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Sarcocystis AND RELATED ORGANISMS IN AUSTRALIAN WILDLIFE: II. SURVEY FINDINGS IN BIRDS, REPTILES, AMPHIBIANS AND FISH

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Abstract: *Sarcocystis* was found in 105 (44 species, 25 families) of 832 (12.6%) (129 species, 43 families) avian muscle samples. Muscle sarcocysts were most prevalent (16-29%) in certain carnivorous, omnivorous or insectivorous birds. Lower prevalences (6-13%) were recorded in other carnivorous, ground-feeding omnivorous and insectivorous birds. In waterfowl, prevalence of infection was only 3.5%. Generally, sarcocysts in bird muscle were thin-walled (<0.5 μ m) with small zoites. However, those in little pied cormorants (*Phalacrocorax melanoleucos*), hoary-headed grebes (*Podiceps poliocephalus*) and a pelican (*Pelecanus conspicillatus*) examined in Victoria had thicker (0.5-1 μ m) walls.

Three of 53 (5.7%) muscle samples from reptiles (14 species, four families) had *Sarcocystis*. Greatest prevalence was found in goannas (*Varanus* spp.) where two of three specimens were positive.

Ninety samples from nine amphibian species (two families) and seven from five species of fish (five families) were negative for muscle sarcocysts.

Sporocysts and oocysts of *Sarcocystis* or *Frenkelia* were found in intestinal scrapings from eight of 18 (44.4%) barn owls (*Tyto* spp.), two of five (40.0%) spotted owls (*Ninox novaeseelandiae*), and two of seven (28.6%) brown falcons (*Falco berigora*). Mucosal scrapings from five of 12 (41.7%) elapid snakes (one *Austrelaps superba* and four *Notechis ater*) were positive for sporocysts and oocysts.

INTRODUCTION

In their recent review of the literature, Kalyakin and Zasukin¹² found references for *Sarcocystis* in muscle from 71 avian species in 28 families, and from 11 reptilian species in nine families. Host records were of *Sarcocystis* sp., with few named species, and there was no inclusion of prevalence data, or life cycle investigations. Sarcocysts in muscle from amphibians and fish were not recorded.¹²

Later, two psittacine species² and the cowbird (*Molothrus ater*)^{3,10} were added as hosts for muscle sarcocysts. In a recent survey of 636 ducks, geese and swans, comprising 32 species, in British Columbia, Canada, sarcocysts were

found in only three (0.5%) birds; the species harboring *Sarcocystis* were not listed.¹³

There are no published records of *Sarcocystis* in muscle from wild birds in Australia, but infection recently has been reported in chickens.¹⁶ Among reptiles, muscle sarcocysts have been recorded in carpet pythons (*Morelia spilotes*).²¹

Sexual stages of *Sarcocystis* occur in the intestinal mucosa of predators, resulting in production of sporulated sporocysts, either free or enveloped in pairs within a fine oocyst wall. Sporocysts and oocysts, typical of those of *Sarcocystis* or *Frenkelia*, have been seen in feces and intestinal mucosal

scrapings from predatory birds^{1,5-7,14,15} and reptiles.^{4,19,24}

The lack of published information on *Sarcocystis* in Australian wildlife prompted a survey of available collection material for its prevalence. Results of our findings in mammals were presented recently,¹⁷ and survey data for birds, reptiles, amphibians and fish are presented herein.

MATERIALS AND METHODS

Examination for Muscle Cysts

Muscle samples were obtained from 832 birds (129 species, 43 families), 53 reptiles (14 species, four families), 90 amphibians (nine species, two families), and seven fish (five species, five families) (Table 1). Most samples were obtained during various scientific collections, as part of pest-control programs, or fortuitously as road kills, in Tasmania, Victoria and New South Wales.

Skeletal muscle samples from pectoral and limb muscles from each animal were usually examined. Heart muscle and gastrointestinal smooth muscle also were examined from many specimens. Tissues fixed in 10% formol saline or 70% alcohol were paraffin embedded, sectioned at 6-10 μ m and stained with haematoxylin and eosin (H & E). Samples were not examined by squash preparation or digestion techniques.

Scrapings from intestinal mucosa were examined for sporocysts of *Sarcocystis* and/or *Frenkelia* in 69 birds (14 species, seven families) and 17 reptiles (four species, two families) (Table 2).

