– Parallel presentation –

The longevity legacy

– The problem of old mammals in zoos –

Andrew Kitchener[1] and Alastair MacDonald[2]

1 National Museums of Scotland, Chambers Street, Edinburgh EH1 1JF, United Kingdom
2 University of Edinburgh, Summerhall, Edinburgh, EH9 1QH, Scotland, United Kingdom

Zoos once demonstrated their skill in keeping wild mammals in captivity by longevity records. However, as our knowledge of animal husbandry in zoos has increased and breeding in most species has become commonplace, so the emphasis has shifted to continuing breeding success and the management of sustainable zoo populations. There has also been undoubtedly an increase in the maximum and mean longevities of most species. For example, in a period of thirty years, the maximum longevities of gorillas (*Gorilla* spp.) increased by 62% to 54 years, that of orang utans (*Pongo* spp.) by 92% to 59 years, pygmy marmosets (*Callithrix pygmaea*) by 267% to 17.9 years and Goeldi's monkeys (*Callimico goeldii*) by 678% to 18 years (Jones, 1962; Nowak, 1999).

However, old age brings its own problems. This includes physical decline such as degeneration of the skeleton and teeth, muscle wastage, accumulation of fat deposits, reproductive senescence, and mental deterioration such as memory loss, behavioural and cognitive decline. For zoos there is a number of problems associated with old animals, which may compromise conservation breeding programmes and which affect the whole issue of how best to manage populations of animals undergoing conservation breeding. With lower mortality rates owing to a lack of predation, and minimal trauma and disease, zoo populations have proportionally many older individuals than wild populations. As a result older individuals may be beyond breeding age and may take up valuable enclosure space. Therefore, there could be a tendency towards overpopulation, resulting in prevention of breeding or the culling of young. This has been a particular problem of conservation breeding programmes for most bear species, which are particularly long lived and have a potentially high reproductive output (Kitchener, 2004). A third of polar bears (*Ursus maritimus*) in the world's zoological collections are over twenty years of age (Linke, 1998), but only 3% survive to this age in a wild population from Hudson's Bay, Canada (Ramsey and Stirling, 1988).

Over the last ten years or so the National Museums of Scotland have been collecting dead animal specimens from many zoos in order to provide a research resource and to provide a number of specimens for educational displays. As a consequence it has come to our notice that many of the large mammals are commonly suffering from a variety of skeletal and dental pathologies. This was most noticeable in bears, of which more than 96% have skeletal pathologies at the age of 15 years or greater (Kitchener, 2004; Kitchener *et al.*, 2001). In this paper, we expand the range of species in order to determine how widespread these problems are and to see if there are any significant interspecific differences that might be influenced by species-specific behaviour, environment and morphology.

Table 1) Skeletal and dental pathologies recorded in the skeletons of zoo mammals.

1. Osteophytes on limb bones
2. Osteophytes on vertebrae
3. Osteophytes on pelvis
4. Fusion of vertebrae
5. Erosion of head of femur
6. Erosion of centra of vertebrae
7. Fistulae in maxillae e.g. abscesses
8. Fistulae in mandibles
9. Open-tipped or broken upper canines
10. Open-tipped or broken lower canines

Materials and methods

A total of 64 skeletons from 13 species of mammals (table 1) were examined for evidence of skeletal and dental pathologies as previously reported in Kitchener (2004; table 2). This was done in order that we could make a direct comparison with the existing data for bears. Big cats and great apes were chosen as mammals that are commonly displayed in zoos, which often live to a great age, and about which there is often discussion concerning euthanasia and population management. Babirusas (*Babyrousa babyrussa*) and pygmy hippos (*Hexaprotodon liberiensis*) were also examined as these species are herbivores/omnivores that often live to great ages in captivity. The pathologies were scored on a presence or absence basis rather than trying to make an assessment of how severe the condition was. At this stage we were only interested in how widespread the problems are, rather than how they progress with age or how they appear in particular individuals. For each pathology, the percentage of individuals showing a specific pathology was calculated based on the total number of individuals of the minimum age and greater that first showed any sign of a skeletal or dental pathology, as listed in table 2. In other words, the youngest tiger that had skeletal pathologies was six years old, so that our sample for tigers included all animals six years old or greater regardless of whether they displayed any skeletal or dental pathologies.

Table 2) Sample sizes of zoo mammals that were examined for skeletal and dental pathologies. Figures in parentheses refer to additional data from pathology reports from zoos.

