Queensland Government
Natural Resources and Mines

Monitoring Systems for Feral Pigs

: Monitoring the Economic Damage to Agricultural Industries and the Population Dynamics of Feral Pigs in the Wet Tropics of Queensland

Final Report

To

Bureau of Resource Science

National Feral Animal Control Program

By

Jim Mitchell and William Dorney

Department of Natural Resources and Mines

Queensland

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Executive Summary

- This project quantified the economic damage (in terms of real on farm costs) caused by feral pigs to sugar cane and banana production on the tropical north coast of Queensland.
- 30 representative farms were monitored every 2 to 3 months for 28 months to record the pig population index, costs of direct damage to the crop and costs of pig management programs.
- A feral pig population monitoring system was used to determined the spatial and temporal patterns of feral pig population distribution.
- Feral pigs caused (on average) 0.08% direct damage to the banana industry, equivalent to $828 / farm / annum.
- Only a small proportion of banana farms reported feral pig damage, these farms lost $1824 / farm / annum to pig damage.
- Feral pigs caused (on average) 3.5% damage to the sugar cane industry estimated from landholder assessments, equivalent to $5352 / farm / annum.
- Feral pigs caused (on average) 5.6% damage to the sugar cane industry, estimated from harvest returns, equivalent to $8515 / farm / annum.
- Landholders underestimated the loss to feral pigs by 37%.
- No direct relationship between the amount of damage recorded and the pig population present could be determined. Damage is not determined by the pig population density but by the presence of mature male pigs.
- 1,122 pigs were captured by pig management techniques during the project at an average cost of $250 / pig capture.
- Landholder trapping was the most cost effective control technique at $141 / pig capture; contract trapping cost $209 / pig capture; dogging cost $257 / pig capture and shooting cost $1048 / pig capture.
- Total on farm pig damage and management costs were $4099 / banana farm / annum and $10632 / cane farm / annum.
- Feral pig damage equates to $300 for every 1,000 cartons of bananas produced.
- Feral pig damage equates to $813 for every 1,000 tonnes of cane harvested.

- **"An economic evaluation of the damage by or control of vertebrate pests is essential to an understanding of the pest's role in a production or conservation system" (Hone 1994).**

Abstract.

Agricultural industries in the wet tropics of north Queensland region identify feral pigs as a significant pest species due to the economic damage they cause. Thirty farms were selected as a sample of the two main agricultural industries, (sugar cane and banana production) in this region. Each farm was regularly surveyed over a 28 month period to assess feral pig population levels, to quantify the associated economic damage they cause in terms of actual on farm dollar costs and to quantify the costs associated with control techniques employed. A feral pig population monitoring technique was established to assess temporal trends in pig populations. Pig populations fluctuated in response to climate, crop maturity and control operations. Feral pigs were estimated to cause, on average, direct economic damage of $1824 / banana farm / annum and $5352 / cane farm /annum. This represents 0.08% of the value of banana production and 3.5% of the cane production value of the sampled farms. From sugar cane harvest data, feral pigs caused damage to 16,147 tonnes(valued at $377,517) or 5.65% of the sugar crop. No significant relationship between pig population levels and the economic damage they cause could be detected. The total on farm costs of feral pigs damage and costs of control averaged $4099 / annum for each banana farm and $10,633 / annum for each cane farm. Control techniques cost, on average, $4010 / farm / annum. In total 1,122 pigs were destroyed at an average control cost of $250 / pig. The most cost effective control technique employed was trapping. The cost effectiveness of other control techniques are also discussed.

1. Introduction

Feral pigs (*Sus scrofa*) inhabiting the wet tropics region of north Queensland are perceived to cause substantial and diverse economic damage to most of the agricultural industries within this region, and are regarded as a significant animal pest species. Pest animals can be defined as those animal species that cause economic, environmental or epidemiological harm. It is the harm or damage that feral pigs cause that justifies the

expenditure associated with their control. For effective pest control it is fundamental to determine the pest status of an animal (Hone 1994).

Feral pigs reduce the profitability of agricultural enterprises through reduced yields through consumptive losses, increased costs due to expenditure on pig control and cost of lost profit opportunities of control expenditure (Choquenot *et al* 1996). Feral pigs are an acknowledged economic pest of growing importance due to the severe crop damage they cause to some sugar cane, banana and tropical fruit and small crops farms. Feral pigs also pose a threat of a huge probabilistic cost as a vector for exotic livestock diseases such as Foot-and-Mouth Disease. Pigs are vectors for diseases of humans such as Leptospirosis and Brucellosis, and these pose a health threat and economic costs to communities in north Queensland. Feral pigs could also have a large negative impact on tourism in north Queensland as they are regarded as a significant threat to the conservation values of the Wet Tropics World Heritage Area (WTWHA).

Management of the pig problem must be developed by firstly defining the scope and extent of the problem (Choquenot et al. 1996). Problem definition must have a foundation of quantitative data. Feral pigs cause documented economic losses to individual sugar cane, bananas, tropical fruits and small crops farms in this region (Mitchell, 1993; McIlroy, 1993). However there is a distinct lack of this economic damage information being quantified in terms of real on farm costs and this has restricted the development and adoption of best practice management strategies. The BRS publication "Managing Vertebrate Pests : Feral Pigs" Choquenot *et al* (1996) highlighted three deficiencies in knowledge and practice which are relevant to this region i.e.

1. There is a lack of objective, quantitative data on the impact of feral pigs on agricultural industries.
2. There is a lack of reliable data on the "real" costs of controlling feral pigs in normal on-property control programs. Comparison of impacts/control costs between areas will allow prioritisation of where and when to initialise control effort. This will also allow the threshold density of feral pigs for acceptable levels of pig impact to be established, and the reduction of pig populations required to achieve a desired reduction in impacts.

3. There is a paucity of reliable data on accurate population monitoring techniques and assessing real costs and benefits of control for management/ decision support systems for feral pigs.

To develop effective management plans for this pest animal species, defining the problem is the first priority. The aims of this project were to quantify the above deficiencies in knowledge in the context of economic agricultural impact of feral pigs within the north tropical coastal region of Queensland. Specifically the project objectives were to :-

1. Establish a feral pig population assessment monitoring system.
2. Establish baseline damage assessment levels for sugar cane and banana industries.
3. Derive a relationship between pig population levels and damage assessment.
4. Use this information to develop a best practice management decision system.
5. Disseminate information from this project throughout the region.

2. Methodology

2.1. Study Site

The wet tropical coast of north Queensland, extending from Townsville to Cooktown, is characterised by a narrow strip of coastal lowlands of intensive agricultural production bordering on tropical rainforest which extend to the top of coastal ranges. Feral pig populations exist continuously throughout this region, both within cropping systems and within the Wet Tropics World Heritage Area (WTWHA) and privately owned tropical rainforests. The WTWHA is predominately State owned lands. Feral pigs are perceived to inhabit the rainforests and to move into the surrounding agricultural areas for food.

To provide an accurate cross section of pig population levels, agricultural production and habitat factors within this region, a number of geographically separated experimental units termed “areas” were selected. Each of the selected areas were based on one of the 35 management units established within a Community Based Feral Pig Trapping Program (CBFPTP). Each management unit consists of an area of responsibility of a community or conservation group, rural organisation, Defence Force site or one of seven Cane Pest and Productivity Boards in this region. The

CBFPTP is a regionally based large scale feral pig control program initiated by government agencies to assist landholders in controlling feral pigs.

Preliminary assessments were conducted in most CBFPTP management units in the pilot phase of the program (July to December 1999). Pig populations and economic impacts levels within these management units were subjectively rated by landholders as ranging from severe to none. Seven of these management units were subsequently selected based on their rankings of population and economic impact levels, highest too lowest, so that a range of experimental data could be obtained. The seven areas were spread over 200km between Cairns and Ingham, the main cane and banana producing areas of the wet tropics coastal belt.

To quantify economic parameters of feral pigs, a range of data variables need to be collected over a prolonged period. Collecting data from all landholders and agricultural industries within each area was beyond the scope of this project. Thus a number of participating individual farms within each area were selected as a representative sample of the two main agricultural enterprises within this region (sugar cane and banana production). Most landholders producing banana and/or sugar cane within each area were initially visited and asked to participate in this project. All landholders subsequently agreeing to participate were then surveyed on a regular basis to collect the required data. The survey technique consisted of a personal interview style where the project officer asked standardised questions and recorded the answers on pro-forma data sheets. Interviews were conducted as often as possible but were constrained by landholder availability, distances involved, seasonal farming activity, seasonal flooding and inaccessibility to farms as a consequence of road damage during wet weather. Each participating farm was surveyed a maximum of 10 times from January 2000 to June 2002. All participating farms were assigned a code to protect the privacy of the landholders.

2.2. Population monitoring.

No reliable method of estimating feral pig populations or densities has been documented within rainforest environments. A novel population index monitoring system (based on population monitoring research in other regions) was therefore established to quantify pig population level fluctuations between survey periods and

to enable comparison of population levels between the areas. The population index was derived from regularly monitoring a series of permanently established 10m x 2 m "activity plots" (Hone 1988b). The observer walked down the centre of each plot and recorded as a presence or absence any of the pig sign criteria occurring within the plot. The number of plots established on each farm was determined by the farm size and the available length of tracks and headlands.