RESULTS

Examination for Muscle Cysts

Birds: Of the 832 bird samples examined, *Sarcocystis* was recorded in 105 (12.6%), representing 44 species in 25 families (Table 1). Greatest prevalences of infection occurred in certain carnivorous birds (cormorants, herons,

TABLE 1. Prevalence of thin-walled sarcocysts in muscle of some Australian birds, reptiles, amphibians and fish.

CLASS	FAMILY Species	Number Examined		Prevalence (%)
		Total	Infected	
AVES*	DROMAIDAE (emus)	2	0	—
	SPHENISCIDAE (penguins)	19	0	—
	PROCELLARIIDAE (petrels)	25	0	—
	HYDROBATIDAE (storm-petrels)	1	0	—
	PODICIPEDIDAE (grebes) <i>Podiceps poliocephalus</i>	2	2	(100.0)
	PELECANIDAE (pelicans) <i>Pelecanus conspicillatus</i>	5	1	(20.0)
	ANHINGIDAE (darters) <i>Anhinga rufa</i>	4	2	(50.0)

TABLE 1. (continued)

PHALACROCORACIDAE (cormorants)			
<i>Phalacrocorax carbo</i>	1	0	—
<i>Phalacrocorax sulcirostris</i>	10	4	(40.0)
<i>Phalacrocorax varius</i>	3	2	(66.7)
<i>Phalacrocorax melanoleucos</i>	5	1	(20.0)
Totals	15	3	(20.0)
	34	10	(29.4)
ARDEIDAE (herons)			
<i>Ardea pacifica</i>	6	0	—
<i>Egretta alba</i>	5	2	(40.0)
<i>Nycticorax caledonicus</i>	4	1	(25.0)
Totals	7	2	(28.6)
	22	5	(22.7)
THRESKIORNITHIDAE (ibis)			
<i>Platelea flavipes</i>	26	0	—
Totals	1	1	(100.0)
	27	1	(3.7)
ANATIDAE (ducks and geese)			
<i>Anseranas semipalmata</i>	41	0	—
<i>Anas superciliosa</i>	8	1	(12.5)
<i>Anas gibberifrons</i>	30	1	(3.3)
Totals	6	1	(16.7)
	85	3	(3.5)
ACCIPITRIDAE (hawks and kites)			
<i>Elanus notatus</i>	4	0	—
<i>Accipiter fasciatus</i>	2	1	(50.0)
Totals	6	1	(16.7)
	12	2	(16.7)
FALCONIDAE (falcons and kestrels)			
<i>Falco berigora</i>	5	0	—
Totals	8	3	(37.5)
	13	3	(23.1)
GRUIDAE (cranes)			
	1	0	—

TABLE 1. (continued)

CLASS	FAMILY Species	(common name)	Number Examined		Prevalence (%)
			Total	Infected	
RALLIDAE (native hens & coots)	<i>Tribonyx mortierii</i>		7	0	—
	<i>Porphyrio porphyrio</i>		12	1	(8.3)
	<i>Fulica atra</i>		27	8	(29.6)
			27	10	(37.0)
	Totals		73	19	(26.0)
OTTIDAE (bustards)			2	0	—
	CHARADRIIDAE (plovers)		5	0	—
	STERCORARIIDAE (skuas)				—
	<i>Catharacta lonnbergi</i>		2	1	(50.0)
LARIDAE (gulls)			1	0	—
	<i>Larus pacificus</i>		1	1	(100.0)
	<i>Larus novaehollandiae</i>		16	2	(12.5)
	Totals		18	3	(16.7)
COLUMBIDAE (pigeons)			3	0	—
					—
PSITTACIDAE (parrots)	<i>Platycercus elegans</i>		41	0	—
	<i>Platycercus eximus</i>		25	2	(8.0)
	<i>Psephotus haematonotus</i>		2	1	(50.0)
	<i>Psephotus varius</i>		1	1	(100.0)
			4	1	(25.0)
Totals			73	5	(6.8)
					—
CUCULIDAE (cuckoos)			6	0	—
TYTONIDAE (barn owls)			8	0	—
STRIGIDAE (owls)			5	0	—

TABLE 1. (continued)

