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CASE SERIES

Outbreaks of sarcoptic mange in free-ranging koala populations in Victoria and South Australia: a case series

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Objective To describe outbreaks of sarcoptic mange caused by *Sarcoptes scabiei* in free-ranging koalas in Victoria (December 2008 to November 2015) and South Australia (October 2011 to September 2014).

Methods Koalas affected by mange-like lesions were reported by wildlife carers, veterinary practitioners or State Government personnel to the Faculty of Veterinary and Agricultural Sciences at The University of Melbourne and the School of Animal and Veterinary Sciences at The University of Adelaide. Skin scrapings were taken from live and dead koalas and *S. scabiei* mites were identified. Tissues from necropsied koalas were examined histologically.

Results Outbreaks of sarcoptic mange were found to occur in koalas from both Victoria (n = 29) and South Australia (n = 29) for the first time. The gross pathological and histopathological changes are described.

Conclusion We present the first reported cases of sarcoptic mange outbreaks in free-ranging koalas.

Keywords koalas; mange; mites; *Phascolarctos cinereus*; *Sarcoptes scabiei*

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Sarcoptic mange, caused by the mite *Sarcoptes scabiei*, has caused outbreaks in populations of wild canids, felids, ungulates and primates in Europe, North America and Africa.[1] Sarcoptic mange has been reported sporadically in a limited number of Australian native species[2] and it is recognised as a significant disease in common wombats (*Vombatus ursinus*).[3,4] In wombats, sarcoptic mange causes severe parakeratotic scale and dermatitis covering more than 30% of the body, particularly the anterolateral body, and is associated with poor body condition, secondary dermal bacterial infection, myiasis and death.[5] Although the first record of sarcoptic mange in wombats dates back to 1818, the first outbreak in free-ranging common wombats was recorded in New South Wales in 1937.[3] Currently, mange occurs endemically at 0–15% prevalence in common wombat populations throughout south-east Australia and the mite is thought to be spread between wombat populations by infected foxes or dogs.[6] Confirmed outbreaks of sarcoptic mange have also occurred in the southern hairy nosed wombat (*Lasiorhinus latifrons*) in the Murraylands of South Australia, with variable prevalence (0–76%) found between year and site in a study conducted between 2004 and 2005.[7] Sarcoptic mange has been observed rarely in *L. latifrons* between 2011 and 2015 (Woolford and Boardman, unpubl. obs.).

Sarcoptic mange has rarely been observed in captive and free-ranging koalas (*Phascolarctos cinereus*).[8] The first case was reported in a captive juvenile koala in Victoria in 1974, with a wombat implicated as the source of infection.[9] An outbreak of sarcoptic mange in a captive koala colony in 1980 was associated with koala deaths and was thought to have been introduced by a wild koala brought into captivity.[10] In a subsequent study, two free-ranging koalas on Phillip Island, Victoria, were confirmed to have sarcoptic mange.[11] These animals showed dry, pruritic, encrusted lesions, particularly affecting the face, nose and lips but also generally over the entire body, with exudative cracks on their digits and paws.[11]

Koalas in Victoria are currently widely distributed in areas of suitable habitat, but were near extinction in the early 20th century. At that time, small numbers of koalas were translocated to island sanctuaries in an attempt to protect the species. These island populations flourished and some koalas were later either returned to mainland Victoria or translocated to South Australia, where koalas had become extirpated.[12] As a result of these translocations, South Australian koalas are primarily descendants of those in Victoria.

Here we describe outbreaks of sarcoptic mange in free-ranging koalas from Victoria and South Australia.

Materials and methods

Koalas with skin lesions were reported to the Faculty of Veterinary and Agricultural Sciences at The University of Melbourne, Victoria, as part of the Wildlife Health Surveillance Victoria project, or the School of Animal and Veterinary Sciences at The University of Adelaide, South Australia, by state government agriculture and national parks personnel, wildlife carers and veterinarians at wildlife/private veterinary clinics.

