

ASPECTS OF THE EPIDEMIOLOGY OF *CHLAMYDIA PSITTACI* INFECTION IN A POPULATION OF KOALAS (*PHASCOLARCTOS CINEREUS*) IN SOUTHEASTERN QUEENSLAND, AUSTRALIA

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ABSTRACT: A population of free-ranging koalas in southeastern Queensland was examined to determine the prevalence of *Chlamydia psittaci* infections. Although *C. psittaci* was isolated from 46 of 65 (71%) koalas studied, only six (9%) of these had clinical signs of disease. Most adult females (82%) had back or pouch young present even though 67% of them were infected. There were no significant correlations between age, sex or site of sampling (urogenital versus conjunctival tissues) and the isolation of *C. psittaci*. No other important bacterial or fungal pathogens were isolated. The complement fixation test had a sensitivity of 7% and a specificity of 94% in detecting chlamydial infections, suggesting that it is unsuitable for use as a screening test. *Chlamydia psittaci* infection within this population appeared to represent a generally well-balanced host-parasite relationship and few animals had clinical signs of disease. Only four of 27 (15%) healthy koalas infected with *C. psittaci* followed for 24 wk after sampling developed eye disease or "dirty tail." Two koalas with keratoconjunctivitis recovered without treatment during the study period. Additional factors, including the stresses imposed by loss of habitat, may act to produce overt disease in koalas with latent *C. psittaci* infections.

Key words: *Phascolarctos cinereus*, koala, *Chlamydia psittaci*, epidemiology, survey, complement fixation test, prevalence versus clinical disease.

INTRODUCTION

The koala (*Phascolarctos cinereus*) is the only Australian marsupial known to experience disease caused by *Chlamydia psittaci*. A complex of four chlamydiae-associated syndromes has been identified in koalas: keratoconjunctivitis (Cockram and Jackson, 1981); reproductive tract disease in female koalas, leading to infertility (Brown and Grice, 1984; McColl et al., 1984); urinary tract infection, also known as "dirty tail" or "wet bottom"; and rhinitis/pneumonia (Brown and Grice, 1984, 1986). All four syndromes were recognized in the early part of this century although their etiology was undetermined at the time (Pratt, 1937). Previous authors (Pratt, 1937; Strahan and Martin, 1982) have speculated on the potential importance of disease, especially infertility, as a limiting factor in

koala population dynamics. Other workers have demonstrated the occurrence of keratoconjunctivitis (Cockram and Jackson, 1981) and reproductive tract disease and infertility (Brown et al., 1984; Handasyde, 1986) across a wide range of koala habitats. However, there have been no prior surveys of the frequency of these syndromes in association with the prevalence of *C. psittaci* infection.

This paper investigates aspects of the epidemiology of chlamydial disease in free-ranging koalas together with the associated risk factors for infection. The findings presented here came from a population of 65 koalas in southeastern Queensland which was surveyed over a period of 3 wk. Repeated resightings of koalas from this population allowed for extended followup on a majority of the individuals. Attention is drawn to chronic stress factors, especially

those imposed by loss of habitat, and their possible role in promoting the escalation of koalas with latent *C. psittaci* infections to overt disease.

MATERIALS AND METHODS

Koalas and study site

A forest region within Redland Shire in southeastern Queensland, Australia (27°35'S, 153°18'E) was selected as the study site (Fig. 1). A survey conducted near the suburban portions of the Shire during October 1986 found 385 koalas (R. Patterson, Queensland National Parks and Wildlife Service, pers. comm.), indicating the presence of a large koala population in the area. Approximately 25% of the mainland portion of Redland Shire contains forested lands which remain undeveloped. However, this region is one of the fastest developing areas in Queensland with the main impact being urban encroachment.

