



PARKS VICTORIA TECHNICAL SERIES

NUMBER 55

Birds as Environmental Indicators
Review of Literature

S. A. Chambers

December 2008

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First published 2008

Published by Parks Victoria
Level 10, 535 Bourke Street, Melbourne Victoria 3000

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National Library of Australia
Cataloguing-in-publication data

Includes bibliography
ISSN 1448-4935

Citation:

Chambers, S.A. (2008) *Birds as Environmental Indicators: Review of Literature*. Parks Victoria Technical Series No. 55. Parks Victoria, Melbourne.



Printed on environmentally friendly paper

Parks Victoria Technical Paper Series No. 55

Birds as Environmental Indicators

Review of Literature

Scott A. Chambers

Birds Australia

December 2008

EXECUTIVE SUMMARY

Under the Signs of Healthy Parks initiative, Parks Victoria seeks to establish a monitoring program throughout the Victorian reserves network to provide information on natural values, threatening processes, emerging conservation issues and the efficacy of management activities. One of the most obvious and readily observable of faunal groups is birds. This report reviews the potential for birds to function as indicator species for other parameters of the environment and assesses the potential for a reliable surrogate monitoring program based on birds to be implemented within the Victorian reserves network.

The report finds that the use of indicator species is contentious and the approach has several limitations. However, indicator species may provide a crude but useful index of environmental parameters when other monitoring is not feasible, provided that precautions are taken in the selection of species and the interpretation of monitoring data. Birds are often claimed to be good indicator species, but in reality they possess qualities that can both enhance and diminish their value as indicator species. In at least some circumstances, birds are likely to be a less suitable target for surrogate monitoring than other taxa.

The report identifies that monitoring breeding success and/or causes of breeding failure, can provide a more accurate surrogate assessment of environmental properties than presence/absence or abundance data alone, especially in relation to coastal and highly mobile species. However, this typically requires targeted studies to be undertaken where the costs or resources needed for the study could approach or even exceed the costs or resources required to undertake direct sampling of the variable of interest.

Currently, systematic monitoring is conducted in only a small proportion of Victorian reserves and many reserves lack even basic inventories of fauna and flora. In this context, population trends in selected species of birds may alert Parks Victoria to emerging conservation issues in reserves for which other forms of monitoring are not feasible. A set of candidate avian indicator species is identified that may fulfil such a role in light of the identified limitations of the indicator species approach.

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1 INTRODUCTION

1.1. Indicators and Indicator Species

To preserve and manage the natural environment, it is necessary to monitor the condition of many constituent ecosystems. Ideally, conservation agencies would like to monitor all properties of interest within a natural ecosystem. In reality, finite resources and the vast complexity of natural ecosystems permit only a small proportion of these properties to be monitored. In the absence of comprehensive data on whole ecosystems, conservation agencies may choose to monitor a set of indicators: physical, chemical or biological properties that indicate the status of un-sample parameters of the environment. Often, individual species or groups of species are selected to function as biological indicators.

This report has two aims:

- To review the ability of birds to function as indicator species in light of the published scientific literature.
- To determine the prospects for establishing a reliable surrogate monitoring program based on birds within the Victorian reserves network.

In the context of this report, the following definition of indicator species has been adopted:

“A species whose characteristics (e.g. presence or absence, abundance, density, mortality rate, breeding success) indicate the condition of ecosystems, the status of other taxa, the presence and impacts of stressors, or patterns of biological diversity” (after Landres et al. 1988 and McGeoch 1998).

1.2 A Note on Definitions

The term indicator is routinely applied in the scientific literature to both a species to be monitored (*i.e.* the indicator species) and the specific characteristic of the indicator species that informs the status of the ecological property of interest (*e.g.* presence or absence, density, mortality rate, reproductive success). For example, Carignan & Villard (2002) state “...the Ovenbird, *Seiurus aurocapillus*, is a good indicator of closed-canopy, mature forests with a sparse understorey”, when in fact “...the [presence/absence of the] Ovenbird...is a good indicator of [the presence/absence of] closed-canopy, mature forests with a sparse understorey”. This report uses the term ‘indicator species’ where applicable to avoid confusion.

2 INDICATOR SPECIES

2.1 Types of Indicator Species

Indicator species can be classified in many different ways (Lindenmayer & Burgman 2005) according to their function. For example, McGeoch (1998) recognised three broad classes of indicator species:

- **Environmental indicators** indicate the presence and/or intensity of stressors. McGeoch (1998) included in this class five types of pollution indicator species identified by Spellerberg (1991):
 1. **Sentinels** are sensitive species that are introduced into a target environment, for example, to provide early-warning of the presence of pollutants or to determine the effects of pollutants on biota.
 2. **Detectors** are species that are endemic to a target area and may exhibit a measurable response to change in their environment, e.g. changes in behaviour, mortality or age-class structure.
 3. **Exploiters** are species whose presence indicates probable disturbance or pollution. Exploiter species often thrive in disturbed or polluted areas because competitors are unable to persist in the altered environment and/or because they can utilize polluted ecosystems or the pollutants themselves.
 4. **Accumulators** are species that accumulate pollutants in measurable quantities in their body tissue.
 5. **Bioassay organisms** are used in laboratory studies to detect the presence and/or concentration of pollutants or to determine pollutant toxicity.
- **Ecological indicators** indicate the impacts of stressors on other taxa.
- **Biodiversity indicators** indicate the diversity of other taxa within a habitat or set of habitats.

However, Lindenmayer & Burgman (2005) recognised five main classes of indicator species (after Lindenmayer *et al.* 2002):

- **Bio-indicator species** respond to changes in the environment. For example, the North American species Kirtland's Warbler *Dendroica kirtlandii* has been proposed as an indicator of global warming (Botkin *et al.* 1991).
- **Site-type indicator species** indicate the presence of particular environmental conditions, such as certain rock or soil types or habitat elements at a particular site.
- **Recovery indicator species** reflect the extent of recovery of an ecosystem (Lindenmayer & Burgman 2005). For example, birds have been used to determine the success of habitat restoration programs in the United States (Weller 1995; Gardali *et al.* 2006).
- **Management indicator species** indicate the impacts of management regimes on biota. For example, the return of palatable plant species after the removal of grazing mammals.
- **Pollution indicator species** indicate the effects of pollutants on the biotic environment. Lindenmayer & Burgman (2005) included in this class the five types of pollution indicator species identified by Spellerberg (1991) and described above.

Lindenmayer & Burgman (2005) also acknowledged keystone species and dominant species in their discussion of the indicator species concept. The defining characteristics of these species make them attractive targets for environmental monitoring, but they need not necessarily function as indicator species as defined in this report:

- **Keystone species** interact strongly with sympatric taxa. Because of these interactions, keystone species may have a disproportionately large influence on natural ecosystems relative to their abundance (Mills *et al.* 1993; Paine 1995; Simberloff 1998). For example, the Southern Cassowary *Casuarius casuarius* is considered a keystone species because it is the main dispersal agent for approximately 100 fruiting plant species in rainforests of north-eastern Queensland (Moore 2007).
- **Dominant species** comprise a large proportion of the biomass of an ecosystem or numerically dominate an ecosystem (Lindenmayer *et al.* 2002; Lindenmayer & Burgman 2005).

The indicator species concept is often also associated with other taxon-based surrogate approaches in the literature. Like keystone and dominant species, the surrogates listed below possess attributes that are attractive for environmental monitoring, but they may not necessarily function as effective indicator species:

- **Umbrella species** require large areas of habitat to maintain viable populations. By conserving habitat for umbrella species, it is presumed that sympatric species with less demanding spatial habitat requirements will also be protected (Simberloff 1998; Carignan & Villard 2002; Favreau *et al.* 2006).
- **Focal species** are the subject of a taxon-based surrogate conservation approach developed by Lambeck (1997). The focal species approach builds on the concept of umbrella species by (1) identifying the threatening processes that are operating in an ecosystem or landscape; (2) selecting a suite of focal species, each of which is considered to be the most sensitive species in the ecosystem or landscape to one or more of the identified threats; and (3) using the requirements of the nominated focal species to set conservation targets (Lambeck 1997; Favreau *et al.* 2006). Lambeck (1997) recognised four sub-classes of focal species:
 1. **Area-limited ‘umbrella’ species** require large areas of habitat to maintain viable populations (Carignan & Villard 2002).
 2. **Dispersal-limited species** are limited in their ability to move from one patch of habitat to another or face a high risk of mortality in doing so (Carignan & Villard 2002).
 3. **Resource-limited species** depend on specific resources (*e.g.* nectar, fruit, tree hollows) that may be spatially or temporally scarce (Carignan & Villard 2002).
 4. **Process-limited species** are sensitive to ecological processes such as fire, flood, grazing, predation or competition with invasive species (Lambeck 1997; Carignan & Villard 2002).
 5. **Flagship species** are charismatic species that easily attract public support for conservation (*e.g.* Giant Panda *Ailuropoda melanoleuca* and whales; Carignan & Villard 2002; Favreau *et al.* 2006).

2.2 Characteristics of Indicator Species

To be considered for use in an environmental monitoring program, an indicator species must possess two essential qualities:

- The indicator species must be sensitive to change in the environmental property or properties of interest (Landres *et al.* 1988; Simberloff 1998). This association is intuitively necessary for the status of the environmental property or properties of interest to be inferred from trends in the indicator species.
- The indicator species must be sufficiently detectable and the targeted characteristic(s) of the indicator species sufficiently measurable for monitoring data to be collected in a reliable and repeatable fashion. This attribute is necessary to ensure that sample sizes are large enough for change to be detected.

An indicator species may also possess a combination of non-essential but desirable attributes that enhance their utility. Examples of these qualities are provided in Table 1 below.

Table 1. Desirable attributes of an indicator species used for environmental monitoring.

Indicator Species Attribute	Importance for monitoring	References
Resolved Taxonomy	This is stable and well-resolved which minimises the potential for monitoring data to be confounded by misidentification of species in the field	Pearson & Cassola 1992; Furness <i>et al.</i> 1993; Carignan & Villard 2002; Gregory <i>et al.</i> 2005
Well understood Biology, ecology and life history	A comprehensive understanding of these elements is necessary to correctly interpret monitoring data	Landres <i>et al.</i> 1988; Noss 1990; Pearson & Cassola 1992. Furness <i>et al.</i> 1993
History of previous monitoring	Where available, historical monitoring data provides a baseline against which contemporary data can be compared and monitoring methods that are tried and tested.	
Broad distribution	This permits multiple sites to be monitored and compared using a single indicator species although comparisons between sites can be problematic	Noss 1990; Pearson & Cassola 1992. Landres <i>et al.</i> 1988.
Resident species	Recommended because non-resident species such as migrants or nomads (1) may be able to avoid the impacts of stressors operating within the target area by utilising resources elsewhere and (2) may be impacted by stressors operating outside of the target area. An additional bonus of targeting resident species is that direct monitoring can be conducted throughout the year Although resident species are the preferred targets for ecological monitoring, the inclusion of both resident and non-resident species in a monitoring scheme may enable a greater range of stressors to be detected than would be possible by monitoring resident species alone	Szaro & Balda 1982; Bock & Webb 1984; Landres <i>et al.</i> 1988; Koskimies 1989; Hilty & Merenlender 2000. Koskimies 1989.

Table 1. (continued)

Indicator Species Attribute	Importance for monitoring	References
Detectability	Easy to detect and inexpensive to monitor	Noss 1990; Pearson & Cassola 1992
Specialised species	Species that rely on a limited range of habitat types and/or food resources are likely to be more sensitive to disturbance than generalist species. This is because generalist species may be able to avoid or lessen the impacts of disturbance by switching food resources or altering patterns of habitat use	Koskimies 1989; Pearson & Cassola 1992; Hilty & Merenlender 2000; Carignan & Villard 2002
Tolerance	The tolerance of the indicator species to change in the environmental property or properties of interest has been determined and well understood	Hilty & Merenlender 2000
Species exhibits consistent response to changes and threats	The indicator species exhibits minimal variation in its response to change in the environmental property or properties of interest	Landres <i>et al.</i> 1988
Provides early-warning	The indicator species provides early-warning of change in the environmental property of interest	Kelly & Harwell 1990; Noss 1990
Directly indicates the cause of change	The indicator species directly indicates the cause of change rather than simply the existence of change	Morrison 1986; Carignan & Villard 2002
Species responds to multiple stressors	Indicator species provide a means for continuous assessment of multiple stressors operating over a broad range of intensities. This permits multiple stressors to be monitored using a single indicator species and ensures that the indicator species will not become ineffective beyond certain stressor intensity thresholds	Noss 1990; Woodley 1996; O'Connell 1998; Gibbs <i>et al.</i> 1999
Social, political and economic importance	The indicator species is aligned with relevant social, political or economic agendas	Pearson & Cassola 1992; Hilty & Merenlender 2000
Generation time	Species with short generation times (e.g. invertebrates) tend to react more quickly to ecosystem changes than species with longer generation times. It can be useful when the generation time of the indicator species matches the aims of the monitoring program	Niemelä <i>et al.</i> 1993; Carignan & Villard 2004. Peters 1983.

No single indicator species will possess all of the desired attributes identified (Noss 1990). Indeed, some desired attributes conflict with one another, for example, cosmopolitan distribution versus habitat specialism (Hilty & Merenlender 2000).

An issue that may be encountered when assessing candidate indicator species is that many of the desirable attributes listed above assume a sound and detailed knowledge of the biology and ecology of the species in question. However, this is often not the case. In

instances where scientific data are lacking, it may be necessary to judge the merit of candidate indicator species based on alternative sources of information such as expert opinion, personal observations or non-scientific literature, pending additional research.

2.2.1 Control Populations

One additional factor to consider when discussing the desired qualities of an indicator species is the existence of 'control' populations. In the context of monitoring indicator species to determine the presence or impacts of stressors, it may prove instructive to compare populations in target areas in which the stressor or stressors of interest are known or suspected to be operating ('treatment' populations) with populations in similar habitat in non-target areas in which the stressor or stressors of interest are known to be absent ('control' populations). However, caution must be exercised if such comparisons are made. As Landres *et al.* (1988) note, spatially-separated ecosystems that appear similar may actually differ in vegetation structure, floral and/or faunal species composition, spatial patterning of habitats and resources or natural disturbance regimes. Any of these elements may influence the status or role of an indicator species in an ecosystem.

2.3 Selection of Indicator Species

Many procedures have been proposed to select indicator species (Carignan & Villard 2002). For example, Hilty & Merenlender (2000) proposed a step-wise filtering process based on 13 selection criteria recommended by nine published studies. Hutto (1998) identified candidate indicator species based on their occurrence within one or a few *a priori*-defined habitat types. Kremen (1992), Dufrêne & Legendre (1997) and Hausner *et al.* (2003) used statistical techniques to test for associations between species and particular habitat attributes.

Carignan & Villard (2002) considered that indicator species for monitoring environmental condition should be selected by quantitative criteria in preference to more subjective qualitative criteria. They proposed a simple procedure with two quantitative selection criteria: (1) the frequency of occurrence of the indicator species differs among areas with contrasting degrees of anthropogenic disturbance; and (2) the indicator species is a habitat specialist.

2.4 Benefits of Using Multiple Indicator Species

Many contemporary authors advocate the use of multiple indicator species or groups of indicator species (Koskimies 1989; Noss 1990; Kremen 1994; Griffith 1997; Hutto 1998; Carignan & Villard 2002; Kavanagh *et al.* 2005). This is because one or a small number of indicator species is unlikely to adequately represent the full range of biotic responses to a particular set of environmental conditions (Carignan & Villard 2002). Furthermore, multiple species can usually be monitored by common methods, providing additional data at little or no extra cost (Hutto 1998; Kavanagh *et al.* 2005).

3 BIRDS AS INDICATOR SPECIES

3.1 Use of Birds as Indicator Species

Birds have been proposed, assessed or used as indicator species for a range of environmental parameters, including the following:

- Biodiversity and species richness (Block *et al.* 1987; Jansson 1998; Blair 1999; Chase *et al.* 2000; Vielliard 2000; Mikusinski *et al.* 2001; Juutinen & Mönkkönen 2004; Kati *et al.* 2004; Sauberer *et al.* 2004; Fleishman *et al.* 2005; Mattsson & Cooper 2006; Sergio *et al.* 2006), including patterns of occurrence of rare and threatened species (Balmford & Garson *et al.* 2002; Lawler *et al.* 2003; Thomson *et al.* 2007). In some instances, birds have been used as surrogate taxa for biodiversity to prioritise areas for conservation (Baltzer *et al.* 2000; Moore *et al.* 2003; Jiguet & Julliard 2006; Loyola *et al.* 2007).
- Environmental contamination by pollutants such as pesticides (especially persistent organochlorines), heavy metals and polychlorinated biphenyls (Brisbin 1993; Furness 1993; Wren *et al.* 1994; Dauwe *et al.* 2002; Mochizuki *et al.* 2002; Boncompagni *et al.* 2003; Matz & Parsons 2004; DeWitt *et al.* 2006; Papp *et al.* 2007).
- The condition of ecosystems (Kushlan 1993; O'Connell 2000; Tankersley 2004; Zockler 2005) including forests (Canterbury *et al.* 2000; Uliczka & Angelstam 2000; Becker & Agreda 2005; Venier & Pearce 2005); rainforests (Lee *et al.* 2005); grasslands (Browder *et al.* 2002); rangelands (Bradford *et al.* 1998; Whitford *et al.* 1998); riparian ecosystems (Croonquist & Brooks 1991; Bryce *et al.* 2002); terrestrial wetlands (Tamisier & Boudouresque 1994; Sorace *et al.* 1999, 2002; O'Connor *et al.* 2000; Paillisson *et al.* 2002; Deluca *et al.* 2004); marine ecosystems (Powell & Powell 1986; Furness & Nettleship 1991; Mallory *et al.* 2006; Sydeman *et al.* 2007); and urban areas or mosaics (Jedicke 2000; Reynaud & Thioulouse 2000).
- Ecosystem responses to disturbances and processes including urban expansion (Lee *et al.* 2005), logging regimes (Holmes *et al.* 2004; Venier & Pearce 2004; Kavanagh *et al.* 2005), hydrological regimes (Paillisson *et al.* 2002; Desgranges *et al.* 2006), eutrophication (Fernandez *et al.* 2005), replacement of endemic ecosystems with plantations (Hausner *et al.* 2003), grazing (Bock & Webb 1984; Sedgwick & Knopf 1987), hunting (Paillisson *et al.* 2002) and habitat restoration programs (Weller 1995; Gardali *et al.* 2006).

Birds have been utilised as indicator species by government agencies in Australia and elsewhere. The best examples perhaps come from Europe and North America.

In the United Kingdom, composite bird indices are one of 20 'framework' indicators (and one of 68 indicators in total) used to measure progress towards a government goal of achieving sustainable development by 2020. Composite indices for farmland birds, woodland birds, coastal/estuarine birds and wintering waterbirds are produced in a collaborative effort by the British Trust for Ornithology (BTO), The Royal Society for the Protection of Birds (RSPB) and the Department for Environment, Food and Rural Affairs (DEFRA) and are mainly based on abundance data obtained via the Common Bird Census, Breeding Bird Survey and Wetland Bird Survey (H. M. Government 2005; http://www.bto.org/research/indicators/uk_indicators.htm).