The criteria of pig signs recorded within each plot is shown below.

1. Diggings – soil disturbance due to pigs digging in the soil.
2. Wallowing – diggings in mud used for wallowing activity.
3. Footprints – one or more pig footprints contained with each plot.
4. Faeces – any part of faecal material within the plot.
5. Pads – distinguishable active travel pads that may or may not contain footprints.
6. Sightings – Live pigs sighted within a plot.
7. Plant damage – damage to plants caused by pig foraging activity.
8. Rub trees – trees that pigs use to rub on.

For each farm for each survey period, an index score for each pig sign criteria was calculated based on the frequency of occurrence of each pig sign being present within the activity plots. All pig sign criteria frequencies were then averaged to derive a population index (average frequency of occurrence of all pig sign) for each cane and banana farm for each survey period. The population index for each farm was then plotted over time to derive temporal trends in population indices for cane and banana farms.

Population index plots were to be replicated in "control" areas where feral pig management was not conducted (rainforest areas), and monitored over time to standardise the population index taking into account normal seasonal population fluctuations. This aspect of the project was not undertaken due to the difficulty of finding sites in proximity to the experimental areas where the influence of pig management was not felt. Seasonal fluctuations in populations indices were therefore contrasted with seasonal digging indices data obtained in highland rainforest areas where no pig management has been conducted (Mitchell 2000).

2.3. Economic Damage Assessment

All participating farms within the seven selected areas were interviewed on a regular basis to provide an estimate of the level and scope (spatial and temporal) of the economic damage, in terms of real on farm losses ($), that feral pigs cause to the two major agricultural industries within this region (sugar cane and bananas). The damage data was the landholders estimation of the amount of damage caused by pig activity that had occurred since the last survey. Although the data was subjective in nature, all participating landholders were experienced farmers with many years in their respective industries. The project officer also spent 6 months in the pilot stage of the project verifying each landholder damage estimates and was satisfied of their commitment and experience prior to the initial data survey. The project officer would also verify losses by farm inspections during the course of recording the population index plots. Losses for banana farms were estimated in terms of the number of cases of bananas destroyed, mature trees destroyed, number of man hours and kilometres used in replanting trees, repairing irrigation lines, repairing tracks etc. Losses in cane farms were estimated tonnage of cane damaged or consumed, man hours and kilometres used in repairing irrigation systems, roads, drainage lines and in some cases replanting.

For cane farms, an actual estimate of cane losses was also obtained from harvesting records. Cane Pest and Productivity Boards would predict the tonnage of harvested cane for each farm; after harvest the actual amount of tonnage harvested was obtained from documented mill returns. A proportion of the difference between the estimated harvest tonnage and actual harvest tonnage was allocated to feral pigs damage based on the contract harvesters perception of the damage. The project extended over two sugar cane harvest seasons - September to December for 2000 and 2001. All damage estimates were recorded for each farm survey and standardised by converting all damage into dollar terms. The parameters used in converting damage estimates into dollars are shown in Table 1. The costs were supplied from James Cook university economics department, and represent known parameters derived from industrial awards, standardised vehicle costs and machinery depreciation. Unit prices of banana and cane production were derived from a 10 year average. The value of hunting was a subjective assessment.

Table 1. Costs($)associated with feral pig damage.

Parameters	Conversion Cost ($)
Labour (per hour)	11.52
Vehicle (per km)	0.81
Tractor (per km)	1.5
Trailer Trap Deprecation (per month)	33.3
Box Trap Deprecation (per month)	10.0
Silo Trap Deprecation (per month)	4.17
Sugar cane price (per tonne)	23.38
Banana price (per carton)	20.0
Replacement bananas plant	1.0

2.4. The Relationship of Economic damage and Population levels

Damage values($) were directly compared to the population index for all banana and cane farms at each survey periods. A regression relationship was calculated to derive the association of pig population index and the economic damage they caused for each agricultural industry. The total damage costs of very large farms and the large range of property sizes involved in the survey tended to bias the relationship. Recorded damage costs were therefore converting into a standardised damage costs ($) per unit of farm production. For banana farms, the standard unit of production was 1000 cartons and for cane farms, the standard unit of production was 1000 tonnes of harvested cane.

2.5. Costs and Benefits of Pig Control Techniques

Information was collected to establish the costs associated with the main pig control techniques used by the surveyed farms (trapping, dogging, poisoning, fencing and rifle hunting). For each survey period, each landholders estimated the actual man hours, kilometres travelled and associated effort and costs involved in pursuing these control techniques. All estimates were then converted to dollars for standardisation. The cost effectiveness of each control technique could then be calculated. The direct benefits of pig control, using pigs for human or dog consumption or as crab pot baits etc, were also collected during the surveys. The recreational benefits of hunting was not considered due to the difficulty of allocating a realistic dollar value.

3. RESULTS

A total of 30 farms agreed to participate in the project (11 banana and 19 sugar cane farms) within the seven selected experimental areas. Five of the areas contained banana farms and all seven areas contained sugar cane farms (Table 2). Each farm was surveyed up to ten times during the survey period (2^{nd} February 2000 to 14^{th} June 2002). Two farms joined during the project and were surveyed 8 times, one farm left the project after 7 surveys. In total 270 individual farm surveys were conducted during the total survey period (96 banana farm surveys and 174 sugar cane farm surveys).

Table 2. The number of participating banana and cane farms in each area.

Area	Banana Farms	Cane Farms
Basilisk	2	4
Eubenangee	2	3
Hawkins Creek	0	3
Malbon Thompson	1	4
Tully / Murray	0	2
Walter Hill	3	0
Woopen Creek	3	3
Totals	**11**	**19**

3.1. Feral Pig Population Index

A total of 729 population index activity plots were established within the 30 participating farms. Each activity plot was inspected at each farm survey. Table 3 illustrate the number of activity plots established on each participating farm. The averaged frequency of occurrence of each sign criteria for each farm during the total survey period is presented in Table 4. for all banana farms and Table 5 for all sugar cane farms.

Table 3. The number (n) of population index plots established within each farm.

Area	Farm Code	Crop	No Plots (n)
Basilisk	J1	cane	15
Basilisk	J2	cane	25
Basilisk	M1	banana	25
Basilisk	M2	cane	20
Basilisk	Mo1	cane	30
Basilisk	Mo2	banana	32
Eubenangee	E1c	cane	20
Eubenangee	E1b	banana	12
Eubenangee	E2	cane	25
Eubenangee	E3	cane	17
Eubenangee	E4	banana	25
Hawkins Creek	H1	cane	25
Hawkins Creek	H2	cane	25
Hawkins Creek	H3	cane	30
Malbon Thompson	G1c	cane	17
Malbon Thompson	G1b	banana	13
Malbon Thompson	G2	cane	20
Malbon Thompson	G3	cane	20
Malbon Thompson	G4	cane	20
Tully / Murray	T1	cane	37
Tully / Murray	T2	cane	30
Walter Hill	WH1	banana	20
Walter Hill	WH2	banana	25
Walter Hill	WH3	banana	30
Woopen Creek	W1	banana	18
Woopen Creek	W2	banana	25
Woopen Creek	W3c	cane	26
Woopen Creek	W3b	banana	14
Woopen Creek	W4	cane	20
Woopen Creek	W5	cane	25

Table 4. Average population indices for each sign criteria for all banana farms during the total survey period

Farm Code	Digging	Tracks	Wallows	Dung	Pad	Rub Tree	Sighting	Plant Damage	**Average Population Index**
E1b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E4	2.22	11.11	0.44	0.00	7.11	0.00	0.00	0.00	2.61
G1b	0.00	4.62	0.00	0.00	1.54	0.00	0.77	0.00	0.87
M1	29.48	39.81	0.80	0.00	9.20	0.00	1.60	0.80	10.21
Mo2	2.81	10.08	0.00	0.31	3.50	0.94	0.31	0.00	2.24
W1	2.22	7.22	0.00	0.56	6.67	2.22	0.00	0.56	2.43
W2	4.67	16.00	0.67	0.00	6.67	0.00	0.00	0.00	3.50
W3b	1.55	6.93	0.00	0.00	5.52	0.00	0.00	0.00	1.75
WH1	12.86	32.86	2.86	2.14	26.43	6.43	0.00	2.86	10.80
WH2	4.57	9.71	1.14	0.00	0.57	0.00	0.00	0.00	2.00
WH3	3.81	16.67	0.95	0.95	12.38	0.95	1.43	0.95	4.76

Table 5. Average population indices for each sign criteria for all cane farms during the total survey period.