The study site was located in tall, open, sclerophyll forest typical of the region and was demarcated by plastic flagging tape into five continuous 100 × 1,000-m transects (50 ha). The vegetation of the study site was dominated by *Eucalyptus acmenoides*, *E. fibrosa*, *E. maculata*, *E. phaeotricha*, *E. resinifera*, and *E. umbra*. Total 1986 rainfall in the area was 713 mm, 686 mm below the previous 70-yr average (Bureau of Meteorology, Commonwealth Department of Science, Department of Administrative Services, Canberra, A.C.T. 2601, Australia). The soil is predominantly red-yellow podzolic typical of the entire region (Beckmann, 1967). Fires are rare, the most recent one having been in 1983. In addition to cattle grazing, there is some recreational usage of the area.

The study was divided into two phases spread over 25 wk. Koalas were captured, tagged and sampled in the first phase (12 January to 2 February 1987). The second phase (21 February to 3 July 1987) involved 23 1-day surveys of the study site to resight tagged koalas and note their health status. Four to eight people were used to locate koalas within each of the transects. Koalas were captured, restrained in hessian bags, and anesthetized with a mask containing diethyl ether for examination and sampling. A color-coded numbering system using three plastic (sheep) Swivel-tags (Leader Products Australia Pty. Ltd., Craigburn, Victoria 3064, Australia) in the ears of each animal allowed for later identification of individual koalas without recapture.

Koalas were classified as young when they were found as dependent individuals on the back of a female or in the same tree as a female and

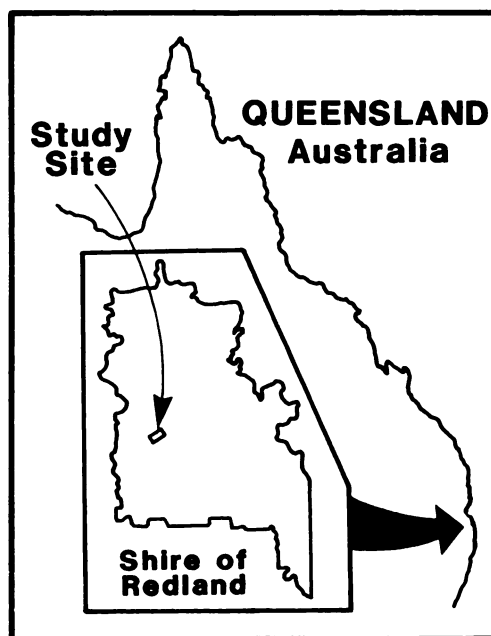


FIGURE 1. Location of koala study site in southeastern Queensland, Australia.

when no wear was visible on any cheek teeth. Subadult koalas were those found not associated with an adult female and having a body weight less than 4 kg and with no more than two parallel lines of dentin wear on their upper premolar teeth. Animals which exceeded these criteria or, in the case of females that had dependent young, were classified as adults.

Occurrence of disease

Every captured koala was examined externally in detail. The stage of ocular disease was determined according to the clinical description given by Cockram and Jackson (1981). Any observations of nasal discharge and/or abnormal respiratory sounds or efforts were recorded. The cloacal region of koalas was examined and individuals with urine-soaked and matted fur were classified as cases of "dirty tail."

Specimens

Five to 10 ml of blood were collected in serum separation tubes (Becton Dickinson, Rutherford, New Jersey 07070, USA) by cephalic venipuncture or by cardiac puncture (13 animals). Two sets of swabs were collected from the conjunctival and urogenital tissues of every koala in order to culture chlamydiae and other bacteria and fungi. Samples for isolation of chlamydiae were collected using sterile, cotton-tipped, plastic or aluminum-shafted swabs (Medical Wire

and Equipment Company, Corsham, Wiltshire, United Kingdom) and transported in chlamydia transport media (Spencer and Johnson, 1983) contained in 2-ml polystyrene vials (Nunc Cryotubes, Roskilde, Denmark). For bacterial and fungal isolation, sterile serum swabs (Johns Professional Products, South Oakleigh, Victoria 3167, Australia) were used and specimens were transported in Amies transport medium (Oxoid Australia Pty. Ltd., Hurstville, New South Wales 2220, Australia).