The Pan-European Common Bird Monitoring Scheme (PECBMS) uses composite indices for common birds to track the state of biodiversity across Europe. In 2007, PECBMS common bird indices were updated with abundance data on 124 species of birds obtained from monitoring programs in 20 countries (PECBMS 2007).

In North America, the United States Department of Agriculture Forest Service are required by internal policy to identify and monitor 'management indicator species' within each national forest. The management indicator species are monitored to determine the impacts of

management regimes on forest communities (U.S. Congress Office of Technology Assessment 1992).

There are few documented examples of the use of birds as indicator species by government agencies in Australia. At national and state/territory scales, birds have been utilised as indicator species for State of the Environment (SoE) reporting (<http://www.environment.gov.au/soe/index.html>). For example, 'seabird populations' and the 'abundance and distribution of waterbirds' were two of 263 indicators used to assess the state of the Australian environment for the 'Australia State of the Environment 2006' report (Beeton *et al.* 2006; <http://www.environment.gov.au/soe/index.html>) and the 'current distribution of threatened terrestrial bird species' was one of ten indicators used to assess the state of biodiversity in Western Australia for the 'Environment Western Australia 1998: State of the Environment Report' (Government of Western Australia 1998).

At the regional scale, at least one government project in Victoria has used birds as indicators. The Wimmera Catchment Management Authority in western Victoria is currently coordinating a five-year project – the Wimmera Bird Monitoring Project (WBMP) – that aims to use bird monitoring as a means to monitor regional biodiversity and the condition of catchment ecosystems. However the WBMP is not targeting selected indicator species; instead, the project aims to sample region-wide avian diversity, although analysis is likely to focus particularly on two woodland species, Jacky Winter *Microeca fascinans* and Hooded Robin *Melanodryasi cucullata*, that are (1) in regional decline, (2) sensitive to habitat change and (3) considered to be good indicators of woodland condition (Birds Australia 2003; Jon Starks, *pers. comm.*; <http://wcma.vic.gov.au>).

Although there has been only limited actual use of birds as indicator species by government agencies in Australia, a variety of Australian birds have been proposed as potential indicator species in the literature because of their association with certain conditions and/or sensitivity to certain stressors (Appendix 1). Furthermore, a number of focal species studies have been conducted in Australia, most of which have focused on birds (Huggett 2007). The focal species identified by these studies could be regarded as potential candidates for monitoring because of their demonstrated sensitivity to certain threatening processes (examples of avian focal species identified by studies conducted in southern Australia are provided in Appendix 1). However, the use of focal species as indicator species could prove problematic.

An intrinsic problem of the focal species approach is the difficulty of determining which species is most sensitive to a particular threat (Freudenberger *et al.* 2001; Lambeck 2002; Lindenmayer *et al.* 2002). For example, rare species that are excluded from focal analyses because of a lack of data may be more sensitive to a particular threat than the nominated focal species (Short & Parsons 2004). Furthermore, birds are likely to be less suitable as focal species for fragmentation and isolation of habitat than less mobile taxa such as plants, amphibians and reptiles (Freudenberger *et al.* 2004). Consequently, nominated focal species such as those listed in Appendix 1 may be capable of indicating the presence and impacts of threatening processes, but it is possible that other species or taxa excluded from or rejected during focal analyses may be more sensitive to the threatening process in question. In the context of the indicator species concept, this means that a species overlooked or rejected during focal analyses could be affected by a threatening process, but the threatening process would not be detected or redressed if the process was operating at an intensity below the threshold sensitivity of the focal species.

It is worth noting that work has commenced to develop composite indices to determine population trends of birds in Australia. Cunningham & Olsen (2007) have designed a set of composite statistical measures that make use of volunteer-collected presence-absence data from the Atlas of Australian Birds. Some preliminary trials have taken place in temperate woodlands to identify a suite of representative species to monitor, but substantial work is still needed before a full set of suitable indicator species can be selected.

3.2 Advantages and Disadvantages of Using Birds as Indicator Species

Birds are often considered to be good indicators of the general condition of the environment, although doubt exists over their ability to directly and rapidly indicate changes in ecosystem properties and the impacts of such changes on other taxa (Morrison 1986; Temple & Wiens 1989; Mac Nally *et al.* 2004; Gregory *et al.* 2005). There are both positive and negative aspects to using birds as indicator species. The following attributes are considered to enhance the value of birds as indicator species:

- Birds are easy to detect and observe (e.g. birds are often the most conspicuous faunal taxon in an ecosystem; many species are diurnal and/or brightly-coloured and/or advertise their presence by call) (Hutto 1998; Carignan & Villard 2002; Mac Nally *et al.* 2004).
- The taxonomy of birds is well-resolved and species are generally easy to identify in the field (Furness *et al.* 1993; Gregory *et al.* 2005).
- Birds are widely distributed and occupy a broad range of habitat types and ecological niches.
- The distribution, biology, ecology and life history of birds are well known compared with other taxa (Furness *et al.* 1993; Gregory *et al.* 2005). For example, since 1998 the Atlas of Australian Birds has collected more than 7,300,000 bird records obtained from more than 433,000 surveys across Australia.
- Birds are typically positioned at or near the top of the food chain. This makes birds sensitive to changes at lower levels of the food chain and to environmental contaminants (e.g. persistent organochlorines) that accumulate at each level of the food chain (Furness *et al.* 1993; Mac Nally *et al.* 2004; Gregory *et al.* 2005).
- Many bird species pollinate or disperse the seeds of plants. These species may be directly or indirectly linked to the fitness of many other species and play a critical role in the maintenance of natural ecosystems.
- Birds are of interest and concern to both the public and decision-makers (Mac Nally *et al.* 2004; Gregory *et al.* 2005). This interest generates strong support for conservation programs that involve birds and provides an opportunity for skilled volunteers to be recruited from a large number of amateur birdwatchers. The inclusion of volunteer personnel in a monitoring program may reduce costs or facilitate an increase in the scope of the monitoring program (Furness *et al.* 1993).
- Survey techniques for birds are comparatively simple and are capable of capturing information on a multitude of species simultaneously (Hutto 1998).
- Birds are generally less expensive to monitor than other taxa such as invertebrates, reptiles and mammals (Landsberg *et al.* 1999; Mac Nally *et al.* 2004).

The following attributes can either be beneficial or detrimental depending on the spatial and temporal scales and aims of monitoring:

- Birds are highly mobile. This allows monitoring to be conducted over broad spatial scales but may make it difficult to link responses of birds to specific conditions or stressors on the ground (Furness *et al.* 1993; Mac Nally *et al.* 2004; Gregory *et al.* 2005). Furthermore, because birds are exceedingly more mobile than almost all other terrestrial taxa, and because many species of bird make greater use of resources in three-dimensional space than other animals, the responses of birds may not accurately reflect the responses of more sedentary, spatially-restricted faunal taxa such as invertebrates, reptiles and small mammals (Mac Nally *et al.* 2004; Gregory *et al.* 2005).

- Generation times of birds range from a few years to a few decades in length (Garnett & Crowley 2000). This means that birds are capable of signalling impacts over a period of time (*i.e.* the effects of long-term exposure), but are probably less suitable for indicating short-term disturbances than other taxa with shorter generation times (Furness *et al.* 1993; Gregory *et al.* 2005).

The following attributes are considered to diminish the value of birds as indicator species:

- Birds often respond to secondary or tertiary effects of stressors (Morrison 1986; Koskimies 1989; Temple & Wiens 1989). For example, the El Niño-Southern Oscillation (ENSO) phenomenon has a severe but indirect impact on some species of fish-eating birds in the Pacific Ocean. During ENSO events, a current of cold, nutrient-rich waters originating from southern latitudes (the Humboldt Current) is replaced by a current of warm, nutrient-poor waters originating from the tropics. This change has no direct effect on fish-eating birds, but the nutrient-poor waters associated with ENSO events sustain substantially fewer fish than the nutrient-rich waters of the Humboldt Current. This reduction in the availability of food may lower breeding success and cause crashes in some populations of fish-eating birds. (Barber & Chavez 1983; Schreiber & Schreiber 1984; Duffy 1990). In situations such as this, time lags exist between the onset of the stressor and the response of birds. The existence of time lags is undesirable because (1) the impact of the stressor may be more difficult to mitigate or irreversible by the time a problem is detected and (2) time lags may make it more difficult to trace the correct cause of an indicator species' response (Temple & Wiens 1989).
- In certain circumstances, some opportunist birds may respond positively to environment degradation (Gregory *et al.* 2005), at least initially. For example, the widespread clearing of eucalypt forests and woodlands in eastern Australia since settlement has allowed Noisy Miners to colonise areas that were formerly unsuitable for this species (Catterall *et al.* 2002; Clarke *et al.* 2006).
- Birds possess behavioural and physiological traits that may make them less sensitive to ecosystem changes than some other taxa. For example, birds can regulate fat stores and metal concentrations in their body tissues to a much greater degree than invertebrates. Traits such as these help to buffer birds against the impacts of ecosystem changes and, consequently, may limit the ability of birds to indicate ecosystem changes and their effects on other taxa (Furness *et al.* 1993).

4 BENEFITS AND DEFICIENCIES OF THE INDICATOR SPECIES APPROACH

A primary motivation for using indicator species as a tool to assess the condition of ecosystems without looking at all elements, is an assumption of their ability to provide information on properties of the environment that are otherwise difficult, inconvenient or expensive to be measured directly (Landres *et al.* 1988). For this reason, the indicator species approach holds tremendous appeal for conservationists, land managers and politicians (Carignan & Villard 2002).

However, there are four critical problems that undermine the validity of the indicator species concept:

- Species can respond in different ways to the same environmental conditions or stressors (e.g. Woodwell & Rebeck 1967; Mannan *et al.* 1984; Block *et al.* 1987; Reader 1988; Thiollay 1992; Niemelä *et al.* 1993; Taper *et al.* 1995; Dormann *et al.* 2007; Ficetola *et al.* 2007). This is not surprising considering that all species vary to some degree in their behaviour, habitat requirements and/or life history traits (Mannan *et al.* 1984; Verner 1984; Szaro 1986; Block *et al.* 1986; Landres *et al.* 1988; Martin & Li 1992; Martin 1995; Lindenmayer 1997). In effect, each individual species is exposed to a unique set of environmental conditions and ecological interactions (Landres *et al.* 1988; Koskimies 1989). This variation in strategies and responses suggests that it is unlikely that any one species will act as a perfect indicator for any other species (Landres *et al.* 1988; Koskimies 1989; Taper *et al.* 1995; Carignan & Villard 2002).
- Birds and other animals tend to respond in similar ways to the many different factors that may influence their populations (e.g. quality or quantity of habitat, predation, competition, diseases, parasites, weather conditions and natural stochastic fluctuations). This can make it difficult to accurately identify the root cause of an indicator species response (Steele *et al.* 1984; Morrison 1986; Landres *et al.* 1988; Koskimies 1989; Carignan & Villard 2002).
- The impact of disturbance on a species may not become fully apparent until sometime after the onset of the disturbance. For example, a population of Splendid Fairy-wrens in Western Australia began to decline more than three years after a major fire, evidently because of reduced breeding productivity and the replacement of experienced breeders with novices, which were less productive and suffered higher rates of mortality (Russell & Rowley 1993). The potential for species to exhibit delayed responses to disturbance means it may be possible for a disturbance to go undetected by indicator species monitoring until its impacts are difficult to reverse or, worse, are irreversible (Temple & Wiens 1989; Lindenmayer *et al.* 2000).
- To indicate biodiversity or the status of other taxa, indicator species must be highly congruent with the taxa for which they are proposed to be indicative (Lindenmayer 1999; Kavanagh & Stanton 2005). However, many studies have collectively demonstrated that species-rich areas for one taxon do not consistently coincide with species-rich areas for other taxa at sub-global scales (e.g. Prendergast *et al.* 1993; Prendergast & Eversham 1997; Oliver *et al.* 1998; Mikusinski *et al.* 2001; Lund & Rahbek 2002; Söderström *et al.* 2002; Vessby *et al.* 2002; Kati *et al.* 2004; Sauberer *et al.* 2004; Schulze *et al.* 2004; Grenyer *et al.* 2006; Similä *et al.* 2006; Pawar *et al.* 2007; Pearman & Weber 2007).

5 CONCLUSIONS AND FUTURE DIRECTIONS

The concept of using a set of indicator species to monitor the condition of the environment possesses undoubted appeal for conservationists, land managers and politicians alike. However, in reality, the ability of birds and other taxa as useful surrogates for other properties of the environment is debatable (Landres *et al.* 1988; Carignan & Villard 2002; Lindenmayer & Burgman 2005).

Direct monitoring of environmental properties of interest should be undertaken wherever possible (Landres *et al.* 1988), but ultimately, the finite resources available to conservation agencies and the vast complexity of natural ecosystems make the use of indicators virtually unavoidable (Simberloff 1998). If indicator species are to be used, it is important to recognise their limitations. As Hutto (1998) stated, there is little reason to expect that a small group of indicator species will provide much more than a crude index of ecosystem condition.

Despite problems associated with their use, Carignan & Villard (2002) considered that indicator species can be a useful tool for conservation if (1) many species representing various taxa and life histories are included in a monitoring program, (2) their selection is primarily based on sound quantitative data from the region of interest and (3) caution is exercised when interpreting indicator trends to separate actual signals from fluctuations that may be unrelated to ecosystem deterioration.

At present, very little systematic monitoring of natural attributes is undertaken within the Victorian reserves network. Indeed, many reserves lack basic inventories of fauna and flora. In this context, the establishment of a state-wide monitoring program for birds would provide valuable information on avifaunal populations and, in instances where no other data exists, might also provide insights into ecosystem character (*e.g.* habitat types necessary to sustain recorded bird species). The observations of ecosystem characteristics can be further utilised to provide assessment information on land management issues, such as degradation of habitat from over grazing; or perhaps overcrowding of the understorey from weed invasion, which can assist with identifying appropriate management strategies.

For reserves in which direct monitoring of environmental parameters other than avifauna is not feasible, it is possible that trends in selected species of birds could alert Parks Victoria to conservation issues that may otherwise go undetected, although monitoring of these species or groups can not be guaranteed to capture all threatening processes operating within a reserve, or to reflect impacts on other taxa. It is important to stress that targeting selected species or groups of birds alone is a non-ideal option for monitoring reserve values, but may be useful when the alternative is no monitoring at all.

In the following section, a set of candidate avian indicator species is nominated that may provide some indication of reserve values in the absence of other forms of monitoring.

6 CANDIDATE INDICATOR SPECIES

A set of potential indicator species for Victorian reserves is presented below and in Table 2. Species were identified based on expert opinion, peer-reviewed literature and/or grey literature. Species were selected because they were considered to be associated with one or more environmental elements or processes and because they possessed some combination of the desirable attributes listed in Table 2. Generally, it was not possible to assess candidate species against the other desirable attributes described in Section 3 of this report.

Table 2. Beneficial attributes of candidate indicator species for the Victorian reserves system.

Candidate Species	Easy to Detect	Well-studied	Resident	Specialist	Prior Monitoring
Australian Owlet-nightjar			+		
White-browed Treecreeper	+	+	+	+	
Brown Treecreeper	+	+	+		
Speckled Warbler			+	+	
Noisy Miner	+	+	+		
Hooded Robin	+	+	+		
Diamond Firetail			+	+	
Malleefowl		+	+	+	+
Mallee Emu-wren			+	+	+
Yellow-throated Miner	+	+	+		
Chestnut Quail-thrush			+	+	
Red-kneed Dotterel	+			+	+
Red-capped Plover	+	+	+		+
Ground Parrot		+	+	+	+
Southern Emu-wren		+	+	+	
Banded Lapwing	+				
Sooty Owl		+	+	+	+
Superb Lyrebird	+	+	+		+
Red-browed Treecreeper	+		+		
Rose Robin					
Olive Whistler	+		+		
Azure Kingfisher			+	+	
Striated Fieldwren	+		+		
Eastern Curlew	+	+			+
Australian Pied Oystercatcher	+	+	+		+
Hooded Plover	+	+	+	+	+

The 'properties indicated' component of the species profiles presented below lists the environmental properties that the candidate species are known or believed to be associated with. The 'justification' component of the species profiles summarises the evidence for associations between the candidate species and the environmental properties they are proposed to indicate.

In most instances, rigorous dedicated studies are needed to validate relationships between candidate indicator species and the environmental properties they are proposed to indicate (Lindenmayer 1999). Some of the candidate indicator species listed below may only prove useful if monitoring target parameters other than the presence/absence of the species (e.g. rates of breeding success, causes of breeding failure). These parameters would typically require targeted studies to be measured accurately. It is highly plausible that in some situations the costs or resources needed to complete targeted studies of an indicator species could approach or be equal to or exceed the costs or resources required to undertake direct sampling of the variable of interest. In such circumstances, managers should undertake direct sampling of the variable of interest.

Australian Owlet-nightjar *Aegotheles cristatus*

Natural Ecosystem Group: Dry Forest and Woodlands, Mallee.

Properties Indicated: Hollow-bearing (*i.e.* mature) trees.

Justification: Australian Owlet-nightjars usually nest and roost in small hollows in trees and tree-stumps (Hollands 1991; Brigham & Geiser 1997; Higgins 1999). However, they sometimes also nest and/or roost in cavities in other substrates including river-banks, cliff-faces and man-made structures (e.g. nest boxes, fence posts, pipes and crevices in buildings; see summary in Higgins 1999), which suggests that the presence of Australian Owlet-nightjars may not perfectly indicate the presence of hollow-bearing trees in all instances. A wide range of other fauna species require small hollows for nesting and shelter and in some habitats, such as in mallee woodlands, the presence of hollow-dependent species can indicate mature habitat.

White-browed Treecreeper *Climacteris affinis*

Natural Ecosystem Group: Dry Forest and Woodlands (semi-arid).

Properties Indicated: Hollow-bearing (*i.e.* mature) trees and coarse woody debris; habitat connectivity.

Justification: In Victoria, White-browed Treecreepers selectively inhabit open, semi-arid woodlands dominated by Belah *Casuarina cristata* or Slender Cypress-Pine *Callitris gracilis* and Buloke *Allocasuarina luehmannii* (Emison *et al.* 1987; Radford & Bennett 2004). They nest in hollows in dead or partially-dead trees (especially Belah) or occasionally in decaying tree-stumps (Emison *et al.* 1987; Higgins *et al.* 2001). Their foraging sites include coarse woody debris (*i.e.* fallen trees and branches) and tree stumps (Emison *et al.* 1987; Higgins *et al.* 2001).

White-browed Treecreepers are sensitive to loss, fragmentation and degradation of their woodland habitats. For example, they were not detected in remnants that contained less than 18.5 ha of Belah woodland in the Millewa district of north-western Victoria (Radford & Bennett 2006), they require landscape-scale habitat connectivity to facilitate movement between remnants (Radford & Bennett 2004, 2006) and they exhibit a preference for un-grazed or lightly-grazed remnants (Emison *et al.* 1987; Radford & Bennett 2006).

