Efficacy of a Baiting Technique to Control Feral Cats on Christmas Island

A Report to Christmas Island Phosphates

Plate 1. Feral cat sighted along South Point Rd.

D. Algar[1] and R.I. Brazell[2]

February 2005

[1]Department of Conservation and Land Management, Science Division P.O. Box 51, Wanneroo, Western Australia 6065.

[2]Department of Conservation and Land Management, South West Region, Wellington District, P.O. Box 809, Collie, Western Australia 6225.

Government of Western Australia

DEPARTMENT OF Conservation AND LAND MANAGEMENT

Conserving the nature of WA

Introduction

An initial assessment of the feasibility to control feral/stray cats on Christmas Island was conducted in September 2003 (Algar and Brazell 2003). A further research program was undertaken the following year to facilitate refinement and validation of the principle control technique to be used in the proposed feral cat eradication program. The program would also enable collection of further information to highlight the need for feral cat control on the island and maintain and foster support and enthusiasm by the local community. This second research program was initiated and facilitated by Joy Wickenden and Mark Bennett (Environmental Adviser and previous Environmental Manager respectively), of Christmas Island Phosphates.

The main focus of the research program was to assess the efficacy of the baiting technique, to be used in the eradication campaign, across the feral cat population (ie. was there any bias in bait consumption with respect to age and sex classes). It was therefore necessary to collect and identify individual cats when they interacted with specific bait stations. In addition to assessing the efficacy of the technique for feral cats, it was essential to confirm the target specificity of the cat bait delivery mechanism. Baiting is recognized as the most effective method of controlling feral cats (van der Lee 1997; Anon. 1999; Algar and Burbidge 2000; Algar *et al*. 2001; Algar *et al*. 2002), when there is no risk posed to non-target species. The capture of cats would also provide detailed information on cat distribution and abundance, the diet of the feral cat population and also allow sampling the population for diseases and parasites.

This study was undertaken over the period 9th October – 4th November 2004. Documented below are the results of this research.

Methodology

The previous study (Algar and Brazell 2003) recommended that the eradication program for feral cats (i.e. those outside the settlement and light industrial area) should be centred on a ground-based 1080 baiting strategy utilizing the road/track network. The road/track network on Christmas Island provides excellent coverage of the island such that the vast majority of the island is within 1 km either side of any particular road. The home range of cats is generally

greater than 1 km^2 especially when food resources are low. One would therefore expect virtually all cats to encounter the road network during their general home range movement patterns. The only area outside this 1 km of the road "sphere of influence" is the limestone pinnacles on the south east of the island. The proposed baiting strategy for the eradication program would involve placement of bait stations at 100 m intervals along the entire 122.6 km of road network on the island. The baits would be suspended to eliminate exposure to non-target species.

Recent on-track baiting exercises on the Cocos (Keeling) Islands (Algar *et al*. 2004) have highlighted the potential problem of certain non-target species removing ground-laid baits. Land crabs (*Cardisoma carnifex*), which dominate the forest floor, hermit crabs (*Coenobita perlata*) and black rats (*Rattus rattus*) along the coastal areas and feral chickens readily consumed baits placed on the ground. Similarly, robber crabs (*Birgus latro*) readily removed baits laid on the ground during the previous study on Christmas Island (Algar and Brazell 2003). Bait removal by non-target species reduces bait availability to feral cats and therefore control efficacy. Preliminary trials on Cocos (Algar *et al*. 2004), suggested that suspending baits approximately 30-40 cm above the ground prevented most non-target animals from removing the baits while maintaining their attractiveness to feral cats. Further refinement of this "bait suspension technique" was conducted during the previous study on Christmas Island (Algar and Brazell 2003) where robber crabs and rats were likely to pose a problem to bait distribution. During this earlier trial, using a limited number of suspension devices, it was found that presenting baits at bait stations using a gantry device (see Plates in Algar and Brazell 2003) prevented removal by robber crabs and rats but did not hinder their take by cats. Design of the bait suspension device was further modified, to reduce manufacturing costs and time to place in the field, on return to the mainland.

The proposed eradication strategy (Algar and Brazell 2003), outside the settlement, involves placement of a non-toxic feral cat bait suspended at each bait station until it is removed by a cat. After the bait is removed, toxic baits dosed at 4.5 mg of sodium monofluoroacetate (compound 1080) per bait will be placed at this bait station and those either side. Toxic baits not consumed will be removed at dawn. To be able to assess the efficacy of this baiting technique across the feral cat population in this current study, it was necessary to collect and identify individual cats when they interacted with specific bait stations. To be able to collect individual cats it was necessary to employ a trapping technique. The methodology adopted in this program used non-toxic baits as the lure and leg-hold traps as the collection technique The capture of animals at

individual bait stations also provided a technique to measure cat density and distribution, enabled sampling the population to determine diet, the incidence of diseases and parasites and assess the target specificity of the bait delivery technique.

Bait and bait delivery technique

The bait is similar to a chipolata sausage in appearance, approximately 20 g wet-weight, dried to 15 g, blanched (that is, placed in boiling water for one minute) and then frozen. The bait is composed of 70 % kangaroo meat mince, 20 % chicken fat and 10 % digest and flavour enhancers (Patent No. AU13682/01). Baits are generally thawed and placed in direct sunlight prior to laying. This process, termed 'sweating', causes the oils and lipid-soluble digest material to exude from the surface of the bait. All baits are sprayed, during the sweating process, with an ant deterrent compound (Coopex®) at a concentration of 12.5 g l^{-1} Coopex as per the manufacturer's instructions. This process is aimed at preventing bait degradation by ant attack and deterring bait acceptance by the physical presence of ants on and around the bait medium. Feral cat baits are routinely manufactured at the CALM Bait Manufacturing Facility in Harvey.

Each bait station (see Plates 2 and 3) comprised a non-toxic cat bait suspended from a gantry, approximately 30-40 cm above the ground using 6-8 lb fishing line. The gantry design consisted of a vertical steel rod (12 mm diam. 1000 mm in length) with a sheared point at the ground end; the other end inserted into a 30 mm steel washer (2.5 x 30 mm, internal hole 13.5 mm), which was spot-welded 90 mm from the top. The gantry arm was a 5 mm diameter rod, 480 mm long and spot-welded to a 20 mm pipe (20 mm OD x 2.5 mm wall black pipe x 50 mm), 10 mm from the end at an angle of approximately 120^0 from the long end of the pipe. The opposing end of the arm had a 30 mm steel washer spot-welded vertically on its outer edge for tying the suspended bait. The gantry was installed at each bait station by hammering the vertical rod into ground until it was firmly held. A plastic plate (230 mm diam. Plastic plate or bucket lid with a 13 mm hole in the centre) was then placed on top of the rod, seating it firmly on top of the washer. The gantry arm pipe was then seated on top of the plate so that it rested approximately 120^0 to the vertical. The arm was then pivoted to the desired location and locked in place by hammering a 20 mm clout at the top of the vertical rod, between the rod and the inside of the pipe.