Farm Code	Digging	Tracks	Wallows	Dung	Pad	Rub Tree	Sighting	Plant Damage	**Average Population Index**
E1c	2.00	7.61	0.50	0.00	2.06	0.00	0.00	0.50	1.58
E2	5.11	28.33	0.90	0.00	2.05	0.00	0.00	1.25	4.71
E3	0.00	1.31	0.65	0.00	0.65	0.00	0.00	0.00	0.33
G1c	6.71	14.27	0.59	0.00	1.76	0.00	0.00	0.59	2.99
G2	17.22	23.33	1.67	0.00	9.44	0.00	1.67	0.00	6.67
G3	3.89	11.67	0.56	0.00	7.22	0.00	0.00	0.00	2.92
G4	3.33	6.67	0.00	0.00	7.22	0.00	1.11	0.00	2.29
H1	19.11	23.11	1.78	0.00	6.67	0.44	0.44	0.00	6.44
H2	8.00	16.00	1.33	0.00	7.11	0.00	0.00	0.44	4.11
H3	10.00	20.48	1.43	0.00	3.81	0.48	0.48	0.95	4.70
J1	7.62	20.00	1.90	0.00	1.90	0.00	0.00	0.00	3.93
J2	4.80	7.20	0.00	0.00	0.40	0.00	0.00	0.00	1.55
M2	6.50	7.50	0.00	0.00	2.00	0.00	0.00	1.00	2.13
Mo1	0.69	3.71	0.33	0.00	0.36	0.00	0.33	1.00	0.80
T1	10.75	23.11	3.45	0.00	4.94	0.00	0.34	1.01	5.45
T2	12.45	25.42	5.42	0.00	9.63	0.42	1.67	3.98	7.37
W3c	2.51	12.31	0.00	0.00	3.45	0.33	0.00	0.00	2.32
W4	6.50	7.76	0.00	0.00	3.09	0.00	0.00	0.00	2.17
W5	8.40	11.20	0.00	0.00	4.40	1.60	0.00	2.00	3.45

The average population indices for each of the sign criteria were also calculated for each crop type (Table 6). The average population index of all sign criteria for all banana farms was 4.6%, (S.E. = 0.54, 95% C.I. = 1.07), and 4.32% (S.E. = 0.35, 95% C.I. = 0.68) for cane farms. No significant differences could be detected during this survey between the average pig population indices of banana and cane farms.

Table 6. Population indices for each sign criteria average for each crop type.

Crop	Sign Criteria								**Average**
	Diggings	Tracks	Wallows	Dung	Pads	Rub Trees	Sightings	Plant Damage	
Banana	5.8	13.51	0.53	0.32	6.71	0.87	0.37	0.47	**4.6**
Cane	6.93	13.85	0.98	0.00	4.01	0.17	0.67	0.32	**4.32**

The population index for each farm survey were plotted against time for all survey periods to illustrate temporal fluctuations in pig populations indices (Figure 1 for banana farms and Figure 2 for sugar cane farms). A plot of the average population index for all surveyed farms over the total survey period is shown in Figure 3.

Figure 1. The average population index of all sign categories for each banana farm for each farm survey. The moving average of population indices (10) over time is also indicated.

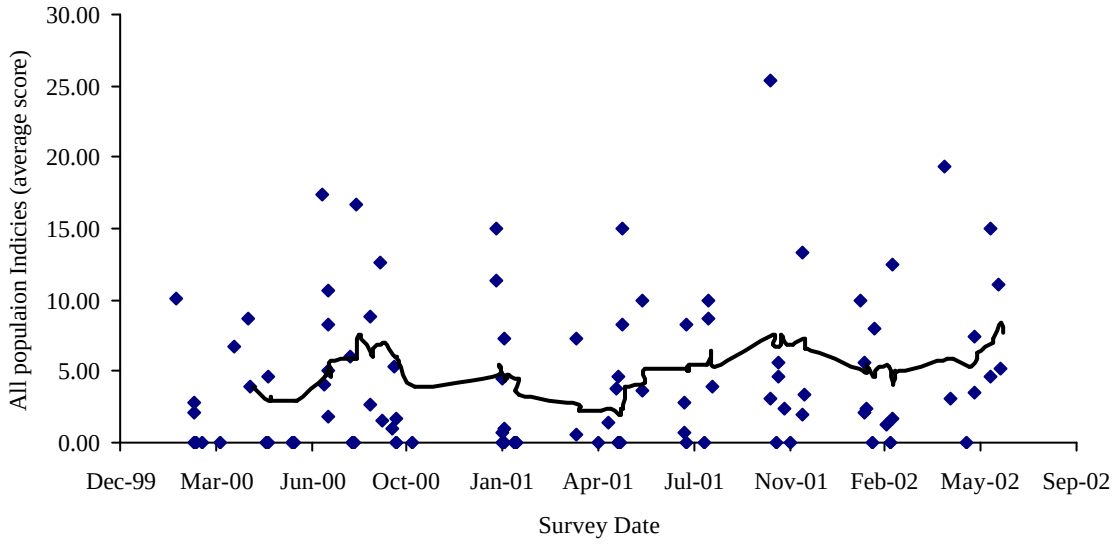


Figure 2. The average population index of all sign categories for each cane farm for each farm survey. The moving average of population indices (10) over time is also indicated.

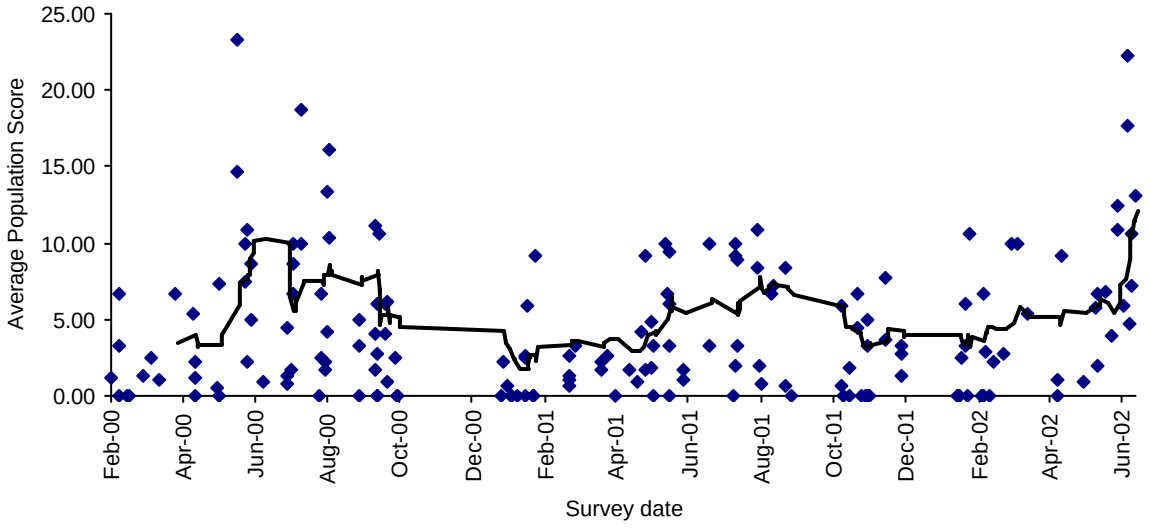
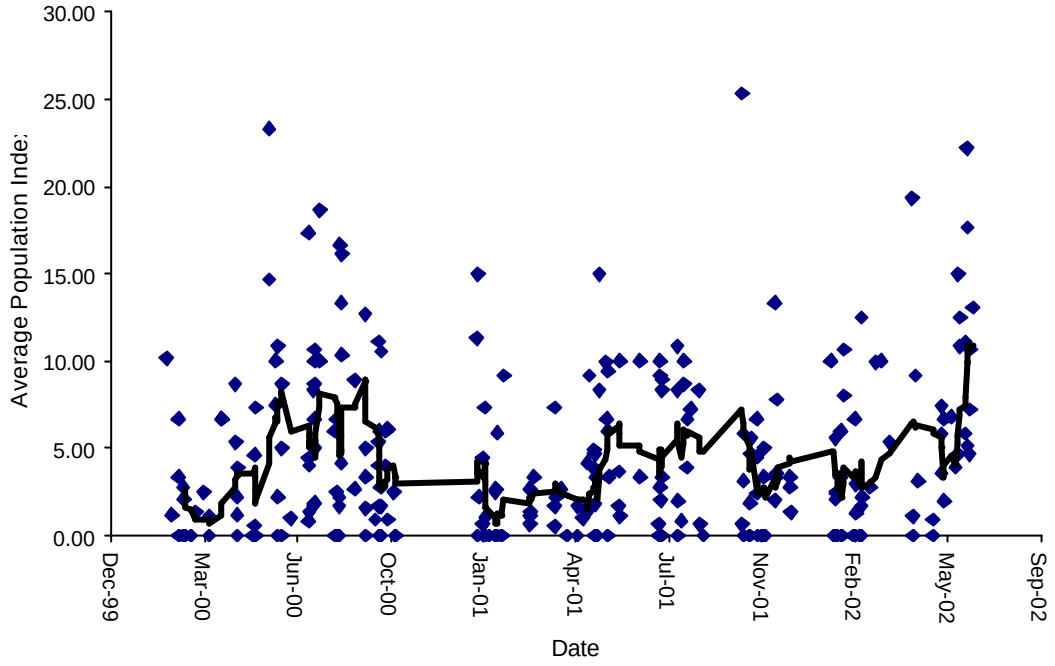


Figure 3. The average population index of all sign criteria for each survey for all farms. The moving average of population indices (10) over time is also shown.