Gorilla, *Gorilla* spp.	7
Sumatran orang utan, *Pongo abelii*	5
Brown bear, *Ursus arctos*	5
Polar bear, *Ursus maritimus*	3 (+3)
Asian black bear, *Ursus thibetanus*	7 (+3)
American black bear, *Ursus americanus*	0 (+2)
Sloth bear, *Melursus ursinus*	1
Sun bear, *Helarctos malayanus*	1
Spectacled bear, *Tremarctos ornatus*	0 (+2)
Lion, *Panthera leo*	8
Tiger, *Panthera tigris*	8
Babirusa, *Babyrousa babyrussa celebensis*	12
Pygmy hippo, *Hexaprotodon liberiensis liberiensis*	7

Results

Using bears as a point of comparison, tigers of six years and above show lower incidences of all pathologies (table 1). However, more than 50% showed both skeletal and dental problems. No individuals had fused vertebrae and none had abscesses in the jaws, although most had broken canines. Lions of similar age showed similar proportions of these pathologies with more than 80% of the individuals having osteophytes on the vertebrae and a few individuals had abscesses in both maxillae and mandibles (table 2).

Gorillas of 15 years or greater had very high incidences of skeletal abnormalities, with 100% showing erosion of the centra of the vertebrae (figure 1). Dental problems were also common, with broken canines and abscesses apparent. In contrast orang-utans of 18 years and greater had significantly lower incidences of erosion of the femoral head and fusion of vertebrae than bears, but exhibited similar levels of osteophytes and erosion of centra (figure 1). Interestingly, although orang utans had similar levels of broken canines, we found no evidence of abscesses in their jaws.

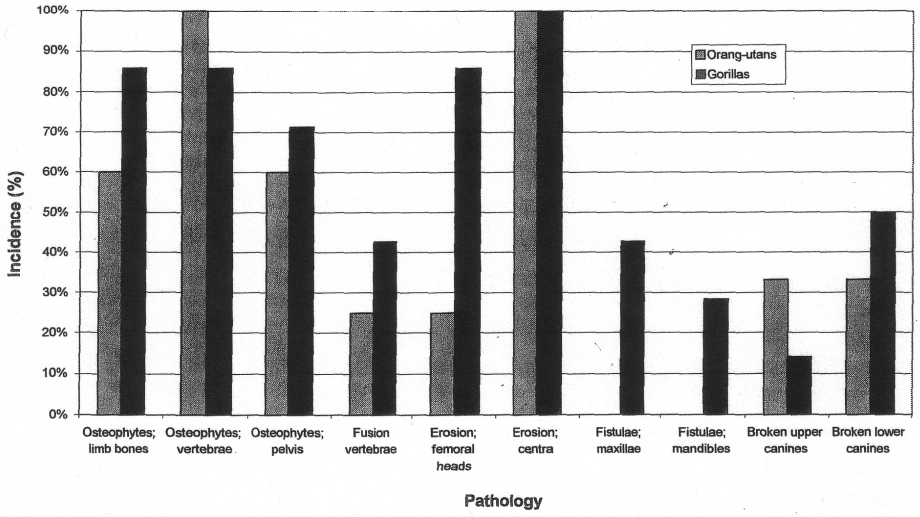

Figure 1) The incidences of skeletal and dental pathologies in the skeletons of zoo orang utans (28 years and older) and gorillas (15 years and older).

Babirusas of nine years and older showed remarkably similar incidences of skeletal pathologies to those of bears (figure 2), with 100% of individuals exhibiting osteophytes on their vertebrae. However, dental problems were much fewer in number. Pygmy hippos of 18 years or greater showed a different pattern of skeletal pathologies to those of babirusas (figure 3). Although 100% of individuals had osteophytes on their vertebrae, osteophytes on limb bones and the pelvis were much lower, as was the incidence of fusion of vertebrae and erosion of femoral heads. Dental problems in pygmy hippos were confined to the lower jaw with more than 70% of individuals with abscesses.

