Ageing feral pigs (*Sus scrofa*) through tooth eruption and wear

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Introduction

Feral pigs (*Sus scrofa*) were introduced to the Pantanal more than 200 years ago. It is thought that domestic pigs became feral during the Paraguay War (1865–1870), when ranches in the Pantanal were devastated and abandoned. Today, social groups of feral pigs can be found throughout the floodplain (Mourão *et al.,* 2002). The ecological impact of feral pigs in the Pantanal is still not well understood. Through their rooting activities, feral pigs can disturb large areas (Hone, 1988). In the Pantanal, when present at high densities, herds of feral pigs are reported by local people to cause extensive damage to pasture. In forested areas feral pigs uproot saplings and seedlings and may affect the recruitment of certain species (Desbiez *et al.,* 2009). Feral pigs predate eggs of ground nesting birds (Desbiez *et al.,* 2009), and some reptiles such as the *Caiman yacare* (Campos, 1993). Most importantly, feral pigs are potential reservoirs of diseases (Doran & Laffan, 2005; Herrera *et al.,* 2005; Corner, 2006; Ruiz-Fons *et al.,* 2007). Understanding the population ecology of this introduced species is important for both conservation and economic reasons. Data on mortality rates of adult feral pigs is one of the demographic parameters necessary for this purpose. The objective of this study was to obtain quantitative data on adult feral pig mortality rates through the analysis of tooth emergence and tooth wear from skulls collected within the central region of the Pantanal.

Premises and assumptions

Analysis of the sequence of tooth emergence and tooth wear was used to estimate mortality rates of adult feral pigs. The main assumption of this method is that age distribution is stable (Caughley, 1966, 1977). Further assumptions include that (1) pig teeth form and erupt in a regular sequence at predictable intervals, (2) tooth emergence and sequence for feral pigs in the Pantanal is similar to those of the European wild boar (*Sus scrofa*), (3) tooth wear occurs progressively throughout an animal's life and can therefore be categorized to reflect an animal's age, (4) the attrition rate of pig teeth is similar amongst individuals of the study area.

The first assumption is validated by several documented tooth emergence sequences for both wild and domestic suids using samples of animals of known age (Matschke, 1967; Choquenot & Saunders, 1993). The second assumption is justified by the relatively late timing of tooth emergence of the European wild boar in comparison to modern domestic pigs, particularly in the case of the second and third molar. Tooth emergence of the European wild boar is comparable to wild and late maturing domestic pigs (Bull & Payne, 1982). The feral pig in the Pantanal is a domestic pig turned feral and for which ancestral characteristics of pigs are present. Therefore, it is most likely that the teeth of feral pigs from the Pantanal form and erupt in a sequence similar to that of the European wild boar and late-maturing domestic breeds. In addition, we have found that the first premolar is present in populations of feral pigs in the Pantanal. This tooth, which only appears as a permanent tooth, is present in European wild boar while it is often absent in modern domestic breeds of pigs. The third assumption, that tooth wear increases with the age of an individual, is a characteristic used by archaeologists, anthropologists, palaeontologists and of course biologists (Grant, 1982; Klein & Cruz-Uribe, 1983; Anderson & Stone, 1993; Rolett & Min-yung, 1994; Ashby & Santiapillai, 1998; Tuen *et al.,* 1999; Mysterud *et al.,* 2001; Fernandez-Llario & Mateos-Quesada, 2003; Maffei, 2003). Finally, the last assumption is reasonable since similar resources and feeding areas are available to the whole population from the study area.

Methods

Feral pig skulls were collected from the Embrapa Pantanal Nhumirim Farm (UTM 21 K 0538193 7901838) and five surrounding ranches in the centre of the Pantanal for over two years between July 2002 and December 2004. It is thought that almost all of the skulls from animals that died during this period were collected. After killing a feral pig, hunters typically cut off the animals head and feet to facilitate carrying the carcass back to the ranch on horseback. Skulls collected in the field therefore included animals that died as a result of hunting as well as natural causes. Male and female feral pig skulls can be easily distinguished. One of the most striking characteristics is the size, shape and angle of the incisors, as well as the bone structure from which they protrude (Figure 1a & b). A total of 222 feral pig skulls or parts of skulls were collected representing 126 males and 96 females of different ages.