3.2. Economic Damage Estimates

The economic damage caused by feral pigs were the estimated crop losses (converted to dollar values) on each farm that had occurred since the last farm survey was conducted (usually 2 to 3 months). Damage estimates for the two cropping systems are discussed separately below.

3.2.1. Banana Farms

Total production of the 11 banana farms was 540,000 cartons / annum, equivalent to $10.8 million / annum (based on an average value of $20 / carton). During the total survey period (28months), 1,409,350 cartons were produced, valued at $28.187 million. The total damage costs reported for all banana farms during the project was $21,198. This damage costs correlates to $1,927 per farm or $828 / farm / annum. The average damage cost at each farm survey was $221 s.e. $93. The total damage to all farms represents 0.08 % of the total production value. Only five farms recorded some pig damage during the project, damage was reported in only 15 out of the total 96 bananas farm surveys. The average damage costs for farms that did report damage was $4240 corresponding to $152 / farm / month ($1824 / farm / annum). The categorization of the damage costs for each banana farm is listed in Table 7.

Table 7. Total damage ($) caused to each banana farms during the survey period.

Farm Code	Total Carton Production (n).	Cartons lost (n)	Trees damaged (n)	Replanting Effort		Other damage ($)	Total Damage ($)	Production Lost (%)
				Labour (hrs)	Machine (hrs)			
1b	51260	0	0	0	0	0	0	0
E4	163100	0	0	0	0	0	0	0
G1b	230000	0	0	0	0	0	0	0
M1	139800	0	9	12	12	724	856	0
Mo2	51260	114	20	0	0	0	2280	0.22
W1	69900	0	0	0	0	0	0	0
W2	151450	0	0	0	0	0	0	0
W3b	37280	16	0	0	0	0	320	0.04
WH1	139800	90	30	8	4	0	1898	0.06
WH2	163100	0	0	0	0	0	0	0
WH3	419400	791	68	0	0	24	15844	0.19
Total	1,409,350	1011	127	20	16	na	na	0.08
Costs ($)	28,187,000	20,220	na	230	24	748	21,198	na

The temporal distribution of damage costs over the survey period is illustrated in Figure 4. A non-significant linear trend of increasing pig damage over time was evident due to the large damage cost of an individual farm in 2002. This tended to bias the trend so a plot of the temporal trend in damage per unit of production estimates was conducted and is illustrated in Figure 5. No significant temporal trend in damage estimates was detected.

Figure 4. Total damage ($)for each banana farm for each farm survey

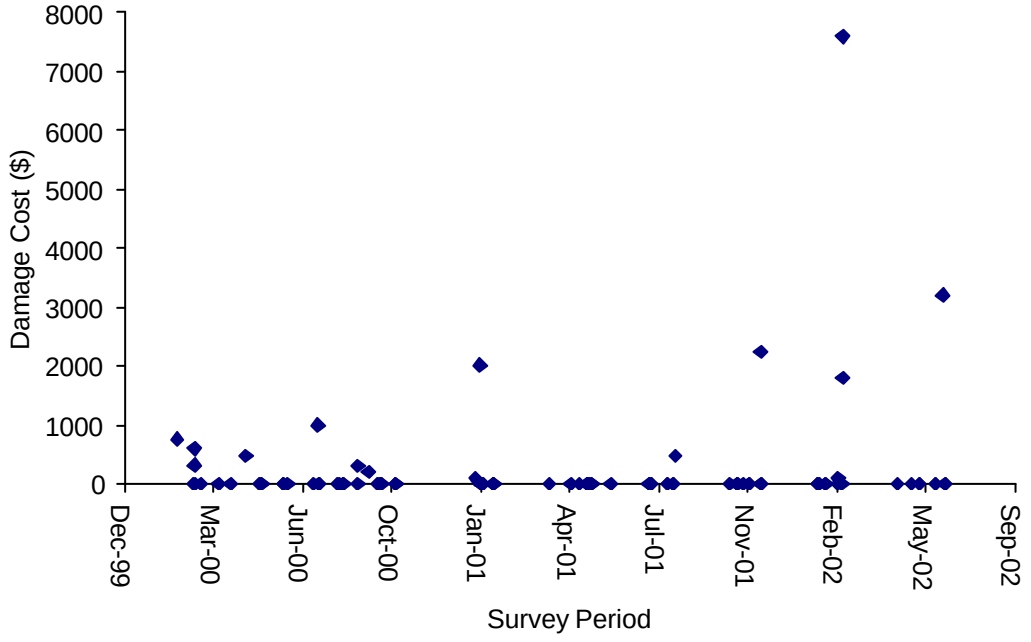
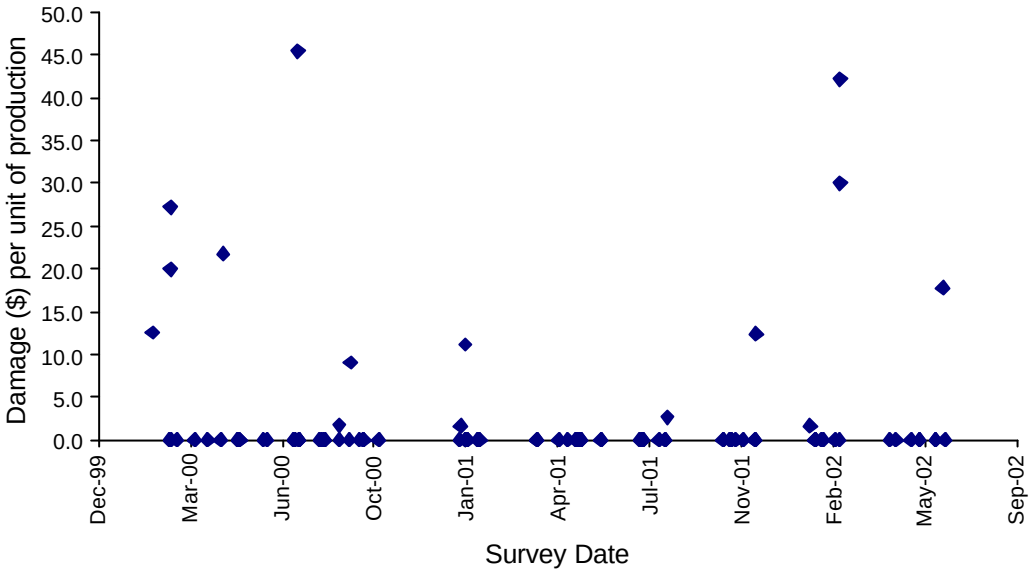


Figure 5. Damage ($) of feral pigs (per 1000 cartons of production) for each banana farm for each survey.



3.2.2 Sugar Cane Farms

The combined 2000 and 2001 harvest estimates for the 19 sugar cane farms was 289,362 tonnes or the equivalent value of $6.77million (based on the standard value of $23 / tonne). The average farm production was 45,918 tonnes / annum. In total, 8,715.5 tonnes or 39.2 ha of cane was damaged by pigs during the project. The total costs of this damage was $237,268 equivalent to an average damage cost of $446 / farm / month or $5352 / farm / annum. The total damage costs for all farms represents 3.5% of the total production value. All farms recorded some degree of feral pig damage during the project.

In contrast with the damage estimates from the farm surveys obtained during the cane growing season, damage estimates were also obtained from the actual harvest data. The contract harvester provided records of the actual cane tonnage harvested and an estimate of the tonnage destroyed by feral pigs. The estimated and harvested damage tonnage is presented in Table 8. A comparison of the survey estimates and the actual harvest estimates for each area are shown in Table 9. The harvest shortfall (difference of estimated crop harvest and actual harvest tonnage) was 72,460 tonnes. The tonnage attributed to pig damage was 16,147 tonnes which cost $377,517. Actual harvest damage estimates were approximately twice as much as the damage estimated by landholders during the farm surveys.

Table 8. Damage (tonnes) estimated from farm surveys during the growing season for all sugar cane farms.

Farm Code	Estimated Harvest (tonnes)	Actual Harvest (tonnes)	Estimated Total Shortfall (tonnes)	Harvested Total Shortfall (tonnes	Loss (% of Estimated Harvest)	Loss (% of Cane Harvested
E1c	5070	3932	70	110	1.4	2.2
E2	18000	14000	735	1600	4.1	8.9
E3	20000	20400	9	20	0.0	0.1
G1c	2400	1850	145	150	6.0	6.3
G2	12850	7100	121	225	0.9	1.8
G3	3600	2600	17	45	0.5	1.3
G4	12000	9600	20	20	0.2	0.2
H1	3200	2150	627	775	19.6	24.2
H2	33100	22400	23	200	0.1	0.6
H3	4000	1300	53	1000	1.3	25.0
J1	3150	2800	91	100	2.9	3.2
J2	2450	1496	136	20	5.6	0.8
M2	5700	3912	9	34	0.2	0.6
Mo1	3772	983	47	777	1.2	20.6
T1	74000	60000	2211	6000	3.0	8.1
T2	78499	57565	4100	5017	5.2	6.4
W3c	5500	3600	4	4	0.1	0.1
W4	1200	1130	201	50	16.8	4.2
W5	871	684	96	126	11.0	14.5
Total (t)	**289,362**	**216,818**	**8, 715**	**16,147**	**3.5**	**5.6**
Costs ($)	**6,777,000**	**4,986,814**	**237,268**	**377,517**		

Table 9. Summary of production totals and pig damage from farm surveys and harvest estimates for all sugar cane farms within each survey areas.