Brown Treecreeper *Climacterus picumnus*

Natural Ecosystem Group: Dry Forest and Woodlands, Mallee.

Properties Indicated: Hollow-bearing (*i.e.* mature) trees; coarse woody debris; habitat connectivity; patch-size; fire regime.

Justification: Brown Treecreepers usually, but not always, nest and roost in hollows in dead or partially-dead trees (Noske 1977, 1982a, b; Higgins *et al.* 2001). They often forage on coarse woody debris (Noske 1979; Antos & Bennett 2006).

The presence and density of Brown Treecreepers appears to be influenced by the presence and volume of coarse woody debris. Experimental manipulation of fallen timber loads in River Red Gum *Eucalyptus camaldulensis* forest in central-northern Victoria, showed that densities of Brown Treecreepers increased rapidly (*i.e.* within six months of manipulation) and substantially at sites where loads of fallen timber were manually raised to ≥ 40 Mg/ha (Mac Nally *et al.* 2002). Follow-up surveys conducted in the same forest revealed that densities of Brown Treecreepers remained elevated at sites where fallen timber loads had been increased to ≥ 40 Mg/ha three years after experimental manipulation (Mac Nally 2006). Analysis of four years data (1998-2001) from the Atlas of Australian Birds also revealed a positive association between the presence of Brown Treecreepers and the presence of fallen timber (Barrett *et al.* 2002).

Brown Treecreepers are sensitive to fragmentation of their habitat. They appear unable or reluctant to disperse across fragmented landscapes with non-wooded habitat (Walters *et al.* 1999; Cooper 2002; Cooper *et al.* 2002a, b). For example, in central New South Wales, Brown Treecreepers were not detected in remnants located more than 700 m from the next nearest remnant (Cooper *et al.* 2002). In north-eastern New South Wales, Brown Treecreepers moved within and between patches in contiguous habitat, with a maximum recorded movement of 4.5 km, but moved only within patches in fragmented habitat, with a maximum recorded movement of 1.4 km (Cooper & Walters 2002a).

Brown Treecreepers may indicate the minimum size of remnant woodland patches. For example, surveys in north-eastern and central New South Wales failed to detect Brown Treecreepers in remnants of less than 9 ha and 10 ha respectively (Barrett 1995; Cooper *et al.* 2002).

Brown Treecreepers may also indicate the fire history of their habitat. A study in dry sclerophyll forest in south-eastern Queensland found that Brown Treecreepers preferred sites with intermediate fire intervals (2.5-4.0 years) and were more common in sites with short mean fire intervals than long mean fire intervals. This may be associated with the species' preference for open areas with bare ground and short grasses (Smyth *et al.* 2002).

Speckled Warbler *Chthonicola sagittata*

Natural Ecosystem Group: Dry Forest and Woodlands.

Properties Indicated: Open understorey; sparse ground cover; coarse woody debris; habitat connectivity.

Justification: Speckled Warblers inhabit dry forests and woodlands with an open understorey and sparse or patchy ground cover (*e.g.* Conole 1981; Ford & Bell 1981; Ford *et al.* 1985; Emison *et al.* 1987; Gosper 1992; Er & Tidemann 1996; Tzaros 1996). They mostly forage among grasses and leaf-litter and on patches of bare ground, often around coarse woody debris (Ford *et al.* 1986; Tzaros 1996). Their nests sometimes abut or are placed among coarse woody debris (Tzaros 1996; Gardner 2002a; Higgins & Peter 2002).

Speckled Warblers are sensitive to habitat fragmentation. The species appears to be/become locally extinct in regions where habitat fragments are less than 100 ha in size (Traill & Duncan 2000). Larger habitat fragments are probably required to maintain viable populations. For example, Gardner (2002b) only recorded the species in remnants of 300 or more hectares. Watson *et al.* (2005) found that a 50% probability of occurrence was only attained by remnants of 180-390 ha, depending on the surrounding landscape. A population viability analysis by Gardner & Heinsohn (2007) predicted that in the absence of an Allee effect (*i.e.* slowed growth in small or low density populations), only high-density populations in remnants of more than 300 ha and low-density populations in remnants of more than 700 ha had more than an 80% probability of persisting beyond 100 years.

Noisy Miner *Manorina melanocephala*

Natural Ecosystem Group: Dry Forest and Woodlands.

Properties Indicated: Degraded and simplified forests and woodlands, fragmentation.

Justification: Noisy Miners are typically absent from intact, high-quality wooded habitat that supports dense understorey vegetation. They infiltrate dry forests and woodlands only where these exist in small, open patches that lack understorey shrubs, or possess only a sparse layer of understorey shrubs, and/or are located adjacent to more open habitat(s) (*e.g.* Morris 1975; Gepp & Fife 1975; Jones 1986; Emison *et al.* 1987; Clarke *et al.* 1995, 2006; Possingham & Possingham 1997; Catterall *et al.* 2002). The presence of Noisy Miners may therefore indicate that habitat is degraded and fragmented.

Hooded Robin *Melanodryas cucullata*

Natural Ecosystem Group: Dry Forest and Woodlands.

Properties Indicated: Complex woodlands; coarse woody debris; habitat connectivity; patch-size.

Justification: Hooded Robins inhabit large and intact areas of woodland that have a complex understorey and dead or fallen timber (Sullivan 1993; Fitri & Ford 1997, 2003a, b; Higgins & Peter 2002; Maron & Lill 2005; Antos & Bennett 2006; Ford & Thompson 2006; see below). They are highly sensitive to alteration of their preferred woodland habitats. For example, in the northern region of the Australian Capital Territory and adjacent areas of New South Wales, Freudenberger (1999) found that Hooded Robins required structurally complex woodlands (>20% tree canopy cover with >20% cover of shrubs 0.5-4.0 m in height and >40% cover of ground plants and logs or rocks and leaf litter) that were more than 100 ha in area and that were located within about 1 km of other remnant patches of woodland. In the same region, Watson *et al.* (2001) only recorded Hooded Robins in structurally complex woodland remnants of 100 or more hectares in area. In south-central New South Wales, Freudenberger & Stol (2002) only recorded Hooded Robins in woodland remnants that were more than 20 ha in area, contained a complex of shrubs and fallen timber, and were located within 1-2 km of other woodland remnants. Because of their sensitivity to habitat alteration, Hooded Robins have been nominated as an indicator species for woodland condition (Ford & Thompson 2006) and targeted by focal species approaches (*e.g.* Watson *et al.* 2001).

Diamond Firetail *Stagonopleura guttata*

Natural Ecosystem Group: Dry Forest and Woodlands.

Properties Indicated: Understorey shrubs and regrowth; native ground cover; habitat connectivity; patch-size.

Justification: Diamond Firetails mostly inhabit open forests and woodlands that are dominated by eucalypts (or sometimes by casuarinas or cypress-pines) and support an understorey of shrubs, small trees and regrowth, and a ground-cover of grasses. They also frequently occur in lightly timbered grasslands and farmlands with scattered or remnant patches of trees (Emison *et al.* 1987; Higgins *et al.* 2006).

Diamond Firetails are sensitive to loss, fragmentation and degradation of grassy woodlands (Ford & Thompson 2005, 2006). For example, Diamond Firetails were selected as a focal species for the Goulburn Broken catchment in north-central Victoria because they were only recorded in woodland remnants more than 20 ha in size, which had patches of dense shrubs and a short cover of native plants, and were located within 1 km of other woodland remnants (Robinson & Howell 2003). In the Boorowa River catchment of New South Wales, Freudenberger (2001) only recorded Diamond Firetails in woodland remnants which were five or more hectares in size, which had a moderately complex understorey, and which were located at most 2.7 km from a woodland remnant more than 10 ha in size. Ford & Thompson (2005, 2006) considered the presence/absence or abundance of Diamond Firetails to be a useful indicator of (grassy) woodland condition.

Malleefowl *Leipoa ocellata*

Natural Ecosystem Group: Mallee.

Properties Indicated: Fire regime; ground-litter; habitat connectivity; predator densities.

Justification: Malleefowl exhibit a preference for long-unburnt habitat. They are generally absent from recently burnt habitat, but may forage in areas burnt 1-2 years earlier (Benshemesh 1990). They may not breed in burnt areas for up to 17 years after fire (Tarr 1965; Cowley *et al.* 1969) and are most abundant in long-unburnt habitat. For example, Benshemesh (1990, 1992) reported that breeding densities were three times greater in sites with post-fire ages of ≥ 40 years than in neighbouring sites with post-fire ages of 20-30 years. Similarly, Woinarski (1989a, b) detected more Malleefowl in habitat with post-fire ages of 60-80 years earlier than in habitat with post-fire ages of 40 years or less.

Malleefowl require abundant ground-litter with which to construct their nest mounds (Benshemesh 2005). They are susceptible to fragmentation of their habitat: they appear to disperse on foot and require connections between patches of suitable habitat to facilitate movement (Benshemesh 1992, 2000, 2005).

In addition to their association with the properties discussed above, Malleefowl are highly susceptible to predation, especially by foxes (Frith 1959; Booth 1987; Priddel & Wheeler 1994, 1996, 1999; Benshemesh 2005). This susceptibility suggests that Malleefowl may offer some potential as an indicator species to monitor predator densities. However, Frith (1962) reported that Malleefowl could remain abundant in areas with high number of foxes, which if true would present problems for using presence/absence or abundance data on this species to indirectly assess predator numbers.

Mallee Emu-wren *Stipiturus mallee*

Natural Ecosystem Group: Mallee.

Properties Indicated: Fire regime; habitat connectivity; condition of *Triodia* grasslands.

Justification: Mallee Emu-wrens have been recorded in habitats with a range of post-fire ages (Silveira 1993). They can infiltrate burnt habitats as early as three years after fire (Garnett & Crowley 2000; Clarke 2005) and have been recorded breeding in high densities five years after fire (Garnett 1993), but their densities do not peak until 8-10 years after fire. They may sustain peak densities until 30 years after fire, at which time numbers begin to decline. However, some individuals may persist in habitats with post-fire ages of up to 50 years (Carpenter & Matthew 1986; Silveira 1993; Garnett & Crowley 2000; Clarke 2005; Mustoe 2006).

Mallee Emu-wrens are resident or sedentary birds (Rowley & Russell 1997) that have a limited ability to disperse across unsuitable habitat. This makes them susceptible to habitat fragmentation (Baker-Gabb 2005). Their minimum requirements for habitat connectivity have not been quantified, but they are capable of colonising recovering habitat at least 6 km away after fire (Garnett & Crowley 2000).

Yellow-throated Miner *Manorina flavigula*

Natural Ecosystem Group: Mallee.

Properties Indicated: Open or fragmented mallee.

Justification: Yellow-throated Miners avoid woody communities with dense and continuous vegetation. In regards to mallee communities, Yellow-throated Miners are typically recorded in open mallee or small mallee remnants that lie adjacent to open areas (e.g. natural clearings, roads or farmland). Yellow-throated Miners readily infiltrate formerly unsuitable areas when dense and continuous vegetation is fragmented or otherwise degraded (Joseph 1986; Emison *et al.* 1987; Starks 1987; Storr 1987; McLaughlin 1990; Franklin 1996).

Chestnut Quail-thrush *Cinclosoma castanotum*

Natural Ecosystem Group: Mallee.

Properties Indicated: Low shrubby undergrowth; well-developed leaf-litter; fire history.

Justification: Chestnut Quail-thrushes inhabit three main habitat types: (1) low shrubby undergrowth in woodlands dominated by mallee eucalypts or other tree species, (2) shrublands dominated by *Acacia* or *Melaleuca* and (3) heathlands (e.g. Ford 1970, 1971; Greenslade *et al.* 1986; Woinarski 1989b; Matthew & Carpenter 1990; Baxter & Paton 1998; Luck *et al.* 1999; Higgins & Peter 2002). They inhabit vegetation with post-fire ages ranging from 4-40 years, but are most abundant in more recently burnt habitats (<http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10168>).

Red-kneed Dotterel *Erythrogonys cinctus*

Natural Ecosystem Group: Inland Waters and Wetlands.

Properties Indicated: Wetlands with fringing emergent vegetation and exposed sediment margins.

Justification: Red-kneed Dotterels frequent ephemeral or permanent wetlands with shallow water, emergent or fringing vegetation and margins of exposed mud or clay or sand. They are most common at freshwater and brackish wetlands, tending to avoid wetlands with more saline waters (e.g. McGill 1944; Hobbs 1961; Maclean 1977; Fjeldså 1985; Schulz 1986; Emison *et al.* 1987; Morris *et al.* 1990; Johnstone & Storr 1998; Lyons *et al.* 2007). Wetlands favoured by this species are often also suitable for a host of threatened migratory and resident shorebirds such as the Australian Painted Snipe *Rostratula australis*.

Red-capped Plover *Charadrius ruficapillus*

Natural Ecosystem Group: Coastal, Inland Waters and Wetlands.

Properties Indicated: Anthropogenic disturbance; predators.

Justification: Red-capped Plovers are sensitive to disturbance when nesting. Adult plovers flush from their nests when approached by humans or domestic animals, leaving the unprotected eggs or chicks vulnerable to predation (Lane 1987). Nests may be destroyed by humans or domestic animals and raided by predators such as foxes and gulls (Hobbs 1972; Lane 1987; Marchant & Higgins 1993). To most accurately determine the level of human disturbance or the presence or density of predators, monitoring should target breeding records (including rates of breeding success and causes of breeding failure) rather than simply presence/absence or abundance data.

Ground Parrot *Pezoporus wallicus*

Natural Ecosystem Group: Heathland.

Properties Indicated: Anthropogenic disturbance; fire regime.

Justification: In Victoria, Ground Parrots inhabit comparatively undisturbed, closed coastal graminoid or shrub heathlands and dense sedgeland (Isles & Menkhurst 1975; Meredith & Isles 1980; Meredith 1984; Meredith *et al.* 1984; Meredith & Jaremovic). They are adversely affected by degradation and fragmentation of their habitat (Meredith 1984; Baker 1997). For example, one area of formerly suitable habitat at Wilson's Promontory was abandoned after it was grazed and trampled by cattle (Cooper 1975).

Fire frequency is an important determinant of the suitability of heathland habitats for Ground Parrots. Fire eliminates vegetation that provides cover and food for Ground Parrots; frequent fires may prevent vegetation from recovering to a level suitable for Ground Parrots whereas infrequent fires may permit dense stands of tall woody shrubs to develop and replace low herbaceous vegetation favoured by Ground Parrots (Baker 1997). Ground Parrots may use recently burnt heathland vegetation that lies immediately adjacent to an established population in suitable habitat (McFarland 1989; Burbidge *et al.* 2007), but where such a situation does not exist, burnt heathlands may remain unsuitable for up to four years after fire (Garnett & Crowley 2000). Densities of Ground Parrots in heathlands peak 4-15 years after fire. Densities may decline to zero in some heathlands that have remained unburnt for 15-25 years (Meredith & Isles 1980; Jordan 1987a; Wall 1989; McFarland 1991; Bryant 1991), but

individuals may persist at lower densities in other heathlands that have remained unburnt for up to 90 years (Watkins 1985; Bryant 1991, 1994; Burbidge *et al.* 2007).

Southern Emu-wren *Stipiturus malachurus*

Natural Ecosystem Group: Heathland.

Properties Indicated: Comparatively undisturbed habitat; habitat connectivity; fire regime.

Justification: Southern Emu-wrens inhabit dense low vegetation in heathlands and other vegetation communities (Emison *et al.* 1987; Higgins *et al.* 2001; Wilson & Paton 2004; Maguire 2006). They are adversely affected by multiple forms of anthropogenic disturbance including clearing, fragmentation, drainage or salinisation of wetlands, grazing and altered fire regimes (Garnett 1993; Mount Lofty Ranges Southern Emu-wren Recovery Team 1998; Pickett 2002). They require corridors of dense vegetation to move between patches of suitable habitat (Pickett 2002).

Southern Emu-wrens are absent from recently burnt areas (Jordan 1987b; McFarland 1988). They may colonise regenerating heathland within one year and attain high densities within 2-3 years after fire (Jordan 1987b), although in heathland-woodland and swampland communities they may not return for more than three and more than four years after fire respectively (Reilly 1991). In Cooloolo Park National in Queensland, Southern Emu-wrens occur in heathlands with post-fire ages of 1.5-9.0 years, but are present in greatest densities in heathlands with post-fire ages of 6-8 years (McFarland 1988, 1994). The results of this study suggest that the species is best suited by a regime of mosaic burns at intervals of 7-8 years (McFarland 1988).

Banded Lapwing *Vanellus tricolor*

Natural Ecosystem Group: Grasslands.

Properties Indicated: Open short grasslands; predator densities; .

Justification: Banded Lapwings occur in open, short native grasslands on treeless plains and in other endemic and modified open habitats with short ground-cover vegetation (Emison *et al.* 1987; Marchant & Higgins 1993; Johnstone & Storr 1998). As a ground-foraging and ground-nesting species, Banded Lapwings are vulnerable to terrestrial predators; monitoring of breeding success and causes of breeding failure may therefore provide some indication of local predator densities. Short, open native grasslands inhabited by Banded Lapwings are also the preferred habitat of the Plains-wanderer (Emison *et al.* 1987; Baker-Gabb 1990), which is listed as a threatened species under both federal government and Victorian state government legislation. Banded Lapwings and Plains-wanderers are considered to co-occur in some areas of Victoria, which suggests that the presence of Banded Lapwings on open, short native grasslands may be a useful indicator of Plains-wanderer habitat.

Sooty Owl *Tyto tenebricosa*

Natural Ecosystem Group: Wet Forest and Rainforest.

Properties Indicated: Tall (old-growth) eucalypts (including hollow-bearing trees); arboreal hollow-dependent mammals; large areas of continuous forest.

Justification: Sooty Owls inhabit large and intact areas of tall montane eucalypt forest. They are most abundant in old-growth forests, but they often also occur in younger forests that are located near old-growth forest stands or that contain patches of old trees and high densities

of stags (which provide habitat for hollow-dependent prey). Sooty Owls almost always nest and often roost in large hollows in tall trees.

A high proportion of their diet consists of arboreal, hollow-dependent mammals (Schodde & Mason 1980; Smith 1984a; Beruldsen 1986; Loyn *et al.* 1986; Emison *et al.* 1987; Hollands 1991; Milledge *et al.* 1991, 1993; Lundie-Jenkins 1993; Debus 1994; Holmes 1994; Kavanagh 1997; Kavanagh & Jackson 1997; Higgins 1999; Bilney *et al.* 2007). Sooty Owls have been proposed as an indicator species to guide the ecologically sustainable management of timber production forests in Australia (Milledge *et al.* 1991; Kavanagh *et al.* 2004).

Superb Lyrebird *Menura novaehollandiae*

Natural Ecosystem Group: Wet Forest and Rainforest.

Properties Indicated: Open ground cover; leaf-litter.