Plate 2. Bait station with plastic plate

Plate 3. Bait station with bucket lid

Bait stations were placed at 100 m intervals along the edge of the road and their locations were recorded using a Garmin GPS 12XL. The road was not comprised of a sandy substrate that would permit identification of individual species tracks so a "sand pad", using crushed rock phosphate dust, 40 x 40 cm, cleared of track activity was located beneath each bait. To be able to adequately sample the feral cat population, placement of bait stations was restricted to the main haul roads (e.g. Plates 4 and 5). The survey route was 33.7 km in length and provided a total of 332 bait stations. The haul roads used are listed in Table 1 and shown in Figure 1 (Figure not included).

Plates 4 and 5. East-West Baseline to North South Baseline haul road

Table 1. Location of bait stations

Location	Distance (km)	Bait station No.s
Murray Rd. to North West Rd.	5.4	1-54
North West Rd. to Dales	7.1	55-126
East West Baseline to Murray Rd.	2.9	127-156
Corner of Murray Rd. and East-West Baseline to North South Baseline	4.4	157-201
North South Baseline to South Point Temple Rd.,	6.2	202-264
North South Baseline to Airport	6.7	265-332

Each bait station was examined daily, over a twenty-day period. Each sand pad was examined for cat activity (see Plates 6 and 7) and whether the bait had been taken. Removal of the bait by non-target species was also recorded. When baits had been removed by cats from individual bait stations on at least two consecutive days, that bait station was designated for trap placement (see below). Baits were replaced following removal and all bait stations were re-baited with fresh baits at five-day intervals. During the course of bait station placement and monitoring, opportunistic sightings of cats (see Plates 1, 8 and 9) were also recorded.

Plates 6 and 7. Sand pads located beneath each bait, showing cat activity

Plates 8 and 9. Opportunistic sightings of cats e.g. ginger cat sighted on 22/10/04 at bait station 271 and grey tabby (sample no. CI 23) sighted on 23/10/04 at bait station 313

The trap system and trapping program

The trapping technique used to capture feral cats utilized Victor 'Soft Catch' traps® No. 3 (Woodstream Corp., Lititz, Pa.; U.S.). This trapping and lure system has been used successfully previously both on Cocos and Christmas Islands (see Algar *et al*. 2004 and Algar and Brazell 2003 respectively). Each trap site consisted of four traps, arranged in two pairs of two, the centre of which was directly beneath the suspended bait (see Plate 10). The trap bed was made so that when lightly covered with soil, the traps were level with the surrounding ground surface. A foam pad of dimensions (12x8x2 cm) was placed below the pressure plate to prevent soil from falling into the trap bed and compacting under the plate. The traps were then lightly covered with soil. It was unlikely that the traps would pose a threat to non-target species; rats and robber crabs were the only species likely to come into contact with them when bait stations were used. Robber crabs have been reported unlikely to set off the traps (van der Lee 1997). The limited number of traps available and logistic constraints precluded all the bait stations with cat activity being trapped on any given day, as such; the trapping program focussed on key activity areas. All traps were routinely checked at first light each day.

Plate 10. Trap site consisted of four traps, arranged in two pairs of two, the centre of which was directly beneath the suspended bait

Necropsies and Analyses

Trapped cats (e.g. see Plates 11-13) were released from the leg-hold traps, placed in cage traps and transported back to the Parks Australia North Compound where they were humanely destroyed using a 0.22 calibre rifle. All animals captured were sexed, weighed and a broad estimation of age (as either kitten, juvenile or adult) was recorded according to their weight. The pregnancy status of females was determined by examining the uterine tissue for embryos or placental scarring from the previous litter. Stomach contents were removed, their volume assessed as either trace or in quartiles and stored frozen for later diet analysis.

Plates 11 and 12. Cats (sample No.s CI 20 and CI 22) trapped at bait station 261

Plate 13. Cat (sample No.s CI 15) trapped at bait station 329

Samples of brain, muscle, and faeces were collected from each cat to examine parasite presence. Samples were stored in vials containing Dimethyl Sulphoxide, 20 % in saturated salt (NaCl) solution and sent to Dr Peter Adams, Post-doctoral Fellow, Div., of Veterinary and Biomedical Sciences, Murdoch University (South St., Murdoch, WA) for microscopic analysis. Blood samples were taken; serum samples collected and these were tested for antibodies to the protozoan parasite *Toxoplasma gondii*. Analyses were conducted by Vetpath Laboratory Services (Epsom Ave., Ascot, WA). Serum titres for IgG and IgM antibodies were generated using the immunofluorescent antibody test (IFAT), and these results were confirmed using the latex agglutination test (LAT).

Results

Bait station response

Cat activity was recorded on 113 of the 332 bait stations across the 20-day monitoring period. Of the 113 stations with activity, 78 stations were visited on more than one occasion and 35 stations were visited only once. It was not possible to determine how many stations an individual cat visited on a given day. It appeared some individuals would visit a number of bait stations while others visited one. There were a number of instances where multiple station visits were recorded, which ceased following the removal of one individual cat and on the other hand a number of cats were captured at the same bait station. As bait station activity could not be ascribed to individuals, the minimum number of cats present over the survey route could not be determined.

Rather it was decided to present a figure for the maximum number of individuals present where each bait station visit was the result of one animal's activity. Cat numbers based on total stations visited was thought to provide a sounder and more realistic figure of presence, as it was unlikely that stations would be visited by more than one cat following bait removal. The number of bait stations (maximum number of cats) where cat activity was recorded per day over the monitoring period is presented in Figure 2.

