

Distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria

D. M. Forsyth, K. Stamation and
L. Woodford

July 2015

Arthur Rylah Institute for Environmental Research,
Department of Environment, Land, Water and Planning

Unpublished Client Report for the Biosecurity Branch,
Department of Economic Development, Jobs, Transport and Resources



Distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria

David M. Forsyth, Kasey Stamation and Luke Woodford

Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
123 Brown Street, Heidelberg, Victoria 3084

July 2015

Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
Heidelberg, Victoria

Report produced by: Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
PO Box 137
Heidelberg, Victoria 3084
Phone (03) 9450 8600
Website: www.delwp.vic.gov.au/ari

© The State of Victoria Department of Environment, Land, Water and Planning 2015



This work is licensed under a Creative Commons Attribution 3.0 Australia licence. You are free to re-use the work under that licence, on the condition that you credit the State of Victoria as author. The licence does not apply to any images, photographs or branding, including the Victorian Coat of Arms, the Victorian Government logo and the Department of Environment, Land, Water and Planning logo. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/3.0/au/deed.en>

Citation: Forsyth, D.M., Stamation, K. and Woodford, L. (2015). Distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Biosecurity Branch, Department of Economic Development, Jobs, Transport and Resources. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

ISSN 1835-3827 (print)

ISSN 1835-3835 (online)

Disclaimer: This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

Front cover photo: Adult female Sambar Deer photographed by a remote camera (photo: Arthur Rylah Institute for Environmental Research).

Authorised by: Victorian Government, Melbourne

Edited by: Organic Editing

Contents

Acknowledgements	1
.....	
Summary	2
.....	
Background	2
Objective	2
Methodology	2
Results and Conclusions	2
Recommendations	3
1 Introduction	4
.....	
2 Objective	4
.....	
3 Methodology	5
.....	
3.1 Data sources	5
3.2 Data storage and visualisation	6
4 Results	6
.....	
4.1 Sambar Deer	6
4.2 Rusa Deer	11
4.3 Sika Deer	13
5 Discussion	13
.....	
5.1 Sambar Deer	13
5.2 Rusa Deer	15
5.3 Sika Deer	15
6 Conclusions	16
.....	
7 Recommendations	16
.....	
References	17
.....	
Appendix	20
.....	

Acknowledgements

This work was commissioned by the Biosecurity Division, Department of Environment and Primary Industries (now Biosecurity Branch, Department of Economic Development, Jobs, Transport and Resources). We thank all the interviewees (listed in the Appendix), who kindly shared their knowledge about the distributions of deer in Victoria, New South Wales and South Australia. Mike Braysher (University of Canberra) kindly provided background information about the importation of Sika Deer into Australia. We thank Andrew Woolnough (Biosecurity Branch, Department of Economic Development, Jobs, Transport and Resources) for reviewing a draft of this report, and Jeanette Birtles (Organic Editing) for editorial services.

Summary

Background

Introduced deer species are important game animals in Victoria, but in some situations they can have negative impacts on agricultural and environmental values. There is concern that deer species are expanding their Victorian distributions through natural and human-assisted dispersal. Understanding the current distributions of deer species in Victoria will help inform their management. In general, preventing the establishment of 'new' populations provides a higher return on investment than eradication, and containment provides a higher return on investment than managing the impacts of widespread species. Understanding the distribution of deer species following their establishment would assist in the delineation of management areas. The Biosecurity Division of the Department of Environment and Primary Industries¹ commissioned the Arthur Rylah Institute for Environmental Research (ARIER) to investigate the historical and current distributions of three deer species (Sambar Deer *Rusa unicolor*, Rusa Deer *Rusa timorensis* and Sika Deer *Cervus nippon*) in Victoria. All three species can be legally hunted in Victoria. Sambar Deer were introduced into Victoria during the 1860s and are widespread in eastern Victoria. However, the current status of Rusa Deer and Sika Deer in Victoria is unclear.

Objective

To determine the historical and current distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria.

Methodology

We obtained information on the historical and current breeding distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria from four sources: first, from books, journal articles and published/unpublished reports; second, from sightings recorded in the Victorian Biodiversity Atlas; third, from ARIER staff and contractors; fourth, from interviews with people with expert knowledge of deer in Victoria (and New South Wales and South Australia).

Sightings of deer were collated in a spreadsheet. The breeding distributions of deer were aggregated onto hard-copy maps and digitised in ArcMap 10.1 (ArcGis 10.1 for Desktop, ESRI software). A shapefile of hand-drawn polygon features, representing Sambar Deer distributions, was created using the construction tools in ArcMap. The Sambar Deer sightings were then projected onto these distribution polygons and displayed on a map of Victoria.

Results and Conclusions

There was insufficient information to robustly delineate the historical distributions of the three deer species in Victoria. However, the historical information we collected helped us determine the current breeding distributions of the three species in Victoria.

Of the three species, only Sambar Deer were confirmed to have a wild, self-sustaining breeding population in Victoria in 2015. The current breeding distribution of Sambar Deer in Victoria was estimated to be 66,915 km² (29% of Victoria's land area), and consists of four discrete (i.e. reproductively isolated) populations: Eastern Victoria (66,300 km²), French Island (170 km²), Mount Cole (330 km²) and Timboon (115 km²).

The French Island and Mount Cole Sambar Deer populations were established from deliberate releases prior to 1900, and neither population appears likely to further expand its distribution due to an absence of adjacent suitable habitat.

¹ The Biosecurity Division transferred to the Department of Economic Development, Jobs, Transport and Resources on 1 January 2015.

The Timboon Sambar Deer population was established in the 1980s, most likely from farmed animals that escaped and/or were deliberately released. The population has increased and now inhabits private properties and a variety of land tenures. This population could greatly expand its breeding distribution, particularly eastward into the Otway Ranges, which is suitable habitat for Sambar Deer. It may be possible to manage the Timboon Sambar Deer population such that it does not further expand its breeding distribution.

The Eastern Victoria Sambar Deer population constitutes >99% of the Sambar Deer distribution within Victoria. This population is still expanding its distribution, particularly west of the Hume Highway and along the Murray River. There is concern about this population colonising Wilsons Promontory National Park (WPNP), but it is unclear whether WPNP is suitable habitat for Sambar Deer.

Although Rusa Deer were breeding in the Central Highlands/West Gippsland until the late 1940s, and two populations were identified in a 2000 postal survey of deer distributions, we could not find any evidence of a wild, self-sustaining Rusa Deer population in Victoria. However, two recently cast Rusa Deer antlers were found in the upper Snowy River in 2014 and there were unconfirmed reports of Rusa Deer – Sambar Deer hybrids at Wangarabell and Timboon. The Snowy River Rusa Deer most likely immigrated into Victoria from a nearby population in New South Wales. Although female Rusa Deer may eventually disperse into eastern Victoria from New South Wales, the presence of Sambar Deer in eastern Victoria may mean that Rusa Deer do not establish or persist as a distinct species in Victoria, due to hybridisation.

Sika Deer are being farmed in Victoria, but there is no evidence of a wild Sika Deer population in Victoria.

Recommendations

Encouraging the general public (including hunters) and agency staff to enter their observations of introduced species (including wild deer) into the Victorian Biodiversity Atlas would greatly improve our knowledge of their distributions and aid their management.

A pilot study should be conducted to assess the potential of molecular techniques for identifying the sources of 'new' deer populations and for helping managers understand the potential for reinvasion if eradication of a new population is attempted.

The probability of eradicating a deer population is highest when the population is smallest (in distribution and abundance). Managers wishing to eradicate a new deer population should therefore implement an appropriate eradication plan as soon as possible.

1 Introduction

Introduced deer species are important game animals in Victoria (Department of Environment and Primary Industries 2013; Moloney and Turnbull 2013; Game Management Authority 2015), but in some situations they have negative impacts on agricultural (Lindeman and Forsyth 2008) and environmental (Department of Sustainability and Environment 2009; Bennett and Coulson 2011) values. There is concern that deer species are expanding their Victorian distributions through natural and human-assisted dispersal. One approach to managing deer populations is to delineate areas of their distribution within which they are to be managed as game and to manage them differently in other areas. Understanding the distributions of deer species at various time-steps following their establishment would assist in the delineation of management areas. In general, preventing the establishment of 'new' populations provides a higher return on investment than eradication, and containment provides a higher return on investment than managing the impacts of widespread species (Department of Environment and Primary Industries 2014).