Urogenital swabs were collected from approximately 3 cm inside the urogenital canal of female koalas and 2 cm inside the penile urethra of males, except in the case of five males when only preputial swabs were possible. When sampling the urogenital tissues, swabs for bacterial and fungal culture were taken following the swabs for isolation of chlamydiae. For sampling the conjunctival tissues of each koala, the palpebral conjunctiva of one eye was swabbed for chlamydia and the other for bacteria/fungi. The eye selected for each swab was randomized between animals, except during cases of unilateral eye disease when only the abnormal eye was sampled.

Swabs were transported on water-ice to the laboratory within 2–9 hr of collection. Vials containing swabs with material intended for the isolation of chlamydiae were vortex mixed for 15 sec with sterile glass beads, the swabs were extracted, and the vials were then frozen in liquid nitrogen (-196 C) for 1–4 wk before culture. Bacterial/fungal swabs were stored at 4 C within Amies transport medium for up to 7 days before processing. Koala sera were withdrawn from blood clots upon arrival at the laboratory and stored frozen at -20 C for a maximum of 1 wk before testing.

Isolation of chlamydiae

The isolation of chlamydiae from swab extracts followed the procedure of Grice and Brown (1985) in BGM cell coverslip cultures with the following modifications: three coverslips were inoculated with each specimen and these were harvested at 5, 7 and 9 days; maintenance medium containing cycloheximide ($1\text{ }\mu\text{g/ml}$) was incubated on cultures for 48 hr; and preparations were examined in a single-blind fashion under bright-field light microscopy at $\times 100$ magnification. Specimens were scored positive when at least 10 typical intracytoplasmic chlamydial inclusions were encountered on any one of the three coverslips prepared from each specimen.

Complement-fixation test

A complement-fixation (CF) test was performed on koala serum samples in a microtitra-

tion system using guinea pig complement and rabbit hemolysin for sheep red blood cells. The test antigen consisted of yolk-sac propagated *C. psittaci* at optimum dilution isolated from a case of ovine enzootic abortion (Commonwealth Serum Labs, Parkville, Victoria 3052, Australia). Koala serum with a CF titer of 2:64 was included as a positive control. Endpoint titers were considered to be the highest two-fold serum dilutions producing $<50\%$ (2+) hemolysis.

Bacteriology and mycology

Swabs were streaked onto sheep blood agar (SBA) (CM 271, Oxoid Ltd.) and MacConkey's agar (CM 115, Oxoid Ltd.) for 18–24 hr aerobic culture at 37 C . Airdried smears were made for Gram staining. Fungi grew on some SBA plates from conjunctival swabs and these were cultured on Sabouraud dextrose agar (CM 41, Oxoid Ltd.) at 30 C for 24–72 hr and then identified by characteristic morphology under lacto-phenol-cotton-blue stain. Coliform bacteria were identified using the Enterotube II and Oxi-Ferm Tube II rapid diagnostic kits (F. Hoffmann La Roche & Co. Ltd. Diagnostica, Basle, Switzerland). Colony morphology on SBA and the results of Gram staining were sufficient to identify most other bacteria. The catalase and coagulase biochemical tests were used to differentiate Gram-positive cocci.

Followup observations

Followup surveys during the second phase of the project were conducted using a $\times 20$ magnification spotting scope or binoculars to monitor the condition of the eyes and the occurrence of "dirty tail" in previously tagged and sampled koalas.

Statistical analyses

Test sensitivity, specificity and prevalence estimates were calculated following Schwabe et al. (1977). Exact 95% confidence intervals and Chi-square values were determined using the methods of Fleiss (1981). Summary odds ratios were used to estimate risk factor odds of infection within the study population. The odds of infection between sexes controlling for age, and between ages controlling for sex, were calculated using Miettinen's modification of the Mantel-Haenszel stratification procedure (Kahn, 1983) in order to eliminate the possible confounding effect caused by the interaction between these two variables.

RESULTS

Koalas and study site

Sixty-five koalas were seen and captured within the study site and its immediate

TABLE 1. Composition of koala (*Phascolarctos cinereus*) study population in southeast Queensland and prevalence of infection with *Chlamydia psittaci*.

