Galemys, 16 (nº especial): 211-220, 2004
ISSN: 1137-8700

PREVALENCE OF SELECTED PARASITES AND LEPTOSPIRA IN FERAL PIGS (*Sus domesticus*) FROM TROPICAL NORTH-EASTERN AUSTRALIA

PETER M. HEISE-PAVLOV AND SIGRID R. HEISE-PAVLOV

PAVECOL, Wildlife Management Consultants, 211 Turpentine Road, Diwan, via Mossman. 4873, Queensland. Australia. (pavecol@ledanet.com.au)

ABSTRACT

During an extended sampling period, 1,158 wild pigs were sampled in three locations from north-east Australia. In all three populations, lungworm infection (*Metastronglyus sp)* decreased with age, but was higher in Lowland Rainforest pigs and pigs of Prince of Wales Island than in pigs of the Cape York Peninsula. Young animals of the Lowland Rainforest population show an exceptionally high level of lungworm infection, indicating a mortality factor in this population. The infection with kidney worm (*Stephanurus dentatus*) was higher in young pigs of the Lowland Rainforest (up to 5.5 months of age) compared to pigs of the other two populations investigated. Kidney worm infections remained higher in older pigs (from 13 months on) of all samples and indicate that pigs are infected with this parasite throughout their life. The incidence of Leptospirosis was highest in pigs from the Lowland Rainforest population. These results indicate that populations of wild pigs in the Lowland Rainforest, although living under optimal conditions, are heavily affected by a high burden of disease and some parasites are likely to limit population growth via a high mortality of piglets and infections throughout the lifespan of adults.

Key words: Australia, pigs, diseases, parasites, tropical, feral.

INTRODUCTION

Pigs are known to carry a range of diseases and parasites that can be transmitted to domestic livestock or humans. One important example is Leptospirosis, which causes fertility problems in a wide range of mammals and serious pathology in humans. Pavlov and Edwards (1995) found eleven strains of leptospirosis in feral pigs from Lowland Rainforest, Australia, of which five serotypes have been recorded in humans. A recent development is the attenuation of strains that were previously recorded in wild animals, but now are responsible for human pathology (L. Smythe, World Health Organisation, Centre for Leptospirosis serology, Brisbane, Queensland, personal communication).

Pigs are highly adaptable and a large population is scattered throughout remote tropical regions of northern Australia. The presence of pathogens and parasites varies with environmental conditions. Many pathogens prefer moist, humid conditions for some stage of their life cycle (C.A.B. International 1989). Therefore, it is likely that feral pigs living in different environments show different degrees of parasitic infections. In the present study, we investigated the pathogen burden in three feral pig populations living in different habitats of north-east Australia. Their potential to pose a risk to livestock and humans is discussed.

MATERIALS AND METHODS

Study Areas

The three populations studied are in areas in north Queensland above 16 degrees 12 minutes of Latitude. The first population of feral pigs was studied on Prince of Wales Island (in text POW) (142°12'E, 10°40'S), a 50km^2 island 30 kilometers north of the mainland of Australia.

The second population of feral pigs was sampled on Cape York Peninsula (in text CY) (a triangle shape, with the tip 142°33'E, 10° 42'S, the south western corner 141°25'E, 16°12'S and the south eastern corner 145°24'E, 16° 12'S) approximately 126,000km^2 in area.

The third feral pig population studied was sampled in the wet tropical Lowland Rainforest (in text LR) 145°25'E, 16°5'S, an area of 400 km^2.

Sampling methods

Most pigs were sampled by shooting after hunting on foot with dogs used to find and bail them. In the Lowland Rainforest habitat, many pigs were caught in traps and shot. On Price of Wales Island, 351 pigs were sampled, on Cape York 470 pigs, and in the tropical Lowland Rainforest 337 pigs. In total, 1158 pigs were analysed.

Blood collection and Aging of pigs

The pig was laid on its left side and a blood sample was taken from the carotid artery within 5 min of death. The sample was held in 2 x 30-ml collecting vials with screw caps (Disposable Products No. Y0012, Adelaide. South Australia). The sample was allowed to clot at ambient temperature and the serum was decanted into 2x 5mm screw-cap disposable vials (Product No. X315, Selby Biolab. Brisbane). The samples were frozen and taken to the Queensland Department of Health, Coopers Plains (Brisbane). The determination of Leptospirosis serology was made by the WHO centre for Leptospirosis Serology, Queensland Department of Health, Brisbane.