Justification: Superb Lyrebirds require an open forest floor with overlying leaf-litter for foraging (Ashton & Bassett 1997; Morgan *et al.* 1995; Higgins *et al.* 2001). As a terrestrial species, Superb Lyrebirds are vulnerable to terrestrial predators such as foxes, cats and dogs (Emison *et al.* 1987; Reilly 1988; Smith 1994, 1995). For example, one observer recorded 42 lyrebird tail-plumes in a single fox lair (Leach 1929) and predation by foxes was a primary factor in a decline in Superb Lyrebird numbers in Dandenong Ranges National Park (Smith 1994).

Red-browed Treecreeper *Climacteris erythrops*

Natural Ecosystem Group: Wet Forest and Rainforest.

Properties Indicated: Mature forest and rainforest; hollow-bearing (*i.e.* mature) trees.

Justification: Red-browed Treecreepers prefer mature forest but also occur less frequently in younger, regenerating stands (Milledge & Recher 1985; Loyn 1985; Smith 1984b, 1985a, b; Emison *et al.* 1987). They typically nest and roost in hollows of small to large, living or dead trees (Noske 1982a, 1985; Higgins *et al.* 2001). Red-browed Treecreepers were identified by Kavanagh *et al.* (2004) and Kavanagh & Stanton (2005) as candidate indicator species to monitor the impacts of logging in production forests because they depend on large, mature trees for nesting, foraging and roosting.

Rose Robin *Petroica rosea*

Natural Ecosystem Group: Wet Forest and Rainforest.

Properties Indicated: Tall mid-storey or understorey vegetation.

Justification: Rose Robins mainly occur in eucalypt forests and woodlands that contain a sparse to dense mid-storey or understorey of tall shrubs and low trees, especially species of Acacia (Loyn 1985, 1993; Emison *et al.* 1987; Gosper 1992; Slater 1995; Mac Nally 1997). They are occasionally recorded in coastal scrub (Bedggood 1980), mangroves (NSW Bird Report 1998) and modified habitats (e.g. residential gardens), the latter typically when on migration (Emison *et al.* 1987; Whiteside 1987; Templeton 1992).

Olive Whistler *Pachycephala olivacea*

Natural Ecosystem Group: Wet Forest and Rainforest.

Properties Indicated: Dense understorey vegetation.

Justification: Olive Whistlers usually occur in tall, dense undergrowth in a variety of wooded habitats (Loyn 1985; Emison et al. 1987; Higgins & Peter 2002).

Azure Kingfisher *Ceyx azureus*

Natural Ecosystem Group: Inland Waters and Wetlands, Wet Forest and Rainforest.

Properties Indicated: Overhanging branches; snags; earthen banks; conditions capable of sustaining aquatic prey species.

Justification: Azure Kingfishers inhabit well-vegetated wetlands with overhanging branches or tree-roots, or snags, logs or debris, that provide perches for loafing and foraging (Marshall 1931; Forshaw & Cooper 1983; Green 1995; Curl 1998 in Higgins 1999; Johnstone & Storr 1998). They are generally absent from wetlands that lack fringing vegetation (Barnard & Barnard 1925; Boekel 1980). They usually nest in burrows excavated in earthen banks on the margins of waterways or wetlands, or in soil clumped around roots of fallen trees (Marshall 1931; Bedggood 1973; Forshaw & Cooper 1983; Green 1995; Johnstone & Storr 1998; Curl 1998 in Higgins 1999). They sometimes nest in artificial banks (Curl 1998 in Higgins 1999).

Azure Kingfishers feed on aquatic vertebrates and invertebrates (Johnstone & Storr 1998; Higgins 1999). Their presence is therefore likely to indicate the existence of hydrological conditions capable of sustaining prey species.

The Azure Kingfisher was nominated by Kavanagh *et al.* (2004) as a potential target indicator species to monitor the impacts of logging in production forests.

Striated Fieldwren *Calamanthus fuliginosus*

Natural Ecosystem Group: Coastal.

Properties Indicated: Low, dense vegetation.

Justification: Striated Fieldwrens inhabit low, dense vegetation. They mainly occur in heathlands, sedgeland, samphire shrublands, saltmarsh and grassy swamplands, but are occasionally recorded in forests with dense understorey vegetation, grasslands, lightly-grazed pastures adjacent to more typical habitat, rank pastures and softwood plantations (Ridpath & Moreau 1966; Ratkowsky & Ratkowsky 1977; Thomas 1979; Emison et al. 1987; Gosper & Baker 1997; Higgins & Peter 2002). Although Striated Fieldwrens sometimes occur in disturbed habitats, they are adversely affected and/or threatened by degradation of their natural habitats through clearing, overgrazing and invasion by weeds (Napier 1969; Burbidge 1985; <http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10126>).

Eastern Curlew *Numenius madagascariensis*

Natural Ecosystem Group: Coastal.

Properties Indicated: Anthropogenic disturbance of intertidal flats.

Justification: Eastern Curlews are sensitive to some forms of human disturbance (Close & Newman 1984; Peter 1990; Reid & Park 2003). For example, at Corner Inlet in Victoria,

Eastern Curlews took flight when approached by a single person on foot to a distance of 50-250 m, but a single bird failed to flush when approached by a boat to a distance of 20 m (Peter 1990). Despite this sensitivity, Eastern Curlews may not be a suitable indicator species for human disturbance, at least if analysis is based on presence/absence or abundance data, as Finn et al. (2007) found that the local level of human disturbance and the distance to urban development were both poor predictors of Eastern Curlew densities on intertidal flats at Moreton Bay in Queensland.

Australian Pied Oystercatcher *Haematopus longirostris*

Natural Ecosystem Group: Coastal.

Properties Indicated: Anthropogenic disturbance of sandy beaches.

Justification: Pied Oystercatchers are exposed to and adversely affected by disturbance from humans or associated recreational activities, e.g. nests, eggs or young may be destroyed by walkers, horses, domestic dogs or off-road vehicles (Hewish 1990; Newman 1990; McFarland 1993; Wilson 1994). The presence/absence or abundance of Pied Oystercatchers alone may not accurately reflect the existence or intensity of human disturbance. For example, the density of humans and 4WD vehicles appeared to have no significant influence on the distribution of Pied Oystercatchers along ocean beaches in northern New South Wales (Owner & Rohweder 2003). Instead, data analysis would need to focus on breeding records, including rates of breeding success and causes of breeding failure.

Hooded Plover *Thinornis rubicollis*

Natural Ecosystem Group: Coastal.

Properties Indicated: Anthropogenic disturbance of high-energy sandy beaches.

Justification: Hooded Plovers are highly vulnerable to anthropogenic disturbance (Dowling & Weston 1999; Weston 2003; Weston & Elgar 2005, 2007). There are several mechanisms by which anthropogenic disturbance may impact on Hooded Plovers:

- Adults may be flushed from their nests by humans or domestic dogs, leaving unprotected eggs or chicks vulnerable to predation or to thermal or energetic stress (Schulz 1992; Retallick & Bolitho 1993; Weston 2000).
- Nests or young may be crushed by humans, vehicles, domestic dogs, privately-owned horses and camels used in commercial tourism operations (Buick & Paton 1989; Schulz 1992; Weston 1993, 2003; Dowling & Weston 1999).
- Adults may be killed by collisions with vehicles (Rose 2000; Weston & Morrow 2000).
- Nests may be interfered with by humans, e.g. mischievous or well-meaning collection of eggs or chicks (Schulz 1992; Weston 2000, 2003).
- Eggs, young or adults may be preyed upon by domestic dogs (Retallick & Bolitho 1993; Hanisch 1998; Weston 1998, 2003; Weston & Morrow 2000).
- Scavengers may be attracted to breeding sites by discarded litter (Schulz & Bamford 1987).

It is likely that monitoring breeding success and causes of breeding failure would provide a more accurate surrogate assessment of human disturbance than analysing presence/absence or abundance data alone. Monitoring of breeding success is regularly undertaken in various coastal sites in Victoria by Birds Australia and volunteers.

7 REFERENCES

- Abbott I. (1999) The avifauna of forests of south-west Western Australia: changes in species composition, distribution, and abundance following anthropogenic disturbance. *CALMScience Supplement*. **5**, 1-175.
- Abbott I. & Whitford K. (2002) Conservation of vertebrate fauna using hollows in forests of south-west Western Australia: strategic risk assessment in relation to ecology, policy, planning, and operations management. *Pacific Conservation Biology*. **7**, 240-55.
- Antos M. J. & Bennett A. F. (2006) Foraging ecology of ground-feeding woodland birds in temperate woodlands of southern Australia. *Emu*. **106**, 29-40.
- Ashton D. H. & Bassett O. D. (1997) The effects of foraging by the Superb Lyrebird (*Menura novae-hollandiae*) in *Eucalyptus regnans* forests at Beenak, Victoria. *Australian Journal of Ecology*. **22**, 383-94.
- Baker J. (1997). *Ground Parrot Recovery Plan 1997-2002*. New South Wales National Parks and Wildlife Service, Sydney.
- Baker-Gabb D. (1998) Native grasslands and the Plains-wanderer. *Wingspan (Supplement)*. **8**, 1-8.
- Baker-Gabb D. (2005). *Recovery Plan for the Mallee Emu-wren Stipiturus mallee, Red-lored Whistler Pachycephala rufogularis, Western Whipbird Psophodes nigrogularis leucogaster, and Other Threatened Mallee Birds*. Second draft. Natural Heritage Trust, Canberra.
- Baltzer M., Mathews R., Howard P., Kigenyi F. & Viskanic P. (2000) Birds as biodiversity indicators in the planning of Forest Nature Reserves in Uganda. *Ostrich*. **71**, 191.
- Barber R. T. & Chavez F. P. (1983) Biological consequences of El Nino. *Science*. **222**, 1203-10.
- Barnard C. A. & Barnard H. G. (1925) A review of the bird life on Coomooboolaroo Station, Duaringa district, Queensland, during the past fifty years. *Emu*. **24**, 252-65.
- Barrett G., Silcocks A., Donnelly C., Cunningham R. & Poulter R. (2002) *Atlas of Australian Birds (1998-2001) Supplementary Report No. 2 – Atlas Bushcare*. Birds Australia, Melbourne.
- Barrett G. W. (1995) Woodland bird assemblages on the New England Tablelands, north-eastern New South Wales. Unpublished PhD thesis, University of New England.
- Baxter C. & Paton P. A. (1998) Further notes on the birds of the Gawler Ranges. *South Australian Ornithologist*. **33**, 1-15.
- Becker C. D. & Agreda A. (2005) Bird community differences in mature and second growth Garua forest in Machalilla National Park, Ecuador. *Ornitologia Neotropical*. **16**, 297-319.
- Bedggood D. W. (1973) Birds of the Caniambo district, Victoria. *Australian Bird Watcher*. **5**, 12-22.
- Bedggood G. W. (1980) Birdlife between Lake Tyers and Marlo, Victoria. *Australian Bird Watcher*. **8**, 142-62.
- Beeton R. J. S., Buckley K. I., Jones G. J., Morgan D., Reichelt R. E. & Trewin D. (2006 Australian State of the Environment Committee) (2006) *Australia State of the Environment 2006*. Independent report to the Australian Government Minister for the Environment and Heritage, Department of the Environment and Heritage, Canberra.

- Benshemesh J. (1990) Management of Malleefowl with regard to fire. In: *The Malleelands. A Conservation Perspective* (Eds J. C. Noble, P. J. Joss & J. K. Jones) pp. 206-11. CSIRO, Melbourne.
- Benshemesh J. (1992) The conservation ecology of Malleefowl, with particular regard to fire. Unpublished PhD thesis, Monash University.
- Benshemesh J. (2000) *National Recovery Plan for Malleefowl*. Department for Environment and Heritage, South Australia.
- Benshemesh J. (2005) *National Recovery Plan for Malleefowl 2006-2010*. Department of Environment and Heritage, Adelaide.
- Beruldsen G. R. (1986) Observations on the Sooty Owl *Tyto tenebricosa* in south-east Queensland. *Australian Bird Watcher*. **11**, 230-6.
- Bilney R. J., Kavanagh R. P. & Harris J. M. (2007) Further observations on the diet of the Sooty Owl *Tyto tenebricosa* in the Royal National Park, Sydney. *Australian Field Ornithology*. **24**, 64-9.
- Birds Australia (2003) *Integrating Biodiversity into Regional Planning – the Wimmera Catchment Management Authority Pilot Project*. Scoping report prepared for the Wimmera Catchment Management Authority. Birds Australia, Melbourne.
- Blair R. B. (1999) Birds and butterflies along an urban gradient: surrogate taxa for assessing biodiversity? *Ecological Applications*. **9**, 164-70.
- Blakers M., Davies S. J. J. F. & Reilly P. N. (1984) *The Atlas of Australian Birds*. Melbourne University Press, Melbourne.
- Block W. M., Brennan L. A. & Gutiérrez R. J. (1986) The use of guilds and guild-indicator species for assessing habitat suitability. In: *Wildlife 2000: Modelling Habitat Relationships of Terrestrial Vertebrates* (Eds J. Verner, M. L. Morrison & C. J. Ralph) pp. 109-13. University of Wisconsin Press, Madison.
- Block W. M., Brennan L. A. & Gutiérrez R. J. (1987) Evaluation of guild-indicator species for use in resource management. *Environmental Management*. **11**, 265-9.
- Bock C. E. & Webb B. (1984) Birds as grazing indicator species in southeastern Arizona. *Journal of Wildlife Management*. **48**, 1045-9.
- Boekel C. (1980) Birds of Victoria River Downs Station and of Yarralin, Northern Territory. *Australian Bird Watcher*. **8**, 171-93.
- Boncompagni E., Muhammad A., Jabeen R., Orvini E., Gandini C., Sanpera C., Ruiz X. & Fasolo M. (2003) Egrets as monitors of trace-metal contamination in wetlands of Pakistan. *Archives of Environmental Contamination and Toxicology*. **45**, 399-406.
- Booth D. T. (1987) Home range and hatching success of Malleefowl, *Leipoa ocellata* Gould (Megapodiidae), in Murray Mallee near Renmark, S.A. *Australian Wildlife Research*. **14**, 95-104.
- Botkin D. B., Woodby D. A. & Nisbet R. A. (1991) Kirtland's Warbler habitats: a possible early indicator of climate warming. *Biological Conservation*. **56**, 63-78.
- Bowman D. M. J. S., Woinarski J. C. Z. & Russell-Smith J. (1994) Environmental relationships of Orange-footed Scrubfowl *Megapodius reinwardt* nests in the Northern Territory. *Emu*. **94**, 181-5.
- Bradford D. F., Franson S. E., Neale A. C., Heggem D. T., Miller G. R. & Canterburg G. E. (1998) Bird species assemblages as indicators of biological integrity in Great Basin rangeland. *Environmental Monitoring and Assessment*. **49**, 1-22.

- Brigham R. M. & Geiser F. (1997) Breeding biology of Australian Owlet-nightjars *Aegotheles cristatus* in eucalypt woodland. *Emu*. **97**, 316-21.
- Brisban L. (1993) Birds as monitors of radionuclide contamination. In: *Birds as Monitors of Environmental Change* (Eds R. W. Furness & J. J. D. Greenwood) pp. 144-78. Chapman & Hall, London.
- Brooker L. (2002) The application of focal species knowledge to landscape design in agricultural lands using the ecological neighbourhood as a template. *Landscape and Urban Planning*. **60**, 185-210.
- Brooker L. & Lefroy T. (2004) Testing Approaches to Landscape Design in Cropping Lands: Habitat Neighbourhoods for Conserving Viable Populations of Birds (CSE 9, Component 2). A CSIRO report commissioned by Land and Water Australia. CSIRO Sustainable Ecosystems, Perth.
- Brothers N. P. & Brown M. J. (1987) The potential use of Fairy Prions (*Pachyptila turtur*) as monitors of heavy metal levels in Tasmanian waters. *Marine Pollution Bulletin*. **18**, 132-4.
- Browder S. F., Johnson D. H. & Ball I. J. (2002) Assemblages of breeding birds as indicators of grassland condition. *Ecological Indicators*. **2**, 257-70.
- Bryant S. L. (1991) *The Ground Parrot, Pezoporus wallicus, in Tasmania: Distribution, Density and Conservation Status*. Wildlife Division Scientific Report 91/1. Department of Parks, Wildlife and Heritage, Hobart.
- Bryant S. L. (1994) Habitat and potential diet of the Ground Parrot in Tasmania. *Emu*. **94**, 166-71.
- Bryce S. A., Hughes R. M. & Kaufmann P. R. (2002) Development of a bird integrity index: using bird assemblages as indicators of riparian condition. *Environmental Management*. **30**, 294-310.
- Buick A. M. & Paton D. C. (1989) Impact of off-road vehicles on the nesting success of Hooded Plovers *Charadrius rubricollis* in the Coorong Region of South Australia. *Emu*. **89**, 159-72.
- Burbidge A. (1985) Birds. In: *Rotamah Island Bird Observatory Report 2 1982-1984* pp. 23-55. Royal Australasian Ornithologists Union Report 16. Royal Australasian Ornithologists Union, Melbourne.
- Burbidge A. H., Rolfe J., McNee S., Newbey B. & Williams M. (2007) Monitoring population change in the cryptic and threatened Western Ground Parrot in relation to fire. *Emu*. **107**, 79-88.
- Cairns J. & van der Shalie W. H. (1980) Biological monitoring part 1 – early warning systems. *Water Research*. **14**, 1179-96.
- Canterbury G. E., Martin T. E., Petit D. R., Petit L. J. & Bradford D. F. (2000) Bird communities and habitat as ecological indicators of forest condition in regional monitoring. *Conservation Biology*. **14**, 544-58.
- Carignan V. & Villard M. A. (2002) Selecting indicator species to monitor ecological integrity: a review. *Environmental Monitoring and Assessment*. **78**, 45-61.
- Carignan V. & Villard M. A. (2004) Biological indicators in environmental monitoring programs: can we increase their effectiveness? In: *Environmental Monitoring* (Ed. G. B. Wiersma) pp. 567-581. RC Press, Boca Raton, Florida.
- Carpenter G. & Matthew J. S. (1986) The birds of Billiatt Conservation Park. *South Australian Ornithologist*. **30**, 29-37.