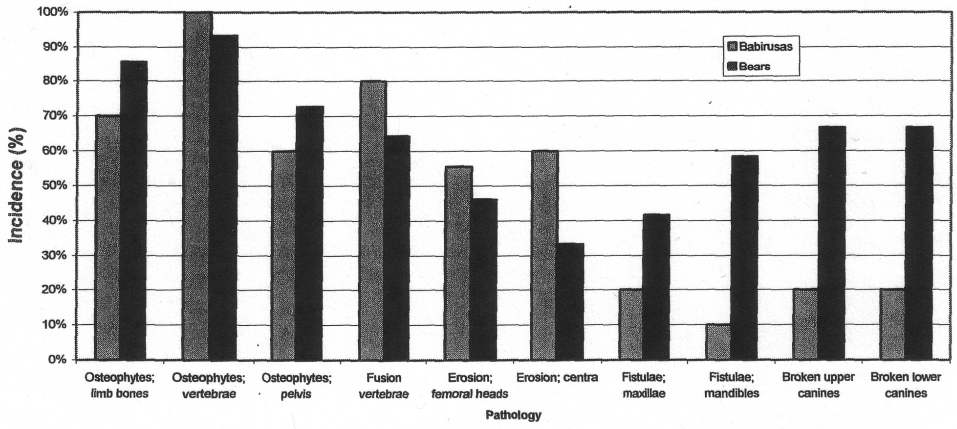

Figure 2) The incidences of skeletal and dental pathologies in the skeletons of zoo babirusas (9 years and greater) and bears (15 years and greater).

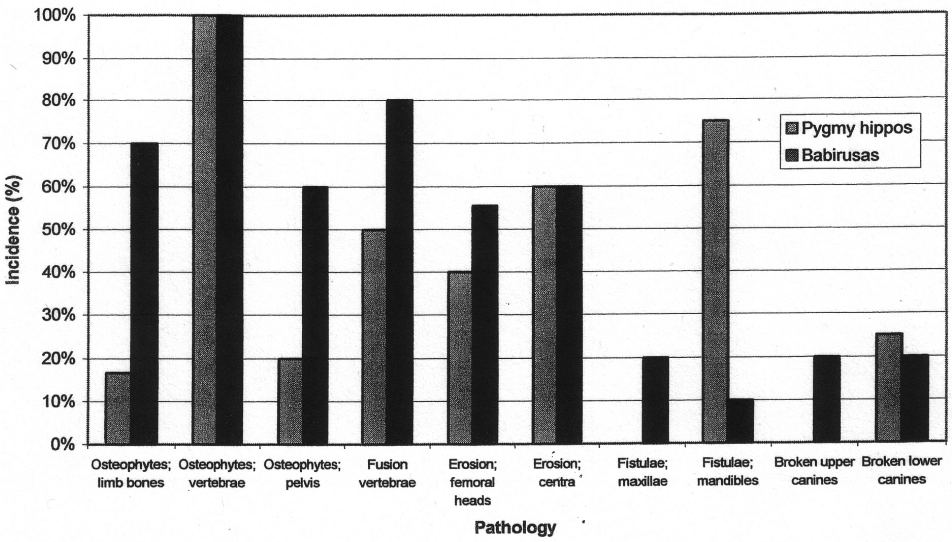

Figure 3) The incidences of skeletal and dental pathologies in the skeletons of zoo pygmy hippos (18 years and greater) and babirusas (9 years and greater).

Discussion

From the species that we have examined so far, it would appear that skeletal and dental pathologies are widespread in older individuals, although incidences vary between species. The minimum age at which pathologies are recorded also varies. Big cats and babirusas have problems from quite a young age, but this may reflect their overall shorter longevities of about 20 years or so. Not surprisingly, species which can live 20-30 or more years display these problems from their mid-teens.

Closely-related taxa show mostly similar incidences of skeletal and dental pathologies. Lions and tigers showed very similar, low-level patterns of skeletal pathologies with no evidence, so far, of fusion of vertebrae compared with the other taxa. This may reflect the very much more flexible vertebral column of the cats, which needs to move in order to assist locomotion, especially when running and climbing. The more terrestrial gorillas showed a higher incidence of erosion of the heads of their femora, osteophytes on the limb bones and pelvis, and fusion of vertebrae, which may reflect greater wear and tear resulting from their terrestrial existence. It is unclear why there are differences in dental problems between the gorilla and the orang utan, but it is possible that this may reflect either differences in their diets and or the feeding techniques. Pygmy hippos showed few osteophytes on their limb bones compared with babirusas (and most other taxa). This may be because they have access to heated indoor pools, where they can literally take the weight off their feet, resulting in less wear and tear. Babirusas showed few dental problems because their canines are either non-functional (upper) or they are adapted to a high degree of wear through their use in foraging. Breakages do not matter because they continue to grow throughout life. The few abscesses in babirusas were associated with the premolars and molars.