The Biosecurity Division of the Department of Environment and Primary Industries² commissioned the Arthur Rylah Institute for Environmental Research (ARIER) to investigate the historical and current distributions of three deer species (Sambar Deer *Rusa unicolor*, Rusa Deer *Rusa timorensis* and Sika Deer *Cervus nippon*) in Victoria. All three species can be legally hunted in Victoria (Game Management Authority 2015). Sambar Deer, sourced from Sri Lanka, India and the Philippines, were introduced at four sites in Victoria during the 1860s and have subsequently expanded their distribution to north, north-east and south-east Victoria (Menkhorst 1995; Bentley 1998). There is particular concern about the continued expansion of the distribution of Sambar Deer in Victoria because of their potential negative impacts on native biodiversity (Department of Sustainability and Environment 2009; Bennett and Coulson 2011) and agriculture (Lindeman and Forsyth 2008). There is a substantial annual harvest of Sambar Deer in Victoria (e.g. an estimated 42,847 in the 2012–2013 financial year; Moloney and Turnbull 2013), but Rusa Deer and Sika Deer were only added to the list of game animals that can legally be hunted in Victoria in 2009 (Z. Powell, Game Management Authority, pers. comm.), and the current wild status of these species in Victoria is unclear. It is possible that, if established in Victoria, these two species could substantially further increase their distributions.

2 Objective

The aim of this study was to determine the historical and current distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria.

² The Biosecurity Division transferred to the Department of Economic Development, Jobs, Transport and Resources on 1 January 2015.

3 Methodology

3.1 Data sources

We obtained information on the historical and current breeding distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria from four sources. First, we searched books, journal articles and published/unpublished reports. Second, we searched the Victorian Biodiversity Atlas (VBA; Department of Environment, Land, Water and Planning 2015) for records of these three deer species. The VBA is a web-based information system for managing information about wildlife in Victoria. Dated and georeferenced records of wildlife (including deer) can be uploaded to the VBA by registered users; all records are vetted by experts before being accepted, with those outside the accepted range receiving additional vetting. The VBA records used in our analyses were current at 8 April 2015. We discarded the indirect sightings (i.e. sighting type = 'indirect evidence' or 'heard' or 'identified from hair' or 'pers. comm.' or 'literature') and included the sighting types 'seen' or 'observation' or 'observation with supporting evidence'. Third, we asked ARIER staff and contractors for sightings of Sambar Deer that had not been entered into the VBA. Fourth, we used our networks to identify people with potential knowledge of the distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria. We conducted telephone and/or face-to-face interviews with those people with the objective of recording new or edge-of-distribution sightings of these deer species. During this process it became apparent that Rusa Deer and Sika Deer are not established (i.e. do not have wild self-sustaining populations in Victoria), but that Rusa Deer are established not far from the Victorian border in New South Wales (NSW). We therefore also interviewed people with potential knowledge of the closest known Rusa Deer populations within NSW (and also within South Australia close to the Victorian border).

Like most mammals, male deer typically have larger home ranges and disperse more frequently and further than female deer (e.g. Catchpole et al. 2004; Kjellander et al. 2004; Loe et al. 2009). These traits have important implications for understanding and delineating the distributions of deer. First, male deer may be seen many tens of kilometres from the nearest females (*sensu* Caughley 1970). For example, in 1971 an adult male Sambar Deer was photographed near Berrigan, NSW, at least 130 km from the nearest breeding population (Bentley 1998). Such males may either be dispersing (i.e. moving through an area when they are sighted) or have dispersed and established a home range in which they are sighted. We used Caughley's (1970) definition of 'breeding distribution' (i.e. where males and females with offspring are known to be present) to differentiate between sighting locations of dispersing/dispersed males and where the species is breeding. This definition has management implications because long-distance male dispersers will eventually die out if females do not establish in that area. We therefore believe that knowing 'breeding distribution' is more useful than knowing 'total distribution'.

One objective of this study was to compare the historical and current distributions of Sambar Deer in Victoria. However, we could find no historical maps of the distribution of this species within Victoria that were sufficiently accurate for this purpose. The three previous summaries of wild deer distributions (Murray and Snowden 1976; Wilson et al. 1992; Moriarty 2004a) were conducted at the national scale and did not delineate the distributions of deer within Victoria at a scale useful for our purposes. Bentley (1998) and other Victorian Sambar Deer experts did not accurately map the historical distributions of Sambar Deer because "distribution ... is difficult to delineate – the country is generally very inaccessible" (Slee 1985:6). Another reason is that Sambar Deer, although large (c. 200 kg; Bentley 1998), are a cryptic and mostly nocturnal forest-dwelling species (Downes 1983; Bentley 1998; Leslie 2011), and hence may not be detected, even when present at high densities. We therefore could not sensibly delineate the historical distributions of Sambar Deer in Victoria. Rather, we used the historical records of Sambar Deer sightings and descriptions in the literature to help inform the current breeding distribution and to assess the potential for further expansion.

Breeding distributions were transcribed onto maps by – or in consultation with – the interviewee. Distributions were usually transcribed onto Gregory's Victoria Map 319 Edition 5 (scale = 1:975 000),

although larger-scale maps were sometimes used, depending on the scale of the information provided by the interviewee. We also asked whether that person could recommend other people for us to interview. The people interviewed, and their affiliations (if any), are listed in the Appendix. Some information was provided to us confidentially, and we include this with 'name withheld'.

3.2 Data storage and visualisation

Sightings of deer were collated in a spreadsheet. The breeding distributions of deer were aggregated onto hard-copy maps and digitised in ArcMap 10.1 (ArcGIS 10.1 for Desktop, ESRI software). A shapefile of hand-drawn polygon features, representing Sambar Deer distributions, was created by overlaying a blank polygon layer on road, locality, hydrology and land tenure shapefiles available through the DELWP Corporate Spatial Data Library (CSDL). Polygons were drawn using the construction tools in ArcMap. The Sambar Deer sightings were then projected onto these distribution polygons and displayed on a map of Victoria.