Area	Estimated harvest (tonnes)	Estimate damage (tonnes)	Estimated damage (%)	Actual Harvested (tonnes)	Actual damage (tonnes)	Actual damage (%)
Basilisk	15072	283	1.9	9191	931	6.2
Eubenangee	43070	814	1.9	38332	1730	4.0
Hawkins Creek	40300	703	1.8	25850	1975	4.9
Malbon	30850	303	1.0	21150	440	1.4
Tully	152499	6311	4.1	117565	11017	7.2
Walter Hill	7571	301	4.0	5414	180	2.4
Totals	**289,362**	**8,715**	**3.5**	**217,502**	**16,273**	**5.6**

Temporal trends in damage over the survey period is shown in Figure 6. No significant trend in damage over time was detected. Due to the bias associated with large variations in farm size and associated large variations in damage costs, all damage estimates were converted into damage cost per unit of production (1000 tonnes of cane). The temporal trend in damage/ unit of production over the survey periods is illustrated in Figure 7. A negative trend in damage over time was apparent although this trend was not statistically significant.

Figure 6. Temporal trends in damage estimates for all sugar cane farms for each survey.

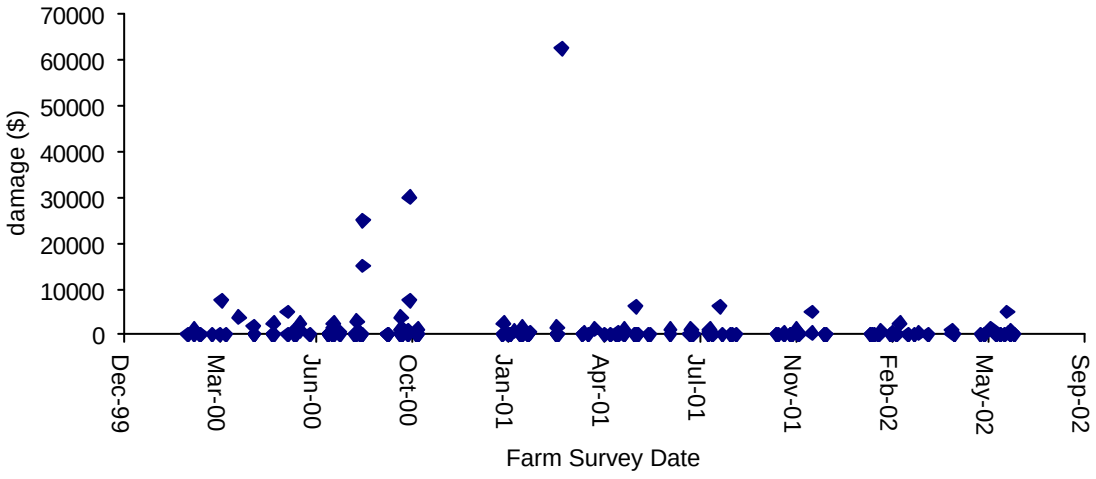
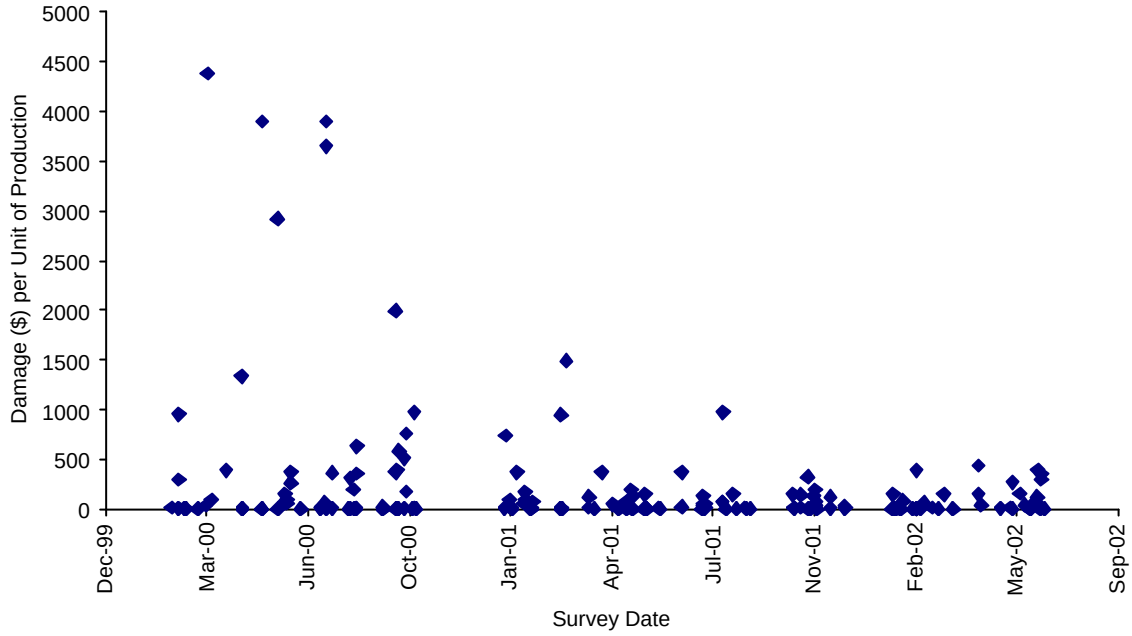


Figure 7. Temporal trends in unit of production damage estimates ($ damage per 1000 tonnes of cane produced) for all sugar cane farms for each survey.



3. 3. Association of pig damage with pig population index

For each cropping system the damage costs ($ per unit of production) were compared with the average population index (derived from all sign criteria) recorded at each farm survey. A plot of the relationship for each cropping system is shown in Figure 8 for bananas and Figure 9 for cane farms.

For banana farms, no significant relationship was detected for best fit regression analysis. A large proportion of banana farms reported no damage occurred during each farm survey although a positive pig population index showed feral pigs were present. Also on a number of occasions damage was reported although the pig population index recorded no pig signs were present. No significant best fit regression relationship could be detected in cane farms. Again a positive pig population index was recorded on farms where no damage was reported and conversely damage occurred on a number of occasions where a zero pig population index was recorded.

Figure 8. Best fit relationship (and 95% C.I.) of the average population index (for each farm survey) with damage ($) per 1000 cartons of production for all banana farms.

