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Feral pigs in tropical lowland rainforest of northeastern Australia: ecology, zoonoses and management

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Feral pigs are well established in the lowland tropical forests of northeastern Queensland, Australia. Circumstantial evidence, e.g. the presence of a Melanesian tick, an exotic nematode and a dominant coat colour other than black, indicates that they do not originate from escaped domestic animals as feral pigs throughout other parts of Australia. It is likely that the ancestral population was established from animals originating from islands to the north and northwest of Australia, i.e. pigs domesticated from naturally occurring wild pigs in Indonesia and southeastern Asia. Pigs in lowland rainforests show relatively stable populations with a high reproductive potential in age classes 4-7. Seasonally there are negative interactions between residents and pigs. Pigs not only damage gardens and fruit orchards due to their rooting, they are also important vectors of zoonoses. Feral pigs are carriers of 11 *Leptospirosis* serovars, some of which are important zoonoses, e.g. *L. australia*, *L. hardjo* and *L. zanoni*. They also have a high burden of parasites. Lice *Hematopinus suis* and thorny headed worm *Macracanthorhynchus hirudinaceous* have been more frequently found in females than in males, whereas males seem to be more susceptible to ticks *Ambylomma cyprium cyprium*. The infection with lungworms *Metastrongylus* sp. is higher in younger pigs than older ones indicating that lungworms represent a major mortality factor of young pigs. In contrast, kidneyworm *Stephanurus dentatus* and thorny headed worm is present at all ages. *Leptospirosis*, lung worm and kidneyworm are known causes of infertility and/or mortality in pigs and can be assumed to contribute to the lower than expected population density in this environment.

Key words: Australia-Queensland, diseases, ecology, feral pig, management, parasites

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Feral pigs have been living in the lowlands north of the Daintree River in northeastern Queensland, Australia, for many years. Agricultural activity commenced in this area in the 1930s and, according to early settlers, pigs were well established at that time.

The presence of the nematode *Simmondsia paradoxa* (Spratt & Pavlov 1996), previously only recorded from eastern Europe, southeast Asia and Papua New Guinea, indicates that pigs in this area pre-dated the European settlements. Kemp & Wilson (1979) recorded the presence of a large Polynesian tick *Ambylomma cyprium cyprium* (Acari: *Ixodidae*) on Cape York Peninsular and in the Cape Tribulation area. This tick had also been recorded from Papua New Guinea (Talbot 1972). With no aboriginal name for the pig and no old cave painting of pigs, it is likely that the pigs did not precede the European settlement by many years (Baldwin 1983). In New Guinea, there is archeological evidence that pigs have been associated with humans for approximately 5,000 years (Talbot 1972). Groves (1981) deter-

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mined that New Guinea pigs were hybrids of *Sus scrofa vittatus* (Indonesian wild boar) and *S. celebensis* (Celebes wild boar).

After the original agricultural settlement in the 1930s, the human population in the study area remained low because of low incomes. Many of the properties were bought by a developer in the 1970s who was first able to change the land tenure from lease hold to a more secure free hold tenure. Then, in the late 1970s he was able to get a subdivision of 1,100 one-hectare blocks approved over his land.

Human settlement on these blocks has steadily increased to the present time, where 500 people are living on around 300 of the properties. The natural forest remaining on the lowland is fragmented by a road network, but with a high proportion of the properties unsettled, extensive areas of lowland rainforest, disturbed only by the original survey that established the subdivision, still exist. Throughout the lowland area, there is a range of settlement types from one hectare to several hundred hectares and extensive areas of national parks.

People who have come to live in the area have a wide range of attitudes to natural rainforests. Some prefer to live in the area with limited impact and others are keen to develop formal gardens and orchards. The latter activities bring residents into direct conflict with seasonal pig activity. Pigs, being opportunists seeking maximum protein intake, dig for earthworms and seek out any possible concentrations of earthworms (Giles 1980). In formal gardens and around newly established fruit trees, there is often a higher concentration of earthworms, and the lack of forest cover means less dense root mass and easier digging for the pigs.

When bananas are encountered, pigs chew through the stem causing the weight of the banana bunch to make the plant fall over. After the stems and fruits (in an immature state) have been consumed, the pigs concentrate on the fresh shoots from the banana plants until the plant is killed.