CAPRIMULGIDAE (frogmouths)	5	0	—
ALCEDINIDAE (kookaburras)	23	5	(21.7)
<i>Dacelo gigas</i>			
ALAUDIDAE (larks)	4	0	—
HIRUNDINIDAE (swallows)	3	0	—
<i>Petrochelidon nigricans</i>	3	1	(33.3)
Totals	6	1	(16.7)
GRALLINIDAE (magpie-larks)	2	0	—
TURDIDAE (thrushes)	7	0	—
MALURIDAE (wrens)			
<i>Malurus cyaneus</i>	27	3	(11.1)
ACANTHIZIDAE (warblers)	22	0	—
<i>Sericornis frontalis</i>	15	4	(26.7)
Totals	37	4	(10.8)
MUSCICAPIDAE (robins)	21	0	—
<i>Petroica phoenicea</i>	9	1	(11.1)
Totals	30	1	(3.3)
PACHYCEPHALIDAE (whistlers)	1	0	—
<i>Colluricincla harmonica</i>	9	1	(11.1)
Totals	10	1	(10.0)
DICAEDIDAE (pardalotes)	2	0	—
<i>Pardalotus punctatus</i>	7	1	(14.3)
<i>Pardalotus striatus</i>	35	2	(5.7)
Totals	44	3	(6.8)
ZOSTEROPIDAE (silvereyes)			
<i>Zosterops lateralis</i>	37	2	(5.4)

TABLE 1. (continued)

CLASS	FAMILY Species	(common name)	Number Examined		Prevalence (%)
			Total	Infected	
	MELIPHAGIDAE (honeyeaters)		31	0	—
	<i>Melithreptus validirostris</i>		29	15	(51.7)
	<i>Meliphaga flavicollis</i>		15	5	(33.3)
	Totals		75	20	(26.7)
	SPERMESTIDAE (grass finches)		4	0	—
	<i>Emblema bella</i>		5	2	(40.0)
	Totals		9	2	(22.2)
	PLOCEIDAE (sparrows)		3	0	—
	FRINGILLIDAE (finches)		5	0	—
	STURNIDAE (starlings)		6	0	—
	CRATICIDAE (magpies & currawongs)				
	<i>Gymnorhina hypoleuca</i>		23	2	(8.7)
	<i>Strepera graculina</i>		8	2	(25.0)
	Totals		31	4	(12.9)
	CORVIDAE (ravens)				
	<i>Corvus tasmanicus</i>		18	1	(5.6)
REPTILIA**	<i>Corvus</i> spp.		6	1	(16.7)
	Totals		24	2	(8.3)
	DERMOCHELYIDAE (leathery turtles)				
	VARANIDAE (goannas)		1	0	—
	<i>Varanus gouldii</i>		2	1	(50.0)
	<i>Varanus varius</i>		1	1	(100.0)
	Totals		3	2	(66.7)

TABLE 1. (continued)

SCINCIDAE (skinks)	<i>Leiopeltis metallica</i>				
	Totals		32	0	—
			5	1	(20.0)
			37	1	(2.7)
ELAPIDAE (snakes)			12	0	—
LEPTODACTYLIDAE (southern frogs)			70	0	—
HYLIDAE (tree frogs)			20	0	—
SALMONIDAE (trout)			2	0	—
ARRIPIDAE (Australian salmon)			1	0	—
CARANGIDAE (trevally)			1	0	—
PLATYCEPHALIDAE (flathead)			2	0	—
POMATOMIDAE (tailor)			1	0	—
TOTAL BIRDS			832	105	(12.6)
TOTAL REPTILES			53	3	(5.7)
TOTAL AMPHIBIANS			90	0	(0.0)
TOTAL FISH			7	0	(0.0)
OVERALL TOTAL			982	108	(11.0)

*NEGATIVE BIRDS. DROMAIIDAE: *Dromaius novaehollandiae* (2); SPHENICIDAE: *Aptenodytes patagonica* (2); *Pygoscelis papua* (3); *Eudyptes chrysocome* (1); *E. schlegeli* (4); *E. minor* (9); PROCELLARIIDAE: *Macronectes giganteus* (2); *Pachyptila desolata* (3); *Adamastor cinereus* (1); *Puffinus griseus* (1); *P. tenuirostris* (17); *P. gavia* (1); HYDROBATIDAE: *Pelagodroma marina* (1); PHALACROCORACIDAE: *Phalacrocorax albiventer* (1); ARDEIDAE: *Egretta garzetta* (6); THRESKIORNITHIDAE: *Threskiornis molucca* (5); *T. spinicollis* (21); ANATIDAE: *Dendrocygna eytoni* (1); *Cygnus atratus* (8); *Cereopsis novaehollandiae* (1); *Tadorna tadornoides* (3); *Anas castanea* (8); *A. rhynchotis* (2); *Chenonetta jubata* (14); *Biziura lobata* (4); ACCIPITRIDAE: *Accipiter cirrocephalus* (1); *Aquila audax* (2); *Haliaeetus leucogaster* (1); FALCONIDAE: *Falco longipennis* (4); *F. cenchroides* (1); GRUIDAE: *Grus rubicunda* (1); RALLIDAE: *Porzana tabuensis* (1); *Gallinula australis* (1); *Gallinula tenebrosa* (5); OTITIDAE: *Eupodotis australis* (2); CHARADRIIDAE: *Vanellus miles* (5); LARIDAE: *Sterna bergii* (1); COLUMBIDAE:

TABLE 1. (continued)

<i>Streptopelia chinensis</i> (1); <i>Phaps chalcoptera</i> (2); PSITTACIDAE: <i>Trichoglossus haemotodus</i> (2); <i>Calyptrorhynchus funereus</i> (2); <i>Cacatua galerita</i> (2); <i>C. leadbeateri</i> (1); <i>Eolophus roseicapillus</i> (4); <i>Polytelis anthopeplus</i> (1); <i>P. alexandrae</i> (1); <i>Alisterus scapularis</i> (5); <i>Platycercus caledonicus</i> (12); <i>Neophema bourkii</i> (2); <i>N. splendida</i> (1); <i>Melopsittacus undulatus</i> (7); <i>Barnardius barnardi</i> (1); CUCULIDAE: <i>Cacomantis pyrrhophanus</i> (1); <i>Chrysococcyx lucidus</i> (5); TYTONIDAE: <i>Tyto alba</i> (5); <i>T. novaehollandiae</i> (3); STRIGIDAE: <i>Ninox novaeseelandiae</i> (5); CAPRIMULGIDAE: <i>Podargus strigoides</i> (5); ALAUDIDAE: <i>Alauda arvensis</i> (4); HIRUNDINIDAE: <i>Hirundo neoxena</i> (3); GRALLINIDAE: <i>Grallina cyanoleuca</i> (2); TURDIDAE: <i>Zoothera dauma</i> (1); <i>Turdus merula</i> (6); ACANTHIZIDAE: <i>Acanthiza pusilla</i> (15); <i>A. ewingii</i> (7); MUSCICAPIDAE: <i>Petroica multicolor</i> (4); <i>P. rodinogaster</i> (3); <i>P. vittata</i> (9); <i>Eopsaltria australis</i> (1); <i>Rhipidura fuliginosa</i> (3); <i>R. leucophrys</i> (1); PACHYCEPHALIDAE: <i>Pachycephala pectoralis</i> (1); DICAEIFIDAE: <i>Pardalotus substriatus</i> (2); MELIPHAGIDAE: <i>Acanthorhynchus tenuirostris</i> (4); <i>Melithreptus affinis</i> (17); <i>Phylidonyris pyrrhoptera</i> (5); <i>Manorina melanophrys</i> (1); <i>Acanthochaera paradoxa</i> (4); SPERMESTIDAE: <i>Bathilda ruficauda</i> (1); <i>Taeniopygia guttata</i> (1); <i>Poephila acuticauda</i> (2); PLOCEIDAE: <i>Passer domesticus</i> (3); FRINGILLIDAE: <i>Carduelis carduelis</i> (5); STRUNIDAE: <i>Sturnus vulgaris</i> (4); <i>Acridotheres tristis</i> (2).
**NEGATIVE REPTILES, DERMOCHELYIDAE: <i>Dermochelys coriacea</i> (1); SCINCIDAE: <i>Egernia whitii</i> (9); <i>Leiopisma delicata</i> (5); <i>L. entrecasteauxii</i> (5); <i>L. ocellata</i> (5); <i>L. trilineata</i> (6); <i>Tiliqua nigrolutea</i> (2); ELAPIDAE: <i>Austrelaps superba</i> (1); <i>Notechis ater</i> (6); <i>Pseudechis porphyriacus</i> (2); <i>Pseudonaja nuchalis</i> (3).
+NEGATIVE AMPHIBIANS. LEPTODACTYLIDAE: <i>Crinia signifera</i> (10); <i>C. tasmaniensis</i> (10); <i>Geocrinia laevis</i> (10); <i>Lymnodynastes dumerillii</i> (10); <i>L. peronii</i> (10); <i>L. tasmaniensis</i> (10); <i>Pseudophryne semimarmorata</i> (10); HYLIDAE: <i>Litoria ewingii</i> (10); <i>L. aurea</i> (10).
++NEGATIVE FISH. SALMONIDAE: <i>Salmo trutta</i> (2); ARRIPIIDAE: <i>Arripis trutta</i> (1); CARANGIDAE: <i>Usacaranx georgianus</i> (1); PLATYCEPHALIDAE: <i>Platycephalus</i> spp. (2); POMATOMIDAE: <i>Pomatomus saltator</i> (1).