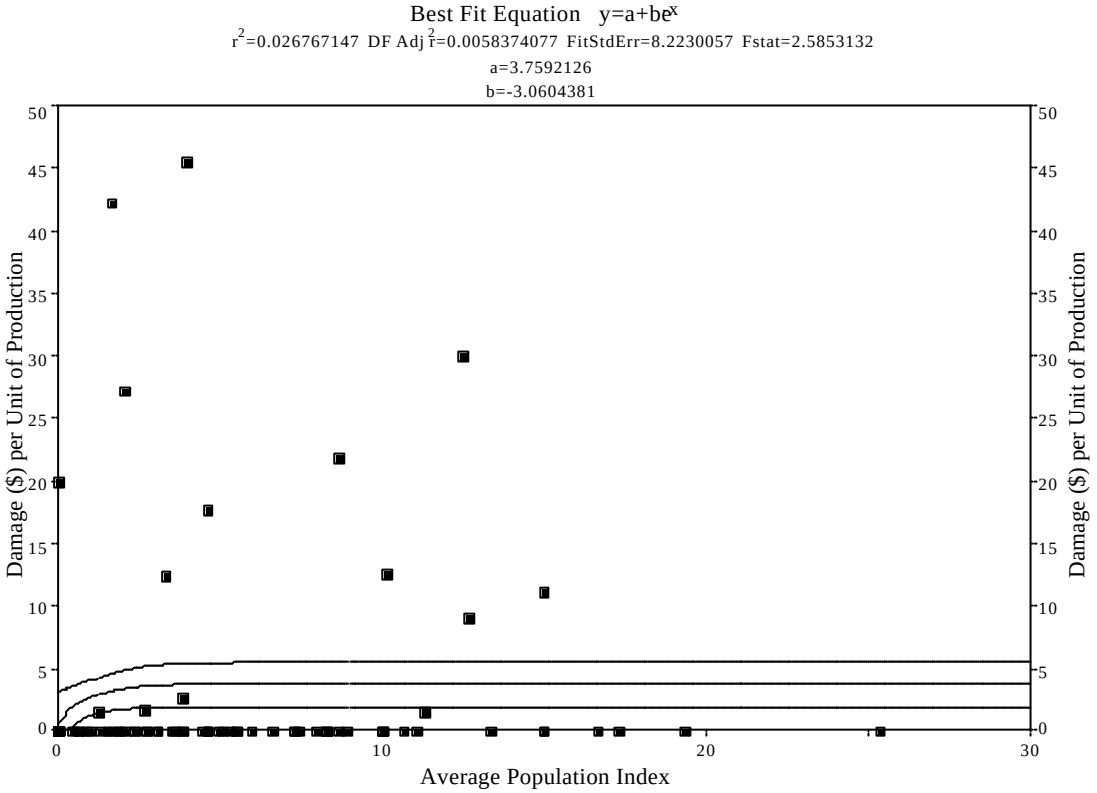
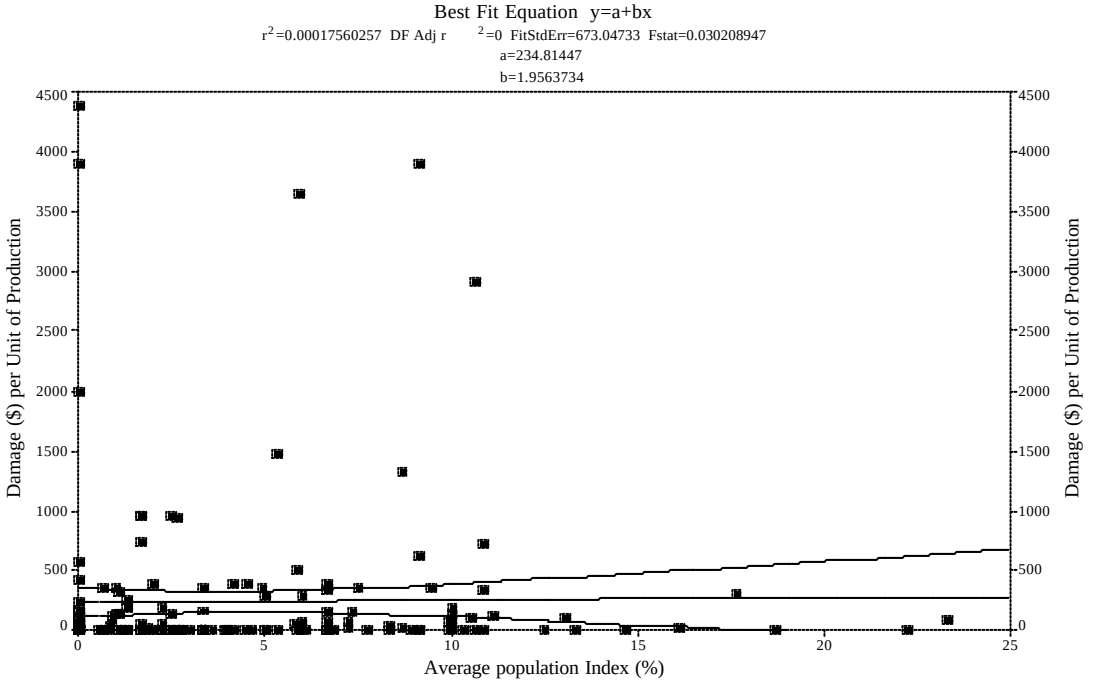
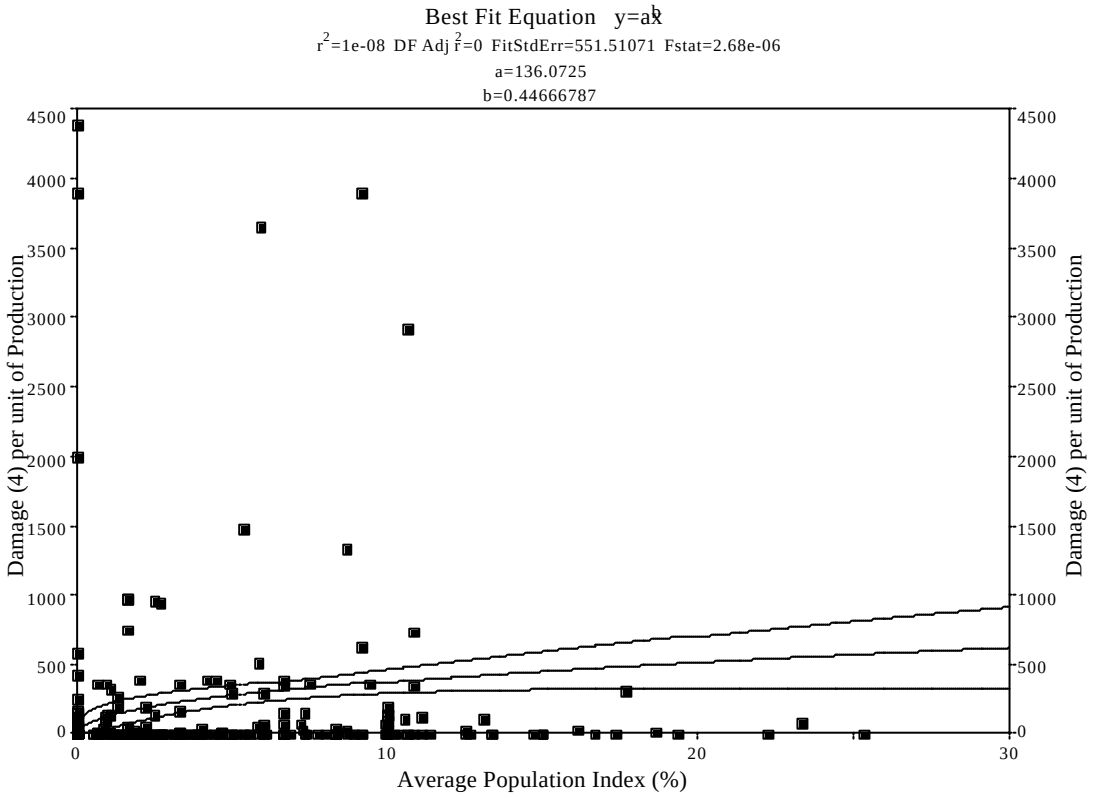


Figure 9. Best fit relationship (and 95% C.I.) of average population index with damage ($) per 1000 tonnes of production for all sugar cane farms.



The overall relationship for all farms in the survey is shown in Figure 10. The best fit regression analysis of the relationship was not significant.

Figure 10. Best fit regression analysis (and 95% C.I.) of damage per unit of production and the average population index for all cane and banana farms for the total survey period.



4.0 Management Costs and Benefits

During the project, 1,122 pigs were captured or destroyed by 98 pig control operators (acting as individuals or as teams) On average, each operator captured approximately 11 pigs during the project. Dogging as a control technique captured 555 pigs, trapping 533, and shooting 34 pigs. The total costs associated with all feral pig control techniques employed during the project totalled $280,667; $74,258 for banana farms and $206,409 for cane farms. The cost associated with the control of each captured pig average $250. The 98 control operators for the 30 farms spent, on average, $3204 dollars each over the 28 month survey period. A summary of the effectiveness and cost associated with the various control techniques are presented in Table 10.

Table 10. Summary table of feral pig control costs for each cropping system and for all farms.

Note – * includes operators that worked on both cane and banana farms.

** Trapping done by Community Based Feral Pig Trapping Program operators

Crop	Control Method	Number operators (n)	Total Hours ($)	Total Travel ($)	Additional Costs ($)	Number Pigs Caught (n)	Total Trap Nights (n)	Trap nights/ pig capture (n)	Total Cost ($)	Total Costs/pig ($)	Total Pigs/ Operator (n)	Total costs / per operator ($)
Banana	Trap-CBFPTP**	3	628	6417	0	124	1250	10	12435	100	41.3	4145
	Trap-private	5	936	2140	600	73	4627	63	13120	180	14.6	2624
	Dogging	13	2339	9166	2148	146			36530	250	11.2	2810
	Poisoning	1	9	17	0	0			117			117
	Shooting	5	887	2264	0	7			12056	1722	1.4	2411
Total banana		**27**	**4799**	**20004**	**2748**	**350**			**74258**	**212**	**13**	**2750**
Cane	Trap-CBFPTP**	10	3305	22459	880	209	8268	40	57153	273	20.9	5715
	Trap-private	4	660	9144	56	127	5070	40	15069	119	31.8	3767
	Dogging	54	6122	40223	2876	409			106011	259	7.6	1963
	Fencing	1	0	0	4350				4350			4350
	Poisoning	2	13	37	70	0			250			125
	Shooting	15	1493	7838	27	27			23576	873	1.8	1572
Total Cane		**86**	**11593**	**79701**	**8259**	**772**			**206409**	**267**	**9**	**2106**
Combined	Trap-CBFPTP**	11	3933	28876	880	333	9518	29	69588	209	30.3	6326
	Trap-private	8	1596	11284	656	200	9697	48	28189	141	25.0	3524
	Dogging	62	8462	49389	5024	555			142541	257	9.0	2299
	Fencing	1	0	0	4350				4350			4350
	Poisoning	2	22	54	70				367			184
	Shooting	14	2380	10102	27	34			35631	1048	2.4	2545
Totals		**98***	**16392**	**99705**	**11007**	**1122**			**280667**	**250**	**11**	**2864**

The cost / benefits of all pig control techniques were calculated for each farm. Table 11 lists the total direct management costs and the management costs per unit of production for each banana farm. Similarly Table 12 lists the total management costs for all cane farms. The total management cost of pigs to each farm is calculated as the direct damage cost, the addition of costs associated with implementing control techniques and subtracting the value of any indirect benefit derived from pig control.