Feral pigs take advantage of any extra food they encounter, e.g. compost heaps, and revisit the site until the food supply is exhausted.

Feral pigs in this area have been studied on a part-time basis since 1992, and Pavlov & Edwards (1995) estimated a density of 1-2 per km^2. This estimate translates to a population size of 1,000-2,000.

The aims of our study are to investigate: 1) the general ecology of feral pigs in lowland tropical rainforest, 2) the impact of feral pigs on the seasonally utilized lowland forest and, 3) food competition with native animals. The long-term reduction of negative impacts of feral pigs will justify the research effort. The results we present in this paper focus on clarification of the origin of pigs in the lowland forests of northeast Queensland, their population structure, disease and parasite burdens.

Material and methods

Study area

The study area is situated in the northern section of the Wet Tropics World Heritage area of northeastern Australia, that extends along the eastern coastline from Townsville to Cooktown. It is approximately 550 km long and up to 50 km wide. In two areas 130 km south of Cairns and 100 km north of Cairns, respectively, the coastal lowland rainforest is preserved. The northern area is the study site (145° 20'E-145° 29'E, 15° 55'S-16° 17'S; Fig. 1), and it is bounded to the south by the Daintree River, to the west by the coastal range and to the north by the Bloomfield river.

Sampling

In the first part of the study (1992-1994), pigs were hunted with Australian cattle dogs or cattledog x Kelpie hybrids that were trained to locate and bail individual animals. Because of the dense vegetation and difficult terrain, all hunting was carried out on foot with the dogs hunting in a systematic pattern, approximately 100 m to each side of the hunter. When a pig was encountered, the dogs barked and chased it until it stopped (= bails), which usually happened within a range of 100 m. At this stage, all the dogs (three or four) would surround the pig and bark loudly. Short charges were made by the pigs at individual dogs, but they were easily avoided. The

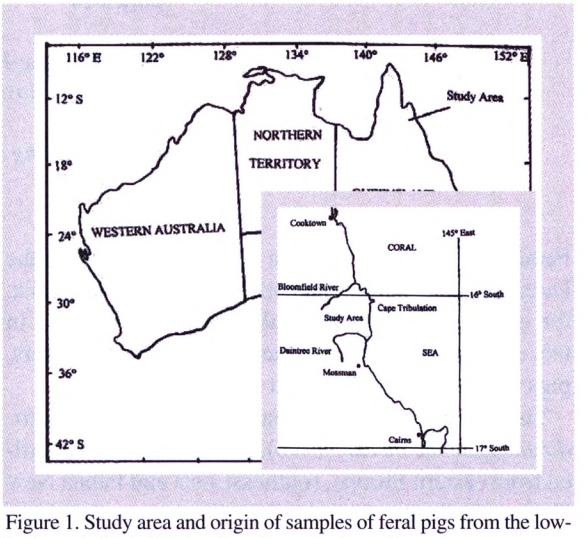


Figure 1. Study area and origin of samples of feral pigs from the lowland tropical rainforests of northeastern Australia.

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hunter would then assess the situation and approach the pig from the front. When a clear shot was possible from less than 20 m, a bullet was fired into the pig's brain. A proportion of the animals in our sample were also caught in traps.

In the second part of the study (1999-2000), pigs were caught in traps, baited with split coconuts or other available fruit, and then shot in the brain. The traps were made of welded mesh in either a round trap, 10 m in circumference or a rectangular trap approximately 2 x 3 m and 1.5 m high. Both traps were operated by spring-loaded gates and a heavy wooden trigger bar behind which the bait was placed.

In total, we sampled 305 pigs comprising 144 males and 161 females.

A blood sample was taken from the carotid artery in the neck immediately after death. The sample was held in 2 x 30 ml collecting vials with screw caps (Disposable Products No. Y0012, Adelaide. South Australia) and was allowed to clot at ambient temperature. The serum was then decanted into 2 x 5 mm 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) where 36 were tested for *Leptospirosis* serotypes using a *Leptospirosis* Microscopic Agglutination test.

Standard morphometric measurements, which included snout-vent length, girth and body weight, were taken. The pigs were then checked for lice *Hematopinus suis* and ticks *Ambylomma cyprium cyprium*. The following four basic colours were recorded:

Agouti - black bristles with either red or white discoloured tips;
Black - black body but could have white feet;
Saddleback - black body with a wide or narrow white stripe across the shoulders;
Black/white - basic white body colour with black patches.