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Live koalas were confirmed to have sarcoptic mange by microscopic examination of superficial skin scrapings. Koalas that had been euthanased on animal welfare grounds because of the severity of skin lesions were examined by necropsy at the Faculty of Veterinary and Agricultural Sciences (Victoria) and at the School of Animal and Veterinary Sciences or the Adelaide Koala and Wildlife Hospital (South Australia). Samples were collected under The University of Melbourne Animal Ethics Committee Application Number 1312813.1 and Victorian Department of Environment and Primary Industries Research Permit Number 10006948 and the University of Adelaide Animal Ethics Committee Application Number S2013-198 and Department of Environment, Water and Natural Resources, South Australia Permit Y26054.

Samples of affected skin were collected into 10% neutral buffered formalin, processed by routine histological techniques and stained with haematoxylin and eosin for microscopic examination. Mites from representative cases were cleared in Hoyer's medium and their identity as *S. scabiei* confirmed microscopically.[13] Representative specimens of *S. scabiei* from affected koalas have been deposited in the South Australian Museum, Adelaide. Chi-squared analyses were used to detect differences between groups, with statistical significance accepted at $P < 0.05$.

Results

Victoria

The first case of sarcoptic mange was identified in an adult female koala from Ulupna Island, on the Murray River in northern Victoria (Figure 1), that underwent a veterinary assessment in December 2008 at Healesville Sanctuary. The koala was dehydrated, malnourished and had hyperkeratosis with deep fissures on both forelimbs, with scabs continuing up the neck and ventral mandible. A skin scraping taken at the time of examination confirmed the presence of *S. scabiei* mites. Because of the poor prognosis the animal was euthanased. In February 2009 another affected koala was found a few kilometres further south of the Ulupna Island site, north of Strathmerton. In March 2010, a wildlife carer reported three dead koalas with mange-like lesions within 500 m of each other on Ulupna Island. Between December 2008 and May 2010 a total of seven koalas were reported with sarcoptic mange in this area (Table 1).

Following the cases on Ulupna Island, koalas with sarcoptic mange were identified from other locations (Jeeralang Junction in Gippsland; Bullengarook in central Victoria). Sporadic cases were also seen between 2011 and mid-2013 in western Victoria (Portland, Wye River, Mt Eccles) and at Somers on the Mornington Peninsula. Between November 2013 and January 2015, 10 koalas with mange were necropsied from areas south of the Murray River near Ulupna Island (Mywee and Koonoomoo). In 2014 and 2015 there were several koalas with mange reported by wildlife carers from Sandy Point on the south-east coast; three were necropsied. Overall, a total of 29 cases of sarcoptic mange were identified across Victoria between 2008 and 2015: 15 were males, 9 were females and the remainder were unrecorded.

South Australia

The first confirmed case of sarcoptic mange in South Australia was in a sub-adult male rescued in the suburb of Glenalta on the southern border of the Belair National Park in the Mount Lofty Ranges