kookaburras, pelicans, hawks and falcons), and in omnivorous or insectivorous birds (honeyeaters, coots and native hens, grass finches, gulls and swallows). Lower prevalences of *Sarcocystis* infection was recorded in other carnivorous birds (magpies, currawongs and ravens), ground-feeding omnivores (wrens, scrub-wrens, shrike-thrushes, parrots, ibis and spoonbills) and insectivorous species (pardalotes, silvereyes and robins). Of 85 samples from waterfowl, only three (3.5%) were positive, but many of the birds examined were very young. Positive findings also were recorded in the small numbers of grebes, darters and skuas examined (Table 1). Negative results in many families simply may be due to the small sample size. However, for certain birds where reasonable numbers were examined, the absence of *Sarcocystis* may be a valid observation.

Generally sarcocysts were uniform in appearance, having a thin (<0.5 μ m), sometimes imperceptible wall, and small zoites. The maximum cyst size was 2000 by 90 μ m (Figs. 1,2). Most appeared to be *Sarcocystis* but it was not possible to positively differentiate them from *Hammondia* or *Toxoplasma* in all instances. Sarcocysts with more definite walls, 0.5-1 μ m thick, and measuring up to 2500 by 150 μ m, were found in three of 10 little pied cormorants, *Phalacrocorax melanoleucos*, and two of two hoary-headed grebes, *Podiceps poliocephalus*, and one of three pelicans (*Pelecanus conspicillatus*) examined from eastern Victoria (Fig. 3). Cysts with walls like these were not detected in any Tasmanian waterbirds. An additional finding in the parasites in the pelican was the presence of very fine trabeculae.

Sarcocysts usually were not found in the myocardium, even in those birds with heavy infections in their skeletal muscles; however, the myocardium of every bird was not examined. Myocardial sarcocysts were found in a southern skua, *Stercoraria skua*, two white-backed

TABLE 2. Prevalence of oocysts or sporocysts of *Sarcocystis* or *Frenkelia* species in the intestines of Australian birds and reptiles.

CLASS	FAMILY Species	(Common name)	Number Examined		Prevalence (%)
			Total	Infected	
AVES*		ACCIPITRIDAE (hawks and kites)	9	0	—
		FALCONIDAE (Falcons and kestrels)	5	0	—
		<i>Falco berigora</i>	7	2	(28.6)
		Totals	12	2	(16.7)

TABLE 2. (continued)

CLASS	FAMILY Species	(Common name)	Number Examined		Prevalence (%)
			Total	Infected	
	TYTONIDAE (barn owls)				
	<i>Tyto alba</i>		2	2	(100.0)
	<i>Tyto novaehollandiae</i>		16	6	(37.5)
	Totals		18	8	(44.4)
	STRIGIDAE (owls)				
	<i>Ninox novaeseelandiae</i>		5	2	(40.0)
	CAPRIMULGIDAE (frogmouths)		2	0	—
	ALCEDINIDAE (kookaburras)		1	0	—
	CORVIDAE (ravens)		22	0	—
REPTILIA**	SCINCIDAE (skinks)		5	0	—
	ELAPIDAE (snakes)				
	<i>Austrelaps superba</i>		4	1	(25.0)
	<i>Notechis ater</i>		8	4	(50.0)
	Totals		12	5	(41.7)
	TOTAL BIRDS		69	12	(17.4)
	TOTAL REPTILES		17	5	(29.4)
	OVERALL TOTALS		86	17	(19.8)

*NEGATIVE BIRDS. ACCIPITRIDAE: *Accipiter fasciatus* (5); *A. cirrocephalus* (1); *Aquila audax* (1); *Circus approximans* (1); *Haliaeetus leucogaster* (1); FALCONIDAE: *Falco longipennis* (5); CAPRIMULGIDAE: *Podargus strigoides* (2); ALCEDINIDAE: *Dacelo gigas* (1); CORVIDAE: *Corvus mellori* (14); *C. tasmanicus* (8).