An autopsy was then undertaken, organs were weighed and checked for parasites and the gutted weight was recorded.

The parasites surveyed were lungworm *Metastrongylus* sp., kidneyworm *Stephanurus dentatus* and thorny headed worm *Macracanthorhynchus hindunaceus*. Parasite infection rates were estimated as zero, light, medium or heavy by an experienced observer. Infection rates were compared between males and female by χ^2-test and between the age classes using ANOVA with Tukey's tests.

Table 1. Distribution (in %) of the four colour types in 305 sampled feral pigs in the lowland rainforests of northeastern Australia.

	% of caught pigs		
Colour	All	♀	♂
Agouti	54.8	56.05	53.57
Black	37.03	36.94	37.14
Saddleback	2.35	0.63	5.71
Black/white	5.72	6.36	5

The age of caught pigs was assessed on the basis of a classification given by Matschke (1968). A progressive tooth eruption takes place until 36 months of age, and a generalised wear pattern of the molars occur until 72 months. This is a simplified ageing method, but in the absence of knowledge of wear patterns on wild animals, no further precision can be attained. The following age classes were used: 1 (0-5.5 months), 2 (6-12.5 months), 3 (13-24.5 months), 4 (25-36.5 months), 5 (37-48.5 months), 6 (49-60.5 months), 7 (61-72.5 months) and 8 (>73 months).

Results

Colour, age and sex

The distribution of colour patterns in the 305 sampled pigs (Table 1) shows that the dominant colour is agouti followed by pure black animals.

The age and sex structure of the sample (Fig. 2) indicates a stable population with small numbers in the younger age classes, good representation in the middle age classes and smaller numbers in the older age classes. The proportion of pigs in the age classes 4-7 indicate a high reproductive potential that could increase num-

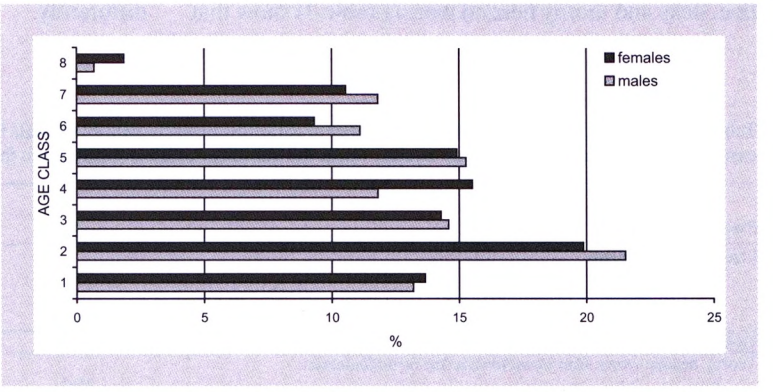


Figure 2. Age and sex composition of the feral pig population in the lowland rainforests of northeastern Australia.

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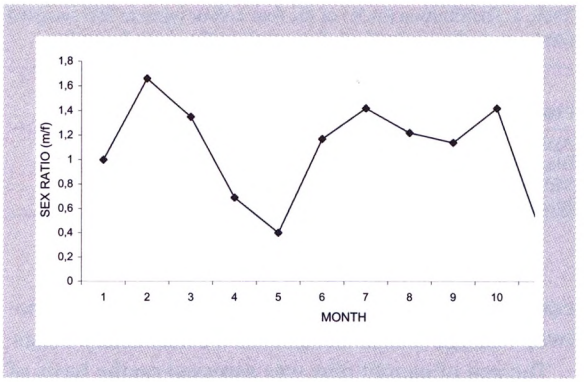


Figure 3. Sex ratio of the pigs caught in the lowland rainforests of north-eastern Australia.

bers if seasonal conditions were favourable and significant mortality factors reduced. A χ^2-test showed no significant difference between the number of males and females per age class.

The sex ratio (males:females) of trapped pigs (Fig. 3) showed that males were caught in a higher proportion in February and in June-October than females, which were caught in higher numbers in April-May and November.

Diseases

The *Leptospirosis* infection rates of pigs in New South Wales, according to Mason, Flemming, Smythe, Dohnt, Norris & Symmonds (1998), the results of studies by Pavlov & Edwards (1995) and of the present study in Queensland (Table 2) indicate the importance of North Queensland pigs in carrying the *Leptospirosis* serovars *L. australis*, *L. hardjo* and *L. zanoni* that are important human pathogens.