4 Results

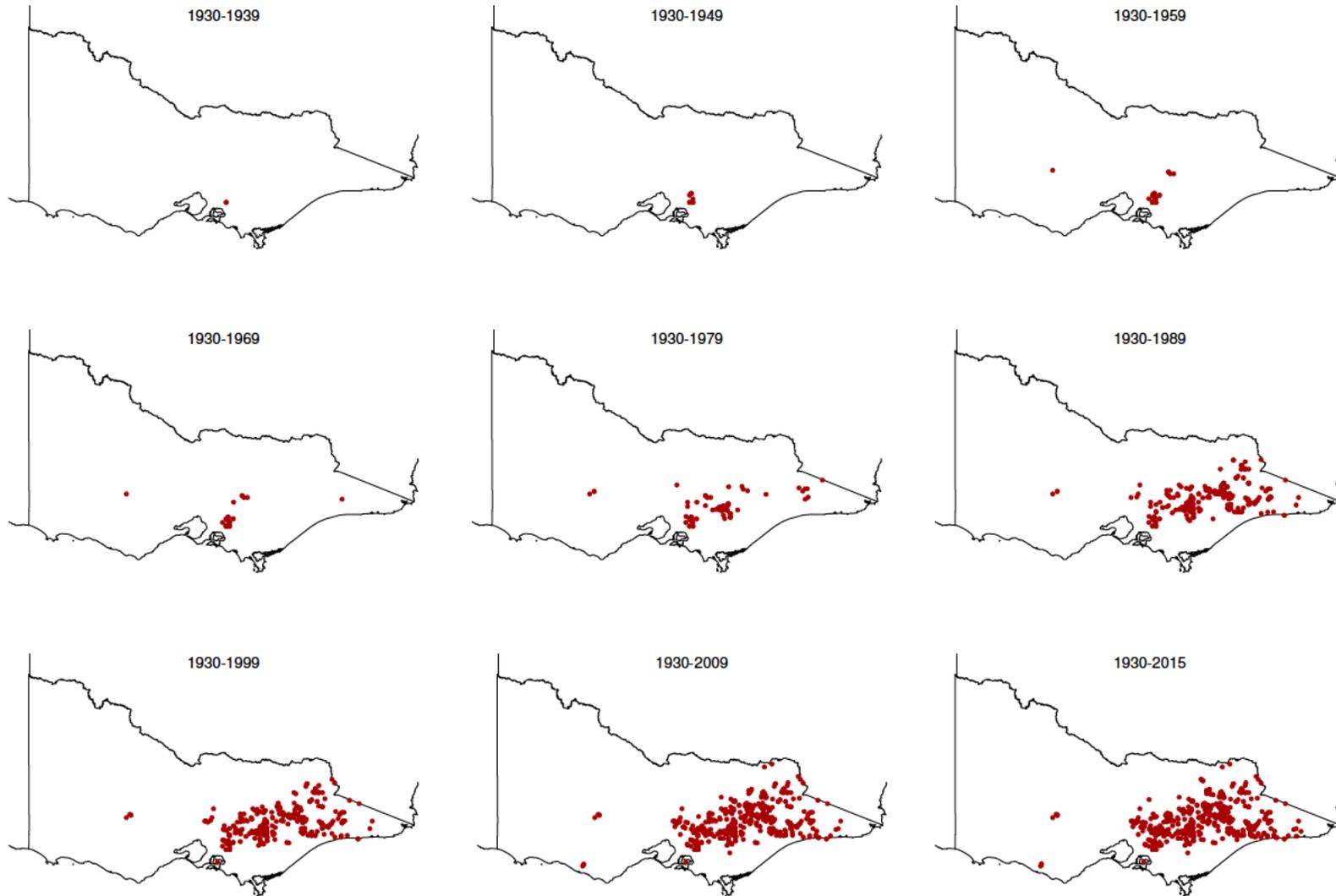
4.1 Sambar Deer

There were 517 sighting records (i.e. classified as 'seen', 'observation' or 'observation with supporting evidence') of Sambar Deer in the VBA. We obtained an additional 60 sighting records still to be added to the VBA from ARIER staff and contractors (50 were photographs from remote cameras), and an additional three sighting records from the Atlas of Living Australia (<http://www.ala.org.au/>). Distributional information gleaned from the literature and interviews were not sufficiently detailed to include as sighting records, but were used to delineate the breeding distribution of Sambar Deer. All 580 sighting records were spatially and temporally referenced and hence were mapped by decade (Fig. 1). The first and last sightings in the VBA were May 1939 and October 2014. When compared with descriptions of the expansion of Sambar Deer distribution in Victoria by Bentley (1998), these sightings clearly underestimate the distribution in any particular decade. However, they do highlight the general pattern of colonisation of eastern Victoria by Sambar Deer, which is described in detail below.

Figure 1 (overleaf). Sighting records of Sambar Deer in Victoria, 1930–2015.

Records are shown cumulatively for each decade (for 1930–2009) or half-decade (for 2010–2015). Data sources are described in the Methodology and Results.

Distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria



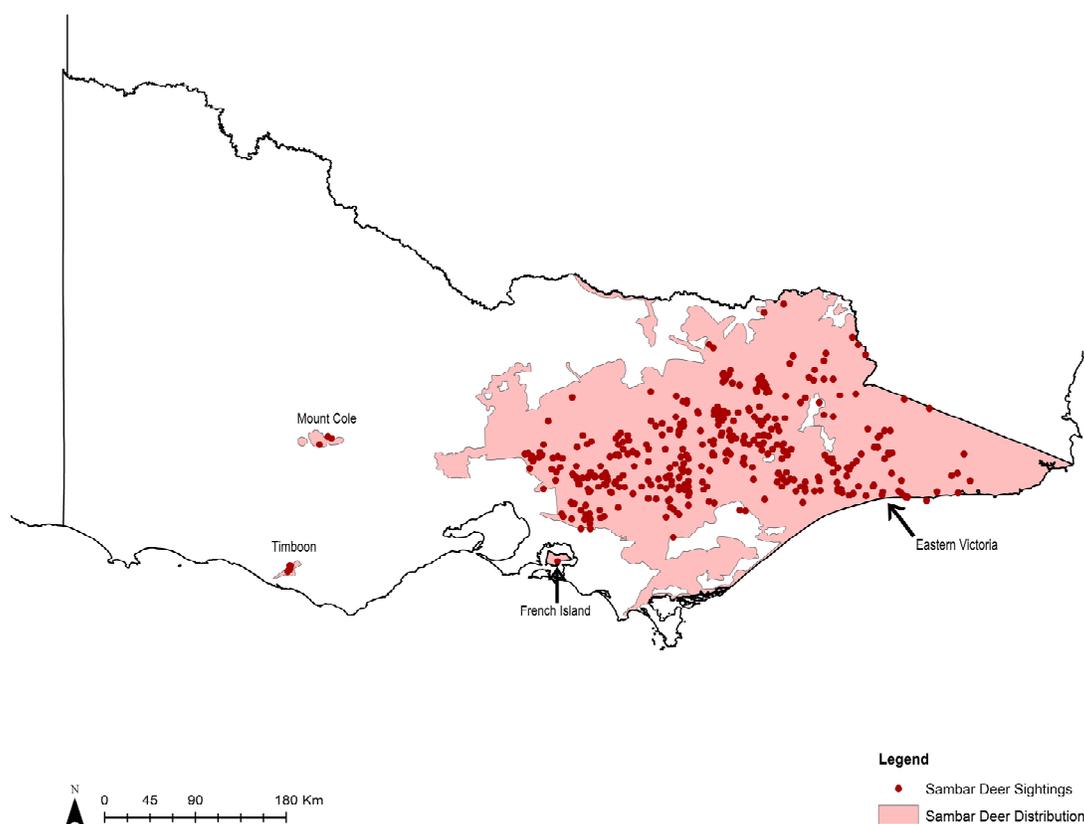


Figure 2. Current (2015) breeding distribution of Sambar Deer in Victoria overlaid on the 580 sighting records. The names refer to four discrete (i.e. reproductively isolated) populations.

Based on the sighting records and distributional information gleaned from the literature and interviews, the current (2015) Victorian Sambar Deer breeding distribution was estimated to be 66,915 km² and consists of four discrete populations: Eastern Victoria, French Island, Mount Cole and Timboon (Fig. 2). These populations are discrete because individuals are not dispersing from one population to another (i.e. they are reproductively isolated). We describe the historical patterns of colonisation and current distributions for these four populations below.

4.1.1 Eastern Victoria Sambar Deer population (66,300 km²)

The Eastern Victoria Sambar Deer population originates from releases in Kinglake National Park (1863), Snake Island (1866), Gembrook (undated and may have included escapes) and Tooradin (1868–1873). Sambar Deer were considered ‘established’ in the Koo Wee Rup swamp at Tooradin by 1878, and this population numbered ‘some hundreds’ in the 1880s (Bentley 1998). The Tooradin population colonised to the north and north-east into the Great Dividing Range, and south-east through Lang Lang, Nyora, Poowong and Tarwin. Bentley (1998) suggests that the population south of the Gippsland Highway peaked in the 1920s, declining thereafter due to the draining of the Koo Wee Rup swamp and more intensive land use. Sambar Deer that were descended from the Tooradin release coalesced with the animals released/escaped at Kinglake and Gembrook. Sambar Deer were living on Philip Island during the 1940s, and were thought to have swum there from French Island (Bentley 1998). Sambar Deer are no longer present on Philip Island.

The first reports of Sambar Deer in the eastern Alps were tracks near Mount Howitt in 1941, and in 1951 Sambar Deer were in the Wonnangatta Valley and along Riley’s Creek (Bentley 1998). Sambar Deer colonised eastward along both the north and south sides of the Great Dividing Range during the 1950s, but

had not yet reached the Nunniong Plateau or the Tambo/Buchan catchments. In 1965, adult male Sambar Deer were seen at Buchan and Gelantipy (Bentley 1998), and they were observed in the Thredbo River area in 1968. Significantly, both adult male and adult female Sambar Deer were observed around Thredbo (Kosciuszko National Park), NSW, in October 1968 (Bentley 1998). By 1980, Sambar Deer from the Eastern Victoria population had colonised the lower third of Kosciuszko National Park (Dunn 1985), and an adult male Sambar Deer was observed in the Australian Capital Territory in 1975 (Bentley 1998).