Both the maxilla and mandible of each skull were analysed. Tooth eruption stage was noted. The eruption stage of the third molar was carefully described: third molar not visible, first cusp erupting, second cusp erupting, and third cusp erupting. Tooth wear stages were assigned using a classification adapted from Rolett and Chiu (1994) and Grant (1982) (Table 1; Figure 2). Classification categorised the shapes of the darker dentine that is revealed as the enamel of the biting surface is gradually worn away. Categories ranged from: *a* to *l* for the third molar, and from *a* to *p* for the second and third molars. Signs of tooth wear increased between categories *a* to *p*. All skulls were analysed by the same observer and a random sample of skulls was reanalysed to ensure uniformity of the results.

Figure 1 (a). Male feral pig skull (left) and female feral pig (right)

Figure 1 (b). Male feral pig skull (left) and female feral pig (right)

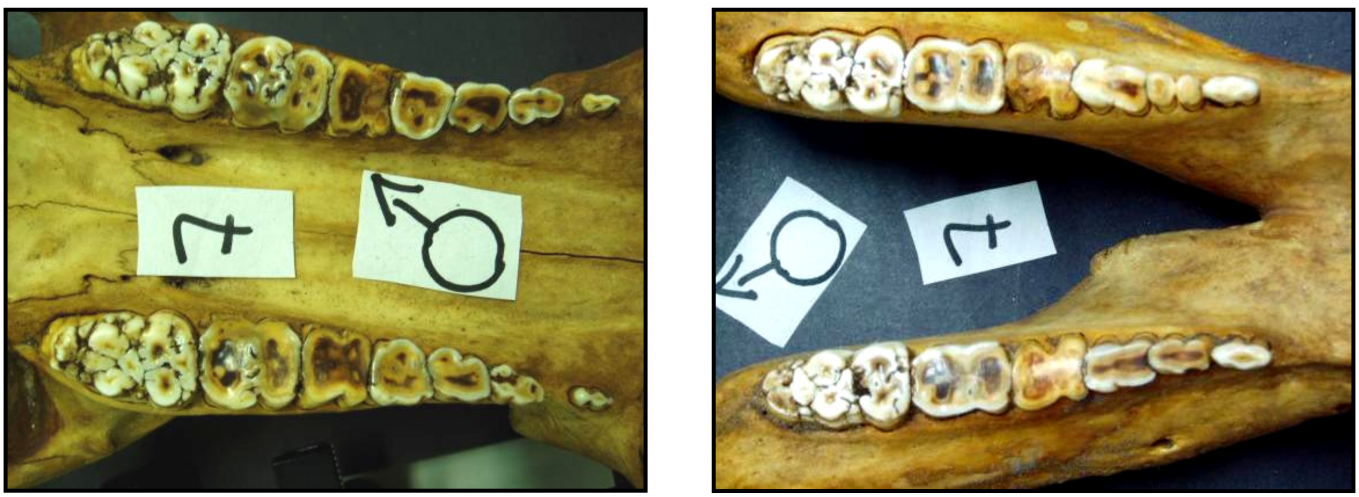

Figure 2. Analysis of tooth wear from an adult male feral pig maxillae and mandible

Ideally a calibration curve of measurements from wild feral pigs of known age that have fed in natural conditions and therefore been subjected to similar abrasiveness of soils and hard foods would be necessary. In the absence of this information, we used comparisons between tooth wear from different eruption sequences to create a classification for tooth wear into age categories for the study site. The first and second molar erupt 24 and 16 months respectively prior to the eruption of the third molar for the maxilla teeth and 20 and 11 months prior to the third molar for the mandible. We also used comparisons of tooth wear between the third molar of the maxilla and mandible that erupt within approximately five months of each other. Using these comparisons as well as the literature (Matschke, 1967; Choquenot & Saunders, 1993; Rolett & Min-yung, 1994), age categories for maxilla and mandible were established in months (Table 2).

Table 1. Classification categories of the shapes of the darker dentine. Signs of tooth wear increased from categories *a* to *p*. The classification is adapted from Rolett and Chiu (1994) and Grant (1982).