Age class ^a	Sex ^b	n	Frequency of <i>Chlamydia psittaci</i> isolations		
			Conjunctival	Urogenital	Combined ^c
Young	F	1	0	1	1
	M	4	1 (25%)	0	1 (25%)
Subadult	F	7	4 (57%)	5 (71%)	6 (86%)
	M	3	1 (33%)	0	1 (33%)
Adult	F	33 ^d	13 (39%)	15 (46%)	22 (67%)
	M	17	12 (71%)	10 (59%)	15 (88%)
Totals		65	31 (48%) ^e	31 (48%)	46 (71%)

^a See text for explanation of age classes.

^b F, female; M, male.

^c Reported as isolations from either or both sites swabbed.

^d Twenty-seven (82%) of these had pouch young or back young present.

^e The conjunctival swab from one koala was not cultured.

peripheral area (100 m) during the first phase of the project. All animals were released at their point of capture following sampling procedures. The composition of this koala population is given in Table 1. Overall, a daily mean of 25 koalas was found within the 50-ha study site, indicating a density of one koala per 2 ha. Immediately following the first phase of the project, 95% of the koalas seen had already been tagged and sampled. Three wk later this proportion had fallen to 85%; 4 wk later it was 75%. Twenty-four (73%) of the adult females had hairless pouch young which were too small to sample and these young were not included in the study. Five adult females (15%) had either back young or semi-independent young and two of these females were also nursing pouch young.

Occurrence of disease

Only six animals revealed clinical signs of disease during the first phase of the study. Three koalas had “dirty tail” (Fig. 2) which involved mild to moderate dermatitis. The urogenital canals of these koalas bled easily upon sampling. Three other koalas were observed with keratoconjunctivitis (Fig. 3), two cases unilateral and one bilateral, ranging in severity from acute conjunctival edema to a chronic in-

fection with peripheral corneal opacity and mild pannus formation.

The comparisons between these cases and the isolation of *C. psittaci* in tissue culture are shown in Table 2. The sensitivity and specificity of diagnosing infected koalas by clinical signs of disease in this study were determined to be 13% (5, 25) and 100% (76, 100), respectively (Schwabe



FIGURE 2. An example of “dirty tail” in a koala.



FIGURE 3. An example of keratoconjunctivitis in a koala.

et al., 1977). These point estimates are reported along with lower and upper bounds of the 95% confidence interval (Fleiss, 1981). Additionally, six other koalas had mild degrees of corneal scarring characterized by centralized, circular opaque regions which did not seem to interfere with vision. The conjunctival tissues from only one of these six koalas yielded *C. psittaci*.

Isolation of chlamydiae

Table 1 lists the results of attempts to isolate *C. psittaci* from the various population strata. Forty-six koalas (71%) were infected in either the conjunctival or urogenital tissues or both. There was no difference in the frequency of isolations from the urogenital tract and the conjunctiva (Chi-square = 0.01, $P = 0.93$). Adult males were more frequently infected than adult females (88% versus 67%), but these values were not significantly different (Chi-square = 1.70, $P = 0.19$). *Chlamydia psittaci* was isolated from two of five males in which preputial swabs were obtained. The overall odds ratio of male to female infections, controlling for age, was 1.07 (0.02, 56.82) calculated using the Mantel-Haenszel stratification procedure along with 95% confidence limits using Miettinen's method (Kahn, 1983). Eighteen (67%) of the females associated with a young of any age were infected at one or the other site. Ten (42%) of the females with pouch young

TABLE 2. Comparison of tissue culture with the complement-fixation test (CF) and clinical signs for the diagnosis of *Chlamydia psittaci* infections.

Tissue culture	CF positive ^a	CF negative	Clinical appearance ^b		Totals
			Dis-eased	Healthy	
Positive ^c	3	43	6	40	46
Negative	1	18 ^d	0	19 ^d	19
Totals	4	61	6	59	65

^a Defined here as any detectable complement fixation titer in koala serum.

^b Defined as a case of keratoconjunctivitis or "dirty tail" or both.

^c Cut-off value of 10 or more inclusion bodies per coverslip culture.