Figure 2. Number of bait stations where cat activity was recorded per day over the monitoring period

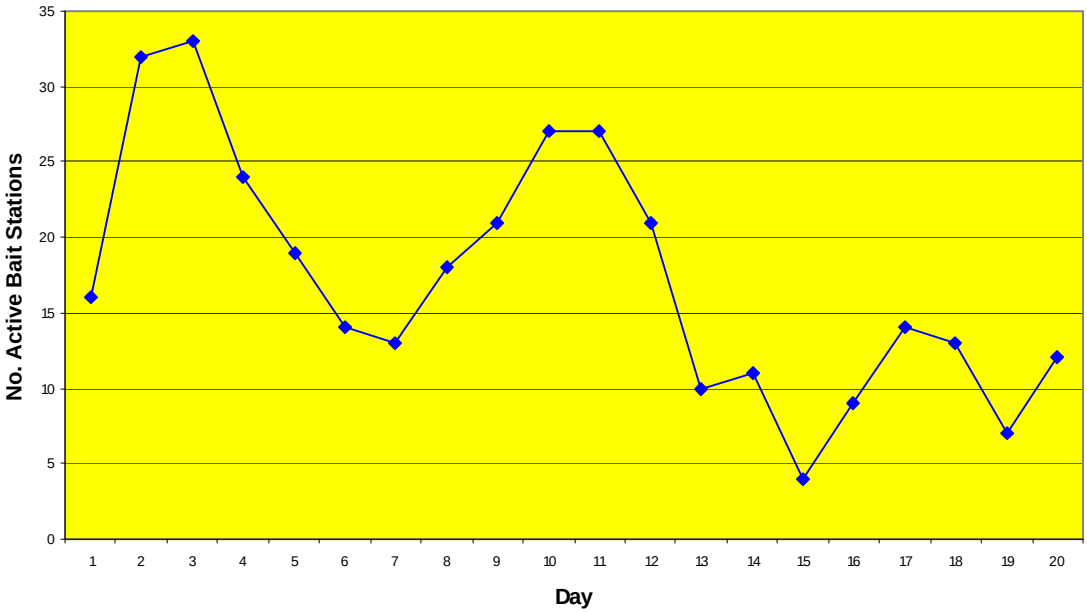


Figure 2 indicates that as trapping commences, day 3 on, the maximum number of cats along the route starts to decline. This decline in cats present is gradual and stepwise and likely constrained by the factors of trap availability and logistics mentioned earlier. It is suggested that the slope of this curve would be much steeper if the trapping program had not been limited.

Bait delivery technique and sampled cat population

The trapping program involved setting traps at 37 bait stations for a total of 108 trap nights (number of traps x number of nights in place). A total of 26 cats was captured along the survey route during this exercise. The male-to-female sex ratio (14 males and 12 females) of these animals was 1.2 and did not differ significantly from unity (χ^2 = 0.15, 1df, P>0.05). The age of individuals was arbitrarily assigned according to weight. The largest weight recorded for a non-

pregnant female, at a time when sexually mature females had bred, was 1.5 kg and this was used as the minimum adult weight for female cats. The weight/age classes for females were 0-0.5 kg for kittens, 0.6-1.5 kg for juveniles and 1.6+ kg for adults; males were 0-0.5 kg for kittens, 0.6-2.0 kg for juveniles and 2.1+ kg for adults. The average weight for adult male cats was 3.6 $\pm$ 0.1 kg ($\mu \pm$ s.e.) with a maximum weight of 4.4 kg. The average weight for adult female cats was 2.6 $\pm$ 0.2 kg ($\mu \pm$ s.e.) with a maximum weight of 3.3 kg. Counts of foetuses *in utero* and placental scars indicated that the average litter size was 2.0 $\pm$ 0.4 kittens ($\mu \pm$ s.e.) with a maximum litter size of three kittens. The capture locations and cat records are presented in Table 2.

Table 2. Capture locations and records of trapped feral cats, * J = Juvenile, A = Adult

Date	Sample No.	Bait Station No.	Sex	Weight (kg)	Coat colour	Age (K/J/A)*
17/10/04	CI 01	102	F	2.6	Grey tabby	A
18/10/04	CI 02	4	F	1.3	Grey tabby	J
18/10/04	CI 03	5	F	2.0	Black/white	A
18/10/04	CI 04	67	M	3.6	Grey tabby	A
18/10/04	CI 05	110	F	1.3	Grey tabby	J
19/10/04	CI 06	264	M	3.0	Grey tabby	A
*	CI 07					
19/10/04	CI 08	9	F	2.5	Grey tabby	A
19/10/04	CI 09	70	F	2.6	Tricolour	A
20/10/04	CI 10	210	M	4.0	Grey tabby	A
*	CI 11					
22/10/04	CI 12	116	M	3.0	Ginger	A
24/10/04	CI 13	194	F	1.3	Grey tabby	J
25/10/04	CI 14	309	M	2.0	Ginger	J
26/10/04	CI 15	329	M	3.9	Grey tabby	A
27/10/04	CI 16	127	F	1.5	Grey tabby	J
27/10/04	CI 17	116	F	2.5	Grey tabby	A
28/10/04	CI 18	197	M	4.4	Grey tabby	A
28/10/04	CI 19	225	M	3.6	Grey tabby	A
28/10/04	CI 20	261	F	2.3	Black/ginger	A
29/10/04	CI 21	205	F	3.3	Grey tabby	A
29/10/04	CI 22	261	M	2.8	Black	A
31/10/04	CI 23	313	M	4.1	Grey tabby	A
01/11/04	CI 24	332	F	3.3	Ginger	A
01/11/04	CI 25	228	M	3.6	Grey tabby	A
01/11/04	CI 26	261	M	3.6	Grey tabby	A
02/11/04	CI 27	205	M	3.8	Grey tabby	A
03/11/04	CI 28	193	M	4.0	Ginger	A

*CI 07 and CI 11 were caged trapped cats, caught near the phosphate dryers and have been omitted from the data set and analyses

As the trapping program did not commence until after a minimum of two days consecutive bait take, it can be assumed that, in the majority of cases, the trapped individual had previously consumed a suspended bait. However, as mentioned earlier several cats were captured at the same bait station and therefore may have been captured on their first visit. These results suggest that there was no bias in capture rates and therefore bait consumption between males and females and similarly, juvenile animals were equally able to access baits. At the time of the program, the majority of adult females were either in the later stages of pregnancy or had recently given birth (lactating), it is therefore unlikely that any kittens would have been represented in the trapped population. It is also probable that small kittens would not be able to access the suspended baits and therefore the timing of a baiting program is important.

Cat abundance and distribution

During the course of bait station placement and monitoring, opportunistic sightings of cats were also recorded (see Table 3).