Parasites

The infection rates for male and female pigs infected with lice, ticks and thorny headed worm (Table 3) show that female pigs are more likely to carry higher infections of lice at low infection rates than do males ($\chi^2 = 4.2$; $P < 0.05$). Tick infections are recorded more often on males than on females, but at the level of $P < 0.05$ no significant difference could be shown. In the case of thorny headed worm, females also had higher infection rates than male pigs for light infections ($\chi^2 = 5.1$; $P < 0.05$).

Lungworm infection (at all infection rates) of pigs in age classes 1-8 (Fig. 4) showed that age classes 2 and 3 had the highest infection rates (ANOVA with Tukey's test: $F = 4.4686$; $P = < 0.0001$).

In contrast, kidneyworm infection (at all infection rates) is significantly higher in age classes 3-7 than in age class 1 (ANOVA with Tukey's test: $F = 3.9616$; $P = 0.0004$). This trend is also followed by the graph for infection rates of thorny headed worm.

It is likely that all parasites contribute to mortality in pigs in this environment, but affect pigs at different ages differently.

Table 2. Infection rate (in %) for feral pigs, with 15 different serovars of *Leptospirosis* in New South Wales and North Queensland, and the human infection rate for Queensland, Australia, based on data from Masonet et al. (1998), Pavlov & Edwards (1995) and the present study.

	New South Wales	North Queensland			Human
Serovars	1998	1992	1995	1999/2000	infections 1999
Total (N)	212	442	52	36	71
australis	1	2	15	11	21.2
bulgarica	0	6	0	0	1.4
canicola	1.5	0	0	16	2.9
celledoni	0	6	0	0	1.4
copenhageni	1	0	0	0	0.4
grippotyphosa	1.5	2	2	0	0.4
hardjo	1	33	8	5	5.6
hurstbridge	0	0	0	39	0
kremastos	0	0	0	2	5.6
medanensis	0	0	2	0	10.4
pomona	13.9	0	6	0	2.8
robinsoni	0	4	0	0	5.6
szwajizac	0.5	2	7	0	5.6
tarrasovi	0.5	3	0	0	5.6
zanoni	1	12	0	11	43.9

Table 3. Infection rate (in %) caused by three different parasite species in male and female feral pigs caught in the lowland rainforest of north-eastern Australia. For lice and thorny headed worm the infection rates are separated in three categories; see text for details.

	Infection rate (%)		
Parasite species	♂	♀	Difference at $P < 0.05$
Lice *Hematopinus suis*			
1	39.5	50.31	*
2	11.8	6.21	n.s
3	9.0	8.69	n.s
Ticks *Ambylomma cyprium cyprium*	52.08	36.64	n.s
Thorny headed worm *Macracanthornynchus hirundinaceous*			
1	25.0	36.0	*
2	3.47	5.5	n.s
3	4.16	3.1	n.s

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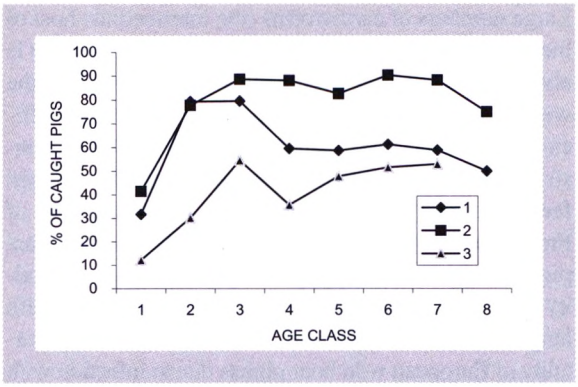


Figure 4. Age-dependency of lungworm (1), kidneyworm (2) and thorny headed worm (3) infections of feral pigs in the lowland rainforests of northeastern Australia.

Discussion

The feral pig sampling on the Cape York Peninsular in the 1980s (Pavlov 1991) was biased towards males, and it was realised that male pigs were more often encountered than females. Males are usually solitary and females generally part of a matriarchal group, which is less likely to be encountered. Trapping did not produce sex-biased results.

