions were exceptionally long-lived, and one male was still breeding successfully when 20 years old.

The fecundity of Ceylon leopards is largely untested. This race has been bred in captivity for less than 15 years and conclusions are inappropriate. At least one male has bred when 15 (Fig. 13), a rather advanced age, but many wild-born females are still alive and breeding; others have been removed from breeding programs because of unusual circumstances.

CONCLUSION

From the data available in the international studbook of four subspecies of leopards *(Panthera pardus)*, it would appear that all four races are increasing numerically among a wide variety of owners spread throughout the world. Such data does indicate a potential for trouble, however, and both the Amur and Chinese subspecies are in need of additional specimens if their otherwise limited founder size and/or inbred populations are to survive. Populations of Chinese and Persian leopards in Europe and North America have evolved separately, but this situation has begun to correct itself.

Leopards of at least the four pedigree races, if not all others as well, can probably live longer in captivity than in the wild. Although little hard data is available on aging in wild leopards, lions in Kruger National Park did not survive beyond 12 years even though captive lions are known to reach 20 years. The considerably smaller leopard probably never reaches 12–14 years old in the wild, a rather common age in captive specimens. Exceptional animals in captivity have reached 20 years.

Most males and females begin breeding when 3 years old and continue until they are 8. Males are capable of breeding throughout their entire life span, and several have bred when 19–20 years old. Females cease breeding at an earlier age, with few breedings after age 12. A small number of males and females breed when they are 2

years old. While females in the wild might also conceive if they cycled at this early age, males would undoubtedly not breed at such a young age due to competition with older males.

Many of the older individuals in captivity are maintained for years after they have ceased breeding. Some males, and particularly those with unique and thus desirable ancestries, are potentially fertile but unavailable to the rest of the captive gene pool because they are maintained with aged, nonbreeding exhibit mates. This situation also presents problems in placing surplus animals or planning further breeding programs because of cage-space limitations within the zoological park community. On the negative side, some of these older males may not be behaviorially suitable for introduction to unfamiliar females. Their ancestries are therefore irretrievable until more advanced techniques in reproductive technology and artificial insemination are developed. Hopefully international management programs similar to the Species Survival Plan (SSP) of the American Association of Zoological Parks and Aquariums (AAZPA) can be developed to conquer these obstacles. For the time being, it is fortunate that populations of at least two of the four pedigree races, although endangered, are not particularly depressed in the wild.

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