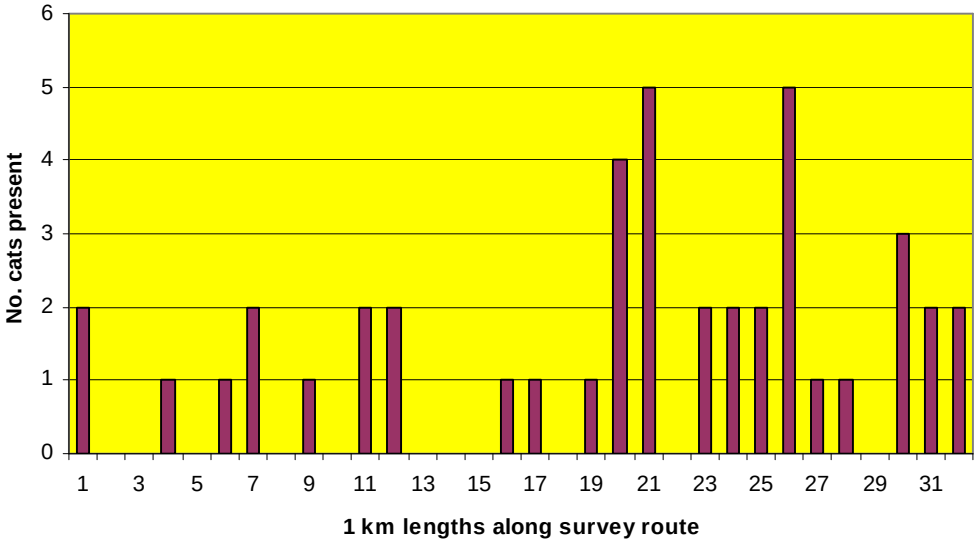
Table 3. Cat sighting records

Date	Location (Bait Station No.)	Time of day (h)	Coat colour	Sample No./comments
10/10/04	70	11:30	Grey tabby	CI 04
10/10/04	3	14:15	Grey tabby	CI 02
10/10/04	150	14:45	Roan/cream	
14/10/04	304	15:45	Tricolour	
15/10/04	263	09:30	Grey tabby	CI 06
16/10/04	263	09:30	Grey tabby	CI 06 (as above)
16/10/04	67	08:10	Grey tabby	CI 04
17/10/04	208	08:30	Black/white	Road kill at 212,
18/10/04	241	10:30	Ginger	
19/10/04	241	06:30	Grey tabby	See Plate 1
19/10/04	259	14:20	Ginger	Small-medium size
19/10/04	308	14:45	Ginger	CI 14
21/10/04	329	12:15	Grey tabby	CI 15
22/10/04	271	15:15	Ginger	See Plate 8
23/10/04	153	07:00	Roan/cream	As 10/10/04
23/10/04	173	10:00	Black	
23/10/04	313	15:30	Grey tabby	CI 23
23/10/04	329	15:35	Grey tabby	CI 15
26/10/04	116	14:30	Grey tabby	CI 17
29/10/04	195	06:00	Ginger	CI 28
30/10/04	288	15:05	Grey tabby	
31/10/04	256	06:45	Grey tabby	CI 26
02/11/04	55	09:25	Grey tabby	Diseased
03/11/04	301	15:01	Black/white	Eating bait

Twenty-four sightings were recorded, comprising 20 individual animals of which nine were trapped and one was a road-kill casualty.

The measurement of cat abundance and their distribution was based on bait station activity, capture and records of cats sighted. Combining data from these three sources, suggested that a total of 45 cats (1.34 cats/ linear km) was present along the survey route. To present data on the distribution of the cat population, the number of cats present was pooled for the individual 1 km segments along the survey route. Activity at the bait stations suggested that cat activity along the roads tended to be confined to intervals of 1 km or less and these segments appeared to be discrete for individuals or groups. Cat distribution along the survey route is presented in Figure 4; refer to Table 1 and Figure 1 for the location of these 1 km segments. Although cats were distributed across most of the survey route, abundance varied with certain areas devoid of cat activity and other sites having a number of cats present.

Figure 4. Distribution of the cat population along the survey route



Target specificity of the cat bait delivery mechanism

Visits to bait stations by non-target species were not recorded unless the bait was removed however, robber crab activity was observed on the majority of bait stations throughout the course of this study (e.g. Plate 14). Of the 332 bait stations; daily bait removal by robber crabs was approximately 1 % [3.5 $\pm$ 0.5 stations ($\mu \pm$ s.e.), range 0-7] and < 1% by rats [0.3 $\pm$ 0.1 stations ($\mu \pm$ s.e.), range 0-2]. Bait removal by non-targets generally occurred at the same bait stations,

probably by the same individuals. Bait removal by robber crabs occurred when overhanging vegetation allowed them to climb onto the plate and gather the bait in (see Plate 18). Certain plates had perforations, which also enabled the crabs to gain purchase and climb over the lip of the plate and onto its surface (see Plate 19). The lengths to which robber crabs would go to access baits are shown in Plates 14-19. Bait consumption by rats only occurred when overhanging vegetation was present; removal of this material prevented any further access by rats.


Plates 14-19. The lengths to which robber crabs would go to access baits

Diet of the feral cat population

Of the 26 cats trapped, 17 had items in their stomachs. The stomach volume and contents of captured cats are reported in Table 4.

Table 4. Stomach volume and contents of trapped cats

Sample N^{o}	Volume (%)	Content
CI 01	75	Unidentified bird, 1 x short-horned grasshopper (Acrididae), 1 x spider (Heteropodidae)
CI 04	Trace	*Toxocara cati* infestation
CI 05	50	3 x acridid, unidentified bird (dark flight feathers - NOT *Gallus*)
CI 08	100	2 x acridid, 1 x *Rattus rattus*, 1 x Emerald Dove
CI 09	Trace	1 x acridid, undifferentiated and decomposed feathers (dark), *Toxocara cati* infestation
CI 10	100	1 x acridid, unidentified bird
CI 12	75	4 x acridid, 5 x centipede, unidentified bird
CI 13	50	11 x acridid, 2 x katydid (Tettigoniidae),
CI 14	25	5 x acridid, 4 x centipede, 1 x heteropodid
CI 17	Trace	1 x acridid,
CI 18	Trace	undifferentiated and decomposed feathers (dark)
CI 19	100	1 x Emerald Dove
CI 21	Trace	1 x acridid
CI 22	Trace	1 x acridid
CI 24	25	5 x acridid, undifferentiated feathers (dark)
CI 27	25	Unidentified bird
CI 28	75	1 x *Rattus rattus*

Diseases and parasites

Serum samples collected from 25 cats were tested for antibodies to the protozoan parasite *Toxoplasma gondii*. Serum titres for IgG and IgM antibodies were generated using the immunofluorescent antibody test (IFAT), and these results were confirmed using the latex agglutination test (LAT) and are presented in Table 5. Both the IFAT and the LAT confirmed that 92% (23/25) of the cats were positive for prior exposure to *T. gondii*. The antibody titres indicated that all of these positive reactions were due to latent infections. Those positive samples whose IgM titres are equal to or greater than 1:128 indicate an infection, which was acquired relatively recently (within the last two years), whilst those whose IgM titres are less than 1:128 (ie. 1:64 and 1:32), indicate that the infection has been acquired two or more years ago.