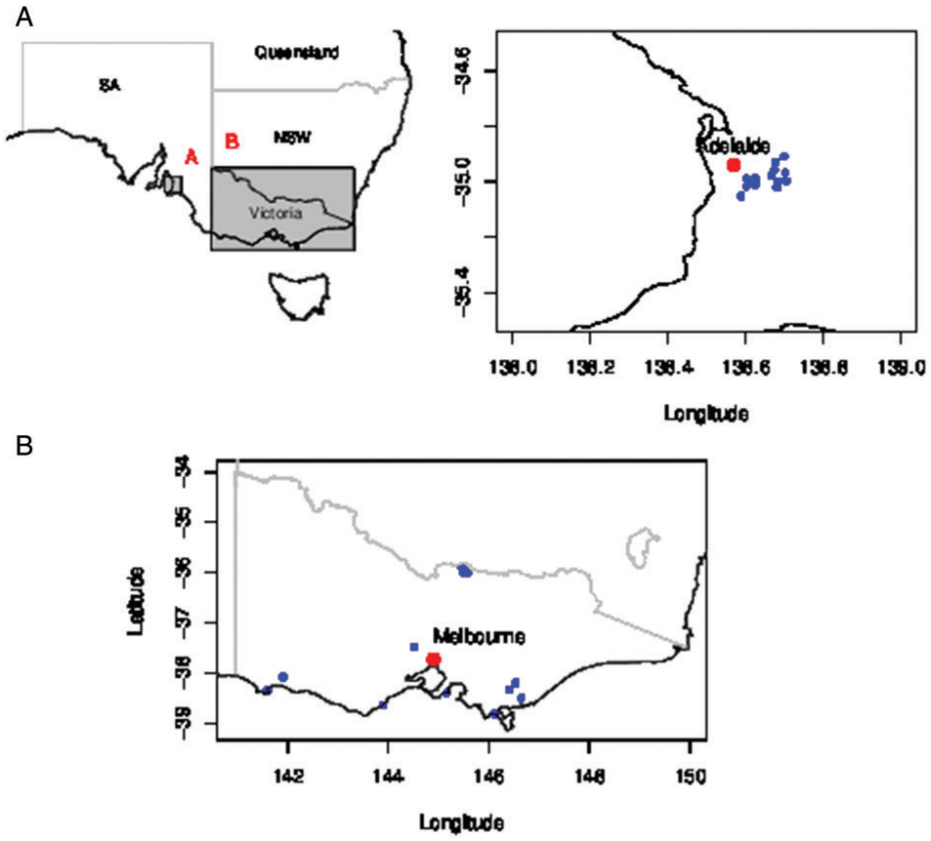

Figure 1A, B. Point locations of the site of capture of koalas with sarcoptic mange in South Australia and Victoria.

Table 1. Summary of 29 cases of sarcoptic mange in koalas* from different locations in Victoria, Australia, December 2008 to November 2015

Year	Month	Location	Sex
2008	Dec	Ulupna Island	F
2009	Feb	Strathmerton North	M
	Sep	Ulupna Island	M
2010	Mar	Ulupna Island	M
		Ulupna Island	M
		Ulupna Island	F
	Apr	Ulupna Island	M
	May	Ulupna Island	NR
		Jeeralang Junction	M
	Nov	Bullengarook	M
2011	Feb	Somers	F
2012	Mar	Portland	M
2013	Apr	Wye River	F
	Oct	Mt Eccles	F
	Nov	Mywee	M[a]
		Mywee	NR[a]
		Mywee	NR[a]
		Mywee	NR[a]
2014	Jan	Sandy Point	M
	May	Koonoomoo	M[a]
	Jul	Koonoomoo	M
	Aug	Koonoomoo	M[a]
	Dec	Koonoomoo	F[a]
		Koonoomoo	M
2015	Jan	Koonoomoo	NR[b]
	Feb	Sandy Point	F[a]
	Mar	Traralgon	F
	May	Devon North	F
	Nov	Sandy Point	M[a]

*All koalas were adults except where noted. [a]Subadult; [b]age not recorded (NR).

Table 2. Summary of 29 cases of sarcoptic mange identified in koalas* in different locations in South Australia, October 2011 to September 2014

Year	Month	Location	Sex
2011	Oct	Glenalta	M[a]
2012	Apr	-	F
	Approx. Apr	-	M
		-	M
	Jul	Hawthorndene	M
	Aug	Glenalta	F
	Approx. Aug	-	M
	Sep	Glenalta	M
	Nov	Belair	NR[b]
2013	Jan	Eagle on the Hill	F
		Eagle on the Hill	M
	Feb	Glenalta	M
		Crafers	M
		-	M
	Mar	Mitcham	M
		Belair	NR
2014	Jan	Clapham	M
		Belair	F
	Feb	Waterfall Gully	F
	Mar	Crafers West	F
		Flagstaff Hill	M
		Cleland	M
	Apr	Belair	M
		Wattle Park	M
		Eden Hills	M
	Jul	Teringie	F
	Sep	Upper Sturt	F[a]
		Mitcham	M
		Crafers West	F

*All koalas were adults except where noted. [a]Subadult; [b]age not recorded (NR).

near Adelaide in early October 2011 (Figure 1). This animal was treated with ivermectin (200 µg/kg SC once; Ivomec 10 mg/mL, Merial, NSW, Australia) and enrofloxacin (10 mg/kg SC once daily; Baytril 50 mg/mL, Bayer, NSW, Australia), but died 3 days later. A further 8 cases were identified between April and November 2012, with 4 of them within approximately 4 km of the index case (Table 2). In 2013, there were 7 reported cases, 6 of which were within approximately 8 km of the index case, and in 2014, a further 13 cases were confirmed within approximately 12 km of the index case. Overall, a total of 29 cases of sarcoptic mange were identified in the Mount Lofty Ranges region of South Australia between 2011 and 2014: 18 were males, 9 were females and the remainder were unrecorded.