Moore (in Menkhorst 1995) claimed that Sambar Deer had died out in South Gippsland, except for on French and Snake islands. A breeding population of Sambar Deer remains on French Island (see below), but Sambar Deer have not been seen on Snake Island since the 1990s (R. Mayze, pers. comm.). There are no records of Sambar Deer breeding in the region south of the Princes Freeway and west of the Korumburra–Warragul Road (Fig. 2). Sambar Deer were first seen in the Strzelecki Ranges in about 2000, but are now widespread there, including in Tarra–Bulga National Park and eastward to Holey Plains State Park and the surrounding pine plantations (S. White, pers. comm.; D. Young, pers. comm.) (Fig. 2). Sambar Deer are thought to be breeding in Mount Worth State Park (C. Davies, pers. comm.) and in the timbered hill country from Mirboo North south to Leongatha and then south-east to Port Franklin, and also in the coastal strip from Loch Sport to Port Franklin and north to Foster (D. Young, pers. comm.). Sambar Deer are breeding in the timbered country from Foster south-west to Fish Creek, at Walkerville, and in Cape Liptrap Coastal Park as far west as Walkerville South Road (D. Farrar, pers. comm.). Although Sambar Deer have been seen in the northern part of Wilsons Promontory National Park (WPNP) (J. Whelan, pers. comm.), the species is not considered to be breeding there (e.g. they were classified as extinct there by Meagher and Kohout 2002).

Slee (1985) attempted to delineate the distribution of Sambar Deer in eastern Gippsland. He noted that “the present distribution ... is difficult to delineate – the country is generally very inaccessible” (Slee 1985:6). Sambar Deer were breeding along the Snowy River within Victoria and into NSW, and in the major tributaries of the Snowy (such as the Yalmy, Rodger and Suggan Buggan Rivers), on the Errinundra Plateau and in coastal areas from Tyers to Bemm River. It was noted that “breeding populations undoubtedly occur in other areas”, but that “active colonisation of new areas is still occurring” (Slee 1985:6). Sambar Deer were considered uncommon in the Gippsland Lakes Catchment in 1983 (Norris et al. 1983) and were not present continuously to the NSW border in East Gippsland, being absent from the Cann, Wingan and Genoa catchments south of the Great Dividing Range, and east of the Snowy on the north side of the Great Dividing Range (Slee 1985). However, other experts believed that by 1985 Sambar Deer were present throughout nearly all suitable habitat from the Hume Highway to the Victorian–NSW border (Dunn 1985; Menkhorst 1995; Bentley 1998). Slee (1985) considered that Sambar Deer were “well established” along the coast between Tyers and Bemm River (Slee 1985). Sambar Deer have been present around Mallacoota since at least the 1980s (C. Franken, pers. comm.), and by the early 2000s were in most Gippsland habitats from coastal to alpine (Peel et al. 2005). Sambar Deer are currently common around Nungurner (near Metung), and have been established in Boole Poole, Blond Bay and Macleod Morass since c. 2010 (D. Young, pers. comm.; R. & R. Bilney, pers. comms). One of the authors (LW) found a Sambar Deer antler on Raymond Island in 2004. There are currently high densities of Sambar Deer on the Perry River north of Lake Wellington, and at Bengworden (R. & R. Bilney, pers. comms). Sambar Deer are now widespread east of the Victorian–NSW border (Office of Environment and Heritage 2011; A. Moriarty, pers. comm.; D. Lunney, pers. comm.; P. West, pers. comm.).

In northern Victoria, Sambar Deer are breeding in the Warby Ranges (Parkes et al. 2011), the Chiltern–Box Ironbark National Park and Mount Pilot Park. From the Warby Ranges, Sambar Deer have colonised north to the Murray River along the Ovens River, and then west along the Murray River at least as far as Tocumwal. Although Sambar Deer have not been reported in Barmah National Park, in 2015 two males were photographed at Gunbower (near Cohuna) and a male was killed by a car 3 km north of Swan Hill (Z. Powell, pers. comm.) It is therefore likely that Sambar Deer are now breeding west of Tocumwal, but we could not confirm this.

There is uncertainty about the current western edge of the Eastern Victoria Sambar Deer population. Sambar Deer have been breeding in Puckapunyal Military Area since at least 2009 (M. Bryce, pers. comm.) and are thought to be breeding in Heathcote–Grayton National Park (M. Bryce, pers. comm.). Southwards, Sambar Deer are not believed to be west of the Lancefield–Tooborac Road, but are breeding in Macedon

Regional Park west to and including Lerderderg State Park. However, we have little certainty in this part of the distribution because we could not find local people with detailed knowledge of deer. Fallow Deer (*Dama dama*), and possibly Red Deer (*Cervus elaphus scoticus*), are also present in this area, leading to confusion about which deer species has been sighted. The current western edge of the Eastern Victoria population is unclear. Sambar Deer are established in Lerderderg State Park (to at least Mount Blackwood in the west of the park; D. Peters, pers. comm.), and in 2014 an adult male Sambar Deer was killed on Gisborne Road (between Lerderderg State Park and Pyrite State Forest) (C. Dickie, pers. comm.). However, we could not find any evidence of Sambar Deer around Creswick. Sambar Deer are present in forest around Kilmore East (K. Pearce, pers. comm.) and have recently been found dead on roads around Bendigo. However, Sambar Deer have not yet been reported around Castlemaine (J. Hosking, pers. comm.). A male Sambar Deer was photographed by a remote camera in Cobaw State Forest in 2012.

Sambar Deer are present in some outer Melbourne suburbs, with females seen in Christmas Hills (K. Reynolds, pers. comm.), Kangaroo Ground (M. Scroggie, pers. comm.) and Warrandyte (S. Saddleir, pers. comm.). A Sambar Deer (sex not recorded) was observed in Stanebrae Reserve, Wonga Park, in 2004. Breeding populations of Sambar Deer are in the Melbourne Water catchments of Yan Yean (Liddicoat 2008), Cardinia, Silvan and Sugarloaf (M. Harrison, pers. comm.), and also O'Shannassy (Bennett and Coulson 2011) and Upper Yarra Ranges (Forsyth et al. 2009). Parks Victoria is managing a Sambar Deer culling program in the Dandenong Ranges (D. Hudson, pers. comm.), and Sambar Deer are frequently killed by vehicles on the Princes Freeway between Tynong and Pakenham (M. Harrison, pers. comm.).

We note that two sightings of Sambar Deer in the VBA are just outside the current Eastern Victoria Sambar Deer breeding distribution (Fig. 2). These sightings were in 1988 and 1995, and the sex was not recorded for either. We checked the locations of both sightings with Google Earth, and the farmland habitat they were recorded in was judged unsuitable for Sambar Deer to breed in: these sightings were most likely dispersing male Sambar Deer outside the breeding distribution.

4.1.2 French Island Sambar Deer population (170 km²)

The origin of the French Island Sambar Deer population (Fig. 2) is uncertain, but some were released there in c. 1859 (Bentley 1998). French Island is 1720 m from the nearest mainland, and since Sambar Deer are strong swimmers (Leslie 2011), animals descended from the Tooradin release apparently swam to the island (Bentley 1998). Land-use changes on the mainland around Westernport mean that French Island is now >30 km from the nearest mainland Sambar Deer population, and it is considered unlikely that Sambar Deer from the mainland would now disperse onto French Island (Parkes and Forsyth 2011). Sambar Deer mostly inhabit the 11,000-ha French Island National Park, although they also make use of salt marsh within the 2800-ha French Island Marine Park (Parkes and Forsyth 2011). The size of the French Island Sambar Deer population is unknown, but Parks Victoria staff working on the island believe that about 10 Sambar Deer are harvested annually there (Parkes and Forsyth 2011). We consider the French Island Sambar Deer population to be reproductively isolated from the Eastern Victoria Sambar Deer population. The current breeding distribution of the French Island Sambar Deer population was assumed to be the size of the island, c. 170 km² (Fig. 2).

4.1.3 Mount Cole Sambar Deer population (330 km²)

Sambar Deer were released at Ercildoune, between Ballarat and Mount Cole, in the 1870s and 1880s (Gilbert 1888; Bentley 1998). These animals bred and founded the current population on Mounts Cole and Langi Ghiran (Bentley 1998) (termed the Mount Cole population; Fig. 2). Interestingly, although male Sambar Deer have been seen as far west as Grampians National Park (presumably dispersers from the Mount Cole population; Bentley 1998; D. Panther, pers. comm.), the current breeding distribution is seemingly unchanged from that described by Bentley (1998). The most likely reason for this population not expanding is a lack of suitable adjacent habitat to expand into: Sambar Deer require dense cover, and the large tracts of open farmland surrounding the Mount Cole population appear to be a barrier to the dispersal of female Sambar Deer (Downes 1983; Bentley 1998). The likelihood that this population will further expand its distribution seems low.