Feral pigs in the lowland forests of tropical north Queensland are predominately agouti coloured, and young are often striped during the first six months of age. This colour pattern reinforces the assessment of several studies (e.g. Baldwin 1983, Pavlov & Edwards 1992), that pigs in this population differ from those in other parts of Australia. Along with the presence of a Melanesian tick, and a nodule worm, it is very likely that they originated from animals introduced from the islands to the north or northwest of Australia. All these characteristics are present in pigs from New Guinea (Talbot 1972).

Groves (1981) completed a comprehensive crainometric and morphological study of the genus *Sus*. Adult *Sus scrofa* are agouti patterned (black bristles with white or red tips), and young animals have black longitudinal stripes during their first six months of life, a common trait which they share with all wild pigs except *S. verrucocus* (Groves 1981). *Sus scrofa* has always been present in Indonesia, and Groves (1981) contends that hybrids of *S. scrofa vittatus* (colour: agouti or brown) and the wild pig of Celebes *Sus celebensis* (colour: mostly black, but also black/white = piebald), were the only ancestors of the feral pig of New Guinea.

Until genetic studies are made, the proportion of wild and domestic pig genes in the population remains unknown. The evidence we present here indicates, that the majority of the population is the phenotypically wild type. With no records of introduction of wild type pigs since the European settlement, it is assumed that they were introduced by coastal trading aboriginies at an earlier stage (Baldwin 1983).

The age structure of the population indicates a stable population with high mortality in the younger age classes. This structure is similar to that of the population of Cape York (Pavlov 1991), where high mortality of piglets occurs due to dingo *Canis dingo* predation, but is in marked contrast to that of the population of Prince of Wales Island where there is low piglet mortality and few old animals. Pavlov (1991) estimated a feral pig population on the Normanby River floodplain at 8-10 per km^2. This habitat seems to be the most productive on the Cape York Peninsular with ephemeral swamps and associated wetland vegetation covering the floodplains for 8-10 months of the year. This population density was equivalent to the density found on the floodplains of the Northern Territory by Barrett (1975 and pers. comm.). In the lowland rainforest of northeastern Queensland, Pavlov & Edwards (1995) estimated a pig population density of 1-2 per km^2.

The sex ratio of pigs from the lowland rainforest varies throughout the year with more females being trapped during April-May and November. Heise-Pavlov & Heise-Pavlov (unpubl. data) documented a high proportion of reproducing females (lactating and pregnant) in the months January-February and June-July. The high proportion of females caught in April-May and November could be due to higher mobility during mating. Food availability may explain the peak in the number of females caught in November as maximum abundance of fruits had been recorded for the 'late dry' (July-November). Little is known about the social grouping and distribution of feral pigs in the lowland rainforest of northeastern Queensland.

Feral pig diet strategies are opportunistic and the impact of feral pigs on the lowland forest is subject to seasonal conditions. The development of a residential subdivision on the lowlands north of the Daintree River in the 1970s has also influenced seasonal food availability. Higher concentrations of earthworms in gardens and orchards, where lower root density enables pigs to dig deeper in the soil than they could in undisturbed rainforest, and the availability of fallen fruit are a major causes of negative pig/human interaction.

Early disease surveys (Pavlov 1991, Pavlov & Edwards 1992, Pavlov & Edwards 1995) indicated the presence of several bacterial infections of feral pigs that are classified as zoonoses (i.e. they can be transmitted

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from pigs to humans). Meliodosis, caused by the bacteria *Pseudomonas pseudomallei*, can be transmitted through direct infection from the contents of active cysts and via hand-eye or hand-mouth contact. Brucellosis, the infective agent being *Brucella suis*, can be transmitted via hand-eye contact, skin penetration or oral ingestion.

The disease Leptospirosis, caused by various serovars of *Leptospirosis interrogans* is a significant zoonoses in North Queensland. In 1999 there were 138 human cases above the average level in the wetter months of the year (Smythe 2000). The main contacts with animals recorded from the infected persons were contacts with rats, dogs, feral pigs and cattle in descending order. Of the 21 serovars recognised in Australia, 11 are recorded from feral pigs in North Queensland (Pavlov & Edwards 1995). The zoonoses are transmitted via direct skin and hand-eye contact, inhalation or oral ingestion. Human symptoms are usually not fatal and include fevers and muscular pains that last 8-10 days.