The age of caught pigs was assessed on the base of a tooth eruption pattern, classified by Matschke (1967) (up to an age of 26 months) and on the base of the 3ed molar wear, classified by Barret (1978). The age classes used are presented in Table 1.

TABLE 1
Considered age classes.

Age Class	Age in months
1	0 – 5.5
2	6 – 12.5
3	13 – 24.5
4	25 – 36.5
5	37 – 48.5
6	49 – 60.5
7	61 – 72.5
8	+ 73

Parasites

Lung Worm (*Metastrongylus sp.*) and Kidney Worm (*Stephanurus dentatus*) were recorded by examining the lungs and kidneys and associated organs, respectively. Veterinarians from the Queensland Department of Primary Industries, Cairns Office, confirmed identification. The infection rates were given a rating of absent, low, medium and high for Lung Worm and Kidney Worm infections. With experience, the observer could consistently assess the infection and the data would then allow a quantification of the infection for each pig population and/or age class.

Statistical analysis of data

The statistical analysis of the data based on the χ^2 test (either 2 x 2 tables or r x k tables with subsequent partitioning (Siegel and Castellan 1988).

RESULTS

The distribution of lung worm infection with age shows that this infection is highest in young animals and decreases with age (Figure 1). That applies to all three of the sample sites. Piglets of age class 1 from the POW sample were almost never affected by lung worm infection. The infection rate was higher in age classes 2, 3 and 4, than in older pigs (age classes 6 and 7) (Table 2).

Figure 1. Percentage of North Queensland wild pigs with Lung worm infection per age class.

Pigs from the Lowland Rainforest had higher lungworm infections in age classes 2 and 3 than in age classes 4, 6 and 7 (Table 2). Pigs of the CY population showed the lowest infection rate with lungworm in age class 7 compared to other age classes, except age class 1 (Table 2).

Cape York pigs showed significantly lower infection rates in all age classes compared to pigs from the LR population (Table 3, Figure 1). CY pigs and POW pigs differed significantly in the infection rate of lungworm in age classes 1, 2, 3, 4 and 5, with CY pigs less infected (Table 3, Figure 1). The infection rate of CY pigs remained around 30% until age class 7. Pigs of age class 1 showed significantly higher infection rates in the LR population than in populations of CY and POW (Table 3, Figure 1).

Kidney worm infections in pigs of north-east Queensland showed increasing infection rates with age (Figure 2). Pigs on CY showed significantly lower infection rates in age classes 1 and 2 compared to all other age classes (Table 4). Pigs of LR and POW showed lower infection rates in age class 1 compared to all other age classes (Table 4).

There was no infection of piglets of age class 1 in the POW and the CY sample, but piglets in the LR population were infected (Table 5, Figure 2). Pigs of age class 2 showed a higher infection rate in LR and POW samples than did those of the CY population (Table 5, Figure 2).

TABLE 2
Results of the comparison of lungworm infection between age classes of three populations of feral pigs in North Eastern Australia.