4.1.4 Timboon Sambar Deer population (115 km²)

The smallest Victorian Sambar Deer population is centred on Timboon (Fig. 2) and originated from a captive herd that was established in the mid-1970s; animals subsequently either escaped and/or were deliberately released, with the first observations of wild Sambar Deer in the early 1980s (Drayton 2009). The wild Sambar Deer bred and increased in abundance and distribution, to the extent that they began to have significant impacts on riparian revegetation programs (Drayton 2009). From 2002 to 2005, the Curdies Valley Landcare Group funded culling of Sambar Deer (and other wild deer), with about 160 Sambar Deer being shot (D. Drayton, pers. comm.; Fig. 3). The senior author visited Dean Drayton at Timboon on 1 October 2014 to delineate the breeding distribution of this population, and one adult female Sambar Deer was seen by the senior author during a visit to a private property in the Curdies Valley (the sighting was submitted to the VBA). There are two previous records of Sambar Deer from within the distribution delineated by Dean Drayton, both in the 2000s. The most distant record of a Sambar Deer from Timboon was c. 12 km south-east of Cobden in 2011 (D. Drayton, pers. comm.).



Figure 3. Two Sambar Deer culled from the Timboon population in 2003 (photo: Dean Dayton, Curdies Valley Landcare Group).

4.2 Rusa Deer

Rusa Deer were released in central Victoria (including at Gembrook) during the 1890s and established a breeding population, with hunters harvesting them until the late 1940s (Bentley 1998). However, there are no reliable records of Rusa Deer in Victoria since then, and they seemingly either died out or interbred with Sambar Deer (see below), so that little (or none) of the Rusa Deer phenotype remains (Menkhorst 1995). There were no records of Rusa Deer in the VBA (as at 8 April 2015). Rusa Deer can legally be farmed in Victoria, and we are aware of the species being held on several game estates in Gippsland.

Our interviews revealed evidence of wild Rusa Deer currently in Victoria. The strongest evidence is two cast left antlers found by Roger Bilney near Sandy's Creek, upper Snowy River, ~6.5 km from the NSW border in June and July 2014 (Figs 4 and 5). Andrew Moriarty (NSW Department of Primary Industries), an expert on Rusa Deer in Australia (Moriarty 2004b), was shown the image of the longest antler and responded that "it has all the traits of a left rusa antler: wanting up the main beam often seen in Rusa Deer antlers, outer tops not inners like Sambar Deer, quite straight main beam not curved as is often the case in Sambar Deer, and due to its size the terminal end of the main beam is starting to blade slightly which is also a Rusa trait" (A. Moriarty, pers. comm.). The size and shape of the second antler indicates it may have been from the same animal, one or two years younger. Interestingly, another interviewee independently claimed that an acquaintance had shot a young male Rusa Deer in the Sandy Creek area in about 2011 (name withheld as hunting in Snowy River National Park is illegal). If true, this indicates that at least two male Rusa Deer have been present in this part of Victoria. However, there is no evidence that female Rusa Deer are present here, with remote cameras set up by Roger Bilney detecting Sambar Deer, Fallow Deer and Red Deer – but no Rusa Deer. It is most likely that the male Rusa Deer at Sandy Creek dispersed into Victoria from a population in the upper Reedy Creek catchment, between Jindabyne and the NSW border, 30–40 km from

where the antler was found at Sandy Creek; however, we could not find any first-hand information on the Reedy Creek population of Rusa Deer. It is possible that female Rusa Deer from the Reedy Creek population will eventually disperse into the upper Snowy River catchment within Victoria.



Figure 4. Recently cast Rusa Deer antler (length = 77 cm) found near Sandy's Creek, upper Snowy River, Victoria, by Roger Bilney on 16 June 2014 (photo: Roger Bilney).

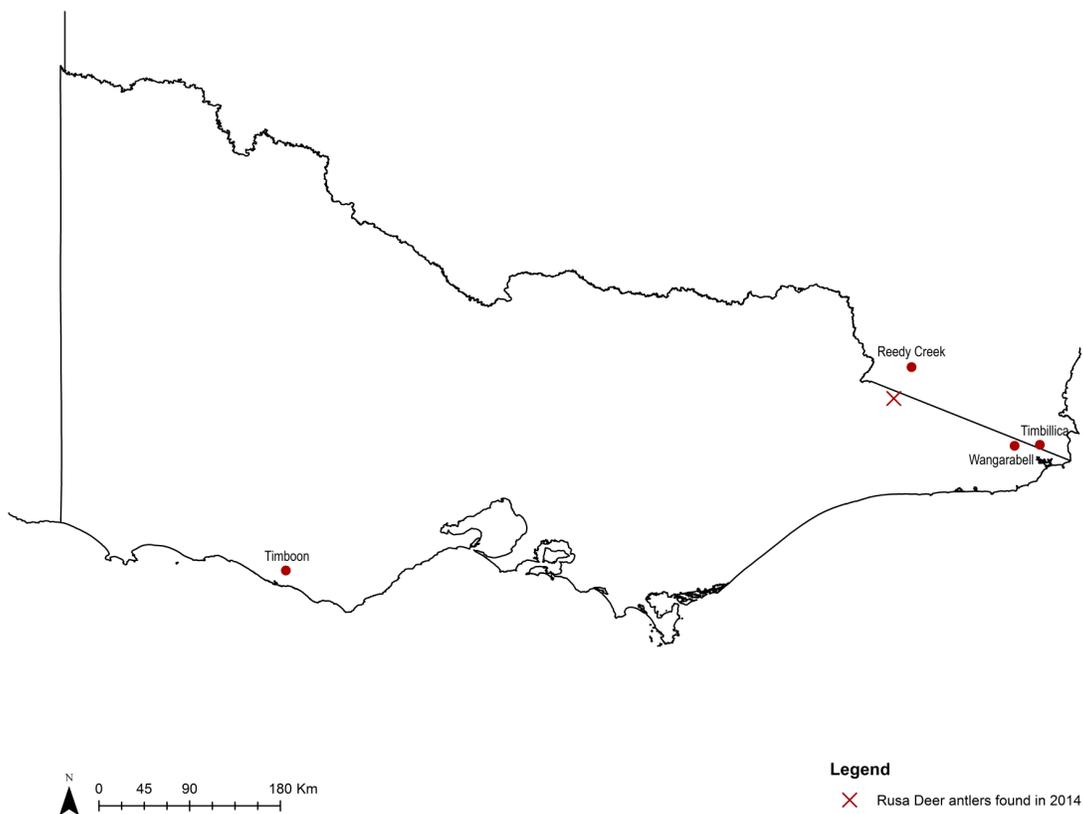


Figure 5. Locations of places mentioned in the text relevant to Rusa Deer in Victoria.

Male Rusa Deer may also have dispersed from NSW into Victoria near Wangarabell (Fig. 5). A landholder at Wangarabell has claimed to have seen a Rusa Deer – Sambar Deer hybrid on his property, and has heard reports of several others in the vicinity (M. Rijs, pers. comm.). A breeding population of Rusa Deer exists at Timbillica State Forest in NSW (M. Rijs, pers. comm.), ~20 km from the Victorian border (Fig. 5). It is possible that male Rusa Deer (or Rusa Deer – Sambar Deer hybrids; see below) have dispersed from Timbillica into the Wangarabell area of Victoria. If the Timbillica Rusa Deer population further increases in abundance and/or its distribution towards Victoria, then the probability that female Rusa Deer will disperse into Victoria will increase.

We also note that some deer culled at Timboon by the Curdies Valley Landcare Group (see ‘Timboon Sambar Deer population’ above) may have been Sambar Deer – Rusa Deer hybrids (D. Drayton, pers. comm.). However, there is no way to verify this report.

As noted above, wild Rusa Deer and Sambar Deer can hybridise (Slee 1984, 1985; van Mourik and Schurig 1985; Idris and Moin 2009). Hybrids grow faster and achieve larger masses than pure Rusa Deer. Male hybrids are fertile with Rusa Deer females, and female hybrids are fertile with Sambar Deer males (Slee 1984). It is therefore possible that any Rusa Deer dispersing into Victoria will hybridise with Sambar Deer such that they become indistinguishable from the latter: this is the scenario proposed by Menkhorst (1995) to explain the demise of the Central Highlands/West Gippsland Rusa Deer population post-1940s. However, we note that there are some areas of Victoria that do not have Sambar Deer, but would likely be suitable habitat for Rusa Deer (e.g. much of the South-West Region) and that it would be incorrect to state that Rusa Deer cannot establish a breeding population in Victoria due to potential hybridisation with Sambar Deer. However, hybridisation with Sambar Deer is likely to affect dispersers from the established wild Rusa Deer populations closest to Victoria (i.e. upper Reedy Creek and Timbillica State Forest).