Table 5. Results of tests for the presence of the protozoan parasite *Toxoplasma gondii*

Toxoplasma IgG and IgM titres			**Latex agglutination test**	
Sample No.	**IgG titre**	**IgM titre**		
CI 01	> 1:512	< 1:32		Positive
CI 02	> 1:512	equals 1:128		Positive
CI 03	> 1:512	equals 1:128		Positive
CI 04	> 1:512	equals 1:64		Positive
CI 05	No sample			
CI 06	equals 1:32	< 1:32		Negative
CI 07	equals 1:64	< 1:32		Negative
CI 08	> 1:512	equals 1:128		Positive
CI 09	> 1:512	< 1:32		Positive
CI 10	> 1:512	< 1:32		Positive
CI 11	> 1:512	equals 1:128		Positive
CI 12	No sample			
CI 13	> 1:512	equals 1:256		Positive
CI 14	> 1:512	equals 1:32		Positive
CI 15	> 1:512	< 1:32		Positive
CI 16	> 1:512	equals 1:32		Positive
CI 17	No sample			
CI 18	> 1:512	< 1:32		Positive
CI 19	> 1:512	equals 1:32		Positive
CI 20	> 1:512	< 1:32		Positive
CI 21	> 1:512	equals 1:32		Positive
CI 22	> 1:512	< 1:32		Positive
CI 23	> 1:512	equals 1:128		Positive
CI 24	> 1:512	< 1:32		Positive
CI 25	> 1:512	equals 1:64		Positive
CI 26	> 1:512	equals 1:64		Positive
CI 27	> 1:512	equals 1:32		Positive
CI 28	> 1:512	< 1:32		Positive

Results of the analysis for the presence of parasites in the cat population are presented below in Table 6 and discussed in detail in Appendix A. All but two of the samples contained parasite burdens.

Table 6. Results of the analysis for the presence of parasites in the cat population

Sample No.	Parasite presence
CI 01	Strongyle egg 45 x 25µm, Aelurostrongylus L3, Toxocara *cati*
CI 02	-
CI 03	*Isospora rivolta* + *Isospora felis* + (Hymenolepis egg artifact)
CI 04	*Toxocara cati*, Capillaria sp
CI 05	*Besnoitia wallacei* 17.5 x 12.5µm
CI 06	Hookworm sp 60 x 37.5µm, Strongyloides *stercorali,* Sarcocystis
CI 07	Hookworm sp 67.5 x 37.5µm
CI 08	*Toxocara cati*, Spiruroid egg 45 x 30µm (smooth shell)
CI 09	*Toxocara cati*, *Strongyloides stercoralis*
CI 10	-
CI 11	*Strongyloides stercoralis*, (*Monocystis* artifact)
CI 12	*Aelurostrongylus* L3
CI 13	*Strongyloides stercoralis*
CI 14	*Toxocara cati*, (*Klossia* artifact)
CI 15	*Taenia taeniaeformis* eggs, Strongyloides *stercoralis*, Hookworm 55 x 35µm, *Toxocara cati*
CI 16	*Strongyloides stercoralis*
CI 17	*Aelurostrongylus* L3
CI 18	*Strongyloides stercoralis*, *Aelurostrongylus* L3, Toxocara *cati*, Whole worm adult *Physaloptera* sp (m)
CI 19	*Strongyloides stercoralis*, Spiruroid egg 47.5 x 32.5µm (rough surface), *Toxocara cati*, *Aelurostrongylus* L3
CI 20	*Cryptosporidium muris* 7-8µm, Isospora *rivolta*, *Isospora felis*, *Strongyloides stercoralis*, *Toxocara cati*
CI 21	*Strongyloides stercoralis*, *Aelurostrongylus* L3, *Capillaria* sp, (*Eimeria* artifact)
CI 22	*Capillaria* sp, Spiruroid 45 x 32.5µm (smooth shell, thick wall, sticky surface), Adult worm bits rictulariid *Pterygodermatites* sp (subgenus *Mesopectines*)
CI 23	*Toxocara cati*, Strongyloides *stercoralis*
CI 24	Hookworm sp 52.5 x 37.5µm, *Strongyloides stercoralis*, *Toxocara cati*
CI 25	*Toxocara cati*, *Taenia taeniaeformis* eggs, *Capillaria* sp
CI 26	Coccidia 20 x 15µm, *Toxocara cati*, *Capillaria* sp, (pinworm 67.5 x 30µm, *Klossia* artifact)
CI 27	*Toxocara cati*, *Aelurostrongylus* L3, *Strongyloides sercoralis*
CI 28	*Toxocara cati*, *Capillaria* sp

Discussion

The main focus of the research program was to assess the efficacy of the baiting delivery technique, to be used in the feral cat eradication campaign. Analysis of the sampled feral cat population indicated that the bait delivery methodology was equally effective for both adult male and female animals, juvenile animals were also equally able to access baits. The use of toxic baits to remove cats, during the proposed eradication, instead of the trapping technique and its associated limitations would permit a more rapid removal of the cat population. One of the problems faced during this current exercise was the temporary disappearance of certain individuals prior to trap placement following repeated earlier and later bait station activity. This temporal change in activity at certain bait stations may have been due to the general pattern of home range usage or in the case of females because they were either in the later stages of pregnancy or had recently given birth. The more readily deployed toxic baits would overcome the problems associated with temporal and logistic constraints.

This study demonstrated the target specificity of the bait delivery technique with only approximately 1 % of baits being removed daily by non-target species. Removal of overhanging vegetation and use of a smooth plate with no perforations in the bait station design should eliminate any non-target bait removal. Preventing access to baits by non-target species while maintaining their availability and attractiveness to the feral cat population will enable successful implementation of a highly effective baiting strategy for the eradication of feral cats from the island.

Feral cats were abundant along the survey route at a density of 1.34-cats/linear km. A spotlight survey conducted along the same survey route during the previous study (Algar and Brazell 2003) indicated a much lower density of 0.15 ± 0.03 cats/km ($\mu \pm$ s.e.). As stated previously (Op cit.), spotlight surveys can only provide a somewhat limited snapshot of animal numbers at a single point in time. Reliance on spotlight data, particularly when surveys are conducted through areas of dense vegetation, can often lead to incorrect indices of abundance. The density of cats has been assessed in other studies on the island and reported at 0.3 cats/km Tidemann (1989) and 0.19 cats/km van der Lee (1997). The cat densities recorded in these studies, despite being of a much longer duration, was lower that that determined during the current program, whether this was due to a dramatic change in abundance over time or technique is unknown. The density of cats

recorded on Christmas Island is also significantly greater than estimates derived in a variety of biomes on the mainland (Algar and Burrows 2005).