^d In one koala only the urogenital sample was cultured (negative).

had urogenital infections. Subadult and young age classes, pooled together into a new "juvenile" class because of the few samples available, appeared to have a lower proportion of infections (60%) than did adults (74%), but the difference was not significant (Chi-square = 0.52, $P = 0.47$). The overall odds ratio of adult to juvenile infections, controlling for sex, was 1.79 (0.16, 20.05). Six of the eight juvenile females (75%) had urogenital *C. psittaci* infections compared with none of the seven juvenile males.

Complement-fixation test

Table 2 lists the results of CF testing performed on koala serum samples compared to the isolation of *C. psittaci* in tissue culture. Only four koalas (6%) had detectable anti-chlamydial CF titers. Two of these (CF titers = 3:8 and 3:16) were free of clinical signs and chlamydiae were not isolated from them. A koala with keratoconjunctivitis and pannus had a CF titer of 3:16 and a koala with hemorrhagic "dirty tail" had a titer of 2:32. Chlamydiae were isolated from both conjunctival and urogenital swabs in these two koalas. Four koalas which were clinically diseased (two keratoconjunctivitis, two "dirty tail") had no detectable CF titer. In relation to tissue culture, the sensitivity of the CF test as a

diagnostic tool for *C. psittaci* infection was 7% (1, 17) and the specificity was 95% (69, 100).

Bacteriology and mycology

Pathogens other than *C. psittaci* were not isolated from koalas in this survey. A summary of the major findings, including the frequency of each isolation, is given in Table 3.

Followup observations

Most of the koalas (75%) were resighted at least once during the second phase of the project from 3 to 22 wk after the time of capture. Two or more resightings were made on 59% of the koalas, from 6 to 22 wk after capture. Among these, four new cases of disease were detected, one of "dirty tail" and three of keratoconjunctivitis (two unilateral). This represents 15% (four of 27) of the previously healthy but chlamydiae-infected koalas which were resighted. In addition, two of the previously diseased koalas (both cases of unilateral keratoconjunctivitis) were resighted more than 13 wk after capture, at which time clinical signs of disease were absent from them. Three other animals with clinical signs of disease at the time of capture were still diseased upon resighting up to 22 wk later. Two of these animals, one case of "dirty tail" and one case of bilateral keratoconjunctivitis, had not changed in severity, while another koala with "dirty tail" was found at 6 wk postcapture to have developed bilateral keratoconjunctivitis.

DISCUSSION

The high prevalence of chlamydial infections in koalas in the study population (71%) without a similarly high prevalence of disease (9%) indicates a host-parasite relationship that is long-established and generally stable (Schwabe et al., 1977). This is not surprising, since a balanced coexistence is probably the most common type of chlamydial infection in other animal species (Storz, 1971; Schachter et al., 1973). Previous records of these syndromes in ko-

TABLE 3. Bacteriological and mycological findings in 65 free-ranging koalas from southeastern Queensland in addition to *Chlamydia psittaci*.

Organism	Frequency of isolation*
Conjunctival swabs	
<i>Penicillium</i> spp.	9
<i>Bacillus</i> spp.	7
<i>Citrobacter freundii</i>	5
Other enterobacteria	7
<i>Staphylococcus aureus</i>	3
Diphtheroid rods	2
<i>Micrococcus</i> spp.	2
α -hemolytic streptococci	2
Unidentified fungus	2
Total	39
Urogenital swabs	
<i>Escherichia coli</i>	26
α -hemolytic streptococci	21
Diphtheroid rods	5
<i>Bacillus</i> spp.	4
<i>Pasteurella</i> spp.	4
<i>Aspergillus</i> spp.	2
<i>Klebsiella oxytoca</i>	2
Total	64

* Any organism isolated two or more times is reported.

alas (Pratt, 1937; Troughton, 1967) date from 1897, suggesting that the pathogen has been present in koalas for at least 90 yr.