- Catterall C. P., Piper S. D. & Goodall K. (2002) Noisy Miner irruptions associated with land use by humans in south-east Queensland: causes, effects and management implications. In: *Landscape Health in Queensland* (Eds A. Franks, J. Playford & A. Shapcott) pp. 117-127. Royal Society of Queensland, Brisbane.
- Chase M. K., Kristan W. B., Lynam A. J., Price M. V. & Rotenberry J. T. (2000) Single species as indicators of species richness and composition in California coastal sage scrub birds and small mammals. *Conservation Biology*. **14**, 474-87.
- Clarke M., Taylor R., Oldland J., Grey M. & Dare A. (2006) Dealing with indigenous despots. *Wingspan (Supplement)*. **16**, 24-5.
- Clarke M. F., Grey M. J., Britton D. R. & Loyn R. H. (1995) The Noisy Miner *Manorina melanocephala* and rural dieback in remnant eucalypt woodlands. *RAOU Report*. **98**, 1-110.
- Clarke R. (2005) *Ecological Requirements of Birds Specializing in Mallee Habitats*. Unpublished report to Department for Environment and Heritage, Adelaide.
- Close D. & Newman O. M. G. (1984) The decline of the Eastern Curlew in south-eastern Australia. *Emu*. **84**, 38-40.
- Conole L. (1981) Birds of the Steiglitz area, Brisbane Ranges, Victoria, 1978-1980. *Australian Bird Watcher*. **9**, 14-23.
- Cooper C. B. (2002) Movements of two experimentally displaced Brown Treecreepers *Climacteris picumnus* in a matrix of woodland and pasture. *Corella*. **26**, 110-13.
- Cooper C. B. & Walters J. R. (2002a) Experimental evidence of disrupted dispersal causing decline of an Australian passerine in fragmented habitat. *Conservation Biology*. **16**, 471-8.
- Cooper C. B. & Walters J. R. (2002b) Independent effects of woodland loss and fragmentation on Brown Treecreeper distribution. *Biological Conservation*. **105**, 1-10.
- Cooper C. B., Walters J. R. & Ford H. (2002) Effects of remnant size and connectivity on the response of Brown Treecreepers to habitat fragmentation. *Emu*. **102**, 249-56.
- Cooper R. P. (1975) The avifauna of Wilson's Promontory. *Australian Bird Watcher*. **6**, 17-34.
- Cowley R. D., Heislors A. & Ealey E. H. M. (1969) Effects of fire on wildlife. *Victoria's Resources*. **11**, 18-22.
- Crome F. H. (1994) Tropical rainforest fragmentation: some conceptual and methodological issues. In: *Conservation Biology in Australia and Oceania* (Eds C. Moritz & J. Kikkawa) pp. 61-76. Surrey Beatty & Sons, Chipping Norton, New South Wales.
- Croonquist M. J. & Brooks R. P. (1991) Use of avian and mammalian guilds as indicators of cumulative impacts in riparian-wetland areas. *Environmental Management*. **15**, 701-14.
- Cunningham R. & Olsen P. (2007) A Statistical Methodology for Tracking Change in Australia's Birds Using Composite Diversity Indices Based on Volunteer-Collected Presence-Absence Data: Preliminary Results. Scoping report to DEWR. Birds Australia, Melbourne.
- Dauwe T., Lieven B., Ellen J., Rianne P., Ronny B. & Marcel E. (2002) Great and blue tit feathers as biomonitors for heavy metal pollution. *Ecological Indicators*. **1**, 227-34.
- Debus S. J. S. (1994) The Sooty Owl *Tyto tenebricosa* in New South Wales. *Australian Birds (Supplement)*. **28**, 4-19.
- Deluca W. V., Studds C. E., Rockwood L. L. & Marra P. P. (2004) Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. *Wetlands*. **24**, 837-47.

- Desgranges J. L., Ingram J., Drolet B., Morin J., Savage C. & Borcard D. (2006) Modelling wetland bird response to water level changes in the Lake Ontario-St. Lawrence River hydrosystem. *Environmental Monitoring and Assessment*. **113**, 329-65.
- DeWitt J. C., Millsap D. S., Yeager R. L., Heise S. S., Sparks D. W. & Henshel D. S. (2006) External heart deformities in passerine birds exposed to environmental mixtures of polychlorinated biphenyls during development. *Environmental Toxicology and Chemistry*. **25**, 541-51.
- Dormann C. F., Schweiger O., Augenstein I., Bailey D., Billeter R., de Blust G., DeFilippi R., Frenzel M., Hendrickx F., Herzog F., Klotz S., Liira J., Maelfait J. P., Schmidt T., Speelmans M., van Wingerden W. K. R. E. & Zobel M. (2007) *Global Ecology and Biogeography*. **16**, 774-87.
- Dowling B. & Weston M. A. (1999) Managing a breeding population of the Hooded Plover *Thinornis rubricollis* in a high-use recreational environment. *Bird Conservation International*. **9**, 255-70.
- Duffy D. C. (1990) Seabirds and the 1982-1984 El Nino-Southern Oscillation. In: *Global Ecological Consequences of the 1982-83 El Nino-Southern Oscillation* (Ed. P. W. Glynn) pp. 395-415. Elsevier Oceanography Series 52. Elsevier, Amsterdam.
- Dufrêne M. & Legendre P. (1997) Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs*. **67**, 345-66.
- Emison W. B., Beardsell C. M., Norman F. I., Loyn R. H. & Bennett S. C. (1987) *Atlas of Victorian Birds*. Department of Conservation, Forests and Lands and the Royal Australasian Ornithologists Union, Melbourne.
- Er K. B. H. & Tidemann C. R. (1996) Importance of Yellow Box-Blakely's Red Gum woodland remnants in maintaining bird species diversity: inferences from seasonal data. *Corella*. **20**, 117-28.
- Fairweather P. & Napier G. (1998) *Environmental Indicators for National State of the Environment Reporting – Inland Waters*. Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.
- Favreau J. M., Drew C. A., Hess G. R., Rubino M. J., Koch F. H. & Eschelbach K. A. (2006) Recommendations for assessing the effectiveness of surrogate species approaches. *Biodiversity and Conservation*. **15**, 3949-69.
- Fernandez J. M., Selma M. A. E., Aymerich F. R., Saez M. T. P. & Fructuoso M. F. C. (2005) Aquatic birds as bioindicators of trophic changes and ecosystem degradation in the Mar Menor lagoon (SE Spain). *Hydrobiologia*. **550**, 221-35.
- Ficetola G. F., Sacchi R., Scali S., Gentili A., De Bernardi F. & Galeotti P. (2007) Vertebrates respond differently to human disturbance: implications for the use of a focal species approach. *Acta Oecologica*. **31**, 109-18.
- Finn P. G., Catterall C. P. & Driscoll P. V. (2007) Determinants of preferred intertidal feeding habitat for Eastern Curlew: a study at two spatial scales. *Austral Ecology*. **32**, 131-44.
- Fitri L. L. & Ford H. A. (1997) Status, habitat and social organisation of the Hooded Robin *Melanodryas cucullata* in the New England region of New South Wales. *Australian Bird Watcher*. **17**, 142-55.
- Fitri L. L. & Ford H. A. (2003a) Foraging behaviour of Hooded Robins *Melanodryas cucullata* in the northern tablelands of New South Wales. *Corella*. **27**, 61-7.
- Fitri L. L. & Ford H. A. (2003b) Breeding biology of Hooded Robins *Melanodryas cucullata* in New England, New South Wales. *Corella*. **27**, 68-74.

- Fjeldså J. (1985) Classification of waterbird communities in south-eastern Australia. *Emu*. **85**, 141-9.
- Fleishman E., Thomson J. R., Mac Nally R., Murphy D. D. & Fay J. P. (2005) Using indicator species to predict species richness of multiple taxonomic groups. *Conservation Biology*. **19**, 1125-37.
- Ford G. & Thompson N. (2005). *Birds of the Darling Downs: A Land Manager's Guide*. North East Downs Landcare, Oakey, Queensland.
- Ford G. & Thompson N. (2006). *Birds on Cotton Farms: A Guide to Common Species and Habitat Management*. Cotton Catchment Communities CRC, Narrabri, New South Wales.
- Ford H. A. & Bell H. (1981) Density of birds in eucalypt woodland affected to varying degrees by dieback. *Emu*. **81**, 202-8.
- Ford H. A., Bridges L. & Noske S. (1985) Density of birds in eucalypt woodland near Armidale, north-eastern New South Wales. *Corella*. **9**, 97-107.
- Ford J. (1970) Distribution of quail-thrushes in the Northern Territory, and their taxonomic relations. *Emu*. **70**, 135-9.
- Ford J. (1971) Distribution and taxonomy of southern birds in the Great Victoria Desert. *Emu*. **71**, 27-36.
- Forshaw J. M. & Cooper W. T. (1983) *Kingfishers and Related Birds. Volume 1. Alcedinidae: Ceryle to Cittura*. Landsdowne Editions, Melbourne.
- Franklin D. (1996) *The Status of the Black-eared Miner Manorina melanotis in New South Wales*. Royal Australasian Ornithologists Union Report 99. Royal Australasian Ornithologists Union, Melbourne.
- Freudenberger D. (1999) *Guidelines for Enhancing Grassy Woodlands for the Vegetation Investment Project*. A report commissioned by Greening Australia ACT & NSW Inc. CSIRO Wildlife and Ecology, Canberra.
- Freudenberger D. (2001) *Bush for the Birds: Biodiversity Enhancement Guidelines for the Saltshaker Project, Boorowa, NSW*. Consultancy report to Greening Australia ACT & SE NSW, Inc. CSIRO Sustainable Ecosystems, Canberra.
- Freudenberger D., Barrett G. & Nicholls A. O. (2004) *Testing Approaches to Landscape Design in Cropping Lands: Do Birds Meet The Needs of Other Taxa in the NSW Riverina?* (CSE 9, Component 3B). A CSIRO report commissioned by Land and Water Australia. CSIRO Sustainable Ecosystems, Canberra.
- Freudenberger D. & Stol J. (2002) *SAND Farmscapes Project: Integrating Production and Biodiversity*. A report commissioned by the Native Dog Landcare Group (sub-committee of Berrigan shire, NSW). CSIRO Sustainable Ecosystems, Canberra.
- Frith H. F. (1959) Breeding of the Mallee Fowl, *Leipoa ocellata* Gould (Megapodiidae). *CSIRO Wildlife Research*. **4**, 31-60.
- Frost F., Lambeck R. J., Dymond W., Rowley T. & Gowdie T. (1999) *Living Landscapes Final Report*. A report commissioned by the Natural Heritage Trust. Greening Australia (WA) and Alcoa World Alumina Australia, Perth.
- Furness R. W. (1993) Birds as monitors of pollutants. In: *Birds as Monitors of Environmental Change* (Eds R. W. Furness & J. J. D. Greenwood) pp. 86-143. Chapman & Hall, London.
- Furness R. W. & Nettleship D. N. (1991). Symposium 41: Seabirds as monitors of changing marine environments. *Acta XX Congressus Internationalis Ornithologici*. 2237-79.

- Furness R. W., Greenwood J. J. D. & Jarvis P. J. (1993) Can birds be used to monitor the environment? In: *Birds as Monitors of Environmental Change* (Eds R. W. Furness & J. J. D. Greenwood) pp. 1-41. Chapman & Hall, London.
- Gardali T., Holmes A. L., Small S. L., Nur N., Geupel G. R. & Golet G. H. (2006) Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, USA. *Restoration Ecology*. **14**, 391-403.
- Gardner J. L. (2002a) Breeding biology of the Speckled Warbler *Chthonicola sagittata*. *Australian Journal of Zoology*. **50**, 169-81.
- Gardner J. L. (2002b) Breeding biology and social behaviour of the Speckled Warbler. Unpublished PhD thesis, Australian National University.
- Gardner J. L. & Heinsohn R. G. (2007) Probable consequences of high female mortality for Speckled Warblers living in habitat remnants. *Biological Conservation*. **135**, 473-83.
- Garnett S. (Ed.) (1993) *Threatened and Extinct Birds of Australia*. RAOU Report 82. Second (corrected) edition. Royal Australasian Ornithologists Union, Melbourne, and Australian National Parks and Wildlife Service, Canberra.
- Garnett S. T. & Crowley G. M. (2000) *The Action Plan for Australian Birds 2000*. Environment Australia, Canberra.
- Garson J., Aggarwal A. & Sarkar S. (2002) Birds as surrogates for biodiversity: an analysis of a data set from southern Quebec. *Journal of Biosciences*. **27**, 347-60.
- Gause G. F. (1934) *The Struggle for Existence*. Williams & Wilkins, London.
- Gepp B. C. & Fife A. J. (1975) Birds seen in forest reserves in South Australia. *South Australian Ornithologist*. **27**, 12-7.
- Gibbs J. P., Snell H. L. & Gaston C. E. (1999) Effective monitoring for adaptive wildlife management: lessons from the Galapagos Islands. *Journal of Wildlife Management*. **63**, 1055-65.
- Green R. H. (1995) *The Fauna of Tasmania: Birds*. Potoroo Publishing, Launceston.
- Grenyer R., Orme C. D. L., Jackson S. F., Thomas G. H., Davies R. G., Davies T. J., Jones K. E., Olson V. A., Ridgely R. S., Rasmussen P. C., Ding T. S., Bennett P. M., Blackburn T. M., Gaston K. J., Gittleman J. L. & Owens I. P. F. (2006) Global distribution and conservation of rare and threatened vertebrates. *Nature*. **444**, 93-6.
- Gosper D. G. (1992) Forest bird communities of the Richmond River district, New South Wales. *Corella*. **16**, 78-88.
- Gosper C. R. & Baker J. (1997) Notes on the birds of Nadgee, particularly the Striated Fieldwren *Calamanthus fuliginosus*. *Australian Bird Watcher*. **17**, 111-25.
- Government of Western Australia (1998) *Environment Western Australia 1998: State of the Environment Report*. Department of Environmental Protection, Perth.
- Greenslade P., Joseph L. & Barley R. (Eds) (1986) *The Great Victoria Desert*. Nature Conservation Society of South Australia, Adelaide.
- Gregory R. D., van Strien A., Vorisek P., Meyling A. W. G., Noble D. G., Foppen R. P. B. & Gibbons D. W. (2005) Developing indicators for European birds. *Philosophical Transactions of the Royal Society B*. **360**, 269-88.
- Griffith J. A. (1997) Connecting ecological monitoring and ecological indicators: a review of the literature. *Journal of Environmental Systems*. **26**, 325-63.

- Hanisch D. (1998) Effects of human disturbance on the reproductive performance of the Hooded Plover. Unpublished BSc thesis, University of Tasmania.
- Hausner V. H., Yoccoz N. G. & Ims R. A. (2003) Selecting indicator traits for monitoring land use impacts: birds in northern coastal birch forests. *Ecological Applications*. **13**, 999-1012.
- Hewish M. (1990) The winter 1989 population monitoring count: Pied and Sooty Oystercatchers at monitored sites. *Stilt*. **17**, 5-16.
- Higgins P. J. (Ed.) (1999) Handbook of Australian, New Zealand and Antarctic Birds. Volume 4: Parrots to Dollarbird. Oxford University Press, Melbourne.
- Higgins P. J. & Peter J. M. (Eds) (2002) Handbook of Australian, New Zealand and Antarctic Birds. Volume 6: Pardalotes to Shrike-thrushes. Oxford University Press, Melbourne.
- Higgins P. J., Peter J. M. & Cowling S. J. (Eds) (2006) *Handbook of Australian, New Zealand and Antarctic Birds. Volume 7: Boatbill to Starlings*. Oxford University Press, Melbourne.
- Higgins P. J., Peter J. M. & Steele W. K. (Eds) (2001) *Handbook of Australian, New Zealand and Antarctic Birds. Volume 5: Tyrant-flycatchers to Chats*. Oxford University Press, Melbourne.
- Hilty J. & Merenlender A. (2000) Faunal indicator taxa selection for monitoring ecosystem health. *Biological Conservation*. **92**, 185-97.
- Hindwood K. A. (1956) *Emu* **56**, 353-6.
- H. M. Government (2005) Securing the Future: Delivering UK Sustainable Development Strategy. The Stationary Office, Norwich.
- Hobbs J. N. (1961) The birds of south-west New South Wales. *Emu*. **61**, 21-55.
- Hobbs J. N. (1972) Breeding of Red-capped Dotterel at Fletcher's Lake, Dareton, NSW. *Emu*. **72**, 121-5.
- Hollands D. (1991) Birds of the Night: Owls, Frogmouths and Nightjars of Australia. Reed, Sydney.
- Holmes G. (1994) Prey of the Sooty Owl in subtropical Australia. *Sunbird*. **24**, 25-7.
- Holmes S. B., Burke D. M., Elliott K. A., Cadman M. D. & Friesen L. (2004) Partial cutting of woodlots in an agriculture-dominated landscape. *Canadian Journal of Forest Research*. **34**, 2467-76.
- Huggett A. (2007) *A Review of the Focal Species Approach in Australia*. Land & Water Australia, Canberra.
- Huggett A., Parsons B., Atkins L. & Ingram J. (2004) *Landscape Design for Bird Conservation in Buntine-Marchagee Catchment, Western Australia (CSE 9, Component 1)*. A CSIRO report commissioned by Land and Water Australia and the WA Department of Conservation and Land Management. CSIRO Sustainable Ecosystems, Perth.
- Hutto R. L. (1998) Using landbirds as an indicator species group. In: *Avian Conservation: Research and Management* (Eds J. M. Marzluff & R. Sallabanks) pp. 75-92. Island Press, Washington.
- Hyem E. L. (1979) Observations on owls in the Upper Manning River district, N.S.W. *Corella*. **3**, 17-25.
- Isles A. C. & Menkhorst P. W. (1975) Ground Parrot habitat at Sand-Patch Point, Victoria. *Australian Bird Watcher*. **6**, 41-4.

- Jansen A. & Robertson A. I. (2001) Riparian bird communities in relation to land management practices in floodplain wetlands of south-eastern Australia. *Biological Conservation*. **100**, 173-85.
- Jansson G. (1998) Guild indicator species on a landscape scale – an example of four avian habitat specialists. *Ornis Fennica*. **75**, 119-27.
- Jedicke E. (2000) Urban and village ecosystems: environmental factors, bird communities, habitat requirements, urbanisation and conservation. *Vogelwelt*. **121**, 67-86.
- Jiguet F. & Julliard R. (2006) Inferences from common species communities for selecting conservation areas. *Biodiversity and Conservation*. **15**, 799-815.
- Johnstone R. E. & Storr G. M. (1998) Handbook of Western Australian Birds. Volume 1: Non-Passerines (Emu to Dollarbird). Western Australian Museum, Perth.
- Jones D. (1986) A survey of the bird community of 'Bullamon Plains' Thallon, southern Queensland R.A.O.U. 1985 campout. *Sunbird*. **16**, 1-11.
- Jordan R. (1987a) The Ground Parrot in Barren Grounds Nature Reserve. In: *Barren Grounds Bird Observatory and Field Study Centre Report 1984-86* (Eds R. Jordan & P. Jordan) pp. 19-23. Royal Australasian Ornithologists Union Report 27. Royal Australasian Ornithologists Union, Melbourne.
- Jordan R. (1987b) The Southern Emu-wren in Barren Grounds. In: *Barren Grounds Bird Observatory and Field Study Centre Report 1984-86* (Eds R. Jordan & P. Jordan) p. 24. Royal Australasian Ornithologists Union Report 27. Royal Australasian Ornithologists Union, Melbourne.
- Joseph L. (1986) The decline and present status of the Black-eared Miner in South Australia. *South Australian Ornithologist*. **30**, 5-13.
- Juutinen A. & Mönkkönen M. (2004) Testing alternative indicators for biodiversity conservation in old-growth boreal forests: ecology and economics. *Ecological Economics*. **50**, 35-48.
- Kati V., Devillers P., Dufrière M., Legakis A., Vokou D. & Lebrun P. (2004) Testing the value of six taxonomic groups as biodiversity indicators at a local scale. *Conservation Biology*. **18**, 667-75.
- Kavanagh R. P. (1991) The target species approach to wildlife management: gliders and owls in the forests of southeastern New South Wales. In: *Conservation of Australia's Forest Fauna* (Ed. D Lunney) pp. 377-383. Royal Zoological Society of New South Wales, Mosman, New South Wales.
- Kavanagh R. P. (1997) Ecology and management of large forest owls in south-eastern Australia. Unpublished PhD thesis, University of Sydney.
- Kavanagh R. P. & Jackson R. (1997) Home-range, movements, habitat and diet of the Sooty Owl *Tyto tenebricosa* near Royal National Park, Sydney. In: *Australian Raptor Studies II* (Eds G. Czechura & S. Debus) pp. 2-13. *Birds Australia Monograph* 3. Birds Australia, Melbourne.
- Kavanagh R. P., Loyn R. H., Smith G. C., Taylor R. J. & Catling P. C. (2004) Which species should be monitored to indicate ecological sustainability in Australian forest management? In: *Conservation of Australia's Forest Fauna* (Ed. D. Lunney) pp. 959-987. Second edition. Royal Zoological Society of New South Wales, Mosman, New South Wales.
- Kavanagh R. P. & Stanton M. A. (2005) Vertebrate species assemblages and species sensitivity to logging in the forests of north-eastern New South Wales. *Forest Ecology and Management*. **209**, 309-41.