	Lowland Rainforest							
	1	2	3	4	5	6	7	8
1		*** $\chi^2 = 18.43$ $p < 0.001$	*** $\chi^2 = 14.53$ $p < 0.001$	ns $\chi^2 = 0.57$ $p > 0.05$	** $\chi^2 = 4.40$ $p < 0.05$	ns $\chi^2 = 0.53$ $p > 0.05$	ns $\chi^2 = 0.96$ $p > 0.05$	ns $\chi^2 = 0.57$ $p > 0.05$
2	ns $\chi^2 = 3.07$ $p > 0.05$		ns $\chi^2 = 0.03$ $p > 0.05$	*** $\chi^2 = 12.84$ $p > 0.001$	** $\chi^2 = 3.89$ $p < 0.05$	* $\chi^2 = 10.51$ $p < 0.01$	* $\chi^2 = 8.75$ $p < 0.01$	ns $\chi^2 = 0.12$ $p > 0.05$
3	ns $\chi^2 = 2.41$ $p > 0.05$	ns $\chi^2 = 0.14$ $p > 0.05$		* $\chi^2 = 10.17$ $p < 0.01$	ns $\chi^2 = 3.39$ $p > 0.05$	* $\chi^2 = 8.69$ $p < 0.01$	* $\chi^2 = 7.32$ $p < 0.01$	ns $\chi^2 = 0.10$ $p > 0.05$
4	ns $\chi^2 = 3.15$ $p > 0.05$	ns $\chi^2 = 0.08$ $p > 0.05$	ns $\chi^2 = 0.04$ $p > 0.05$		ns $\chi^2 = 1.96$ $p > 0.05$	ns $\chi^2 = 0.00$ $p > 0.05$	ns $\chi^2 = 0.09$ $p > 0.05$	ns $\chi^2 = 0.21$ $p > 0.05$
5	ns $\chi^2 = 1.97$ $p > 0.05$	ns $\chi^2 = 0.80$ $p > 0.05$	ns $\chi^2 = 0.19$ $p > 0.05$	ns $\chi^2 = 0.93$ $p > 0.05$		ns $\chi^2 = 1.57$ $p > 0.05$	ns $\chi^2 = 0.99$ $p > 0.05$	ns $\chi^2 = 0.03$ $p > 0.05$
6	ns $\chi^2 = 1.71$ $p > 0.05$	ns $\chi^2 = 1.34$ $p > 0.05$	ns $\chi^2 = 0.46$ $p > 0.05$	ns $\chi^2 = 1.99$ $p > 0.05$	ns $\chi^2 = 0.10$ $p > 0.05$		ns $\chi^2 = 0.06$ $p > 0.05$	ns $\chi^2 = 0.20$ $p > 0.05$
7	ns $\chi^2 = 0.08$ $p > 0.05$	* $\chi^2 = 8.41$ $p < 0.01$	** $\chi^2 = 6.14$ $p < 0.05$	*** $\chi^2 = 12.49$ $p < 0.001$	* $\chi^2 = 7.01$ $p < 0.01$	** $\chi^2 = 6.10$ $p < 0.05$		ns $\chi^2 = 0.12$ $p > 0.05$
8								

CAPE YORK

	Prince of Wales Island							
	1	2	3	4	5	6	7	8
1		*** $\chi^2 = 136.16$ $p < 0.001$	*** $\chi^2 = 162.96$ $p < 0.001$	ns $\chi^2 = 126.30$ $p > 0.05$	** $\chi^2 = 77.57$ $p < 0.05$	ns $\chi^2 = 51.12$ $p > 0.05$	ns $\chi^2 = 12.03$ $p > 0.05$	
2			ns $\chi^2 = 0.13$ $p > 0.05$	ns $\chi^2 = 0.09$ $p > 0.05$	ns $\chi^2 = 0.09$ $p > 0.05$	ns $\chi^2 = 3.74$ $p > 0.05$	* $\chi^2 = 7.00$ $p < 0.01$	
3				ns $\chi^2 = 0.78$ $p > 0.05$	ns $\chi^2 = 1.18$ $p > 0.05$	* $\chi^2 = 7.66$ $p < 0.01$	*** $\chi^2 = 12.37$ $p < 0.001$	
4					ns $\chi^2 = 0.24$ $p > 0.05$	** $\chi^2 = 4.07$ $p < 0.05$	* $\chi^2 = 7.22$ $p < 0.01$	
5						ns $\chi^2 = 0.76$ $p > 0.05$	ns $\chi^2 = 2.46$ $p > 0.05$	
6							ns $\chi^2 = 0.61$ $p > 0.05$	
7								

TABLE 3
Results of the comparison of lungworm infection between three feral pig populations of northeastern Australia (CY-Cape York. POW-Prince of Wales Island. LR-Lowland Rainforest).

Age class	CY-POW	CY-LR	LR-POW
1	** $\chi^2 = 4.98$ $p < 0.05$	** $\chi^2 = 4.53$ $p < 0.05$	*** $\chi^2 = 73.23$ $p < 0.001$
2	* $\chi^2 = 7.66$ $p < 0.01$	*** $\chi^2 = 19.89$ $p < 0.001$	ns $\chi^2 = 3.40$ $p > 0.05$
3	*** $\chi^2 = 18.15$ $p < 0.001$	*** $\chi^2 = 19.65$ $p < 0.001$	ns $\chi^2 = 0.10$ $p > 0.05$
4	*** $\chi^2 = 15.70$ $p < 0.001$	** $\chi^2 = 5.23$ $p < 0.05$	ns $\chi^2 = 3.12$ $p > 0.05$
5	** $\chi^2 = 3.74$ $p < 0.05$	*** $\chi^2 = 18.00$ $p < 0.001$	ns $\chi^2 = 0.05$ $p > 0.05$
6	ns $\chi^2 = 1.12$ $p > 0.05$	* $\chi^2 = 8.66$ $p < 0.01$	ns $\chi^2 = 0.55$ $p > 0.05$
7	ns $\chi^2 = 0.47$ $p > 0.05$	*** $\chi^2 = 23.30$ $p < 0.001$	ns $\chi^2 = 3.16$ $p > 0.05$
8		ns $\chi^2 = 0.33$ $p > 0.05$	ns $\chi^2 = 0.33$ $p > 0.05$