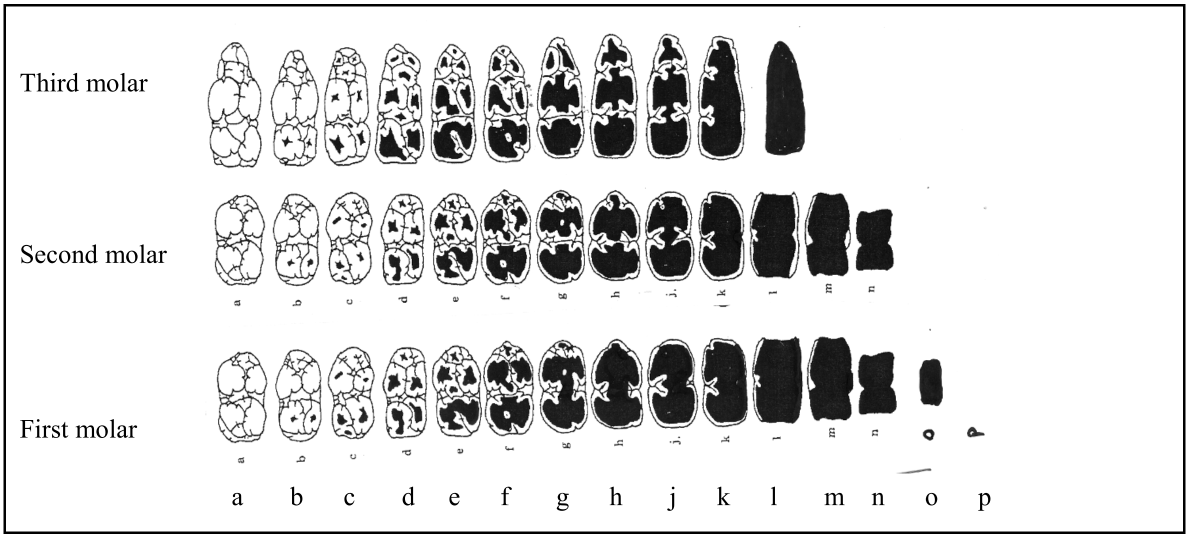

Table 2. Age estimates in months according to tooth eruption and levels of tooth wear.

Second molar	Third molar	Mandible	Maxilla
	V	less than 22	less than 26
c,d,e	1-2 cusps	21 to 30	26 to 36
d,e,f	3 cusps to a	30 to 42	36 to 48
e,f,g,h	b to c	42 to 54	48 to 60
g,h,j,k,l	d to e	54 to 66	60 to 72
k,l,m,n,x	f to g	66 to 78	72 to 84

Due to slight differences in tooth wear between the right and left maxilla or mandible, the right maxilla was selected for analysis in this study. Using the classification estimates, age of death for male (N=114) and female (N=81) feral pigs was obtained. A life table was built and survival and mortality rates for male and female feral pigs based on the right maxilla were calculated. Using a linear regression, average mortality rates for adults were estimated.

Results and Discussion

Most of the skulls collected from both males and female feral pigs belonged to younger age classes, defined as four years or less (Tables 3 & 4). Both males and females appear to have higher mortality rate during their fourth year. Results suggest that when male feral pigs are less than three years of age their mortality rates are lower than females, after that age male mortality rates increase (Figure 3). Female feral pig mortality rates appear to be more constant than males. This may be explained by the traditional hunting practices in the region.

Table 3. Estimates of survival and mortality rates of male feral pigs from maxilla. (N=114)

Tooth wear category	Age estimates	Number of maxilla	Total left	% of animals left	Survival rate	Mortality rate
V	<2	5	114	1.00	0.96	0.04
1-2 cusps	2nd year	16	109	0.96	0.85	0.15
3 cusps to a	3rd year	20	93	0.82	0.78	0.22
b to c	4th year	44	73	0.64	0.40	0.60
d to e	5th year	20	29	0.25	0.31	0.69
f to g	6th year	5	9	0.08	0.44	0.56
beyond	>6	4	4	0.04	0.00	1.00

Table 4. Estimates of survival and mortality rates of female feral pigs from maxilla. (N=81)