4.3 Sika Deer

Sika Deer (*Cervus nippon*) were released at Gembrook between 1887 and 1900 (Bentley 1998). The population apparently increased, “but they have not been reliably reported for many years” (Bentley 1998). Sika Deer and Red Deer freely hybridise in the wild (e.g. Goodman et al. 1999; Diaz et al. 2006; Senn and Pemberton 2009), and Panther (2010) suggests that the Grampians Red Deer herd has some Sika Deer characteristics resulting from two Formosan Sika Deer transported to that area in 1871 (Bentley 1998). However, there is no evidence that those Sika Deer were released or escaped. Molecular studies would be required to determine whether the Grampians Red Deer carry Sika Deer haplotypes. The Sika Deer was not mentioned by Menkhorst (1995) or Moriarty (2004a), and one interviewee (name withheld) suggested that Sika Deer (or Sika Deer – Red Deer hybrids) may have escaped from a property near Buxton during the Black Saturday fires of February 2009. Sika Deer are still being farmed near Buxton (A. Cowan, pers. comm.), but there is no evidence of any animals living in the wild around that property, let alone breeding. We therefore do not believe that there is a wild population of Sika Deer in Victoria.

5 Discussion

5.1 Sambar Deer

We delineated the current Sambar Deer distribution using two sources of information: sightings recorded in the VBA and expert knowledge. Although many thousands of Sambar Deer have been legally harvested annually in Victoria for decades (e.g. White et al. 1991; Moloney and Turbull 2013), there are only 517 records of Sambar Deer in the VBA, with an average of only 16 added annually during the decade beginning in 2000. If hunters provided locations for even 10% of Sambar Deer that they harvested (and some of those that were seen but not harvested), then our understanding of historical changes in the distributions of Sambar Deer would be much greater. More generally, understanding the distribution of any introduced

species is necessary for their effective management (Pereira et al. 2012; Department of Environment and Primary Industries 2014). Encouraging the general public (including hunters) and agency staff to enter their observations of introduced species (including wild deer) into the VBA would greatly assist with their management. Interviewing all people with knowledge of Sambar Deer in Victoria was impractical, and instead we interviewed people with robust knowledge of Sambar Deer in selected parts of Victoria. The people interviewed (see Appendix) were therefore from a wide range of locations and agencies.

The current breeding distribution of Sambar Deer in Victoria was estimated to be 66,915 km², and consists of four discrete populations. Although we could not usefully delineate historical distributions of Sambar Deer, the history of each of the four discrete populations is likely to be useful for informing management options. The French Island and Mount Cole populations were established from deliberate releases prior to 1900, although the French Island population was almost certainly supplemented by animals swimming from the Eastern Victoria Sambar Deer population, and neither population appears likely to further expand its breeding distribution, due to an absence of adjacent suitable habitat. Parkes and Forsyth (2011) investigated the feasibility of eradicating the French Island Sambar Deer population. Based on the assumption that the French Island Sambar Deer population is reproductively isolated from the Eastern Victoria Sambar Deer population (and there is no evidence that this is not the case), it was concluded that the eradication of Sambar Deer is technically achievable but potentially complicated by the mix of national park and multiple private land tenures on the island; access to deer living on private land is not simple if landowners object to deer being removed from their properties.

The Timboon Sambar Deer population was established relatively recently (in the 1980s) compared with the other three populations, most likely from escapes and releases. The population has increased and now inhabits many private properties and a variety of land tenures spanning ~115 km². There were only two records from this population in the VBA, although our field visit in October 2014 provided a third record. The Timboon Sambar Deer population appears to be one of the two Sambar Deer populations identified as being present in or around the Otway Ranges in 2000 by Moriarty (2004a). The two populations mapped by Moriarty (2004a) were both believed to have originated from deliberate releases ('translocations'), and each was thought to consist of 500–1000 animals in 2000 (Moriarty 2004a). We did not find evidence of a second Sambar Deer location in or around the Otway Ranges: it is possible that the two populations reported in Moriarty (2004a) were the same (one) population, or that a second population exists and we did not detect it. A molecular ecology study could resolve this knowledge gap (e.g. as conducted for Starling *Sturnus vulgaris* invading Western Australia; Rollins et al. 2009). The Timboon Sambar Deer population has the potential to expand its distribution, particularly eastward into the Otway Ranges, which is suitable habitat for this species (Downes 1983; Gormley et al. 2011). Given its new and relatively small breeding distribution, it may be feasible to manage the Timboon Sambar Deer population differently to the other three Sambar Deer populations, so that it does not colonise the Otway Ranges.

The Eastern Victoria Sambar Deer population currently constitutes >99% of the Sambar Deer breeding distribution within Victoria. We note that this population has expanded its distribution to include large areas in NSW (e.g. Kosciuszko National Park; A. Claridge, R. Hunt, D. Lunney, P. West, pers. comms.) and ACT (Umwelt 2013), but describing that distribution is beyond the scope of this report. The Eastern Victoria Sambar Deer population was established in the 1860s, but it is still colonising new areas, particularly west of the Hume Highway. It also seems likely that Sambar Deer will continue to colonise west along the Murray River, at least to Barmah National Park. We emphasise that it was particularly difficult to obtain information on Sambar Deer in these areas (e.g. there are no sightings from these areas in the VBA), most likely because Sambar Deer are at low densities there and much of the distribution there is on private land, seldom visited by government agency staff, contractors or the general public.

There is concern about the possibility of Sambar Deer establishing a breeding population within WPNP (J. Whelan, pers. comm.). However, Sambar Deer have seemingly never bred there, even when Sambar Deer were breeding on nearby Snake Island. It may be that WPNP is unsuitable breeding habitat for Sambar Deer.

5.2 Rusa Deer

Although a breeding population of Rusa Deer was present in the Central Highlands and West Gippsland until the 1940s, we could not find any evidence of a breeding population re-establishing in Victoria since then. The 2000 postal survey conducted by Moriarty (2004a) indicated that there was a population of <100 Rusa Deer in Gippsland, established from a deliberate release, and a population of 100–500 Rusa Deer in central Victoria, established from farmed animals that had escaped: both populations may have existed but we could not find any evidence of either of them.

Our interviews did reveal that at least one adult male Rusa Deer has recently been living in the Upper Snowy River (and may still be living there). This animal almost certainly dispersed into Victoria from a population in NSW. The reports of Rusa Deer – Sambar Deer hybrids at Wangarabell and Timboon could not be substantiated. The Wangarabell sightings, if true, could be animals that dispersed there from Timbillica State Forest in NSW. Male deer disperse more frequently and further than female deer, and the pattern of male Rusa Deer being detected first in Victoria fits with the source populations being in NSW. It is therefore likely to be only a matter of time before female Rusa Deer disperse into Victoria from NSW. However, the presence of Sambar Deer in the Upper Snowy River and Wangarabell (and more generally throughout eastern Victoria) may mean that Rusa Deer do not establish or persist as a distinct species in Victoria, due to hybridisation.

5.3 Sika Deer

Although Sika Deer were released into the wild in Victoria prior to 1900, there is no evidence of a wild population having established in Victoria or in any other Australian State or Territory (e.g. Menkhorst 1995; Bentley 1998; Moriarty 2004a; Hall and Gill 2005; Bilney 2008). Sika Deer are a prohibited species under all state and territory legislation except for in Victoria, and in the early 2000s Biosecurity Australia permitted the import of Sika semen and embryos, which were used to establish a captive herd in Victoria, apparently mainly as hybrids with Red Deer (Braysher and Walter 2006). Sika Deer are being farmed on at least one property in Victoria, but there is no evidence of a wild Sika Deer population in Victoria.

6 Conclusions

Of the three species considered, only Sambar Deer were confirmed to have a wild, self-sustaining breeding population in Victoria in 2015. The current breeding distribution of Sambar Deer in Victoria was estimated to be 66,915 km² (29% of Victoria's land area), and consists of four discrete (i.e. reproductively isolated) populations: Eastern Victoria (66,300 km²), French Island (170 km²), Mount Cole (330 km²) and Timboon (115 km²).