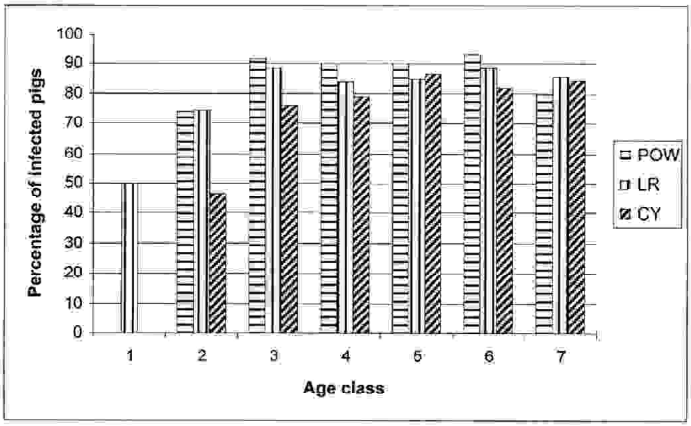

Figure 2. Percentage of North Queensland wild pigs with Kidney worm infection per age class.

TABLE 4
Results of the comparison of kidney worm infection between age classes of three populations of feral pigs in North Eastern Australia.

	Lowland Rainforest							
	1	2	3	4	5	6	7	8
1		* $\chi^2 = 7.66$ $p < 0.01$	*** $\chi^2 = 15.92$ $p < 0.001$	*** $\chi^2 = 12.03$ $p < 0.001$	*** $\chi^2 = 12.46$ $p < 0.001$	*** $\chi^2 = 13.14$ $p < 0.001$	* $\chi^2 = 11.05$ $p < 0.01$	ns $\chi^2 = 0.25$ $p > 0.05$
2	** $\chi^2 = 4.90$ $p < 0.05$		ns $\chi^2 = 3.59$ $p > 0.05$	ns $\chi^2 = 1.43$ $p > 0.05$	ns $\chi^2 = 1.75$ $p > 0.05$	ns $\chi^2 = 2.81$ $p > 0.05$	ns $\chi^2 = 1.72$ $p > 0.05$	ns x_ = 0.31 $p > 0.05$
3	*** $\chi^2 = 12.63$ $p < 0.001$	** $\chi^2 = 5.21$ $p < 0.05$		ns $\chi^2 = 1.08$ $p > 0.05$	ns $\chi^2 = 0.34$ $p > 0.05$	ns $\chi^2 = 0.05$ $p > 0.05$	ns $\chi^2 = 0.10$ $p > 0.05$	ns $\chi^2 = 0.05$ $p > 0.05$
4	*** $\chi^2 = 22.18$ $p < 0.001$	*** $\chi^2 = 12.77$ $p < 0.001$	ns $\chi^2 = 0.12$ $p > 0.05$		ns $\chi^2 = 0.02$ $p > 0.05$	ns $\chi^2 = 0.04$ $p > 0.05$	ns $\chi^2 = 0.07$ $p > 0.05$	ns $\chi^2 = 0.07$ $p > 0.05$
5	*** $\chi^2 = 29.22$ $p < 0.001$	*** $\chi^2 = 18.65$ $p < 0.001$	ns $\chi^2 = 1.38$ $p > 0.05$	ns $\chi^2 = 2.20$ $p > 0.05$		ns $\chi^2 = 0.14$ $p > 0.05$	ns $\chi^2 = 0.01$ $p > 0.05$	ns $\chi^2 = 0.06$ $p > 0.05$
6	*** $\chi^2 = 24.37$ $p < 0.001$	*** $\chi^2 = 14.62$ $p < 0.001$	ns $\chi^2 = 0.53$ $p > 0.05$	ns $\chi^2 = 0.40$ $p > 0.05$	ns $\chi^2 = 0.75$ $p > 0.05$		ns $\chi^2 = 0.02$ $p > 0.05$	ns $\chi^2 = 0.01$ $p > 0.05$
7	*** $\chi^2 = 23.05$ $p < 0.001$	*** $\chi^2 = 13.23$ $p < 0.001$	ns $\chi^2 = 0.88$ $p > 0.05$	ns $\chi^2 = 0.79$ $p > 0.05$	ns $\chi^2 = 0.15$ $p > 0.05$	ns $\chi^2 = 0.14$ $p > 0.05$		ns $\chi^2 = 0.06$ $p > 0.05$
8								
	Cape York							