The pattern of distribution of cats along the survey route indicates that although cats were present along most of its length, abundance varied with certain areas devoid of cat activity and other sites having a number of cats present. Distribution and abundance of cats will vary with habitat preference and resource availability and is unlikely to be uniform across the landscape.

One of the benefits of this current study was that the methodology enabled collection and sampling of the cat population for the incidence of disease and parasites. Analyses indicated a high level of parasite infestation and significantly, the prevalence of *Toxoplasma gondii* in 92% of these cats. Detection of this level of presence indicates that there may be a high level of environmental contamination with *T. gondii* oocysts on Christmas Island. It is believed that cycling of this parasite would be occurring between the cats and the rodent fauna (rats and mice). The cats and rats themselves would not present an infection risk to the population (ie. as pets), however contact with cat faeces and soil in the vicinity of cat defecation points could present an infection risk. Normal hygiene practices such as the washing of hands before eating/coming inside the house, and wearing gloves when gardening should minimise the risk of ingesting the microscopic infective stages. Particular concern is for women becoming infected with *T. gondii* whilst pregnant, as this can lead to birth defects. It is advised that the medical present on Christmas Island be made aware of the potentially high level of *T. gondii* oocysts in the environment so that they may take any steps/precautions they deem necessary.

Some background on *T. gondii* is included (see Appendix A) however this is not by any means an exhaustive discussion of the parasite and its effects. Before taking any action in relation to these findings it is strongly recommended that further consultation and/or reading of the relevant literature be undertaken.

Acknowledgments

We would like to acknowledge the financial support provided by Christmas Island Phosphate for this feasibility study. Thanks are extended to Joy Wickenden (Environmental Adviser) from

Christmas Island Phosphates; Alistair Graham (Government Conservator), Azmi Yon (Senior Ranger) from Parks Australia North for assistance while we were on-island. We would also like to thank the people of Christmas Island for their hospitality during our visit

References

Algar, D. and Burbidge, A.A., (2000). Isle of cats: the scourging of Hermite Island. *Landscope* **15(3)**, 18-22.

Algar, D. and Brazell, R.I. (2003). Results and recommendations, from a feasibility study, to control feral cats on Christmas Island. A report to Christmas Island Phosphate. Department of Conservation and Land Management.

Algar, D. and Burrows, N.D. (2005). A review of Western Shield: feral cat control research. *Conservation Science Western Australia* **5(2)**, 131-163.

Algar, D., Angus, G.J., Brazell, R.I., Gilbert, C. and Withnell, G.B. (2001.). Farewell Felines of Faure. Report to Australian Wildlife Conservancy. Department of Conservation and Land Management.

Algar, D., Burbidge, A.A. and Angus, G.J. (2002). Cat Eradication on the Montebello Islands. In: *Turning the Tide: the eradication of invasive species.* (eds. C.R. Veitch and M.N. Clout) pp14-8. Invasive Species Specialist Group of the World Conservation Union (IUCN). Auckland.

Algar, D., Angus, G.J., Brazell, R.I., Gilbert, C. and Tonkin, D.J. (2004). Feral cats in paradise: focus on Cocos. *Atoll Research Bulletin* **505**, 1-12.

Anon. (1999). Threat Abatement Plan for Predation by Feral Cats. Environment Australia, Biodiversity Group, Commonwealth of Australia.

Lee, van der, G. (1997). The status of cats *Felis catus* and prospects for their control on Christmas Island. A Consultancy for the Australian Nature Conservation Agency. Dept. Ecosystem Management, Univ. of New England.

Tidemann, C.R. (1989). Survey of the terrestrial mammals on Christmas Island (Indian Ocean). A Consultancy for Australian National Parks and Wildlife Service. Forestry Dept., Australian National University.

Appendix A

(Information supplied by P. Adams, Post-doctoral Fellow, Div., of Veterinary and Biomedical Sciences, Murdoch University)

Toxoplasma gondii

Toxoplasma gondii is a ubiquitous, obligate intracellular coccidian parasite that occurs in most areas of the world and is of both veterinary and medical importance worldwide due to its implication in abortion and congenital disease in its intermediate hosts (Dubey and Beattie 1988; Dubey *et al*. 1998). Virtually all species of warm-blooded animals including humans can be infected by *T. gondii*, though only cats and other members of the family Felidae are the definitive hosts (Dubey and Lappin 1998). There are three infectious stages: sporozoites in oocysts, generally found as a contaminant of food or water; tachyzoites, the actively multiplying stage present in intermediate host tissue; and bradyzoites, the slowly multiplying stage enclosed in tissue cysts (Dubey and Lappin 1998; Tenter *et al*. 2000). Oocysts are excreted in faeces only by members of the Felidae, whereas tachyzoites and bradyzoites can be found in tissues of both definitive and intermediate hosts (Dubey and Lappin 1998). *T. gondii* is capable of undergoing both horizontal and vertical transmission within both intermediate and definitive hosts (Figure 1) (Beverley 1959; Dubey and Carpenter 1993; Dubey *et al*. 1995a; Dubey *et al*. 1997b). Because *T. gondii* can be transmitted by multiple sources, it is difficult to establish the definite mode of transmission on an individual basis. Therefore, it is currently not known which of the various routes of transmission is more important, however epidemiologic evidence suggests that cats are ultimately essential for the maintenance of *T. gondii* in the environment (Munday 1972; Wallace *et al*. 1972; Frenkel and Ruiz 1981; Dubey *et al*. 1997a).

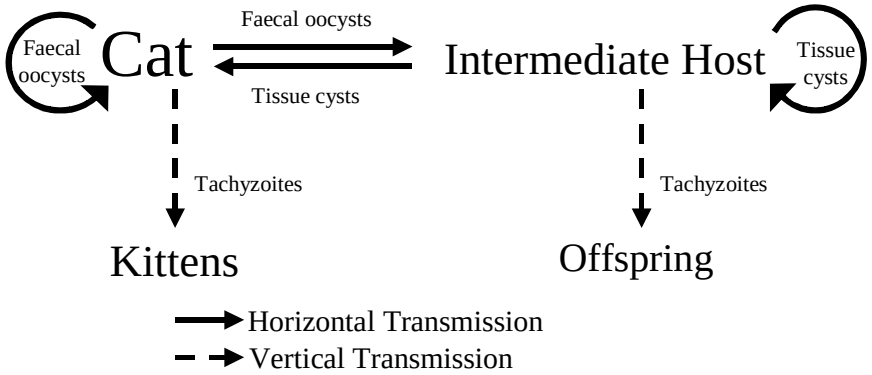


Figure 1. Transmission cycle of *T. gondii*

There are three infectious stages in the life cycle of *T. gondii*: tachyzoites; bradyzoites contained in tissue cysts; and sporozoites contained in sporulated oocysts. All three stages are infectious for both intermediate and definitive hosts which may acquire a *T. gondii* infection mainly via one of the following routes: a) horizontally by oral ingestion of infectious oocysts from the environment, b) horizontally by oral ingestion of tissue cysts contained in raw or undercooked meat or primary offal (viscera) of intermediate hosts, or c) vertically by transplacental transmission of tachyzoites (Dubey and Beattie 1988; Jackson and Hutchison 1989; Dubey *et al*. 1998; Dubey 1991). Additionally, transmission of tachyzoites from mothers to offspring via their milk has been observed in several hosts (Dubey and Beattie 1988; Jackson and Hutchison 1989; Tenter *et al.* 2000; Powell *et al*. 2001), whilst other minor modes of transmission involve transfusion of bodily fluids and transplantation of organs (Dubey and Beattie 1988).