- Kelly J. R. & Harwell M. A. (1990) Indicators of ecosystem recovery. *Environmental Management*. **14**, 527-45.
- Koskimies P. (1989) Birds as a tool in environmental monitoring. *Annales Zoologici Fennici*. **26**, 153-66.
- Kremen C. (1992) Assessing the indicator properties of species assemblages for natural areas monitoring. *Ecological Applications*. **2**, 203-17.
- Kremen C. (1994) Biological inventory using target taxa: a case study of the butterflies of Madagascar. *Ecological Applications*. **4**, 407-22.
- Kremen C., Merenlender A. M. & Murphy D. D. (1994) Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. *Conservation Biology*. **8**, 388-97.
- Kushlan J. A. (1993) Colonial waterbirds as bioindicators of environmental change. *Colonial Waterbirds*. **16**, 223-51.
- Lambeck R. J. (1998) Nature conservation at the landscape scale - adequacy of habitat. In: *Dongolocking Pilot Planning Project for Remnant Vegetation* (Ed. K. J. Wallace) pp. 59-74. Department of Conservation and Land Management, Perth.
- Lambeck R. J. (1999) Landscape Planning for Biodiversity Conservation in Agricultural Regions: A Case Study from the Wheatbelt of Western Australia. Biodiversity Technical Paper 2. Environment Australia, Canberra.
- Lambeck R. J. (2002) Focal species and restoration ecology: response to Lindenmayer *et al.* *Conservation Biology*. **16**, 549-51.
- Landres P. B., Verner J. & Thomas J. W. (1988) Ecological uses of vertebrate indicator species: a critique. *Conservation Biology*. **2**, 316-28.
- Landsberg J., Morton S. & James C. (1999) A comparison of the diversity and indicator potential of arthropods, vertebrates and plants in arid rangelands across Australia. In: *The Other 99%. The Conservation and Biodiversity of Invertebrates* (Eds W. Ponder & D. Lunney). pp. 111-20. Surrey Beatty & Sons, Chipping Norton, New South Wales.
- Lane B. A. (1987) *Shorebirds in Australia*. Nelson, Melbourne.
- Lawler J. J., White D., Sifneos J. C. & Master L. L. (2003) Rare species and the use of indicator groups for conservation planning. *Conservation Biology*. **17**, 875-82.
- Leach G. J. (1996) Changes in populations of bird species in roadside softscrub remnants/farmland and open eucalypt forest in south-east Queensland, 1981 to 1993. *Pacific Conservation Biology*. **2**, 232-43.
- Leach J. A. (1929) The lyrebird – Australia's wonder-bird. *Emu*. **28**, 199-214.
- Lee T. M., Soh M. C. K., Sodhi N., Koh L. P. & Lim S. L. H. (2005) Effects of habitat disturbance on mixed-species bird flocks in a tropical sub-montane rainforest. *Biological Conservation*. **122**, 193-204.
- Lill A. (1980) Reproductive success and nest predation in the Superb Lyrebird, *Menerua superba*. *Australian Wildlife Research*. **7**, 271-80.
- Lindenmayer D. B. (1997) Differences in the biology and ecology of arboreal marsupials in forests of southeastern Australia. *Journal of Mammalogy*. **78**, 1117-27.
- Lindenmayer D. B. (1999) Future directions for biodiversity conservation in managed forests: indicator species, impact studies and monitoring programs. *Forest Ecology and Management*. **115**, 277-87.

- Lindenmayer D. B. & Burgman M. (2005) *Practical Conservation Biology*. CSIRO Publishing, Collingwood.
- Lindenmayer D. B. & Fischer J. (2003) Sound science or social hook – a response to Brooker's application of the focal species approach. *Landscape and Urban Planning* **62**, 149-58.
- Lindenmayer D. B., Margules C. R. & Botkin D. B. (2000) Indicators of biodiversity for ecologically sustainable forest management. *Conservation Biology*. **14**, 941-50.
- Lindenmayer D. B., Manning A. D., Smith P. L., Possingham H. P., Fischer J., Oliver I. & McCarthy M. A. (2002) The focal-species approach and landscape restoration: a critique. *Conservation Biology*. **16**, 338-45.
- Loyn R. H. (1980) Bird populations in a mixed eucalypt forest used for production of wood in Gippsland, Victoria. *Emu* **80**, 145-56.
- Loyn R. H. (1985) Ecology, distribution and density of birds in Victorian forests. In: *Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management* (Eds A. Keast, H. F. Recher, H. Ford & D. Saunders) pp. 33-46. Surrey Beatty & Sons, Chipping Norton, New South Wales.
- Loyn R. H. (1993) *Effects of Previous Logging on Bird Populations in East Gippsland: VSP Retrospective Study*. VSP Technical Report No. 18. Department of Conservation and Natural Resources, Melbourne.
- Loyn R. H., Traill B. J. & Triggs B. E. (1986) Prey of Sooty Owls in East Gippsland before and after fire. *Victorian Naturalist*. **103**, 147-9.
- Loyola R. D., Kubota U. & Lewinsohn T. M. (2007). Endemic vertebrates are the most effective surrogates for identifying conservation priorities among Brazilian ecoregions. *Diversity and Distributions*. **13**, 389-96.
- Luck G. W., Possingham H. P. & Paton D. C. (1999) Bird responses at inherent and induced edges in the Murray Mallee, South Australia. 1. Differences in abundance and diversity. *Emu*. **99**, 157-69.
- Lund M. P. & Rahbek C. (2002) Cross-taxon congruence in complementarity and conservation of temperate biodiversity. *Animal Conservation*. **5**, 163-71.
- Lundie-Jenkins G. (1993) The diet of the Sooty Owl *Tyto tenebricosa* in the Blue Mountains, N.S.W. *Emu*. **93**, 124-7.
- Lyons M. N., Halse S. A., Gibson N., Cale D. J., Lane J. A. K., Walker C. D., Mickle D. A. & Froend R. H. (2007) Monitoring wetlands in a salinizing landscape: case studies from the Wheatbelt region of Western Australia. *Hydrobiologia*. **591**, 147-64.
- Mac Nally R. (1997) Population densities in a bird community of a wet sclerophyllous Victorian forest. *Emu*. **97**, 253-8.
- Mac Nally R. (2006) Longer-term response to experimental manipulation of fallen timber on forest floors of floodplain forest in south-eastern Australia. *Forest Ecology and Management*. **229**, 155-60.
- Mac Nally R, Ellis M. & Barrett G. (2004) Avian biodiversity monitoring in Australian rangelands. *Austral Ecology*. **29**, 93-9.
- Mac Nally R., Horrocks G. & Pettifer L. (2002) Experimental evidence for potential beneficial effects of fallen timber in forests. *Ecological Applications* **12**, 1588-94.
- Maclean G. L. (1977) Comparative notes on Black-fronted and Red-kneed Dotterels. *Emu*. **77**, 199-207.

- Maguire G. S. (2006) Fine-scale habitat use by the Southern Emu-wren (*Stipiturus malachurus*). *Wildlife Research*. **33**, 137-48.
- Mallory M. L., Gilchrist H. G., Braune B. M. & Gaston A. J. (2006) Marine birds as indicators of Arctic marine ecosystem health: linking the Northern Ecosystem Initiative to long-term studies. *Environmental Monitoring and Assessment*. **113**, 31-48.
- Mannan R. W., Morrison M. L. & Meslow E. C. (1984) The use of guilds in forest bird management. *Wildlife Society Bulletin*. **12**, 426-30.
- Marchant S. & Higgins P. J. (Eds) (1993) Handbook of Australian, New Zealand and Antarctic Birds. Volume 2: Raptors to Lapwings. Oxford University Press, Melbourne.
- Marshall A. J. (1931) The Azure Kingfisher. *Emu*. **31**, 44-7.
- Maron M. & Lill A. (2005) The influence of livestock grazing and weed invasion on habitat use by birds in grassy woodland remnants. *Biological Conservation*. **124**, 439-50.
- Martin T. E. (1995) Avian life history evolution in relation to nest sites, nest predation and food. *Ecological Monographs*. **65**, 101-27.
- Martin T. E. & Li P. (1992) Life history traits of open versus cavity-nesting birds. *Ecology*. **73**, 579-92.
- Matthew J. S. & Carpenter G. A. (1990) *A Survey of Birds and their Habitats in Unnamed Conservation Park and Adjacent Eastern Great Victoria Desert*. Unpublished report to South Australian Ornithological Association, Adelaide.
- Mattsson B. J. & Cooper R. J. (2006) Louisiana waterthrushes (*Seiurus motacilla*) and habitat assessments as cost-effective indicators of instream biotic integrity. *Freshwater Biology*. **51**, 1941-58.
- Matz A. C. & Parsons K. C. (2004) Organochlorines in black-crowned night-heron (*Nycticorax nycticorax*) eggs reflect persistent contamination in northeastern US estuaries. *Archives of Environmental Contamination and Toxicology*. **46**, 270-74.
- McFarland D. (1988) The composition, microhabitat use and response to fire of the avifauna of subtropical heathlands in Cooloola National Park, Queensland. *Emu*. **88**, 249-57.
- McFarland D. (1993) Notes on the Pied Oystercatcher *Haematopus longirostris* in the Cooloola-Fraser Island area. *Sunbird*. **23**, 109-13.
- McFarland D. (1994) Notes on the Brush Bronzewing *Phaps elegans* and Southern Emu-wren *Stipiturus malachurus* in Cooloola National Park. *Sunbird*. **24**, 14-7.
- McFarland D.C (1991) The biology of the Ground Parrot, *Pezoporus wallicus*, in Queensland. III. Distribution and abundance. *Wildlife Research*. **18**, 199-213.
- McGeoch M. A. (1998) The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews*. **73**, 181-201.
- McGill A. R. (1944) The Red-kneed Dotterel in coastal south-eastern Australia. *Emu*. **43**, 225-28.
- McLaughlin J. (1990) *Survey and Observations of the Black-eared Miner Manorina melanotis in Victoria 1989-1990*. Royal Australasian Ornithologists Union Report 71. Royal Australasian Ornithologists Union, Melbourne.
- Meredith C. W. (1984) *Management of the Ground Parrot (Pezoporus wallicus) in Victoria – May 1984*. Unpublished report to Victorian Department of Conservation, Forests and Lands and World Wildlife Fund Australia, Melbourne.

- Meredith C. W., Gilmore A. M. & Isles A. C. (1984) The Ground Parrot in south-eastern Australia: a fire-adapted species? *Australian Journal of Ecology*. **9**, 367-80.
- Meredith C. W. & Isles A. C. (1980) *A Study of the Ground Parrot (Pezoporus wallicus) in Victoria*. Environmental Studies Division of the Ministry for Conservation Publication No. 304. Ministry for Conservation, Melbourne.
- Meredith C. W. & Jaremovic R. (1990) *Current Status of Management of the Ground Parrot in Victoria*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 58. Department of Conservation, Forests and Lands, Heidelberg.
- Milledge D. R., Palmer C. L. & Nelson J. L. (1991) "Barometers of change": the distribution of large owls and gliders in Mountain Ash forests of the Victorian Central Highlands and their potential as management indicators. In: *Conservation of Australia's Forest Fauna* (Ed. D. Lunney) pp. 53-65. Royal Zoological Society of New South Wales, Mosman, New South Wales.
- Milledge D. R., Palmer C. L. & Nelson J. L. (1993) A survey of large owls in Mountain Ash forests of the Victorian central highlands. In: *Australian Raptor Studies. Proceedings 10th Anniversary Conference, Australasian Raptor Association, Canberra, September 21-22, 1989* (Ed. P. Olsen) p. 143. Australasian Raptor Association, Royal Australasian Ornithologists Union, Melbourne.
- Mills L. S., Soulé M. E. & Doak D. F. (1993) The keystone-species concept in ecology and conservation. *BioScience*. **43**, 219-24.
- Mikusinski G., Gromadzki M. & Chylarecki P. (2001) Woodpeckers as indicators of forest bird diversity. *Conservation Biology*. **15**, 208-17.
- Mochizuki M., Hondo R., Kumon K., Sasaki R., Matsuba H. & Ueda F. (2002) Cadmium contamination in wild birds as an indicator of environmental pollution. *Environmental Monitoring and Assessment*. **73**, 229-35.
- Moore J. L., Balmford A., Brooks T., Burgess N. D., Hansen L.A., Rahbek C. & Williams P. H. (2003) Performance of sub-Saharan vertebrates as indicator groups for identifying priority areas for conservation. *Conservation Biology*. **17**, 207-18.
- Moore L. A. (2007) Population ecology of the Southern Cassowary *Casuarius casuarius johnsonii*, Mission Beach north Queensland. *Journal of Ornithology*. **148**, 357-66.
- Morgan D. G., Richards N., Braszell L. & Raden A. (1995) *Lyrebirds in the Dandenongs: Their Present and Future Status*. Department of Zoology, University of Melbourne, for Department of Conservation and Natural Resources, Melbourne.
- Morris A. K. (1975) The birds of Gosford, Wyong and Newcastle (County of Northumberland). *Australian Birds*. **9**, 37-76.
- Morris A. K. (2001) New South Wales Annual Bird Report for 1998. *Australian Birds*. **32**, 101-67.
- Morris A. K., Tyler V., Tyler M., Mannes H. & Dalby J. (1990) A waterbird survey of the Parramatta River wetlands, Sydney, New South Wales. *Australian Birds*. **23**, 44-64.
- Morrison M. (1986) Bird populations as indicators of environmental change. *Current Ornithology*. **3**, 429-51.
- Mount Lofty Ranges Southern Emu-wren Recovery Team (1998) *Recovery Plan for the Mount Lofty Ranges Southern Emu-Wren Stipiturus malachurus intermedius 1999 - 2003*. Report to the Threatened Species and Communities Section, Environment Australia. Conservation Council of South Australia, Adelaide.

- Mustoe S. (2006). *Assessment of the Conservation Status of Mallee Emu-wren* *Stipiturus mallee* A. J. Campbell, 1908, Family *Maluridae*. Unpublished report to Save the Food Bowl Alliance.
- Napier J. R. (1969) Birds of the Break O'Day Valley, Tasmania. *Australian Bird Watcher*. **3**, 179-92.
- Neave H. M., Norton T. W. & Nix H. A. (1996) Biological inventory for conservation evaluation II. Composition, functional relationships and spatial prediction of bird assemblages in southern Australia. *Forest Ecology and Management*. **85**, 123-48.
- Newman O. M. G. (1990) A forecast of population decline in Pied Oystercatchers based on breeding disturbance. *Tasmanian Bird Report*. **20**, 21-4.
- Niemelä J., Langor D. and Spence J.R. (1993) Effects of clear-cut harvesting on boreal ground-beetle assemblages (Coleoptera: Carabidae) in western Canada. *Conservation Biology*. **7**, 551-61.
- Noske R. (1977) Roosting of tree-creepers. *Sunbird*. **8**, 41-4.
- Noske R. A. (1979) Co-existence of three species of treecreepers in north-eastern New South Wales. *Emu*. **79**, 120-8.
- Noske R. A. (1982a) Comparative behaviour and ecology of some Australian bark-foraging birds. Unpublished PhD thesis, University of New England.
- Noske R. A. (1982b). The private lives of treecreepers. *Australian Natural History*. **20**, 419-24.
- Noske R. A. (1985) Habitat use by three bark-foragers of eucalypt forests. In: *Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management* (Eds A. Keast, H. F. Recher, H. Ford & D. Saunders) pp. 193-204. Surrey Beatty & Sons, Chipping Norton, New South Wales.
- Noss R. F. (1990) Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology*. **4**, 355-64.
- O'Connell T. J., Jackson L. E. & Brooks R. P. (1998) A bird community index of biotic integrity for the mid-Atlantic highlands. *Environmental Monitoring and Assessment*. **51**, 145-56.
- O'Connell T. J., Jackson L. E. & Brooks R. P. (2000) Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications*. **10**, 1706-21.
- O'Connor R. J., Walls T. E. & Hughes R. M. (2000) Using multiple taxonomic groups to index the ecological condition of lakes. *Environmental Monitoring and Assessment*. **61**, 207-28.
- Oliver I., Beattie A. J. & York A. (1998) Spatial fidelity of plant, vertebrate and invertebrate assemblages in multiple-use forest in eastern Australia. *Conservation Biology*. **12**, 822-35.
- Owner D. & Rohweder D.A. (2003) Distribution and habitat of Pied Oystercatchers (*Haematopus longirostris*) inhabiting ocean beaches in northern New South Wales. *Emu*. **103**, 163-9.
- Paillisson J. M., Reeber S. & Marion L. (2002) Bird assemblages as bio-indicators of water regime management and hunting disturbance in natural wet grasslands. *Biological Conservation*. **106**, 115-27.
- Paine R. T. (1995) A conversation on refining the concept of keystone species. *Conservation Biology*. **9**, 962-4.