Brown and Grice (1986) regard the relationship between *C. psittaci* and the four typical disease syndromes as causal, implying that it is the etiological agent associated with these conditions. The present study found that only six of 46 (13%) infected koalas displayed clinical signs of disease. Two of these cases recovered and four new cases developed during a 22-wk followup period. These observations suggest that additional factors may be required in order to produce disease after an animal has become infected. Furthermore, resightings of two individuals with severe "dirty tail" made up to 22 wk after their initial examination may indicate that diseased koalas can persist for prolonged periods in the population, thus contributing to transmission of the agent. These results are unlikely to be biased by the possibility of a high number of new infections.

Brown and Grice (1986) found an incubation period of 7–19 days for keratoconjunctivitis and 25–27 days for urinary tract disease in laboratory-infected koalas, much less than the period of time encompassed by our resighting data. Their results may have been artificially shortened by use of an abnormally large inoculum of infectious organisms and the stresses imposed by captivity.

Using a radiographic technique, Brown et al. (1984) estimated a 43% prevalence of reproductive tract disease within a combined sample of 237 female koalas spanning eastern Australia. Handasyde (1986) observed infertility in up to 78% of adult female koalas on Phillip Island, Victoria, Australia coinciding with a high prevalence of antichlamydial CF antibodies. Neither of these studies attempted to isolate *C. psittaci* from koalas. Of all adult female koalas in the present study, 27 of 33 (82%) had young, although *C. psittaci* was isolated from 22 of 33 (67%) of them. This includes urogenital infections within 10 of 24 (42%) of the females carrying hairless pouch young, compared with five of nine (56%) infections in female koalas without such young. As in all marsupials, the gestation period in koalas is very short, lasting approximately 34–36 days; pouch life extends for about another 9 mo. Pouch young are not completely haired until 6–7 mo old (Smith, 1979). Thus, the majority of female koalas captured in the present study must have been fertile at least as late as July 1986. Continued followup on these individuals to determine their future reproductive success in the face of *C. psittaci* infection would be informative. However, it appears from the present information that urogenital infection alone correlates poorly with the fertility status of adult females. An improved understanding of the relationship between these factors will be possible once more specific aging criteria are established.

Reasons why the CF test performed poorly in this study are unknown. The CF test relies upon the presence of immuno-

globulins stimulated by the heat-stable, acid lipopolysaccharide (LPS) antigen, which is common to both *C. psittaci* and *C. trachomatis* (Treharne and Forsey, 1983). Humans with ocular and genital infections caused by the related organism, *C. trachomatis*, do not commonly develop CF titers; when they do, the titers are generally low (Darougar, 1985). Storz (1971) notes that chlamydial organisms infecting mucosal surfaces, including the intestines, may not induce humoral antibody production. Interestingly, cattle infected with *C. psittaci* have shown a predominant IgG₂ response which has been associated with the LPS antigen (Schmeer et al., 1986). However, bovine IgG₂ is unable to bind guinea pig complement, a fact which may help to explain the poor performance of the CF test in that species. The present findings suggest that the CF test is unsuitable for use as a screening tool to determine if free-ranging koalas are free of chlamydial infection or disease.

Differing results have come from studies conducted in Victoria, Australia (McColl et al., 1984; Handasyde, 1986) in which a high proportion of seropositive koalas were found in free-ranging populations. These divergent findings might be explained by hypothetical regional differences in the immunogenicity of *C. psittaci* isolates in relation to host factors, especially the ability of koalas to respond with humoral, complement-fixing antibody production. Brown and Grice (1986) reported the poor CF response of four koalas experimentally infected with *C. psittaci*. In that study, one individual took up to 113 days to seroconvert while the other three individuals, all showing clinical signs of chlamydial disease remained seronegative until their death up to 126 days postinfection. Another possibility is that the procedure and components of the CF test is non-standard across laboratories. An unlikely scenario suggests that the entire population in the present study was recently infected and therefore sampled during the lag period of humoral antibody production.

In a concurrent study, Weigler et al. (1988) evaluated a commercially available enzyme immunoassay for the diagnosis of *C. psittaci* infection in koalas and found it also lacked sufficient sensitivity to be useful as a screening tool. Moreover, most koalas subclinically infected with *C. psittaci* probably shed a low concentration of the organism, precluding the effective use of tests which have been designed for clinically affected groups. Therefore, until more sensitive techniques have been developed, the isolation of *C. psittaci* in tissue culture remains the best method of diagnosis.