A recent development has been the slight modification of some Leptospira serovars after affecting different mammal species, leading to more clinically serious symptoms from serovars that previously had little effect on human hosts (L. Smythe, pers. comm.). In pigs, Leptospirosis is an important cause of infertility. Leptospirosis is also a significant disease in domestic dogs in the study area (M. Mansfield, pers. comm.).

Pig feeding activities are likely to bring them into contact with a wide range of intermediate hosts of parasites specific to pigs and some that occur in other animals. Some parasite infections affect only young pigs, some remain at constant infection rates throughout the life of the pig and others are accumulative, reaching high infection levels in older animals (Pavlov 1991).

None of the investigated parasites showed significant differences in the infection rate between males and females, except for lice *Hematopinus suis* and thorny headed worm *Macracanthorhynchus hindunaceus* which were found more frequently in females than in males. Thorny headed worm enters the pigs via the ingestion of infected beetles. The high demand for protein rich food by reproducing females during their summer reproductive peak (P.M. Heise-Pavlov & S.R. Heise-Pavlov, unpubl. data) may coincide with the high availability of beetles at that time of the year resulting in higher infection rates of females.

Of the internal parasites recorded, lungworm *Metastrongylus* sp. and kidneyworm *Stephanurus dentatus* are the ones most likely to cause mortality. Lungworm infection seems to affect more young pigs whereas kidneyworm seems to be a mortality factor of older pigs. Large numbers of earthworms (the intermediate host of lungworm) are ingested by growing pigs, and there is always a localised bacterial infection associated with the worms in the lung that would influence the lung efficiency of infected individuals. Humbert (1991) demonstrated the negative consequences of regularly utilised feeding sites for wild boar in the Chamrod area of France in the winter months. He was able to show that pigs younger than one year of age suffer high mortality due to the presence of earthworms infected with lungworm larvae. Meynhardt (1982) reported a high mortality of European wild boar piglets due to infection with lungworm. Also Briedermann (1984) described Bronchopneumonias due to lungworms in 90% of pigs caught in Germany causing a high mortality in piglets. Pigs in tropical areas are often subjected to high infection rates of lungworm, e.g. southern U.S.A (Springer 1977), New Guinea (Talbot 1972), Hawaii (Diong 1982) and Florida (Forrester, Porter & Belden 1982).

Kidneyworm, which is an important parasite throughout the tropics, produce infective larvae that are able to directly infect animals through the skin. This means that pigs are constantly challenged with infective larvae throughout their lives. Kidneyworm is of high pathogenic importance due to the lesions in the liver caused by migrating larvae which reduce the efficient functioning of the liver. Heavily infected pigs show slow growth rates and poor food conversion efficiency (Leman, Glock & Mengeling 1981, Belschner & Love 1984). On Cape York Peninsular, kidneyworm infection is very high (80%), and is recorded with 94% on the Prince of Wales Island (Pavlov 1991). In the rainforests of New Guinea, Talbot (1972) described the difficulty of controlling kidneyworm amongst village pigs that have access to wallows and muddy areas.

Pig numbers in the lowland rainforest of northeastern Queensland are significantly lower than in other parts of northern Australia (Pavlov 1991), and the high disease and parasite infection rates recorded would contribute to population regulation in this environment. There are no significant predators or dramatic fluctuations in food or water availability.

Feral pigs were established in the Daintree area in northeastern Queensland prior to European settlement. During the drier months of the year, they are commonly seen on the narrow coastal plains where they come into conflict with people. People living with minimal environmental impact are less likely to be affected by pigs than people doing intensive gardening or maintaining orchards. It is on these properties that high concentrations of earthworms build up and subsequently attract pigs. Spraying treated effluent water in the rain-

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forest adjacent to tourist resorts also provide conditions that attract pigs. Larger properties where bananas or tropical fruit are produced provide an extra attraction, as access to banana plants or fallen fruit is a major food source for the animals that forage outside the forest.

Fencing pigs out of any target area is very costly, and maintaining the fences in pig proof condition is quite labour intensive. The main method to control problem animals is by trapping, which is also labour intensive. On residential allotments, the area of concentrated earthworms dug up by pigs may not be large enough to require the pig to feed there more than once. This causes a problem because the pig may not return until the following year rendering trapping impossible. More research needs to be done on methods to attract pigs to traps or to repel them from certain areas.

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