The overall costs that feral pigs cause to banana farms totaled $105, 194. This is equivalent to $4099 / farm / annum. The overall costs of pig damage also equate to an average, for each banana farm, of $300 per 1000 cartons of production. The overall costs that feral pigs caused to sugar cane farms totaled $471,392. This is equivalent to $10,632 / farm / annum or $813 per 1000 tonnes of production.

Table 11. The total actual management costs ($) and costs per unit of production ($ / 1000 cartons) associated with direct feral pig damage, costs of control and the benefits of pig control for each banana farm.

Farm Code	Direct Damage ($)	Direct Damage ($/1000C)	Damage plus Control ($)	Damage plus Control ($/1000C)	Damage plus Control Minus Benefits ($)	Damage plus Control Minus Benefits ($/1000C)
M1	856	14	11668	194	10068	167
Mo2	2280	103	2521	114	2521	114
E1b	0	0	13031	592	12981	590
E4	0	0	4438	63	4353	62
G1b	0	0	11956	1195	11936	1193
WH1	1898	31	13440	224	13440	224
WH2	0	0	87	1	87	1
WH3	15844	88	38496	213	38136	211
W1	0	0	12	0	12	0
W2	0	0	0	0	0	0
W3b	320	20	11816	738	11656	728
Total	**21198**		**107469**		**105194**	
Average		**23**		**303**		**299**

Table 12. The total actual management costs ($) and costs per unit of production ($ / 1000 tonnes) associated with direct feral pig damage, costs of control and the benefits of pig control for each cane farm.

Farm Code	Direct Damage ($)	Direct Damage ($/1000t)	Damage plus Control ($)	Damage plus Control ($/1000t)	Damage plus control Minus Benefits ($)	Damage plus Control Minus Benefits ($/1000t)
E1c	1659	308	14691	1468	14641	1466
E2	19288	290	36031	1460	35891	1460
E3	233	12	1477	285	1477	285
G1c	4325	101	16250	929	16230	925
G2	2875	65	10352	579	10312	577
G3	514	214	9258	400	9243	398
G4	490	2	5663	16	5578	16
H1	15360	960	37165	2322	36585	2286
H2	619	4	20104	135	20014	134
H3	1963	140	16798	1199	16793	1199
J1	6803	360	32389	1354	32334	1352
J2	3553	49	17890	179	17890	178
M2	350	31	8135	571	8135	570
Mo1	1917	9	17527	104	17457	103
T1	51693	174	80708	272	80421	271
T2	102872	327	120062	382	119782	381
W3c	140	5	11637.	423	11477	417
W4	4722	787	8263.	1377	8263	1377
W5	2761	634	8949	2055	8869	2036
Total	**222,137**		**473,349**		**471,392**	
Average		**235**		**816**		**812**

5. DISCUSSION

The determination of the pest status of the feral pig in the wet tropical region of northern Queensland is fundamental for developing effective management options on a regional scale. Economic impact of a pest is an important component of the pest status assessment process. This report quantified, in discrete sampled areas, feral pig population trends, direct and indirect economic burdens to sugar cane and banana producers and established the costs and effectiveness of the various control techniques used by producers to reduce feral pig impacts.

The discussion of the economic pest status of feral pigs in this region will focus on the varied segments of the project by addressing each of the project objectives.

5.1 *Establish a feral pig population monitoring system.*

There is no standardised technique to identify feral pig population trends or relative abundances in this region. Standard techniques used in other regions to estimate pig abundance are restricted in their application due to environmental factors unique to the wet tropics region. For example aerial survey techniques are ineffective in this environment due to the dense ground cover of the rainforests and dung counts and digging indices are often adversely effected by high rainfall. Ground survey techniques are restricted by the lack of access to large areas of the region and by the difficult terrain.

A modified ground survey technique was developed in this project to monitor pig population trends, as no other suitable survey technique was available. Population monitoring was accomplished by establishing a population abundance index, calculated as the frequency of occurrence of pig signs on permanently established monitoring plots. This technique has been used in other habitats and established as a reliable method of monitoring feral pig population trends (Hone 1995). As individual pig signs can vary by the influence of prevailing seasons, habitat preferences, food availability and movements (Choquenot, et al. 1996), a broad range of pig sign criteria were observed to reduce the influence of these factors on individual sign criteria. As the plots were permanently established, this population index technique is accurate in monitoring changes in pig populations. It does not allow calculation of actual pig population densities. This technique was used to monitor temporal changes in pig

populations and to enable relative pig population level comparisons between the sampled areas and between the sampled farms.

Overall trends in the population index were observed during this project. The indices for all of the sign criteria were averaged for each farm survey visit and used to highlight population trends over the total survey time of 28 months. The pig population index tended to fluctuate with prevailing seasons as shown in both the individual cane and banana cropping farms and in the overall combined cropping systems. For both cane and banana farms population indices tended to be highest during the dry season and lowest during the wet season. The overall average frequency of occurrence of pig sign was 4.5% . This level of occurrence of sign was very low compared to previous studies in this region. Mitchell (1993) found for his dry season study a frequency of occurrence of 67% while Mitchell and Mayer (1997) reported a frequency of occurrence of 23% and Laurance and Harrington (1997) reported 22% frequency of occurrence on quadrats. Hone (1995) found in his temperate study a frequency of occurrence of pig sign of 13%.

The low frequency of pig sign is difficult to explain, although differences in methodology between these studies may have an influence. This project measured pig sign essentially on crop headlands which are narrow corridors and have a high disturbance due to machinery and human movements. Headlands would also be seen as a transitional area only, a crossing place between the crop and the rainforest cover. Thus the pig sign would not be expected to be as frequent as would be observed in preferred pig habitats such as creek beds.

Another potential limitation of the monitoring technique used in this project was the time period between the farm surveys. With an average period of 2.8 months between farm surveys, the pig sign observed on the monitoring plots would be subject to a range of environmental conditions that would reduce the persistence of the sign. For example heavy rain would wash all sign away – if rain occurred shortly prior to the farm survey then the population index may be reduced. Similarly varying levels of control effort caused by varying crop conditions (growing season compared to harvesting season for example) occurred during the project. This may also influence the matching of the population index with damage estimates.

Averaging the frequency of occurrence of a range of pig sign criteria was thought to minimise the loss of sign due to weather conditions. Reduction in the time between recording periods would obviously increase the accuracy of the monitoring, in this study logistic considerations prevented monitoring at a higher rate.

The limitations of the monitoring technique are particularly relevant when developing a relationship between the population index and the damage estimate. Inaccuracies in estimating the feral pig population causing the observed damage estimates is believed to be responsible for the lack of any significant trend in the population index / damage relationship.

5.2 Quantify Economic Damage

The extent of damage by pests has been described by Cherrett, et al. (1971) as a function of four variables: (i) the destructive potential per pest which may vary with pest age, size, genotype and environment, (ii) the duration of exposure, (iii) the resistance of the host or object being attacked and (iv) the number of pests. Thus the relationship between damage and pest abundance is not always clear. In this project the variables that influenced the amount of economic damage (listed below) need to be considered when developing a relationship between the pest population and the amount of damage being caused.

1. The destructive potential per individual is variable in feral pigs. Many of the surveyed farms reported that mature boars (adult male pigs) were the major cause of damage and were actively targeted through the use of bounties or other incentives. Immature pigs and small females were regarded as being incapable of knocking down mature banana trees to reach the fruit. Tree damage was reported as the major economic loss caused by pigs on banana farms. Similarly on cane farms mature boars were regarded as the main destructive segment of the pig population.
2. The duration of exposure to damage was relatively constant throughout the year for banana farms although most fruit production is in the summer. However the economic costs associated with this damage was variable due to changing value of production due to market pressure. The value of the damage to bananas varied by seasons. For sugar cane, a marked increase in damage occurred prior to harvest. While some damage can be caused

throughout the growing season, the majority of damage is caused when the cane is enriched with sugar prior to harvest. Thus for both crops the duration of damage is variable.

3. The resistance of the host being attacked variable was evident in banana farms where different varieties of banana grow to different heights. Some tall varieties do not attract pigs as the fruit is out of reach and the trunks are too strong for pigs to knock over. Conversely in some varieties or older crops, the banana trees are smaller and tend to fall over, thus pigs are able to easily knock them over to reach the fruit or damage fruit on fallen trees before the trees can be up-righted. Varieties of sugar cane also have variable levels of sugar and have variable amounts of leaf material influencing the resistance of the crop to damage. Irrigated farms verses dry farmed farms can also influence the level of pig activity due to irrigated soils containing more earthworm populations or green forage then in dry farms.
4. The number of pigs that are in proximity to the crops also influence the amount of damage. Pig movements are seasonal (Mitchell 2000) and are influenced by the availability of food resources. Thus pig populations in proximity to crops can be variable due to weather patterns and crop maturity.