- Pawar S. S., Birand A. C., Ahmed M. F., Sengupta S. & Raman T. R. S. (2007) Conservation biogeography in north-east India: hierarchical analysis of cross-taxon distributional congruence. *Diversity and Distributions*. **13**, 53-65.
- Papp Z., Bortolotti G. R., Sebastian M. & Smits J. E. G. (2007) PCB congener profiles in nestling tree swallows and their insect prey. *Archives of Environmental Contamination and Toxicology*. **52**, 257-63.
- PECBMS (2007) State of Europe's Common Birds, 2007. CSO/RSPB, Prague.
- Pearman P. B. & Weber D. (2007) Common species determine richness patterns in biodiversity indicator taxa. *Biological Conservation*. **138**, 109-19.
- Pearson D. L. & Cassola F. (1992) World-wide species richness patterns of tiger beetles (Coleoptera: Cicindelidae): indicator taxon for biodiversity and conservation studies. *Conservation Biology*. **6**, 376-91.
- Peter J. (1990) *Bird Study in the Nooramunga: The Possible Effects of Oyster Farming*. Royal Australasian Ornithologists Report 74. Royal Australasian Ornithologists Union, Melbourne.
- Peters R. H. (1983) *The Ecological Implications of Body Size*. Cambridge University Press, New York.
- Pickett M. (2002) *Status Review and Action Plan for the Eyre Peninsula Southern Emu-wren Stipiturus malachurus parimeda*. Unpublished report prepared for South Eyre Birds Incorporated and National Parks and Wildlife South Australia.
- Possingham M. L. & Possingham H. P. (1997) Habitat use and abundance of dryland birds in heritage areas in the upper south east of South Australia. *South Australian Ornithologist*. **32**, 145-60.
- Powell G. V. N. & Powell A. H. (1986) Reproduction by great white herons *Ardea herodias* in Florida Bay as an indicator of habitat quality. *Biological Conservation*. **36**, 101-13.
- Prendergast J. R. & Eversham B. C. (1997) Species richness covariance in higher taxa: empirical tests of the biodiversity indicator concept. *Ecography*. **20**, 210-6.
- Prendergast J. R., Quinn R. M., Lawton J. H., Eversham B. C. & Gibbons D. W. (1993) Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature*. **365**, 335-57.
- Priddel D. & Wheeler R. (1994) Mortality of captive-raised Malleefowl, *Leipoa ocellata*, released into a mallee remnant within the wheat-belt of New South Wales. *Wildlife Research*. **21**, 543-52.
- Priddel D. & Wheeler (1996) Effect of age at release on the susceptibility of captive-reared Malleefowl *Leipoa ocellata* to predation by the introduced fox *Vulpes vulpes*. *Emu*. **96**, 32-41.
- Priddel D. & Wheeler R. (1999) Malleefowl conservation in New South Wales: a review. In: *Proceedings of the Third International Megapode Symposium, Nhill, Australia, December 1997* (Eds R. W. R. J. Dekker, D. N. Jones & J. Benshemesh) pp. 125-142. *Zoologische Verhandelingen* 327. National Museum of Natural History, Leiden.
- Radford J. Q. (2004) Breeding biology, adult survival and territoriality of the White-browed Treecreeper (*Climacteris affinis*) in north-west Victoria, Australia. *Emu*. **104**, 305-16.
- Radford J. Q. & Bennett A. F. (2004) Thresholds in landscape parameters: occurrence of the White-browed Treecreeper *Climacteris affinis* in Victoria, Australia. *Biological Conservation*. **117**, 375-91.

- Radford J. Q. & Bennett A. F. (2006) Factors affecting patch occupancy by the White-browed Treecreeper *Climacteris affinis* in an agricultural landscape in north-west Victoria, Australia. *Pacific Conservation Biology*. **12**, 195-206.
- Ratkowsky A. V. & Ratkowsky D. A. (1977) The birds of the Mt Wellington Range, Tasmania. *Emu*. **77**, 19-22.
- Reader R. (1988) Using the guild concept in the assessment of tree harvesting effect on understorey herbs: a cautionary note. *Environmental Management*. **12**, 803-8.
- Recher H. F., Davis W. E. & Calver M. C. (2002) Comparative foraging ecology of five species of ground-pouncing birds in Western Australian woodlands with comments on species decline. *Ornithological Science*. **1**, 29-40.
- Reid T. & Park P. (2003) Continuing decline of Eastern Curlew, *Numenius madagascariensis*, in Tasmania. *Emu*. **103**, 279-93.
- Reilly P. (1991) The effect of wildfire on bush bird populations in six Victorian coastal habitats. *Corella*. **15**, 134-42.
- Reilly P. N. (1988) *The Lyrebird*. University of New South Wales Press, Sydney.
- Retallick R. W. R. & Bolitho E. E. (1993) Disturbance of Hooded Plovers by domestic dogs. *Stilt*. **23**, 23.
- Reynaud P. A. & Thioulouse J. (2000) Identification of birds as biological markers along a neotropical urban-rural gradient (Cayenne, French Guiana), using co-inertia analysis. *Journal of Environmental Management*. **59**, 121-40.
- Ridpath M. G. & Moreau R. E. (1966) The birds of Tasmania; ecology and evolution. *Ibis*. **108**, 348-93.
- Robinson D. & Howell M. (2003) *Local Biodiversity Planning: Longwood Zone Trial*. Unpublished report by Goulburn Catchment Management Authority, Department of Sustainability and Environment and Trust for Nature, Melbourne.
- Rose A. (2000) Hooded Plovers and four wheel drive vehicles. *Western Australian Bird Notes*. **94**, 16.
- Russell E. M. & Rowley I. (1993) Demography of the cooperatively breeding Splendid Fairy-wren, *Malurus splendens* (Maluridae). *Australian Journal of Zoology*. **41**, 475-505.
- Sauberer N., Zulka K. P., Abensperg-Traun M., Berg H. M., Bieringer G., Milasowszky N., Moser D., Plutzar C., Pollheimer M., Storch C., Trostl R., Zechmeister H. & Grabherr G. (2004). Surrogate taxa for biodiversity in agricultural landscapes in eastern Austria. *Biological Conservation*. **117**, 181-90.
- Schodde R. & Mason I. J. (1980) *Nocturnal Birds of Australia*. Lansdowne, Melbourne.
- Schreiber R. W. & Schreiber E. A. (1984) Central Pacific seabirds and the El Nino southern oscillation: 1982 to 1983 perspectives. *Science*. **225**, 713-6.
- Schulz M. (1986) Foot-trembling in the Red-kneed Dotterel. *Stilt*. **8**, 21.
- Schulz M. (1992) *Hooded Plover Charadrius rubricollis – Flora and Fauna Guarantee Action Statement No. 9*. Department of Sustainability and Environment, Melbourne.
- Schulz M. & Bamford M. (1987) *The Hooded Plover – An RAOU Conservation Statement*. Royal Australasian Ornithologists Union Report 35. Royal Australasian Ornithologists Union, Melbourne.
- Schulze C. H., Matthias W., Kessler P. J. A., Pitopang R., Buddin S., Veddeler D., Muehlenberg M., Gradstein S. R., Leuschner C., Steffan-Dewenter I. & Tschardt T. (2004)

Biodiversity indicator groups for tropical land-use systems: comparing plants, birds, and insects. *Ecological Applications*. **14**, 1321-33.

Secretariat of the Convention on Biological Diversity (2000) *Sustaining Life on Earth: How the Convention on Biological Diversity Promotes Nature and Human Well-being*. Secretariat of the Convention on Biological Diversity, Montreal.

Silveira C. E. (1999). *Mallee Emu-wren* *Stipiturus mallee*. *Flora and Fauna Guarantee Action Statement*. Natural Resources and Environment, Melbourne.

Simberloff D. (1998) Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? *Biological Conservation*. **83**, 247-57.

Slater P. J. (1995) The interaction of bird communities with vegetation and season in Brisbane Forest Park. *Emu*. **95**, 194-207.

Smith L. H. (1994) A critical analysis of the factors responsible for the decline of the Superb Lyrebird *Menura novaehollandiae* in Sherbrooke Forest, Victoria. *Australian Bird Watcher*. **15**, 238-49.

Smith L. H. (1995) The Superb Lyrebird *Menura novaehollandiae* – a comment on single-species management. *Australian Bird Watcher*. **16**, 169-71.

Smith P. (1984a) Prey items of the Sooty Owl and the Barn Owl at Bega, New South Wales. *Corella*. **8**, 71-2.

Smith P. (1984b) The forest avifauna near Bega, New South Wales. I. Differences between forest types. *Emu*. **84**, 200-10.

Smith P. (1985a) Effects of intensive logging on birds in eucalypt forest near Bega, New South Wales. *Emu*. **85**, 15-21.

Smith P. (1985b) Woodchip logging and birds near Bega, New South Wales. In: *Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management* (Eds A. Keast, H. F. Recher, H. Ford & D. Saunders) pp. 259-271. Surrey Beatty & Sons, Chipping Norton, New South Wales.

Smyth A., Mac Nally R. & Lamb D. (2002) Comparative influence of forest management and habitat structural factors on the abundances of hollow-nesting bird species in subtropical Australian eucalypt forest. *Environmental Management*. **30**, 547-59.

Sorace A., Colombari P. & Cordiner E. (1999) Bird communities and extended biotic index (EBI) in some tributaries of the Tiber River. *Aquatic Conservation*. **9**, 279-90.

Sorace A., Formichetti P., Boano A., Andreani P., Gramegna C. & Mancini L. (2002) The presence of a river bird, the dipper, in relation to water quality and biotic indices in central Italy. *Environmental Pollution*. **118**, 89-96.

Spellerberg I. F. (1991) *Monitoring Ecological Change*. Cambridge University Press, Cambridge, United Kingdom.

Starks J. (1987) *The Status and Distribution of the Black-eared Miner* (*Manorina melanotis*) *in Victoria*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 49. Department for Sustainability and Environment, Heidelberg.

Steele B. B., Bayn R. L. & Grant C. V. (1984) Environmental monitoring using populations of birds and small mammals: analyses of sampling effort. *Biological Conservation*. **30**, 157-72.

Storr G. M. (1987) Birds of the Eucla Division. *Records of the Western Australian Museum Supplement*. **27**, 1-81.

Sullivan D. (1993) The breeding and non-breeding behaviour of a pair of Hooded Robin *Melanodryas cucullata* in Canberra, 1990-1991. *Australian Bird Watcher*. **15**, 99-107.

- Sydeman W. J., Piatt J. F. & Browman H. I. (2007). Theme section: Seabirds as indicators of marine ecosystems. *Marine Ecology Progress Series*. **352**, 199-309.
- Szaro R. C. & Balda R. P. (1982) Selection and monitoring of avian indicator species: an example from a Ponderosa Pine forest in the southwest. *USDA Forest Service General Technical Report*. **RM-89**, 1-8.
- Tamisier A. & Boudouresque C. (1994) Aquatic bird populations as possible indicators of seasonal nutrient flow at Ichkeul Lake, Tunisia. *Hydrobiologia*. **279-280**, 149-156.
- Tankersley R. D. (2004) Migration of birds as an indicator of broad-scale environmental condition. *Environmental Monitoring and Assessment*. **94**, 55-67.
- Taper M. L., Böhning-Gaese K. & Brown J. H. (1995) Individualistic responses of bird species to environmental change. *Oecologia*. **101**, 478-86.
- Tarr H. E. (1965) The Mallee-fowl in Wyperfeld National Park. *Australian Bird Watcher*. **2**, 140-4.
- Temple S. A. & Wiens J. A. (1989) Bird populations and environmental changes: can birds be bio-indicators? *American Birds*. **43**, 260-70.
- Templeton M. T. (1992) Birds of Nanango, south-east Queensland. *Sunbird*. **22**, 87-110.
- Thiollay J. L. (1992) Influence of selective logging on bird species diversity in a Guianan rain forest. *Conservation Biology*. **6**, 47-63.
- Thomas D. G. (1979) *Tasmanian Bird Atlas*. Fauna of Tasmania Handbook No. 2. University of Tasmania, Hobart.
- Thomson J. R., Fleishman E., Mac Nally R. & Dobkin D. S. (2007) Comparison of predictor sets for species richness and the number of rare species of butterflies and birds. *Journal of Biogeography*. **34**, 90-101.
- Traill B. & Duncan S. (2000) *Status of Birds in the New South Wales Temperate Woodlands Region*. Australian Woodlands Conservancy, Chiltern.
- Tzaros C. L. (1996) Observations on the ecology and breeding biology of the Speckled Warbler *Chthonicola sagittata* near Bendigo, Victoria. *Australian Bird Watcher*. **16**, 221-35.
- Uliczka H. & Angelstam P. (2000) Assessing conservation values of forest stands based on specialised lichens and birds. *Biological Conservation*. **95**, 343-51.
- U.S. Congress Office of Technology Assessment (1992) *Forest Service Planning: Accommodating Uses, Producing Outputs, and Sustaining Ecosystems*. OTA-F-505. U.S. Government Printing Office, Washington.
- Venier L. A. & Pearce J. L. (2004) Birds as indicators of sustainable forest management. *Forestry Chronicle*. **80**, 61-6.
- Venier L. A. & Pearce J. L. (2005) Boreal bird community response to jack pine forest succession. *Forest Ecology and Management*. **217**, 19-36.
- Vessby K., Söderström B., Glimskär A. & Svensson B. (2002) Species-richness correlations of six different taxa in Swedish seminatural grasslands. *Conservation Biology*. **16**, 430-9.
- Vielliard J. M. E. (2000) Bird community as an indicator of biodiversity: results from quantitative surveys in Brazil. *Anais Da Academia Brasileira De Ciencias*. **72**, 323-30.
- Wall C. A. (1989) Post-fire dynamics of the vegetation, habitat and population of the Ground Parrot at Barren Grounds Nature Reserve, New South Wales. BSc Honours Thesis, University of New South Wales.

- Walters J. R., Ford H. A. & Cooper C. B. (1999) The ecological basis of sensitivity of Brown Treecreepers to habitat fragmentation: a preliminary assessment. *Biological Conservation*. **90**, 13-20.
- Ward T., Butler E. & Hill B. (1998) *Environmental Indicators for National State of the Environment Reporting – Estuaries and the Sea*. Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.
- Watkins D. (1985) *Report of the RAOU Ground Parrot Survey in Western Australia*. Royal Australasian Ornithologists Union Report 15. Royal Australasian Ornithologists Union, Melbourne.
- Watson J., Freudenberger D. & Paull D. (2001) An assessment of the focal-species approach for conserving birds in variegated landscapes in southeastern Australia. *Conservation Biology*. **15**, 1364-73.
- Watson J. E. M., Whittaker R. J. & Freudenberger D. (2005) Bird community responses to habitat fragmentation: how consistent are they across landscapes? *Journal of Biogeography*. **32**, 1353-70.
- Weller M. W. (1995) Use of two waterbird guilds as evaluation tools for the Kissimmee River restoration. *Restoration Ecology*. **3**, 211-24.
- Weston M. A. (1998) Nankeen Kestrel takes Hooded Plover chick. *Australian Bird Watcher*. **17**, 266-7.
- Weston M. A. (2000) The effect of human disturbance on the breeding biology of the Hooded Plover. Unpublished PhD thesis, University of Melbourne.
- Weston M. A. (2003) *Managing the Hooded Plover in Victoria: A Review of Existing Information*. Parks Victoria Technical Series No. 4. Parks Victoria, Melbourne.
- Weston M. A. & Elgar M. A. (2005) Disturbance to brood-rearing Hooded Plover *Thinornis rubricollis*: responses and consequences. *Bird Conservation International*. **15**, 193-209.
- Weston M. A. & Elgar M. A. (2007) Responses of incubating Hooded Plovers (*Thinornis rubricollis*) to disturbance. *Journal of Coastal Research*. **23**, 569-76.
- Weston M. A. & Morrow F. (2000) *Managing the Hooded Plover in Western Victoria*. Threatened Bird Network report to Parks Victoria, Melbourne.
- Whiteside R. S. (1987) A Rose Robin *Petroica rosea* visits a Highton garden. *Geelong Naturalist*. **24**, 69-71.
- Whitford W. G., De Soyza A. G., Van Zee J. W., Herrick J. E. & Havstad K. M. (1998) Vegetation, soil and animal indicators of rangeland health. *Environmental Monitoring and Assessment*. **51**, 179-200.
- Williams M. R., Abbott I., Liddelow G. L., Vellios C., Wheeler I. B. & Mellican I. E. (2001) Recovery of bird populations after clearfelling of tall open eucalypt forest in Western Australia. *Journal of Applied Ecology*. **38**, 910-20.
- Wilson G. W. (1994) The status of the Pied Oystercatcher *Haematopus longirostris* on the coastal flats of Keppel Sands and Joskeleigh on the Capricorn Coast of central Queensland. *Sunbird*. **24**, 73-9.
- Woinarski J. C. Z. (1989a). Broombush harvesting in southeastern Australia. In: *Mediterranean Landscapes in Australia: Mallee Ecosystems and Their Management* (Eds J. C. Noble & R. A. Bradstock) pp. 362-378. CSIRO, Melbourne.

- Woinarski J. C. Z. (1989b) The vertebrate fauna of Broombush *Melaleuca uncinata* vegetation in north-western Victoria, with reference to effects of Broombush harvesting. *Australian Wildlife Research*. **16**, 217-38.
- Woodley S. (1996) A scheme for ecological monitoring in national parks and protected areas. *Environments*. **23**, 50-9.
- Woodwell G. M. & Rebeck A. L. (1967) Effects of chronic gamma radiation on the structure and diversity of an oak-pine forest. *Ecological Monographs*. **37**, 53-69.
- Wren C. D., Nygard T. & Steinnes E. (1994) Willow ptarmigan (*Lagopus lagopus*) as a biomonitor of environmental metal levels in Norway. *Environmental Pollution*. **85**, 291-5.
- Zockler C. (2005) Migratory bird species as indicators for the state of the environment. *Biodiversity (Ottawa)*. **6**, 7-13.
- Zonneveld I. S. (1983) Principles of bio-indication. *Environmental Monitoring and Assessment*. **3**, 207-17.

8 ACKNOWLEDGEMENTS

Parks Victoria and Scott Chambers would like to thank Chris Tzaros, Dean Ingwersen, James O'Connor and Mark Antos who have provided technical knowledge, advice and feedback for the development of this document. Editing provided by Illonna Evans.

APPENDIX 1

Table A1.1 Summary of identified indicator or focal bird species in Australia from published studies.