**NEGATIVE REPTILES. SCINCIDAE: *Leiopisma metallica* (3); *Tiliqua nigrolutea* (2).

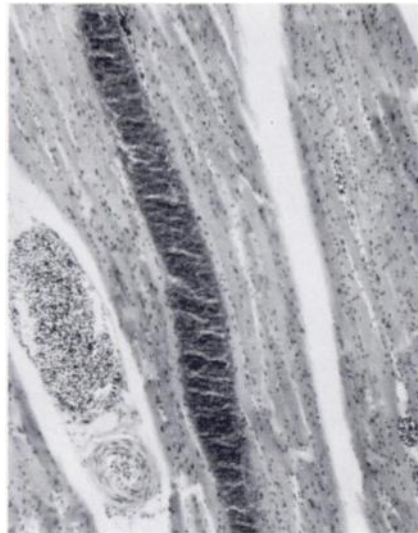


FIGURE 1. Thin-walled sarcocyst in skeletal muscle of *Pardalotus striatus*. Note that the cyst wall is practically imperceptible. H&E $\times 375$



FIGURE 2. Thin-walled sarcocyst in skeletal muscle of *Fulica atra*. Note the thin, but definite, cyst wall (arrowed). H&E $\times 1500$

magpies, *Gymnorhina hypoleuca*, and one hoary-headed grebe (Fig. 4). In each of these instances sarcocysts were not found in muscles other than the myocardium. Even so, the organisms did not appear to differ markedly from those in skeletal muscles except that the contents of some cysts in magpies had a rather homogeneous appearance; these may have been immature cysts containing metrocytes.

A limited number of smooth muscle samples (gastro-intestinal wall) were examined, but sarcocysts were not detected, even in those birds with *Sarcocystis* elsewhere in the musculature.

Reptiles: *Sarcocystis* was seen in three of the 53 reptilian muscle samples examined (Table 1). Numerous sarcocysts were found in a metallic skink, *Leiopisma metallica*. These cysts were 1100 by 160 μm with no visible trabeculae on light microscopic examination. Sarcocysts in two goannas, *Varanus gouldii* and *V. varius*, were thin-walled and had small zites. A cyst in skeletal muscle of *V. gouldii* measured 220 by 165 μm , while one in the myocardium was 30 by 27.5 μm . A cyst, 45 by 37 μm , was located in the myocardium of *V. varius*.

Amphibians and Fish: Muscle samples from 10 specimens of each of nine amphibian species were all negative (Table 1). Negative results also were obtained from examination of a small number of fish, representing five families (Table 1).

Examination for Oocysts and Sporocysts

Sporocysts typical of *Sarcocystis* or *Frenkelia* were found in intestinal mucosal scrapings of four avian and two reptilian species (Table 2). Although the number of specimens examined was small, positive findings were confined to predatory birds (hawks and owls), and two species of elapid snakes, the copperhead, *Austrelaps superba* and black tiger snake, *Notechis ater*.



FIGURE 3. Sarcocyst in skeletal muscle of *Podiceps poliocephalus*. Note definite cyst wall approx. 1 μ m thick (arrowed). H&E \times 1500

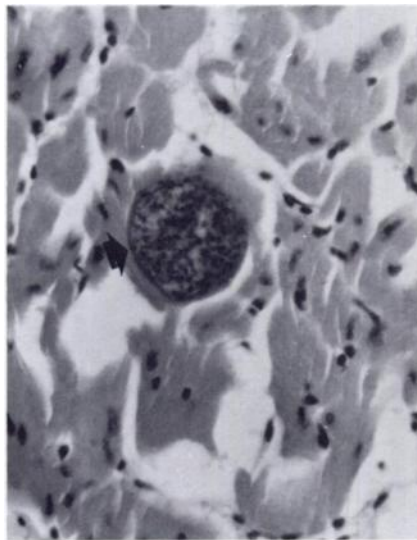


FIGURE 4. Sarcocyst in myocardium of *P. poliocephalus*. Note definite cyst wall (arrowed). H&E \times 1500

Sporocysts from brown falcons, *Falco berigora*, measured 12-14 by 7.25 μ m and contained four sporozoites, as well as scattered residual granules. A few sporocysts occurred in pairs surrounded by a fine oocyst wall.