The French Island and Mount Cole Sambar Deer populations were established from deliberate releases prior to 1900, and neither population appears likely to further expand its distribution due to an absence of adjacent suitable habitat.

The Timboon Sambar Deer population was established in the 1980s, most likely from farmed animals that escaped and/or were deliberately released. The population has increased and now inhabits private properties and a variety of land tenures. This population could greatly expand its breeding distribution, particularly eastward into the Otway Ranges, which is suitable habitat for Sambar Deer. It may be possible to manage the Timboon Sambar Deer population so that it does not further expand its breeding distribution.

The Eastern Victoria Sambar Deer population constitutes >99% of the Sambar Deer distribution within Victoria. This population is still expanding its distribution, particularly west of the Hume Highway and along the Murray River. There is concern about this population colonising WPNP, but it is unclear whether WPNP is suitable habitat for Sambar Deer.

Although Rusa Deer were breeding in the Central Highlands/West Gippsland until the late 1940s, and two populations were identified in a 2000 postal survey of deer distributions, we could not find any evidence of a wild, self-sustaining Rusa Deer population in Victoria. However, two recently cast Rusa Deer antlers were found in the upper Snowy River in 2014, and there were unconfirmed reports of Rusa Deer – Sambar Deer hybrids at Wangarabell and Timboon. The Snowy River Rusa Deer most likely immigrated into Victoria from a nearby population in NSW. Although female Rusa Deer may eventually disperse into eastern Victoria from NSW, the current distributions of Sambar Deer in eastern Victoria may mean that Rusa Deer do not establish or persist as a distinct species in Victoria, due to hybridisation.

Sika Deer are being farmed in Victoria, but there is no evidence of a wild Sika Deer population in Victoria.

7 Recommendations

Encouraging the general public (including hunters) and agency staff to enter their observations of introduced species (including wild deer) into the VBA would greatly improve our knowledge of their distributions and aid their management.

A pilot study should be conducted to assess the potential of molecular techniques for identifying the sources of 'new' deer populations and for helping managers understand the potential for reinvasion if eradication of a new population is attempted.

The probability of eradicating a deer population is highest when the population is smallest (in distribution and abundance). Managers wishing to eradicate a new deer population should therefore implement an appropriate eradication plan as soon as possible.

References

- Atlas of Living Australia*. National Research Infrastructure for Australia. An Australian Government Initiative. <http://www.ala.org.au/> (accessed 8 April 2015).
- Bennett, A. and Coulson, G. (2011). The impacts of Sambar *Cervus unicolor* on the threatened Shiny Nematolepis *Nematolepis wilsonii*. *Pacific Conservation Biology* **16**, 251–260.
- Bentley, A. (1998). *An Introduction to the Deer of Australia*. Bunyip Edition. Australian Deer Research Foundation Ltd, Melbourne.
- Bilney, R.J. (2008). Sambar. Pages 777–778 in Van Dyck, S. and Strahan, R. (eds) *The Mammals of Australia*, 3rd edn. Reed New Holland, Sydney.
- Braysher, M. and Walter, E. (2006). *Draft risk assessment on the import of live Sika deer (Cervus nippon) under the EPBC Act, 1999*. Report prepared for The Department of the Environment and Heritage (November 2006), Braysher Consulting, Canberra.
- Catchpole, E.A., Fan, Y., Morgan, B.J.T., Clutton-Brock, T.H. and Coulson, T. (2004). Sexual dimorphism, survival and dispersal in red deer. *Journal of Agricultural, Biological and Environmental Statistics* **9**, 1–26.
- Caughley, G. (1970). Liberation, dispersal and distribution of Himalayan thar (*Hemitragus jemlahicus*) in New Zealand. *New Zealand Journal of Science* **13**, 220–239.
- Department of Environment and Primary Industries. (2013). *Estimating the economic impact of hunting in Victoria in 2013*. Department of Environment and Primary Industries, Melbourne. 113 pp.
- Department of Environment and Primary Industries. (2014). *Invasive plants and animals policy framework*. <http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/protecting-victoria-from-pest-animals-and-weeds/invasive-plants-and-animals/invasive-plants-and-animals-policy-framework> (accessed 12 December 2014).
- Department of Environment, Land, Water and Planning. (2015). *Victorian Biodiversity Atlas*. <http://www.depi.vic.gov.au/environment-and-wildlife/biodiversity/victorian-biodiversity-atlas> (accessed 8 April 2015).
- Department of Sustainability and Environment. (2009). *Draft Flora and Fauna Guarantee Action Statement: reduction in biodiversity of native vegetation by Sambar Deer (Cervus unicolor)*. Department of Sustainability and Environment, Melbourne, Australia.
- Diaz, A., Hughes, S., Putman, R., Mogg, R. and Bond, J.M. (2006). A genetic study of sika (*Cervus nippon*) in the New Forest and in the Purbeck region, southern England: is there evidence of recent or past hybridization with red deer (*Cervus elaphus*)? *Journal of Zoology* **270**, 227–235.
- Downes, M. (1983). *The Forest Deer Project 1982. Vol. II. Ecology and Hunting*. Forests Commission, Melbourne.
- Drayton, D. (2009). Response to the Draft Flora and Fauna Guarantee Action Statement Reduction in biodiversity of native vegetation by Sambar. Unpublished letter to Department of Sustainability and Environment, East Melbourne. 8 pp.
- Dunn, J. (1985). Sambar deer in the Kosciusko National Park. *Australian Deer* **10** (2), 3–5.
- Forsyth, D.M., McLeod, S.R., Scroggie, M.P. and White, M. (2009). Modelling the abundance of wildlife using field surveys and GIS: non-native sambar deer (*Cervus unicolor*) in the Yarra Ranges, south-eastern Australia. *Wildlife Research* **36**, 231–241.
- Game Management Authority. (2015). *Victorian Hunting Guide 2015*. Game Management Authority, Melbourne. 68 pp.

- Gilbert, R. (1888). Notes on Sambhur and Sambhur stalking. *Journal of the Bombay Natural History Society* **3**, 224–232.
- Goodman, S.J., Barton, N.H., Swanson, G., Abernethy, K. and Pemberton, J.M. (1999). Introgression through rare hybridization: a genetic study of a hybrid zone between red and sika deer (Genus *Cervus*) in Argyll, Scotland. *Genetics* **152**, 355–371.
- Gormley, A.M., Forsyth, D.M. and Griffioen, P.G. (2009). Modelling the distributions of sambar deer, hog deer, red deer, fallow deer, feral goat and feral pig in Victoria using presence-only data. Arthur Rylah Institute for Environmental Research Unpublished Client Report for Biosecurity Victoria, Department of Primary Industries, Victoria. 24 pp.
- Gormley, A.M., Forsyth, D.M., Griffioen, P., Woodford, L., Lindeman, M., Scroggie, M.P. and Ramsey, D.S.L. (2011). Using presence-only and presence-absence data to estimate the current and potential distributions of established invasive species. *Journal of Applied Ecology* **48**, 25–34.
- Hall, G.P. and Gill, K.P. (2005). Management of wild deer in Australia. *Journal of Wildlife Management* **69**, 837–844.
- Idris, I. and Moin, S. (2009). Somatic chromosomes of the Bornean Sambar deer and Rusa deer interspecific hybrids. *American Journal of Applied Sciences* **6**, 862–868.
- Kjellander, P., Hewison, A.J.M., Liberg, O., Angibault, J.-M., Bideau, E. and Cargnelutti, B. (2004). Experimental evidence for density-dependence of home-range size in roe deer (*Capreolus capreolus* L.): a comparison of two long-term studies. *Oecologia* **139**, 478–485.
- Leslie, D.M. Jr. (2011). *Rusa unicolor* (Artiodactyla: Cervidae). *Mammalian Species* **43**, 1–30.
- Liddicoat, E.K.H.-R. (2008). *Population density and habitat use of two deer species in a Victorian water catchment*. BSc (Hons) Thesis, Department of Zoology, The University of Melbourne, Melbourne, Victoria, Australia.
- Lindeman, M.J. and Forsyth, D.M. (2008). *Agricultural impacts of wild deer in Victoria*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 182. Department of Sustainability and Environment, Heidelberg, Victoria. 21 pp.
- Loe, L.E., Myrnerud, A., Veiberg, V. and Langvatn, R. (2009). Negative density-dependent emigration of males in an increasing deer population. *Proceedings of the Royal Society of London B* **276**, 2581–2587.
- Meagher, D. and Kohout, M. (2002). *A Field Guide to Wilsons Promontory*. Oxford University Press, Melbourne. 360 pp.
- Menkhorst, P.W. (1995). *Mammals of Victoria: Distribution, Ecology and Conservation*. Oxford University Press, Melbourne.
- Moloney, P.D. and Turnbull, J.D. (2013). *Estimates of harvest for deer, duck and quail in Victoria: results from surveys of Victorian Game Licence Holders in 2013*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 251. Department of Environment and Primary Industries, Heidelberg, Victoria.
- Moriarty, A. (2004a). The liberation, distribution, abundance and management of wild deer in Australia. *Wildlife Research* **31**, 291–299.
- Moriarty, A.J. (2004b). *Ecology and environmental impact of Javan rusa deer (Cervus timorensis russa) in the Royal National Park*. PhD Thesis, University of Western Sydney, New South Wales, Australia.
- Murray, M.D. and Snowden, W.A. (1976). The role of wild animals in the spread of exotic diseases in Australia. *Australian Veterinary Journal* **52**, 547–554.
- Norris, K.C., Mansergh, I.M., Ahern, L.D., Belcher, C.A., Temby, I.D. and Walsh, N.G. (1983). *Vertebrate fauna of the Gippsland Lakes Catchment Victoria*. Occasional Paper Series Number 1. Fisheries and Wildlife Division, Ministry for Conservation, Melbourne.