Although we have demonstrated high levels of these skeletal and dental pathologies, we should sound a note of caution. Firstly sample sizes are generally small, so that we cannot be certain that these incidences would be found in larger samples of similar age ranges. Secondly, we have so far not assessed the severity of the pathologies, so we cannot be certain whether these would all impair normal behaviour by causing significant pain, or indeed if pain was perceived at all. A possible problem is that wild mammals may, even in zoos, try to hide any pain that they may be suffering so that they are not at a disadvantage in a social group. Alternatively, they may change their behaviour subtly in order to avoid pain. Whatever the case, it is likely that their normal behavioural repertoire will have been affected.

There is a clear need to develop a series of sensitive behavioural indicators to see if normal behaviour has been affected. For example, use of a wobble tree, which encourages bears to stand bipedally to obtain food items (Law and Kitchener, 2002), might allow an assessment of how badly affected hip joints and vertebral columns of individuals are. Long-term studies on individuals might also show how behaviours change over a life time, which can then be correlated with observed skeletal changes. A quick way of assessing the degree of behavioural change may be to give the individuals specific anti-inflammatories or painkillers and see if their behaviour has been transformed.

There is a real problem that data such as those presented here can be seen as a panacea to get over the problem of deciding whether to carry out culling on management grounds. We are not suggesting that all bears should be culled at 15 years or above. Clearly there is individual variation in the incidence and progress of these pathologies. However, we are alerting the zoo and veterinary communities to the fact that these problems may begin at a much younger age than was previously thought and that there is an obligation to develop veterinary protocols which allow for their assessment and to ensure that dental problems are treated. There can be no excuse for allowing an animal to suffer unnecessarily when it should either be treated appropriately or euthanased to end suffering.

It would be invaluable to know what may be causing the skeletal pathologies we have observed, in order that any environmental, dietary or other causal factors can be eliminated or minimised. Kompanje *et al.* (2000) examined the skeletons of three old zoo bears from South East Asia. They found very similar skeletal pathologies to those reported by Kitchener (2004) and in this study. They concluded that osteoarthroses of the joints of the limb bones and the zygapophyses of the vertebrae were the result of general wear and tear, and were a normal consequence of ageing. However, they concluded that the spondyloarthroses associated with the centra of the vertebrae were a reactive arthritis caused by common infections such as *Salmonella, Shigella, Campylobacter* and even roundworms (*Ascaris*). Rothschild *et al.* (1993) suggested that spondyloarthropathies may be transmitted sexually in bears and Sharon Redrobe (pers. comm.) has suggested that dental problems may be the cause of some of the observed skeletal pathologies. In contrast, Kitchener (2004) reported that in two aged Sumatran tigers (aged 13 and 14 years respectively), there were no skeletal or dental problems at all. These tigers had to climb a telegraph pole to get their feed each day (Law *et al.*, 1997) and so were highly active. The musculature used in climbing the telegraph pole is similar to that used when pulling down a larger prey animal (Anton and Turner, 1997). Therefore, this environmental enrichment method simulates the prey-capture method of the tiger. Based on these limited observations, it is suggested that activity levels may also influence the development of oseto- and spondyloarthroses in mammals in zoos. Clearly we need further data, particularly from animals where we have life-time records of their husbandry and behaviour, in order to test this hypothesis.

Conclusion

Osteo- and spondyloarthroses are common in zoo animals and appear to increase with age in bears, big cats, great apes, babirusas and pygmy hippos. Although we cannot be sure when or if they cause pain, zoo managers and veterinarians should be aware that these problems may arise at a much younger age than previously believed. There is a clear need to monitor more closely the skeletal and dental health of mammals in zoological collections and to develop behavioural or other indicators to determine whether the behavioural repertoire of the older mammals is negatively affected by the development of these pathologies. Dental problems must be detected and treated, but skeletal pathologies may only be alleviated by the use of anti-inflammatory drugs, or euthanasia. The decision as to how to treat an individual can only be made on a case-by-case basis, and must consider a number of factors, including conservation (and genetic) importance, role in group cohesion and stability, reproductive potential and importance, as well as keeper and public understanding. Above all it is vitally important that zoos, pathologists and museums work closely together to ensure that more skeletal specimens are preserved to add to our understanding of the incidence, severity, progress and causes of skeletal and dental pathologies in a wider range of mammals as one aspect of the problem of old age.

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