The organisms from three species of owls, *Tyto alba*, *T. novaehollandiae* and *Ninox novaeseelandiae*, appeared to be identical. Oocysts measured 15-19 by 12-14 μ m and sporocysts, 12-15 by 7-10 μ m. Each sporocyst contained four sporozoites and a residual body 6 μ m in diameter (Fig. 5).

Sporulated oocysts in mucosal scrapings of the copperhead were approximately 15 μ m in diameter. Oocysts from the black tiger snake measured 14-15 by 11-14 μ m, while sporocysts were 10-11 by 7 μ m with four sporozoites and numerous residual granules (Fig. 6). Oocyst development appeared to occur in the lamina propria of the small intestine, but this was difficult to determine because the mucosa was autolyzed.

DISCUSSION

Our findings agree with published data¹² that *Sarcocystis* occurs in the musculature of birds and reptiles, but not in amphibians or fish. The avian hosts in which we found muscle sarcocysts are all new records for *Sarcocystis*. These include 18 new hosts in six families (Ardeidae, Anatidae, Accipitridae, Rallidae, Psittacidae and Corvidae) for which records from other countries have been reported.¹² We also add 26 new host records for 19 additional families (Table 1). To the list of reptilian hosts for *Sarcocystis*,¹² we add three new records representing two additional families.

Additional definitive hosts for *Sarcocystis* and/or *Frenkelia* also were found (Table 2). One new owl host has been added to previous records,^{7,15} as well as the brown falcon. Prevalence of infection in these birds of prey was very similar to data reported recently in Czechoslovakia.⁷ The copperhead and