	Prince of Wales Island							
	1	2	3	4	5	6	7	8
1		*** $\chi^2 = 159.1$ $p < 0.001$	*** $\chi^2 = 201.12$ $p < 0.001$	*** $\chi^2 = 177.34$ $p < 0.001$	*** $\chi^2 = 148.57$ $p < 0.001$	*** $\chi^2 = 164.89$ $p < 0.001$	*** $\chi^2 = 129.41$ $p < 0.001$	
2			** $\chi^2 = 5.70$ $p < 0.05$	ns $\chi^2 = 3.28$ $p > 0.05$	ns $\chi^2 = 0.75$ $p > 0.05$	ns $\chi^2 = 1.95$ $p > 0.05$	ns $\chi^2 = 0.06$ $p > 0.05$	
3				ns $\chi^2 = 0.03$ $p > 0.05$	ns $\chi^2 = 0.17$ $p > 0.05$	ns $\chi^2 = 0.12$ $p > 0.05$	ns $\chi^2 = 0.41$ $p > 0.05$	
4					ns $\chi^2 = 0.31$ $p > 0.05$	ns $\chi^2 = 0.05$ $p > 0.05$	ns $\chi^2 = 0.18$ $p > 0.05$	
5						ns $\chi^2 = 0.19$ $p > 0.05$	ns $\chi^2 = 0.06$ $p > 0.05$	
6							ns $\chi^2 = 0.25$ $p > 0.05$	
7								

TABLE 5
Results of the comparison of kidney worm infection between three feral pig populations of northeastern Australia (CY-Cape York. POW-Prince of Wales Island. LR-Lowland Rainforest).

Ageclass	CY-POW	CY-LR	LR-POW
1	ns $\chi^2 = 0.00$ $p > 0.05$	** $\chi^2 = 5.33$ $p < 0.05$	*** $\chi^2 = 93.35$ $p < 0.001$
2	** $\chi^2 = 6.38$ $p < 0.05$	* $\chi^2 = 7.50$ $p < 0.01$	ns $\chi^2 = 0.01$ $p > 0.05$
3	ns $\chi^2 = 3.19$ $p > 0.05$	ns $\chi^2 = 1.77$ $p > 0.05$	ns $\chi^2 = 0.04$ $p > 0.05$
4	ns $\chi^2 = 2.23$ $p > 0.05$	ns $\chi^2 = 0.57$ $p > 0.05$	ns $\chi^2 = 0.47$ $p > 0.05$
5	ns $\chi^2 = 0.05$ $p > 0.05$	ns $\chi^2 = 0.08$ $p > 0.05$	ns $\chi^2 = 0.06$ $p > 0.05$
6	ns $\chi^2 = 0.73$ $p > 0.05$	ns $\chi^2 = 0.85$ $p > 0.05$	ns $\chi^2 = 0.03$ $p > 0.05$
7	ns $\chi^2 = 0.04$ $p > 0.05$	ns $\chi^2 = 0.04$ $p > 0.05$	ns $\chi^2 =0.07$ $p > 0.05$
8		ns $\chi^2 = 0.33$ $p > 0.05$	ns $\chi^2 = 0.33$ $p > 0.05$

A survey of Leptospirosis infection in each population indicated a 2% infection rate on Prince of Wales Island, a 7% infection rate on Cape York Peninsula (Pavlov, 1991) and an infection rate of 52% in 1995 and 58% in the 2000/2001 sample from the lowland rainforest, with 10 different serotypes represented and up to 4 serovars (strains) per pig.

Discussion

Lung Worm infections were higher in pigs of the Lowland Rainforest population than at the other two sites. Because lung worm is transmitted by ingestion of infected earthworms, earthworm availability at the Lowland Rainforest site must be high and spread over a longer period of the year than in the dry monsoon environments found at the Cape York Peninsula and on Prince of Wales Island. The sample of the Lowland Rainforest pigs, however, showed a significantly higher proportion of very young pigs (age class 1) infected by lungworm than those of the other populations investigated. That might be attributable to a generally higher variability of earthworms throughout the year. In the other two sites, there are pronounced dry seasons from April to November, which limits the seasonal availability of earthworms. No surveys have been done on the infection rates of earthworms with lungworm larvae, but earthworms are a preferred dietary item of pigs when soil moisture conditions stimulate earthworm activity. In all three populations, lungworm infection decreases with age, which indicates the capacity of pigs to live with an established infection. High lungworm infections are also associated with a variety of bacterial infections that reduce the lung capacity of the host and affect host viability, which affects the mortality of young pigs (Heise-Pavlov and Heise-Pavlov 2003, Meynhardt 1982).