Pathology

At necropsy, affected koalas had severe hyperplastic and hyperkeratotic dermatitis on the distal forelimbs and/or hindlimbs (Figure 2),

Figure 2. Severe hyperplastic and hyperkeratotic dermatitis of the medial aspect of the distal forelimb in a South Australian koala affected by sarcoptic mange.

usually involving the interdigital regions, with some also showing similar lesions on the face and sternum, ventral thorax and abdomen. Gross presentation was characterised by skin thickening, crusting and deep fissures into the dermis from which originated serosanguineous fluid. Numerous mites were detected on superficial skin scrapings (Figure 3). Adult mites measured up to 450 µm in length, had round or globoid bodies, very short legs and a posteriorly positioned anus and numerous dorsal triangular spines. Lymphadenomegaly of the nodes draining affected skin regions was noted in a number of koalas. Microscopically, skin lesions were characterised by moderate to marked acanthosis and orthokeratotic and segmentally parakeratotic hyperkeratosis with numerous intracorneal mites (Figure 4). Intracorneal pustules and mixed perivascular and interstitial dermatitis were indicative of secondary bacterial infection.

Epidemiology

For the series, a higher proportion were males (n = 33) compared with females (n = 18) (χ^2 test statistic 4.41; P = 0.04). The least number of cases were detected in the winter months (5 cases) and the largest number in the autumn (20 cases) (χ^2 test statistic 8.78; P = 0.03); 16 cases were found in summer and 14 in the spring. In 3 of the cases the specific month of detection was not recorded (Table 2). Differences in the proportions of cases by sex and season of identification were not statistically significant for each state because of the low numbers of koalas in each strata.

Discussion

We describe outbreaks of sarcoptic mange in free-ranging koalas from Victoria and South Australia between 2008 and 2015. The predilection of *Sarcoptes* mites for the superficial layer of the epidermis leads to classic thickening and scale in affected koalas, resulting from parakeratosis and acanthosis. The distribution over the distal fore- and hindlimbs, particularly the interdigital regions, and the face was consistent with that previously reported in an affected captive koala,[14] but differs to that reported in wombats, in which lesions are typically distributed over the anterolateral body.[5] The distribution of lesions in koalas may be related to the areas of skin in contact with trees, suggesting that in some cases the mites may be harboured on the surface of branches and transmitted between koalas. Alternatively, koalas may become infected when they are on the ground moving between trees, from mites that foxes have left on fomites. The severity of skin lesions and the multiple life stages of mites in the examined koalas were consistent with a chronic infestation that would have taken weeks to months to develop, as has been reported in wombats.[6] In this study, many of the koalas were found dead, presumably as a result of septicaemia from severe bacterial infection of affected areas as a result of the lack of treatment.

Figure 3. Superficial skin scraping from a South Australian koala showing *Sarcoptes scabiei* mite with a round or globoid body, very short legs and terminal anus.

The initial cases of sarcoptic mange on Ulupna Island were most likely transmitted from foxes, given several foxes with clinical signs of advanced mange were observed in the region and common wombats are not found in this area of Victoria. In South Australia, the location of the index case near the southern border of the Belair National Park suggested that a fox was also the most likely source of infection, as a fox severely affected by mange was identified and removed from the park during the same week by the Royal Society for the Prevention of Cruelty to Animals (G. Underwood, pers. comm.). However, the proximity of this koala to urbanised areas does not exclude an origin from domestic dogs. It is unknown why the emergence of sarcoptic mange in wild Victorian and South Australian koalas occurred within a similar time frame, but may indicate a spill-over from endemic hosts such as foxes.