It is not fully understood why some infected animals develop clinical toxoplasmosis whilst others do not. Age, sex, host species, strain of *T. gondii*, number of organisms and stage of the parasite ingested may all account for some of the differences, whilst stress, concomitant illness and immunosuppression may also increase host susceptibility to *T. gondii* (Dubey and Lappin 1998). Symptoms of acute toxoplasmosis can include fever, coughing, pneumonia, mastitis, abortion and stillbirths (Dubey 1994). In the sub-clinical form, symptoms may be absent or inapparent with a degree of immunity being acquired by the host (Dubey 1995; Davis Dubey 1995; Liesenfeld 1999). Acute cases may produce inflammation in heart muscle, liver and skin (rash) with localised swelling of lymph nodes as well as lethargy, weight loss, vomiting and diarrhoea (Dubey and Carpenter 1993; Dubey 1995a; Dubey and Lappin 1998).

Tachyzoites are the invasive asexual forms of the parasite that require intracellular existence for replication and survival, (Dubey and Lappin 1998; Carruthers 2002). Cell necrosis is common at localised sites of infection and is due to the intracellular growth of *T. gondii* (Dubey and Lappin 1998). In infections acquired after the ingestion of tissue cysts or oocysts, initial clinical signs are usually due to the necrosis of intestinal epithelium and associated lymphoid organs caused by tachyzoite proliferation (Dubey and Lappin 1998). Tachyzoites are spread to extraintestinal organs via blood or lymph, with the brain, liver, lungs, skeletal muscle and eyes being common sites for the chronic persistence of infection (Dubey and Lappin 1998; Dubey *et al*. 1998).

Approximately three weeks after infection tachyzoites begin to disappear from visceral tissues and may localise as tissue cysts which persist in the host for life, though intermittent relapses may occur if the host becomes immunosuppressed or highly stressed (Dubey and Lappin 1998). The clinical outcome of the infected host is determined by the extent of injury it sustains to its internal organs, particularly heart, lung, liver and adrenal glands (Dubey and Lappin 1998). Generally, most host species will recover from an infection, though acute disseminated *T gondii* infections can often be fatal (Dubey and Lappin 1998).

Parasites

Nematode Parasites

Aelurostrongylus abstrusus = Cat Lungworm

Nematode parasite of cats with a worldwide distribution, with the cat acting as the definitive host. Life cycle involves a required mollusc (typically a snail) intermediate host, whilst rodents and/or birds that ingest the infected snails act as paratenic (transport) hosts, though lizards and amphibians can also serve as paratenic hosts. Infected cats shed *A. abstrusus* eggs into the environment via their faeces thereby infecting the molluscan intermediate hosts, which are then consumed by the paratenic hosts. The life cycle is completed when a cat predates an infected paratenic host. This parasite is generally restricted to cats and the parasite stage shed in their faeces is not infectious to other avian or mammalian animals until after a period of development in a molluscan intermediate host. This parasite does not present a hazard to humans.

Toxocara cati = Roundworm

Large roundworm found in the small intestine of the cat and other wild Felidae. *T. cati* has a cosmopolitan distribution and occurs in 35-85% of young adult cats and about 60% of kittens. Life cycle involves paratenic hosts including small rodents and invertebrates. Cats can become infected by the ingestion of infective eggs, by the ingestion of a paratenic host, or by the transmammary infection of kittens. Infections in humans are rare, though more commonly attributed to *Toxocara canis*.

Hookworm sp.

Hookworm infections in cats are typically caused by *Ancylostoma tubaeforme*, *A. braziliense* and/or *Uncinaria stenocephala*. *U. Stenocephala* infections are generally limited to the southern latitudes whilst *Ancylostoma* species occur in cats throughout Australia. *Ancylostoma* hookworms require a warm climate and moist soil conditions for the eggs passed in faeces to develop into

infective larvae. These infective larvae then enter new hosts by burrowing through the skin following contact with soil containing them. Cats are also known to harbour another hookworm species *A. ceylanicum*, which is closely related to *A. braziliense*. Both species are commonly responsible for infecting humans, though unlike *A. braziliense*, *A. ceylanicum* is able to mature in humans. There are no published reports of *A. braziliense* occurring in Australia, though *A. ceylanicum* appears to be common among cats in north Queensland. Additionally, *A. ceylanicum* was found to be the sole species of hookworm infecting 80% of stray/feral cats sampled from the Cocos Islands (Algar *et al.* 2004), indicating a very high level of environmental contamination.

Strongyles = Strongyloidea

These parasites are typically not pathogenic, and are present in a wide range of different host species. Cats are considered to be hosts to only a single representative genus of the Strongyloidea, *Mammomonogamus*, which is an unusual representative of this group being that the adult worms tend to be parasites of the airways rather than of the large bowel as is typical of strongyles found in other species. However, given the large number of species of strongyles present in numerous hosts, the difficulty in differentiating between them and the potential for cats to pass artefact parasites in their faeces that originate from the stomachs of ingested prey, they could not be accurately speciated.

Strongyloides stercoralis = Threadworm

Nematode worm occasionally found in cats, though considered a more common parasite of humans and dogs. These parasites have a free-living as well as a parasitic generation. No intermediate host is required in the life cycle with infective larvae able to penetrate the skin on contact. Their pathological effect to humans is unknown.

Capillaria sp. = Tracheal Worm

Capillaria aerophila occurs in the trachea, bronchi and rarely the nasal cavities of a number of canid species as well as the cat. It has a direct life cycle, with eggs being coughed up and passed in the faeces. Pathogenesis appears to be proportional to parasite numbers; heavy burdens may cause severe irritation and some obstruction to the airways with chronic coughing.