Animals harboring chlamydial infections without clinical signs of disease may be regarded as latent or “silent” chronic carriers, transmitting the agent to new hosts under the appropriate conditions. Inapparent infections of this type commonly exist within the intestinal tracts of ruminants and birds; for them, fecal shedding may be the most important mode of transmission (Storz, 1971; Schachter et al., 1973). Brown and Grice (1984) isolated *C. psittaci* from the rectums of koalas at post mortem. Handasyde (1986) suggested that venereal transmission is the most important mechanism in koalas, but has disregarded the fact that koala young ingest maternal feces during weaning, thereby allowing for the possibility of fecal-oral transmission of the agent. In contrast to Handasyde’s (1986) findings, our results suggest that chlamydiae can occur in koalas before they have sexually matured.

Standard bacteriological testing of urogenital swabs isolated no unusual organisms, and the organisms present probably represent normal flora for the koala. The presence of several species of enteric bacteria in the eyes is interesting and could be attributed to mechanical movement by the koala, or possibly from contamination during sampling or processing. Small volumes of fecal material could have entered the eyes when the animals were confined within the bag used for restraint following capture. Fecal contamination might ad-

ditionally be responsible for some of the chlamydial isolations found in the present study. However, this risk was minimized by frequently renewing the bags over the course of the study, careful asepsis of animal handlers and disposing of any bag which held an overtly diseased koala.

Age, sex and site of sampling all correlated poorly with the presence of *C. psittaci* infection in koalas. Sexually-active males might be at a greater risk, perhaps representing an important source of transmission, but the present study had insufficient numbers to substantiate this possibility. After pooling age classes a much higher proportion of juvenile females had urogenital infections than did juvenile males. This may in part be due to the difficulty in obtaining adequate samples from the urethra of juvenile males. Another consideration is that it represents misclassification of age by sex, with an underestimation of the age of female individuals. Because of the low number of overtly diseased koalas, we did not investigate risk of clinical disease independent of the risk of infection.

Strahan and Martin (1982) stated that chlamydial diseases may be an important population density control factor in overcrowded koala colonies freed from their previous pressures of predation. No other detailed surveys have been performed in Queensland to suggest whether the prevalence of *C. psittaci* infection in this study exceeded its expected frequency. However, deforestation within southeastern Queensland is continuing and will probably result in high levels of crowding and competition among koalas, a species which normally exhibits solitary behavior (Eberhard, 1978). Conceivably, these effects, acting as a source of chronic stress within the population, could depress the usual defense and immune mechanisms operating in koalas and predispose individuals with latent *C. psittaci* infections to develop clinical disease. A second consideration is that competition and crowding might act to increase the amount of pathogen shed-

ding and subsequently increase the potential for transmission to susceptible koalas. The effects of stress on the depression of host resistance to disease have been discussed elsewhere (McLean, 1982).

Further studies utilizing an epidemiological approach are needed in order to compare koala populations across different regions. Prospective studies would help to elucidate some of the risk factors of chlamydial infection and associated diseases more precisely, allowing for appropriate control measures to be instituted. Meanwhile, it seems prudent in the long-range conservation interests of this popular animal to broadly identify and preserve remaining natural koala habitat.

ACKNOWLEDGMENTS

The authors wish to thank Alvin Alcova, Denis Denais, Dean Holzworth, Shane Mulo, Chris Nash, Stephen Oliver and David Owens for assisting with the fieldwork. We are grateful to the Virology Section for performing serology and to Chris Baldock of the Pathology Branch for statistical advice, both at the Animal Research Institute, Queensland Department of Primary Industries, Yeerongpilly. We thank Trish Kettlewell from the Department of Veterinary Pathology and Public Health for performing bacteriology and mycology. B. Weigler was sponsored under the auspices of the Australian-American Educational Foundation. N. White and N. Kunst were working under a grant made available by the Kagoshima City Zoological Garden Association, Queensland National Parks and Wildlife Service and the Queensland Institute of Technology.

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Received for publication 14 July 1987.