Male koalas were over-represented in both states and may be more likely to become infested with sarcoptic mange because of their roaming and fighting behaviour, particularly during the breeding season in spring.[15] Overall, the least number of cases occurred in winter. By contrast, wombats are reported to be more likely infested with sarcoptic mange in winter, thought to be related to transmission events caused by increased burrow-sharing and prolonged mite survival off the host in the burrow environment.[6] In wombats, another risk factor for *S. scabiei* infestation is thought to be host susceptibility, which may be exacerbated by poor immune response caused by stressors such as drought and food shortage.[6]

Conclusions

This is the first report of outbreaks of sarcoptic mange in free-ranging koalas, with multiple transmission events occurring within a similar timeframe across two states, Victoria and South Australia. Increased surveillance will be necessary to monitor the effect of mange on koalas, with considerations for methods of control and management, and effects on wildlife welfare. The prevalence of *S. scabiei* in koala populations and the risks of infection affecting koala conservation status in populations that may also be affected by chlamydiosis and koala retrovirus also require further investigation.

This investigation also demonstrated the value of wildlife health surveillance collaborations between the public, wildlife carers, veterinary practitioners, zoos, staff of state wildlife, agriculture and national parks agencies and university veterinary faculties. Key cases have also been provided to Wildlife Health Australia's national electronic wildlife health information system (eWHIS).