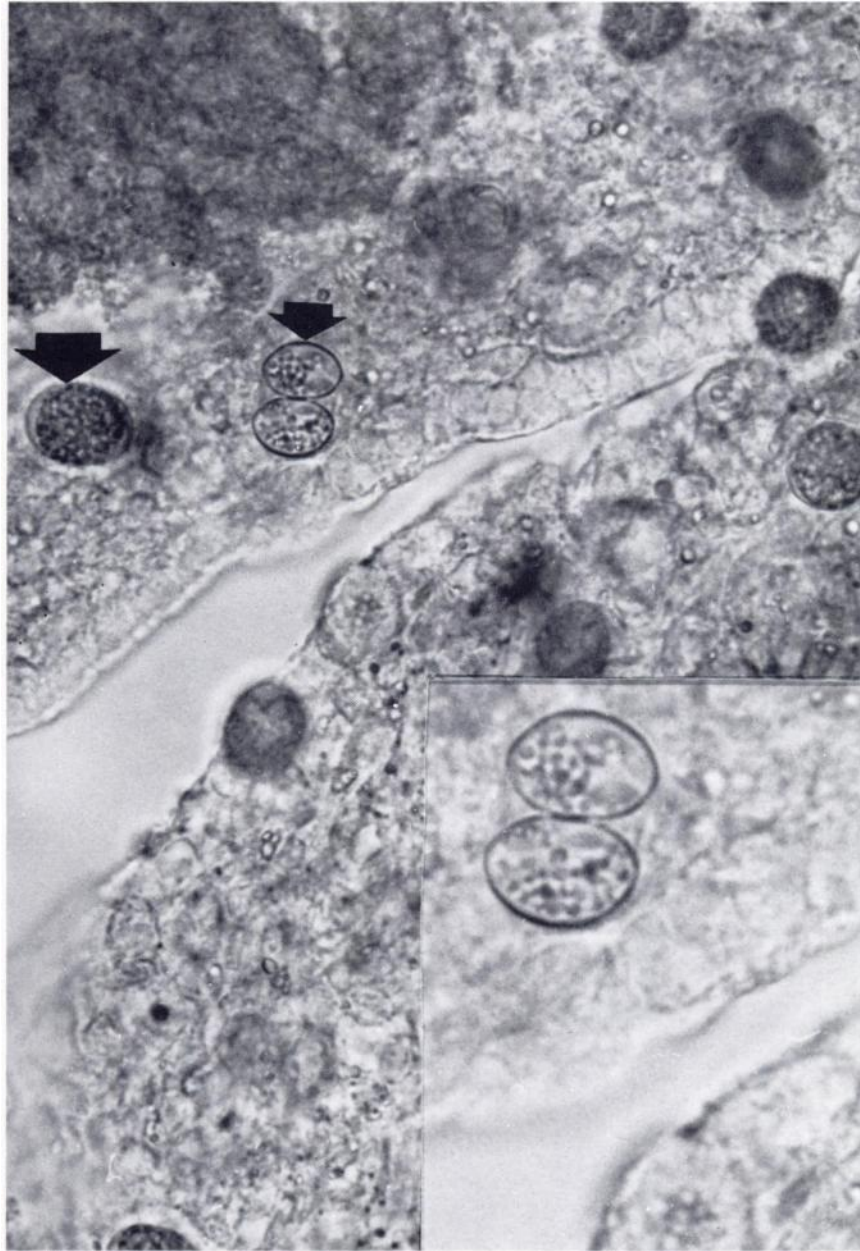


FIGURE 5. Unsporulated (large arrow) and sporulated (small arrow) oocysts in intestinal scraping from *Tyto novaehollandiae* $\times 1500$. Inset; sporulated oocyst $\times 3750$



FIGURE 6. Sporocyst (small arrow) in intestinal scraping from *Notechis ater*. Note relative size of red cell (large arrow) $\times 1500$. Inset; sporocyst $\times 3750$

black tiger snake are now added to the known reptilian definitive hosts.^{19,24}

The bird sarcocysts seen usually were thin-walled and resembled those recovered in skeletal muscle of canaries fed sporocysts from sparrow hawks, *Accipiter nisus*.¹ In this type of cycle, certain predatory birds are definitive hosts with a variety of other avian species serving as potential intermediate hosts. Widespread dissemination of *Sarcocystis* sporocysts in the environment can occur by fecal contamination from infected raptors, particularly beneath the nesting sites of predatory birds. Ground feeding birds (i.e. wrens, grass finches and parrots), attracted to these sites by discarded carcasses, fecal material, or the variety of arthropods congregating there, may acquire infection by accidental ingestion. Temporary transport hosts such as flies, beetles, other arthropods and earthworms might concentrate sporocysts. It has been shown that two genera of filth-flies and cockroaches can transport *Toxoplasma*,^{22,23} and more recently that cockroaches can carry *S. muris*.²⁰ This may explain the moderate prevalence of *Sarcocystis* in insectivorous birds (i.e. pardalotes, silvereyes, robins and swallows). However, even arboreal species may acquire infection while collecting materials for making nests. Since females often are responsible for nest building, this behaviour may explain the greater prevalence of *Sarcocystis* in female grackles compared to that in males.¹¹

Sarcocysts with thicker walls were found in little pied cormorants, hoary-headed grebes and a pelican from Victoria, but not in waterbirds from Tasmania. Thick-walled sarcocysts have been found in some macropodid and dasyurid marsupials from mainland Australia, but not Tasmania. A carnivorous mammal, not present in Tasmania, has been suggested as a possible definitive host.¹⁷ A similar situation

may explain the observed differences between the sarcocysts seen in these three avian species and organisms seen in other birds. The fox, *Vulpes vulpes*, or dingo, *Canis familiaris dingo*, may be the definitive host. Dogs recently have been suggested as the definitive host for a *Sarcocystis* found in a domestic fowl.¹⁶

All sarcocysts found in avian tissues in the present survey were microscopic, the largest measuring 2500 μ m by 150 μ m. No large macroscopic cysts were seen. Visible sarcocysts have been described in various strigiform,¹² psittaciform² and passeriform birds.³ Macroscopic cysts of *S. rileyi* are common in dabbling ducks in North America^{8,12} and heavily infected carcasses frequently are discarded for aesthetic reasons, but this is not known to occur in mainland Australia or Tasmania. In this survey the three anatids infected with microscopic sarcocysts were two dabbling ducks and the magpie goose, another shoreline feeder. The absence of macroscopic sarcocysts in birds of Australia may be explained by the absence of the definitive host, probably a carnivorous mammal, on this continent. A recent observation regarding the macroscopic *S. leporum* in cottontail rabbits strongly suggests that the raccoon (*Procyon lotor*) is the definitive host.⁹ Raccoons and certain mustelid carnivores are widely distributed in North America and may prove to be definitive hosts for macroscopic sarcocysts in mammals and birds. These carnivores, except for small numbers of ferrets, are not free-ranging in Australia.

Both the copperhead and black tiger snake are crepuscular and nocturnal during warm weather. These feeding habits would permit predation on a variety of nocturnally active rodents in this area, and also allow for sporocyst contamination of this environment. The results of experimental infection studies using sporocysts from owls and snakes will be presented in a subsequent communication.¹⁸

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