Tooth wear category	Age estimates	Number of maxilla	Total left	% of animals left	Survival rate	Mortality rate
V	<2	12	81	1.00	0.85	0.15
1-2 cusps	2nd year	9	69	0.85	0.87	0.13
3 cusps to a	3rd year	13	60	0.74	0.78	0.22
b to c	4th year	24	47	0.58	0.49	0.51
d to e	5th year	11	23	0.28	0.52	0.48
f to g	6th year	7	12	0.15	0.42	0.58
beyond	>6	5	5	0.06	0.00	1.00

Feral pigs are the main hunting target of the people living in the area. One of the most striking aspects of feral pig hunting is the harvest of previously castrated fat male feral pigs. Indeed, young male feral pigs are caught, castrated, and then released (Desbiez, 2007). Castrated males then heal, gain weight and are killed several months later. A fat castrated male, is the main target of all hunting expeditions, if it is not found then a female will be killed (Desbiez, 2007). This practice may explain why male mortality is higher after three years old, when castrated males would be killed. Animals at four years of age are in their prime condition which may explain the higher mortality rate for this age class. Average adult mortality rates are 15% per year for males (R^2=0.877; y=-0.130 + 0.149x) and 13% for females

(R^2=0.866; y=-0.093 + 0.133x) (Figures 4 & 5). Since these mortality rates include hunting, they represent average mortality rates of feral pigs under traditional hunting pressure.

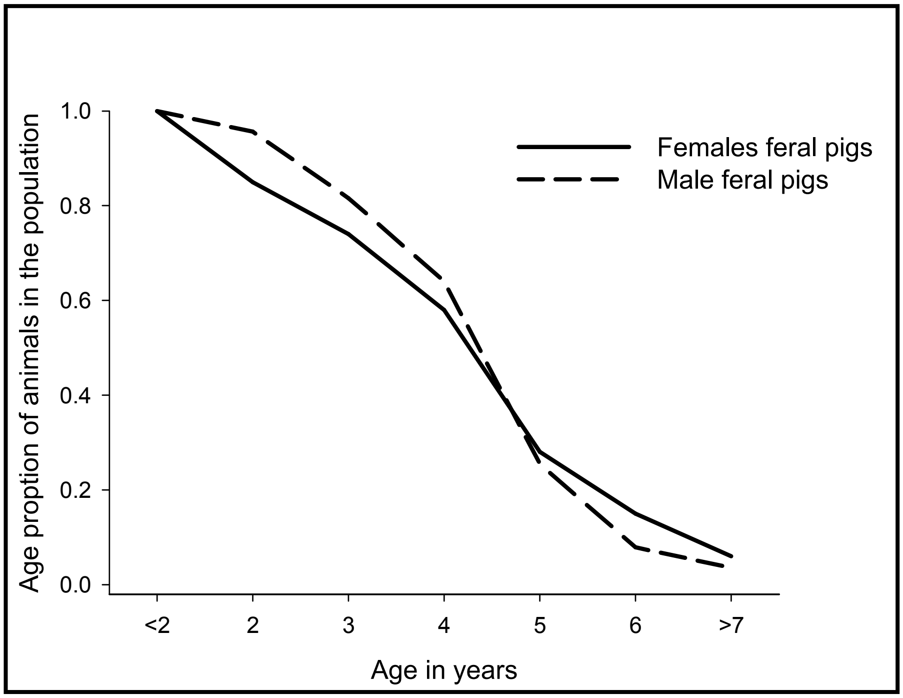

Figure 3. Proportion of male and female feral pigs per age group based on estimates from right maxilla (N=114 for males; N= 81 for females).