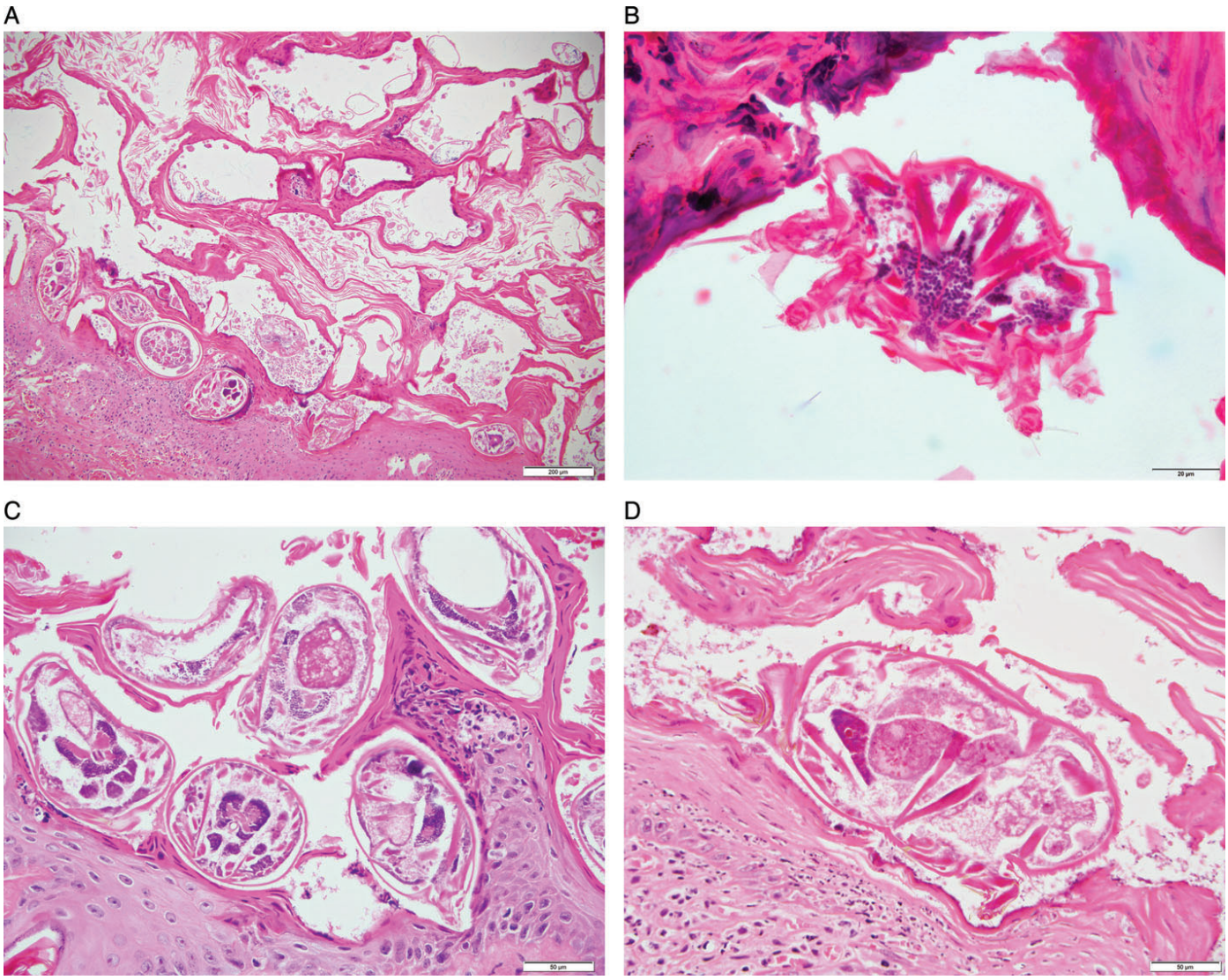

Figure 4. **Histopathology of skin from two Victorian koalas affected by sarcoptic mange (H&E). (A) Marked acanthosis, orthokeratosis and parakeratosis with numerous intracorneal mite tunnels containing several adult mites. (B) Immature mite with articulated appendages, striated muscle, setae and dorsal spines. Image created by layering 5 images using Zerene Stacker software (http://zerenesystems.com/cms/stacker). (C) Dense aggregation of adult mites and marked acanthosis. (D) Sagittal section through an adult mite showing chitinised mouth parts and attachments for striated muscles, dorsal spines and short articulated appendages with terminal claws.**

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Conflicts of interest and sources of funding

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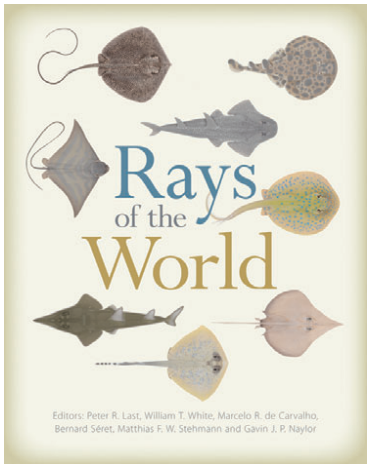
BOOK REVIEW

Rays of the world. P Last, W White, M de Carvalho et al. (editors). CSIRO Publishing, 2016. 800 pages. Price A$220. ISBN 9780643109131.



While there have been several books about sharks over the years (the most recent being *Sharks of the world*, 2013; ISBN 9780957394605), this is the first time a genuine book dedicated solely to the rays of the world has been published. The editors of *Rays of the world* state in their foreword that it was early 1984 that discussions were held regarding the production of such a volume. The wait has been worth it.

Rays are the largest subgroup of the chondrichthyan (cartilaginous skeleton) fish. The other major group is sharks, with their presently 516 recognised species. Rays, or 'flat sharks' as they are sometimes called, are more correctly known as Batoid fish. Some species such as the sawfishes (family Pristidae) are well recognised and often thought of as sharks, but are, in fact, rays.

The initial chapters of the book discuss the evolution and biology of rays, before examining their phylogeny and classification; as with many species, improved DNA techniques has altered the classification of rays. The next few chapters discuss ray conservation, followed by an excellent glossary and several pages of diagrams providing much detail of the various external anatomical structures that are used for identifying a specimen.

Finally, before outlining the 633 individual ray species (which makes up the bulk of the book), there is a general key that assists in identifying to which of the 26 families a particular ray belongs. Each species of ray described is then grouped in chapters by individual family. Each chapter starts with general information about the family and provides a key to identify the species within that family. A page is then dedicated to each species with the headings 'Identification', 'Colour', 'Size', 'Habitat and biology', 'Distribution map' and 'Similar species'. The use of drawings rather than actual photographs enhances the identification of individual species.

Rays of the world fills a gap in the identification of the world's rays and is an excellent reference book. It is clear and easy to follow and would make a worthwhile addition to any veterinarian's library, particularly if they are interested marine wildlife or if rays form part of their consultancy work.

R Jones
Dr Rob Jones (The Aquarium Vet) specialises in aquatic wildlife and consults for some of Australia and New Zealand's largest and best known aquariums. He also provides an online course for aquarists working in the aquarium industry.

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