Kidney worm infections increased with the age of the pig, indicating a lack of age acquired immunity, as the pigs are infected at all ages and the infections are permanent. Incidental ingestion of infective larvae occurs during feeding in moist soil, but the main infection path is direct entry through the skin (especially if slightly damaged) when the animal lies in moist soil (Belschner and Love 1984). Heavy infections with kidney worm cause severe fibrosis (scarring) of liver cells and reduces liver function, which can lead to death. Kidneys can also be extensively damaged by the proximity of adult worms in adjacent tissue (Leman et. al. 1981).

On Prince of Wales Island, only 2% of the pigs were infected by Leptospirosis compared to a range of 2 to 23% (average 7%) from CY and an infection rate of 52-58% in the population of the Lowland Rainforest. The highest incidence was from the 2000/2001 samples, when a 58% infection rate was recorded with 10 serovars (strains) being involved. Because Leptospirosis infections in pigs can cause abortions, stillbirths, and neonatal disease in piglets (Leman et al. 1981), it is likely that diseases and parasites operate in this environment as major factors in controlling population growth. Leptospirosis, which had been found in many pigs of the Lowland Rainforest, can be spread to humans. The Queensland Department of Health (WHO Reference centre for Leptospirosis Serotypes, L. Smythe Pers. Comm.) recorded 216 cases of human infection of Leptospirosis in 1999, the majority from Queensland residents.

Of interest is the possible change in the virulence of previously harmless strains, causing clinical symptoms in humans in recent years.

ACKNOWLEDGEMENTS

The authors wish to thank Government contributors to the Cape York Peninsula/Prince of Wales Island study: The Queensland Departments of Natural Resources, Primary Industries and the Department of the Environment. The Wet Tropics Management Authority and the Department of Environment financed parts of the Lowland Rainforest Study.

Remote area fieldwork also must rely on support from Private Individuals, Property Owners and Townspeople we thank them all collectively for their support and hospitality because there are too many to mention individually.

REFERENCES

BARRET, H.G. (1978). The feral hog on the Dye Creek Ranch California. *Hilgardia*, 46 (9): 283-355.

BELSCHNER, H. G. AND R. J. LOVE (1984). *Pig diseases* Pp. 16-18, 123-126, 131-133. Angus and Robertson,Publishers. Australia.

C. A. B. INTERNATIONAL/CTA (1989). Manual of tropical veterinary parasitology - Part III. Pp 337-437. In: P. Morel. *Tick borne diseases of livestock in Africa*. New York.

HEISE-PAVLOV, P. M. AND S. R. HEISE-PAVLOV (2003). Feral pigs in tropical lowland rainforest of north eastern Australia: ecology, zoonoses and management. *Wildlife Biology*, 9 (Supplement 1): 21-27.

LEMAN, A. D., R. D. GLOCK, W. L. MENGELING, R. H. C. PENNY, E. SCHOLL AND B. STRAW (1981). *Diseases of Swine.* 5th Edition. Iowa State University Press. Ames, Iowa U.S.A. Pp. 386-395; 560-575.

MATSCHKE, G. H. (1968). Aging European wild hogs by dentition. *Journal of Wildlife Management*, 31 (1): 109-113.

MEYNHARDT, H. (1982). *Schwarzwild-report*. Verlag J. Neumann-Neudamm. Melsungen. Berlin. Basel. Wien Pp. 219.

PAVLOV, P. M. (1991). *Aspects of feral pig ecology in semi-arid and tropical regions of eastern Australia.* Unpublished Ph.D. Thesis, Monash University, Melbourne. 233 pp.

PAVLOV, P. M. AND E. EDWARDS (1995). Feral pig ecology in the Cape Tribulation National Park, north Queensland, Australia. 2nd International Wild Boar Conference, Turin, Italy. IBEX, *Journal of Mountain Ecology*, 3: 148-151.

SIEGEL, S. AND N. J. CASTELLAN (1988). *Nonparametric statistics for the behavioural sciences.* Second Edition. McGraw-Hill International Edition. 456 pp.