Location	Habitat	Indicator Species	Indicated	Source
South-western Western Australia.	Jarrah <i>Eucalyptus marginata</i> , Wandoo <i>E. wandoo</i> and Karri <i>E. diversicolor</i> forests.	Live, hollow-bearing trees: Red-tailed Black-Cockatoo <i>Calyptorhynchus banksii</i> and Rufous Treecreeper <i>Climacteris rufa</i> . Riparian forest: Splendid Fairy-wren <i>Malurus splendens</i> , Red-winged Fairy-wren <i>Malurus elegans</i> , White-breasted Robin <i>Eopsaltria georgiana</i> and Red-eared Firetail <i>Stagonopleura oculata</i> . Older regrowth and old growth forest: White-browed Babbler <i>Pomatostomus superciliosus</i> , Black-faced Cuckoo-shrike <i>Coracina novaehollandiae</i> and Restless Flycatcher <i>Myiagra inquieta</i> . Fire history: Golden Whistler <i>Pachycephala pectoralis</i> .	Live, hollow-bearing trees; riparian forest; older regrowth and old growth forest; fire history.	Abbott (1999) ¹
South-western Western Australia.	Jarrah, Wandoo and Karri forests.	Red-tailed Black-Cockatoo, Baudin's Black-Cockatoo <i>Calyptorhynchus baudinii</i> , Western Rosella <i>Platycercus icterotis</i> , Red-capped Parrot <i>Purpureicephalus spurius</i> , Sacred Kingfisher <i>Todiramphus sanctus</i> and Rufous Treecreeper.	Live, hollow-bearing trees.	Abbott & Whitford (2002) ²
South-western Western Australia.	Heathland/shrubland/mallee and woodland.	Heathland/shrubland/mallee patch size: Shy Heathwren <i>Hylacola cauta</i> (Redthroat <i>Pyrrholaemus brunneus</i> and Crested Bellbird <i>Oreoica gutturalis</i>). Heathland/shrubland/mallee patch isolation: Southern Scrub-robin <i>Drymodes brunneopygia</i> (Redthroat). Woodland patch size: Varied Sittella <i>Daphoenositta chrysoptera</i> and Dusky Woodswallow <i>Artamus cyanopterus</i> (Varied Sittella). Woodland patch isolation: Varied Sittella (Varied Sittella). Woodland condition: Varied Sittella (Varied Sittella). Remnant size: Jacky Winter <i>Microeca fascinans</i> (White-eared Honeyeater <i>Lichenostomus leucotis</i>). Remnant condition: White-eared Honeyeater (White-eared Honeyeater).	Heathland/shrubland/mallee patch size; heathland/shrubland/mallee patch isolation; woodland patch size; woodland patch isolation; woodland condition; remnant size; remnant condition.	Brooker (2002) ³
South-western Western Australia.	Woodland and shrubland.	Woodland: Rufous Treecreeper. Shrubland: Shy Heathwren. Generalist: Grey Currawong <i>Strepera versicolor</i> .	Habitat fragmentation.	Brooker & Lefroy (2004) ⁴
South-western Western Australia.	Woodland, shrubland and heathland.	Woodland patch area: Varied Sittella. Shrubland patch area: Spiny-cheeked Honeyeater, Western Yellow Robin <i>Eopsaltria griseogularis</i> and Southern Scrub-robin. Heathland patch area: Redthroat.	Woodland patch area; shrubland patch area; heathland patch area.	Frost <i>et al.</i> (1999) ⁵
South-western Western Australia.	Heathland/shrubland/mallee and woodland.	Heathland/shrubland/mallee patch size: Southern Scrub-robin. Heathland/shrubland/mallee patch isolation: Southern Scrub-robin. Woodland patch size: Red Wattlebird <i>Anthochaera carunculata</i> . Woodland patch isolation: Brown-headed Honeyeater <i>Melithreptus brevirostris</i> . Remnant area: Grey Butcherbird <i>Cracticus torquatus</i> . Remnant condition: Western Yellow Robin.	Heathland/shrubland/mallee patch size; heathland/shrubland/mallee patch isolation; woodland patch size; woodland patch isolation; remnant area; remnant condition.	Huggett <i>et al.</i> (2004)

Location	Habitat	Indicator Species	Indicated	Source
South-western Western Australia.	Woodland, shrubland and heathland.	Woodland patch area: White-eared Honeyeater, Golden Whistler, Restless Flycatcher and Jacky Winter. Shrubland patch area: Western Thornbill <i>Acanthiza inornata</i> and Southern Scrub-robin. Heathland patch area: White-browed Scrubwren, Shy Heathwren, Western Thornbill, Tawny-crowned Honeyeater <i>Glyciphila melanops</i> and White-cheeked Honeyeater <i>Phylidonyris nigra</i> .	Woodland patch area; shrubland patch area; heathland patch area.	Lambeck (1998)
South-western Western Australia.	Woodlands, shrublands/mallee, shrublands/heathlands.	Habitat loss in woodland: Jacky Winter and Varied Sittella. Habitat loss in shrubland/mallee: Shy Heathwren. Habitat loss in shrubland/heathland: Rufous Fieldwren <i>Calamanthus campestris</i> . Fragmentation: Shy Heathwren, Rufous Fieldwren and Western Yellow Robin.	Habitat loss; habitat fragmentation. [Lambeck cites honeyeaters as being resource-limited, but am not sure that this is a valuable property for an indicator as to be used by Parks Victoria?]	Lambeck (1999)
South-western Western Australia.	Tall open Karri forests.	Live, hollow-bearing trees: Red-tailed Black-Cockatoo and Baudin's Black-Cockatoo. Old regrowth and old growth forest: Red-tailed Black-Cockatoo, Baudin's Black-Cockatoo, Red-capped Parrot, Fan-tailed Cuckoo <i>Cacomantis flabelliformis</i> , Rufous Treecreeper, White-browed Babbler, Dusky Woodswallow <i>Artamus cyanopterus</i> and Tree Martin.	Live, hollow-bearing trees; older regrowth and old growth forest.	Williams <i>et al.</i> (2001) ⁹
Arid rangelands of Western Australia, Northern Territory, South Australia, Queensland and New South Wales.	Chenopod and acacia shrublands.	Birds (individual species not identified).	Grazing impacts.	Landsberg <i>et al.</i> (1999) ⁷
Top End of the Northern Territory.	Coastal monsoon rainforest and associated coastal savannas.	Orange-footed Scrubfowl <i>Megapodius reinwardt</i> (nest mounds).	Habitat change.	Bowman <i>et al.</i> (1994)
South-eastern Queensland and north-eastern New South Wales.	Woodlands, wetlands.	Woodlands: Brown Treecreeper <i>Climacteris picumnus</i> , Variegated Fairy-wren, White-winged Fairy-wren <i>Malurus leucopterus</i> , Speckled Warbler, Spiny-cheeked Honeyeater, Striped Honeyeater, Grey-crowned Babbler, Golden Whistler, Hooded Robin <i>Melanodryas cucullata</i> , Eastern Yellow Robin and Diamond Firetail. Wetlands: Purple Swamphen <i>Porphyrio porphyrio</i> .	Biodiversity condition.	Ford & Thompson (2006)
South-east Queensland.	Softwood scrub remnants/farmland and open eucalypt forest.	Habitat change in softwood remnants/farmland: Crested Pigeon <i>Ocyphaps lophotes</i> , Peaceful Dove, Pale-headed Rosella <i>Platycercus adscitus</i> , Variegated Fairy-wren, White-browed Scrubwren, Speckled Warbler, Varied Triller <i>Lalage leucomela</i> , Australasian Figbird <i>Sphecothebes vieilloti</i> , Rufous Whistler <i>Pachycephala rufiventris</i> , Willie Wagtail, Eastern Yellow Robin, Mistletoebird and Zebra Finch <i>Taeniopygia guttata</i> . Habitat change in open eucalypt forest: Peaceful Dove, Buff-rumped Thornbill, Noisy Miner, Rufous Whistler, Olive-backed Oriole, Grey Butcherbird, Pied Butcherbird <i>Cracticus nigrogularis</i> , Pied Currawong, Eastern Yellow Robin and Mistletoebird.	Habitat change.	Leach (1996) ⁸

Location	Habitat	Indicator Species	Indicated	Source
Queensland, New South Wales, Victoria and Tasmania.	Forests.	Wonga Pigeon <i>Leucosarcia picata</i> , White-throated Nightjar <i>Eurostopus mystacalis</i> , Bush Stone-curlew <i>Burhinus grallarius</i> , Red-tailed Black-Cockatoo, Glossy Black-Cockatoo <i>Calyptorhynchus lathamii</i> , Yellow-tailed Black-Cockatoo <i>C. funereus</i> , Gang-gang Cockatoo <i>Callocephalon fimbriatum</i> , Musk Lorikeet <i>Glossopsitta concinna</i> , Little Lorikeet <i>G. pusilla</i> , Australian King-Parrot <i>Alisterus scapularis</i> , Superb Parrot <i>Polytelis swainsonii</i> , Green Rosella <i>Platycercus caledonicus</i> , Crimson Rosella, Swift Parrot <i>Lathamus discolor</i> , Powerful Owl, Barking Owl <i>Ninox connivens</i> , Southern Boobook <i>N. novaeseelandiae</i> , Sooty Owl, Masked Owl <i>Tyto novaehollandiae</i> , Azure Kingfisher <i>Ceyx azureus</i> , White-throated Treecreeper, Red-browed Treecreeper <i>Climacteris erythroptis</i> , Brown Treecreeper, Speckled Warbler, Buff-rumped Thornbill <i>Acanthiza reguloides</i> , Striated Pardalote, Regent Honeyeater <i>Anthochaera phrygia</i> , Strong-billed Honeyeater <i>Melithreptus validirostris</i> , Brown-headed Honeyeater, White-naped Honeyeater <i>M. lunatus</i> , Black-headed Honeyeater <i>M. affinis</i> , Painted Honeyeater <i>Grantiella picta</i> , Grey-crowned Babbler, White-browed Babbler, Spotted Quail-thrush <i>Cinclosoma punctatum</i> , Varied Sittella <i>Daphoenositta chrysoptera</i> , Cicadabird <i>Coracina tenuirostris</i> , Crested Shrike-tit, Olive-backed Oriole <i>Oriolus sagittatus</i> , Leaden Flycatcher <i>Myiagra rubecula</i> , Satin Flycatcher <i>M. cyanoleuca</i> , Scarlet Robin <i>Petroica boodang</i> , Red-capped Robin <i>Petroica goodenovii</i> , Hooded Robin, Tree Martin <i>Hirundo nigricans</i> and Mistletoebird.	Logging impacts.	Kavanagh <i>et al.</i> (2004)
North-eastern New South Wales.	Assorted forests.	Grey Goshawk <i>Accipiter novaehollandiae</i> , Collared Sparrowhawk <i>A. cirrhocephalus</i> , Little Lorikeet, Crimson Rosella, Eastern Rosella, Albert's Lyrebird <i>Menura alberti</i> , Red-browed Treecreeper, White-throated Gerygone <i>Gerygone olivacea</i> , Buff-rumped Thornbill, Little Wattlebird <i>Anthochaera chrysoptera</i> , Yellow-tufted Honeyeater <i>Lichenostomus melanops</i> , Pale-yellow Robin <i>Tregellasia capito</i> , Varied Sittella, Golden Whistler, Leaden Flycatcher, Satin Flycatcher, Willie Wagtail, Spangled Drongo <i>Dicrurus bracteatus</i> , Torresian Crow <i>Corvus orru</i> and Bassian Thrush <i>Zoothera lunulata</i> or Russet-tailed Thrush <i>Z. heinei</i> more abundant in unlogged forest; and Australian Brush-turkey <i>Alectura lathamii</i> , Brown Goshawk <i>Accipiter fasciatus</i> , Brown Cuckoo-Dove <i>Macropygia amboinensis</i> , Wonga Pigeon, Rose-crowned Fruit-Dove <i>Ptilinopus regina</i> , Shining Bronze-Cuckoo <i>Chrysococcyx lucidus</i> , Channel-billed Cuckoo <i>Scythrops novaehollandiae</i> , White-browed Scrubwren, White-throated Needletail <i>Hirundapus caudacutus</i> , Brown Gerygone <i>Gerygone mouki</i> , Bell Miner <i>Manorina melanophrys</i> , Lewin's Honeyeater <i>Meliphaga lewinii</i> , Yellow-faced Honeyeater, White-throated Honeyeater <i>Melithreptus albogularis</i> , Eastern Spinebill <i>Acanthorhynchus tenuirostris</i> , Scarlet Honeyeater <i>Myzomela sanguinolenta</i> , Eastern Whipbird <i>Psophodes olivaceus</i> , Little Shrike-thrush <i>Colluricincla megarhyncha</i> , Black-faced Monarch <i>Monarcha melanopsis</i> , Rufous Fantail <i>Rhipidura rufifrons</i> , Olive-backed Oriole, Figbird <i>Sphecotheres viridis</i> , Pied Currawong <i>Strepera graculina</i> , Paradise Riflebird <i>Ptiloris paradiseus</i> , Regent Bowerbird <i>Sericulus chrysocephalus</i> and Satin Bowerbird <i>Ptilonorhynchus violaceus</i> more abundant in logged forest.	Logging impacts.	Kavanagh & Stanton (2005)
South-central New South Wales.	Woodland remnants.	Southern Whiteface <i>Aphelocephala leucopsis</i> , White-browed Babbler and Hooded Robin.	Remnant size; remnant isolation; habitat complexity.	Freudenberger & Stol (2002)

Location	Habitat	Indicator Species	Indicated	Source
South-central New South Wales.	Floodplain (riparian) eucalypt woodlands.	Grazing activity: Galah <i>Eolophus roseicapillus</i> , Sulphur-crested Cockatoo <i>Cacatua galerita</i> , Eastern Rosella <i>Platycercus eximius</i> , Australian Magpie Cracticus tibicen, Willie Wagtail <i>Rhipidura leucophrys</i> , Magpie-lark <i>Grallina cyanoleuca</i> , Rufous Songlark <i>Cincloramphus mathewsi</i> and Common Starling <i>Sturnus vulgaris</i> more abundant at heavily grazed sites; and Peaceful Dove <i>Geopelia striata</i> , Crimson Rosella <i>Platycercus elegans</i> , Red-rumped Parrot <i>Psephotus haematonotus</i> , Laughing Kookaburra <i>Dacelo novaeguineae</i> , White-throated Treecreeper <i>Cormobates leucophaea</i> , Brown Treecreeper, Superb Fairy-wren <i>Malurus cyaneus</i> , Variegated Fairy-wren, Weebill <i>Smicromnis brevirostris</i> , Striated Pardalote <i>Pardalotus striatus</i> , Noisy Friarbird <i>Philemon corniculatus</i> , Little Friarbird <i>P. citreogularis</i> , Grey Shrike-thrush <i>Colluricincla harmonica</i> , Black-faced Cuckoo-shrike, Grey Fantail <i>Rhipidura albiscapa</i> , Australian Raven <i>Corvus coronoides</i> , White-winged Chough <i>Corcorax melanorhamphos</i> and Mistletoebird <i>Dicaeum hirundinaceum</i> more abundant at least grazed sites. Clearing: Galah, Sulphur-crested Cockatoo, Eastern Rosella, Noisy Miner <i>Manorina melanocephala</i> , Australian Magpie, Willie Wagtail, Magpie-lark, Rufous Songlark and Common Starling more abundant at least forested sites; and Peaceful Dove, Crimson Rosella, Red-rumped Parrot, Laughing Kookaburra, White-throated Treecreeper, Brown Treecreeper, Superb Fairy-wren, Variegated Fairy-wren, White-browed Scrubwren <i>Sericornis frontalis</i> , Striated Pardalote, Noisy Friarbird, Little Friarbird, Black-faced Cuckoo-shrike, Crested Shrike-tit <i>Falcunculus frontatus</i> , Grey Shrike-thrush, Grey Fantail, Australian Raven, White-winged Chough and Mistletoebird more abundant at most forested sites.	Grazing activity; clearing.	Jansen & Robertson (2001) ⁶
South-eastern New South Wales.	Woodlands.	Eastern Yellow Robin.	Habitat loss; habitat complexity; habitat fragmentation.	Freudenberger (2001)
South-eastern New South Wales.	Assorted forests.	Powerful Owl <i>Ninox strenua</i> and Sooty Owl <i>Tyto tenebricosa</i> .	Old-growth forests with large, hollow-bearing trees.	Kavanagh (1991)
South-eastern Australia.	Open eucalypt forests.	Yellow-tufted Honeyeater <i>Lichenostomus melanops</i> and Bell Miner <i>Manorina melanophrys</i> .	Gullies and riparian areas of wet forest; biodiversity.	Neave <i>et al.</i> (1996)
Australian Capital Territory.	Eucalypt woodlands.	Habitat loss: Hooded Robin. Habitat fragmentation: Eastern Yellow Robin. Habitat complexity: Hooded Robin.	Habitat loss; habitat fragmentation; habitat complexity.	Watson <i>et al.</i> (2001)
Central Victorian highlands.	Mountain Ash <i>Eucalyptus regnans</i> forest.	Sooty Owl.	Old-growth forest with large, hollow-bearing trees.	Milledge <i>et al.</i> (1991)
South-east Tasmania.	Ocean.	Fairy Prion <i>Pachyptila turtur</i> .	Heavy metal pollution.	Brothers & Brown (1987)

¹ The absence of established populations of species typical of disturbed or sparsely-wooded habitats (e.g. Black-shouldered Kite *Elanus axillaris*, Nankeen Kestrel *Falco cenchroides*, Singing Honeyeater *Lichenostomus virescens*, White-fronted Chat *Epthianura albifrons*, White-winged Triller *Lalage sueurii*, Grey Butcherbird, Willie Wagtail, Magpie-lark, Red-capped Robin, Australasian Pipit *Anthus novaeseelandiae*) may also indicate habitat condition.

² Two mammal species, Brush-tailed Possum *Trichosurus vulpecula* and Brush-tailed Phascogale *Phascogale tapoatafa*, were also proposed as candidate indicators. Of the eight candidate indicators identified, Brush-tailed Possum was considered likely to provide the earliest indication of change.

³ The most sensitive species for each habitat variable is presented in the 'Candidate Indicator' column followed in brackets by the critical focal species that were chosen by Brooker to meet the aim of the study (*i.e.* to retain existing resident avifauna of the Gabbi Quoi Quoi region). Other focal (sensitive) species identified were Blue-breasted Fairy-wren *Malurus pulcherrimus*, Inland Thornbill *Acanthiza apicalis*, White-browed Babbler, Golden Whistler, Western Yellow Robin and Southern Scrub-robin (heathland/shrubland/mallee patch size); Blue-breasted Fairy-wren (heathland/shrubland/mallee patch isolation); Rufous Treecreeper, Weebill, Red Wattlebird, Brown-headed Honeyeater, Grey Currawong and Red-capped Robin (woodland patch size); Rufous Treecreeper and Red-capped Robin (woodland patch isolation); Brown-headed Honeyeater (woodland patch condition); Common Bronzewing *Phaps chalcoptera*, Chestnut-rumped Thornbill *Acanthiza uropygialis*, Brown Honeyeater *Lichmera indistincta*, Rufous Whistler *Pachycephala rufiventris*, Grey Shrike-thrush, Grey Butcherbird and Red-capped Robin (remnant size); and Common Bronzewing, Brown Honeyeater and Grey Shrike-thrush (remnant condition).

⁴ Other focal (sensitive) species identified were Brown-headed Honeyeater, Varied Sittella, Jacky Winter and Hooded Robin (woodland); Malleefowl, Blue-breasted Fairy-wren, White-browed Scrubwren, Redthroat, Golden Whistler, Crested Bellbird, Western Yellow Robin and Southern Scrub-robin (shrubland); and Bush Stone-curlew, Inland Thornbill and White-eared Honeyeater (generalist).

⁵ Other sensitive species identified were White-eared Honeyeater and Rufous Whistler (woodland patch area); and Shy Heathwren and Rufous Fieldwren (heathland patch area).

⁶ Brown Treecreeper and Superb-fairy Wren were considered the most suitable candidates for monitoring because they were found at most study sites and their abundance appeared to vary with grazing pressure.

⁷ Understorey plants were considered to be the most useful indicators of grazing impacts of the taxa examined (= understorey, overstorey and seed-bank plants; arthropods; reptiles, birds and small mammals). Birds were considered to be the most useful indicators amongst the faunal groups studied.

⁸ This study also recommended that non-migratory species with fluctuating population sizes (*e.g.* Bar-shouldered Dove *Geopelia humeralis* and Yellow Thornbill *Acanthiza nana*) be considered as potential indicators.

⁹ Other potential indicator species identified by this study were species usually absent from or vagrant in undisturbed forest (*e.g.* Laughing Kookaburra *Dacelo novaeguineae*, Splendid Fairy-wren, Brown Honeyeater and Australasian Pipit).

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