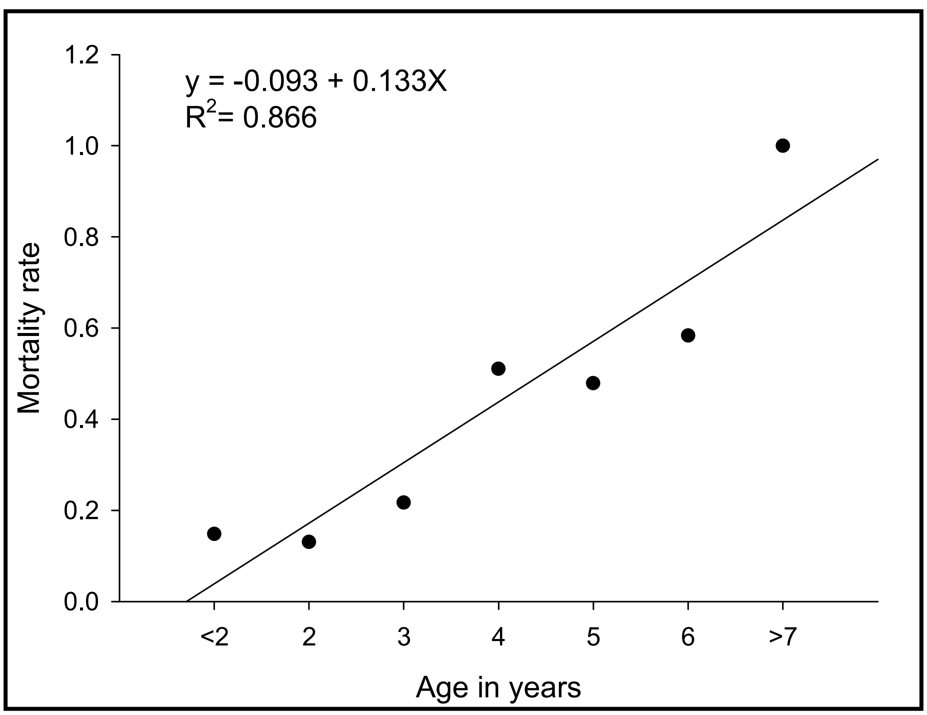

Figure 4. Female feral pig mortality rates estimated from skulls.

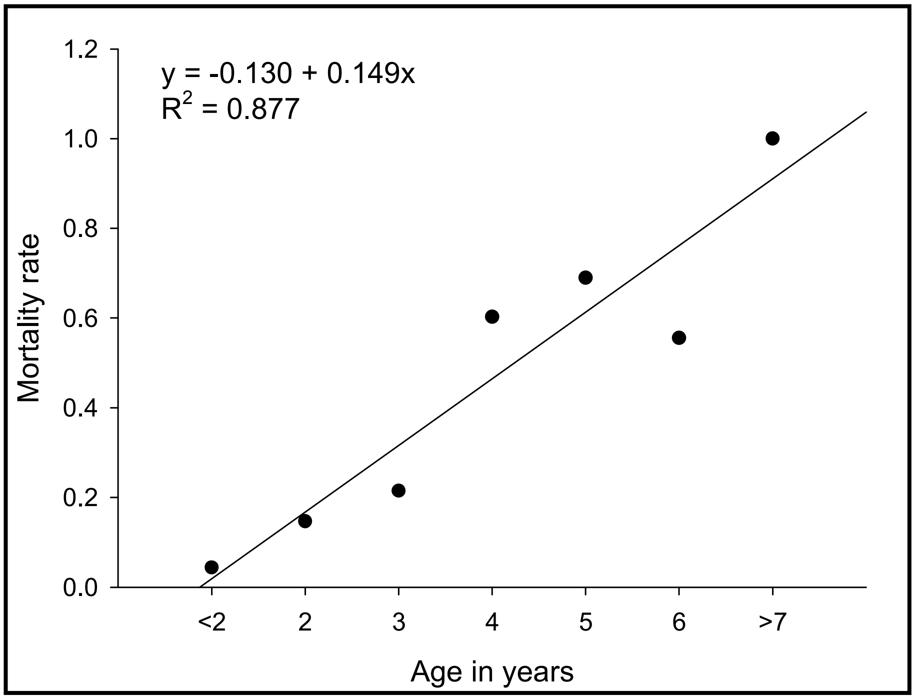

Figure 5. Male feral pig mortality rates estimated from skulls.

Results from this study can be used to model population dynamics of feral pigs from the region. Mortality rates for specific age groups have been used in a Vortex model built for feral pigs from the study area (Desbiez, 2007), and can be used in other types of population dynamic models. The method described in this paper can be used on any feral pig population, but will probably require adjustments. Rate of tooth wear will vary due to diet and environmental conditions. This is particularly true in the Pantanal where the abrasiveness of soils in the feeding areas of feral pigs is extremely high due to its sandy nature (Soriano *et al.,* 1997). For this reason, we recommend that comparisons between tooth wear from different eruption sequences be adapted to create a classification for tooth wear into age categories specific to geographic locations.

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