- Office of Environment and Heritage. (2011). *Kosciuszko National Park Plan of Management (2006) 2010–2011 Implementation Report*. Office of Environment and Heritage, NSW National Parks and Wildlife Service. 45 pp.
- Panther, D. (2010). *Seasons of the Red Deer: 150 Years of Red Deer in Australia 1860–2010*. D. Panther (self-published), Ararat, Victoria.
- Parkes, J. and Forsyth, D. (2011). *Eradicating new populations of introduced large herbivores in Victoria. Part II. Feasibility of eradicating sambar deer on French Island*. Landcare Research Contract Report LC 208. Landcare Research Ltd, Lincoln, New Zealand. 19 pp.
- Parkes, J., Ramsey, D., Forsyth, D., Woodford, L. and Gleeson, D. (2011). *Eradicating new populations of introduced large herbivores in Victoria. Part I. Feasibility of eradicating feral goats in the Warby Ranges*. Landcare Research Contract Report LC 88. Landcare Research Ltd, Lincoln, New Zealand. 30 pp.
- Peel, B., Bilney, R.J. and Bilney, R.J. (2005). Observations of the ecological impacts of Sambar *Cervus unicolor* in East Gippsland, Victoria, with reference to destruction of rainforest communities. *Victorian Naturalist* **122**, 189–200.
- Pereira, H.M. Navarro, L.M. and Martins, I.S. (2012). Global biodiversity change: the bad, the good, and the unknown. *Annual Review of Environment and Resources* **37**, 25–50.
- Rollins, L.A., Woolnough, A.P., Wilton, A.N, Sinclair, R. and Sherwin, W.B. (2009). Invasive species can't cover their tracks: using microsatellites to assist management of starling (*Sturnus vulgaris*) populations in Western Australia. *Molecular Ecology* **18**, 1560–1573.
- Senn, H.V. and Pemberton, J.M. (2009). Variable extent of hybridization between invasive sika (*Cervus nippon*) and native red deer (*C. elaphus*) in a small geographical area. *Molecular Ecology* **18**, 862–876.
- Slee, K.J. (1984). The sambar deer in Victoria. Deer Refresher Course for Veterinarians. *University of Sydney, Proceedings* **72**, 559–572.
- Slee, K.J. (1985). Some observations on captive sambar and sambar hybrid deer in Victoria. *Australian Deer* **10** (2), 7–10.
- Umwelt (Australia) Pty Ltd. (2013). *State of knowledge report: feral deer in the ACT*. Unpublished report prepared for ACT Conservation Planning and Research. Umwelt (Australia) Pty Ltd, O'Connor, ACT.
- Van Mourik, S. and Schurig, V. (1985). Hybridization between sambar (*Cervus (Rusa) unicolor*) and rusa (*Cervus (Rusa) timorensis*) deer. *Zoologischer Anzeiger* **214**, 177–184.
- White, S., Slee, K. and Draisma, M. (1991). A questionnaire survey of sambar deer (*Cervus unicolor*, Kerr 1792) hunting in Victoria, 1980 to 1989. *Australian Deer* **16** (2), 50–55.
- Wilson, G., Dexter, N., O'Brien, P. and Bomford, M. (1992). *Pest Animals in Australia – A Survey of Introduced Wild Mammals*. Bureau of Rural Sciences & Kangaroo Press, Sydney.

Appendix

Individuals consulted about distributions of Sambar Deer, Rusa Deer and Sika Deer. Affiliations are shown for people employed by State/Territory Government agencies; –, no affiliation. Individuals are listed alphabetically by surname for each State/Territory.

Name	Agency
Victoria	
Jerry Alexander	Department of Environment and Primary Industries
Chris Anderson	Department of Environment and Primary Industries
Richard Appleton	HVP Plantations
Helen Barker	Parks Victoria
Ami Bennett	University of Melbourne
Roger Bilney	–
Rohan Bilney	–
Michael Bryce	Department of Defence
Dash Burns	Parks Victoria
David Butterworth	Parks Victoria
Rodney Carter	Game Management Authority
Andy Cowan	Deer Industry Association of Australia
Charles Dickie	Parks Victoria
Mick Douglas ¹	Parks Victoria
Dean Drayton	Curdies Valley Landcare Group
Heath Dunstan	Game Management Authority
David Farrar	Parks Victoria
Charlie Franken	Department of Environment and Primary Industries
Andrew Hammond	Department of Environment and Primary Industries
Mike Harrison	Australian Deer Association
Richard Hill	Department of Environment and Primary Industries
Robin Holmes	Department of Environment and Primary Industries
John Hosking	Parks Victoria
Danny Hudson	Parks Victoria
Greg Ivone	Department of Environment and Primary Industries
Glenn Kilburn	Game Management Authority
David Klippel	Department of Environment and Primary Industries
John Matthews	Department of Environment and Primary Industries
Ron Mayze	–
Geoff McClure	Department of Environment and Primary Industries
Stewart McGlashan	Game Management Authority
Brian McKinnon	Parks Victoria
Tony Mitchell	Department of Environment and Primary Industries
Jesse Nation	Parks Victoria
Dwayne Needham	Department of Environment and Primary Industries
Darryl Panther	–
James Pardew	Department of Environment and Primary Industries
Ken Pearce	Australian Deer Association
Des Peters	Parks Victoria
Chela Powell	VicForests
Zachary Powell	Game Management Authority

Distributions of Sambar Deer, Rusa Deer and Sika Deer in Victoria

Phil Reichelt	Parks Victoria
Jim Reside	Wildlife Unlimited
Keith Reynolds	Parks Victoria
Matt Rijs	–
Steve Saddleir	–
Michael Scroggie	Department of Environment and Primary Industries
Andrew Scott	Victoria Police (Mallacoota)
Ken Slee	Australian Deer Association
David Smith	Department of Environment and Primary Industries
Dave Stephenson ¹	Parks Victoria
Trent Tonissen	Department of Environment and Primary Industries
Mark Tucker	Melbourne Water
John Turnbull	Game Management Authority
Tony Venes	Parks Victoria
Jim Whelan	Parks Victoria
Stuart White	Australian Deer Association
David Young	Department of Environment and Primary Industries
ACT	
Ollie Orgill	ACT Parks and Conservation Service
New South Wales	
Bruce Cameron	New South Wales Department of Primary Industries
Andrew Claridge	Office of Environment and Heritage NSW
Rob Hunt	Office of Environment and Heritage NSW
Dan Lunney	Office of Environment and Heritage NSW
Andrew Moriarty	New South Wales Department of Primary Industries
Duane Shorecross	New South Wales NPWS
Tony Stubbs	New South Wales NPWS
Peter West	New South Wales Department of Primary Industries
South Australia	
David Peacock	Biosecurity SA

¹ Interviewed August 2010 during a site visit for another project (Parkes and Forsyth 2011).

www.delwp.vic.gov.au