The damage caused by feral pigs can vary in space and time (Hone 1994). Spatial patterns of damage can be regarded as fitting a frequency distribution and can vary from negative exponential to normal to positively skewed. Negative exponential frequency distributions have been previously reported for damage by feral pigs in south eastern Australia (Hone 1988) and in this wet tropics region (Mitchell and Mayer 1997). Temporal patterns of feral pig damage (soil disturbance) have also been established in this region (Mitchell 2000).

In this study spatial damage patterns were assessed by comparing damage estimates between the sampling areas and between the two cropping systems. Temporal damage patterns were assessed by comparing damage estimates between each farm survey and plotting damage estimates over time. The recorded economic damage caused by feral pigs was extremely variable between the areas, between the two cropping systems and also between individual farms.

Banana farms

For the banana farms, on average only a 0.08% loss of the total production of cartons of bananas was directly caused by feral pigs. Each farm reported, on average, a real on farm direct loss of $828 / annum. However as only 5 of the 9 banana farms reported any pig damage during the project, a loss of $1824 / annum was calculated for these farms. A feature of the results for the banana farms is the range of damage between the individual farms. Damage ranged from zero for 4 farms to one farm (WH3) reporting a total of 791 cartons lost ($15,800). However, when put in perspective of the size of this farm production ($8.39 million for the study period), this damage estimate represents only 0.19% of the total production for this farm. The maximum proportional crop loss reported was for farm Mo2 which experienced a net production loss of 0.22%. Only one farm incurred costs due to replanting damaged banana trees and only two farms reported other damage costs not related to damaged trees.

There was no overall trend in damage over the survey period but seasonal fluctuations were evident with the majority of economic damage occurring during the dry season. Pigs would be attracted to the irrigated soil in banana plantations especially when the surrounding areas would have hard dry compacted soils during this season. Abundance of green grass on the headlands and the presence of earthworms and other soil invertebrates in the moist soil would also be attractive to pigs.

In summary feral pigs are not a major economic problem to the banana industry as a whole. It is only a minority of banana farmers on a few occasions that receive economic injury levels that cause concern to the farmers. Many banana farmers stated during the survey that they actually benefit from pigs inhabiting their farms as they clean up the waste fruit which will reduce pest infestations such as fruit fly.

Cane farms

All cane farms reported some damage at some time during the project. The estimated direct damage caused by feral pigs to all cane farms was 8,715 tonnes during the total survey period. This represents 3.6% of the estimated harvested (289,362 tonnes). The average on farm direct costs caused by feral pigs to sugar cane farms was $5,352 per annum. Damage to the overall sugar industry (as represented by the sampled

survey farms) is relatively minor. However there was a large variation between individual farms with three farms reporting damage estimates of more than 10% compared with 12 farms of less then 5% damaged.

No significant temporal trends in estimated damage were evident. Landholder estimates of pig damage to cane farms was constant throughout the survey, and throughout the cane growing season. Harvest records from annual crushing returns estimated that the proportion of the harvest shortfall – the difference between estimated yield and actual harvest yield (72,460 tonnes) attributed to feral pigs was 16,147 tonnes compared to 8,715 from landholder estimates. The difficulty of accurately estimating damage in mature cane which can grow to 3 m tall and is difficult to walk through is obvious. This may explain the 50% underestimate from landholder surveys compared to actual harvest estimates. From mill returns the average damage caused by feral pigs to each sugar cane farm was $8,515 or 5.6% of the total harvest.

Rodent and bird damage is significantly more of an economic problem to the sugar industry overall (BSES annual reports). However feral pig damage appears to be more sporadic with some individual farmers enduring up to 20% damage rates while the majority of other farms receive less then 5%. In summary feral pigs are more of an economic problem to cane farmers then banana farmers. Cane farmers receiving three times the economic loss due to feral pigs compared to banana farmers.

5.3 Relationships of Pig Abundance and Damage

Knowledge of the relationship between changes in population levels and the corresponding changes in impact levels can help determine the cost-effectiveness of management. The shape of the relationship is important when considering how to evaluate agricultural impact on a per animal? basis (linear, curvilinear, negative or positive Y intercept, etc).

"Any estimate of the economic damage of feral pigs must be able to estimate yield in the absence of pigs either directly or indirectly through extrapolation of some density-dependent relationship and contrasted with a range of pig densities" (Choquenot, et al. 1996). The generalised curvilinear relationship of pig densities and damage reflects

the density related consumptive impacts of most pest species. Choquenot, et al. (1996) stated that a subjective assessment of the likely shape of the relationship between reduction in yield and pig density for sugar cane and fruit crops would be linear at low pig densities and curvilinear at high pig densities.

A feature of this relationship analysis for both cropping systems is the large variations in damage between individual farms. While many farms reported minimal damage costs at each farm survey, a small number of farms would report substantial damage. Damage was not constant across all farms; individual farmers suffered severe sporadic damage while the remainder suffered only minimal damage for the majority of the survey period. This is very similar to Hone (1995) analysis of feral pig damage being described as a negative exponential frequency distribution; many sites of minimal damage and few sites of major damage.

A confounding feature of this study is the problem of individual animals (usually large males). Many of the survey farms regard lone males as the major cause of the crop damage. These animals target crops as their main food source and cause severe economic damage while they comprise only a very small portion of the pig population. Other sections of the pig population such as adolescents or small females are regarded as causing little to no damage at all. This confounds the population / damage relationship when a low population monitoring index caused by problematic individual is compared with the high damage estimates they cause. The reverse is also true where a high population score caused by a large section of the pig population is compared with the small amount of damage they cause. Thus the calculated population / damage relationship is heavily manipulate by the various segments of the pig population.

5.4 Control Costs

Over the total project period, 1,122 feral pigs were captured by various control techniques employed during the 28 month survey. Each individual control operator captured an average of 11.5 pigs, which cost an estimated $2,864; an average of $250 for each pig capture.

The most cost efficient control technique employed was trapping. Private trapping captured 200 pigs at an overall cost of $141 / pig while the trapping conducted with the CBFPTP captured more pigs (333) but at a higher cost of $209 / pig. Dogging captured the most pigs (555) but was less cost efficient at $259 / pig capture. Hunting was the least cost efficient technique employed at $1048 / pig capture.

Banana farms captured 350 pigs which cost on average $212 per pig captured. Trapping was again the most cost effective control technique employed where each pig cost $100 / pig capture in the CBFPTP system and $180 / pig capture for landholder trapping. Dogging was less cost effective ($250 / pig capture) while hunting was the least cost effective ($1722 / pig capture).

Sugar cane farms captured 772 pigs which cost on average $267 / pig captured, 21% higher costs then for the banana farms. The reason for this higher control costs in cane farms is unquantified, however, the increased difficulty in capturing pigs in dense cane blocks would increase costs and efforts. Trapping was again the most cost effective control technique employed but contrary to the banana farms the landholder trapping system was more cost effective ($119 / pig capture) compared to $273 / pig capture for the CBFPTP.

Dogging ($259 / pig capture) and hunting ($873 / pig capture) was again the least cost effective. Dogging on cane farms however, was very effective in terms of the total number of pigs removed. Dogging has been the primary technique for controlling feral pigs since settlement of this region and is also a traditional recreational pursuit. One feature of this technique was the large variation in the catch / effort rate. This reflects the varying levels of operators skills and dedication and the varying pig population levels between the farms. Also some operators tended to target individual pigs and not the general pig population. This results in a low catch per unit effort rate but a significant damage reduction within the crop. Problematic individual pigs are targeted as they tend to cause the most damage in both cane and banana farms and are often targeted when bounties paid by landholders are offered for their capture.

In conclusion, trapping was the most cost efficient control technique employed for both banana and cane cropping systems. Trapping and dogging were comparable in terms of the total number of pigs captured.

5.5. Management Costs and Benefits of feral Pig Control

The overall real cost of feral pigs to farms in this region is a combination of the cost of the actual direct damage, the costs associated with controlling this damage and the value of any benefits derived from the captured pigs.

The overall costs of feral pigs to all banana farms during the project totalled $105,194 which is equivalent to $4,099 / annum for each banana farm or standardised as $300 for every 1000 cartons ($20,000 value) of bananas produced. The real on farm cost of pigs to the banana industry is equivalent to 1.5 % of the value of production. The actual direct damage estimates for banana farms only comprise 20% of the total costs, 80% of the true cost of pigs is related to the costs associated with the control effort applied. Banana farms are spending on mitigation pig damage even though only a small portion of the industry as a whole is directed effected by pig damage.

The overall cost of pig management to all sugar cane farms during the project totalled $471,392 equivalent to $10632 / annum or standardised as $813 damage for every 1000 tonnes of cane ($23,380 value) produced. The real on farm costs of feral pigs to the cane industry represents 3.5 % of the value of production. The actual damage costs represent 52% of the total costs with 48% representing costs associated with control effort. Again cane farmers are committing financial resources to pig damage mitigation, spending almost as much on damage prevention as the actual damage cost received.

Overall for all surveyed farms, feral pigs cost $576,586 which is equivalent to an average of $8,237 / annum for cane and banana farms in the region.

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