Physaloptera

Nematode worm of cats with several species described. *Physaloptera praeputialis* is a common parasite of cats in most parts of the world. Arthropods are known intermediate hosts for *P.*

praeputialis, though cats may also become infected through the ingestion of paratenic hosts such as lizards. Humans have been known to become infected with *Physaloptera* however these infections were obtained by the ingestion of the intermediate and paratenic hosts. *Physaloptera* species also commonly infect lizards, and this may well be a worm that has originated from ingested prey and was not parasitising the cat.

Pterygodermatites

Nematode worms that parasitize the small intestine of cats and utilise insects as intermediate hosts. Larvae can also survive in paratenic hosts such as lizards and frogs. Does not appear to be pathogenic, nor is it zoonotic. Not previously recorded in Australia or southeast Asia, though most likely unlooked for.

Spiruroid

Represents a number of species that parasitize the stomach of the feline host. Larvae are typically cycled through intermediate arthropod hosts, and are also capable of utilising various vertebrate paratenic hosts that will transmit the worms to the feline final host. Do not represent a health hazard to humans.

Cestode Parasites

Taenia taeniaeformis = Cat Tapeworm

Cestode parasite with a cosmopolitan distribution, occurring in both wild and domestic felids. The cat is the definitive host, with the cystic stage developing in the liver of the intermediate hosts, mainly rats and mice. Adult worms of *T. taeniaeformis* have been recovered from the intestines of humans, however this parasite does not appear to develop well in humans and do not represent a serious risk to public health.

Protozoan Parasites

Isospora felis and *I. rivolta*

Common coccidian parasite of cats with a worldwide distribution. Generally more prevalent in younger cats, with older cats building up a resistance/immunity. Typically a direct life cycle, however mice and other rodents may act as paratenic hosts. Does not represent a health risk to humans.

Cryptosporidium muris

Coccidian parasite highly resistant to disinfection and commonly associated with water borne infection. However, *C. muris* is a host adapted species and is most likely an artefact parasite originating from rodent prey. Not zoonotic, there fore does not represent a health risk.

Besnotia wallacei

Cats are important as definitive hosts for this parasite, with rodents and lizards acting as intermediate hosts. *B. wallacei* is known to cause large, visible lesions in connective tissues cells of intermediate hosts. Clinical signs of infection in cats have not been reported. There is limited information available for this parasite.

Sarcocystis

Cats are important as definitive hosts for at least 11 named species of *Sarcocystis*. The *Sarcocystis* life cycle is obligatorily a two-host cycle, with the intermediate host becoming infected by ingestion of sporocysts from the environment. Rodents and rabbits are common intermediate hosts for several species of *Sarcocystis*.

Coccidia

Unidentified coccidian parasite(s), possibly *I. felis*/*rivolta* or artifact from prey.

Artifacts

Hymenolepis, *Monocystis*, *Klossia*, *Eimeria* and Pinworm are considered to be artifact parasites as they are not recognised as being infectious to cats. Most likely a result of cats consuming rodents infected with these parasites and then passing them in their faeces along with the prey remains.

References

Beverley, J.K.A. (1959). Congenital transmission of toxoplasmosis through successive generations of mice. *Nature* **183**, 1348-9.

Carruthers, V.B. (2002). Host cell invasion by the opportunistic pathogen *Toxoplasma gondii*. *Acta Tropica* **81**, 111-22.

Davis, S.W. and Dubey, J.P. (1995). Mediation of immunity to *Toxopplasma gondii* oocyst shedding in cats. *Journal of Parasitology* **81**, 882-6.

Dubey, J.P. (1994). Toxoplasmosis – an overview. *Southeast Asian Journal of Tropical Medicine and Public Health*.22 Supplement 88-92.

Dubey, J.P. (1994). Toxoplasmosis. *Journal of American Veterinary Medical Association* **205**, 1593-8.

Dubey, J.P. (1995). Duration of immunity to shedding of Toxoplasma gondii oocysts by cats. *Journal of Parasitology* **81**, 410-5.

Dubey, J.P., and Beattie, C.P. (1988). *Toxoplasmosis of Animals and Man*. CRC Press, Boca Raton, FL.

Dubey, J.P., and Carpenter, J.L. (1993). Neonatal toxoplasmosis in littermate cats. *Journal of the American Veterinary Medical Association* **203**, 1546-9.

Dubey, J.P., and Lappin, M.R. (1998). Toxoplasmosis and Neosporosis. *In* "Infectious Diseases of the Dog and Cat." C.E. Greene, editor. W. B. Saunders, Philadelphia. 493-509.

Dubey, J.P., Lappin, M.R., and Thulliez, P. (1995). Diagnosis of induced toxoplasmosis in neonatal cats. *Journal of the American Veterinary Medical Association* **207**, 179-185.

Dubey, J.P., Lindsay, D.S., and Speer, C.A. (1998). Structures of *Toxoplasma gondii* tachyzoites, bradyzoites, and sporozoites and biology and development of tissue cysts. *Clinical Microbiology Reviews* **11**,267-99.

Dubey, J.P., Rollor, E.A., Smith, K., Kwok, a.c., and Thulliez, P. (1997a). Low seroprevalence of *Toxoplasma gondii* in feral pigs from a remote island lacking cats. *Journal of Parasitology* **83**,839-41.

Dubey, J.P., Shell, S.K., Kwok, a.c., and ThulIiez, P. (1997b). Toxoplasmosis in rats (*Rattus norvegicus*): congenital transmission to first and second generation offspring and isolation of *Toxoplasma gondii* from seronegative rats. *Parasitology* **115,** 9-14.

Frenkel, J.K., and Ruiz, A. (1981). Endemicity of toxoplasmosis in Costa Rica, transmission between cats, soil, intermediate hosts and humans. *American Journal of Epidemiology* **113**, 254-69.

Jackson, M.H., and Hutchison, W.M. (1989). The prevalence and source of *Toxoplasma* infection in the environment. *Advances in Parasitology* **28**, 55-105.

Liesenfeld, O. (1999). Immune responses to *Toxoplasma gondii* in the gut. *Immunobiology* **201,** 229-39.

Munday, B.L. (1972). Serological evidence of *Toxoplasma* infection in isolated groups of sheep. *Research in Veterinary Science* **13,** 100-2.

Powell, C.C., Brewer, M., and Lappin, M.R. (2001). Detection of *Toxoplasma gondii* in the milk of experimentally infected lactating cats. *Veterinary Parasitology* **102,** 29-33.

Tenter, A.M., Heckeroth, A.R., and Weiss, L.M. (2000). *Toxoplasma gondii*: from animals to humans. *International Journal for Parasitology* **30,** 1217-58.

Wallace, G.D., Marshall, L., and Marshall, M. (1972). Cats, rats, and toxoplasmosis on a small Pacific island. *American Journal of Epidemiology* **95,** 475-82.