Technical Guidance

Terrestrial vertebrate fauna surveys for environmental impact assessment

Environmental Protection Authority

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1 Contents

1 Introduction

The purpose of this technical guidance is to ensure that terrestrial vertebrate fauna data of an appropriate standard are obtained and used for environmental impact assessment (EIA).

This guidance provides advice on:

- survey preparation and desktop study
- determining the type of survey required
- sampling techniques and survey design
- data analysis and reporting.

This guidance should be applied in conjunction with the Environmental Protection Authority's (EPA) *Environmental Factor Guideline - Terrestrial Fauna*. For information on determining the impacts to terrestrial fauna in the context of a proposal, please refer to the relevant documents under the Terrestrial Fauna factor in the EPA policy suite.

This guidance is applicable to terrestrial vertebrate fauna only. Other groups, including terrestrial short-range endemic invertebrates, are addressed in other EPA guidance documents. For the purposes of this document, the term 'fauna' is used as shorthand for terrestrial vertebrate fauna.

This guidance should be applied when planning and undertaking fauna surveys for EIA under the *Environmental Protection Act 1986* (WA).

In a state as large and diverse as Western Australia, site-specific circumstances may warrant deviation from this guidance. In the case of any deviation, the appropriate agency or agencies should be consulted to discuss the adequacy of the survey design and techniques. Justification for the use of any novel or alternative techniques, and evidence of how best practice has been applied, must be presented.

2 Desktop study

A desktop study is a typical prerequisite for surveys and EIA. The purpose of a desktop study is to gather contextual information about an area from existing surveys, literature, database searches and spatial datasets. A desktop study is not a survey. A desktop study should be undertaken to inform the choice of field survey type and to provide background information for the survey and subsequent reporting.

All information used in a desktop study requires an evaluation of its reliability. This should include consideration of the source and age of the information, suitability of techniques used, data analysis, survey timing, changes in species status since reporting and any changes in habitat (e.g. fire or *Phytophthora* dieback introduction). The reliability of the information should be discussed in the limitations section of the report.

A desktop study should include background environmental information, an inventory of species and habitats likely to occur and a discussion of significant species and habitats identified. At the completion of a desktop study there should be sufficient information to identify the potential fauna species and habitats that may be present, and place them in a regional context.

2.1 Background environmental information

An accurate summary of background environmental information is required to place fauna data into context. This information should include discussion of relevant:

- Interim Biogeographic Regionalisation of Australia (IBRA) bioregions and subregions
- land use and tenure, e.g. land reserved for conservation purposes, pastoral leases, Indigenous Protected Areas, unallocated crown land and private freehold land
- recognised sensitive sites, e.g. Bush Forever Sites, Ramsar Sites, Key Biodiversity Areas, Environmentally Sensitive Areas and Important Wetlands
- landscape characteristics, e.g. land systems, soil-landscapes, geology, topography, elevation, surface water and drainage
- climate information, including rainfall and temperature, from a weather station with adequate long-term data representative of the study area.

2.2 Species and habitat inventories

Comprehensive species and habitat inventories are important for planning surveys and reviewing survey adequacy. These should be compiled using the results of database searches, a literature review and any current survey data. The exclusion of any results from the final inventories should be stated and justified.

2.2.1 Database searches

Database searches should be conducted using search parameters appropriate for the area and its regional context. Databases that should be searched include:

- Department of Biodiversity, Conservation and Attractions (DBCA) and Western Australian Museum (WAM) NatureMap data portal
- DBCA Threatened and Priority Fauna database
- BirdLife Australia's Atlas and Birdata datasets
- Department of Agriculture, Water and the Environment Protected Matters Search Tool
- Atlas of Living Australia database
- Index of Biodiversity Surveys for Assessment (IBSA).

In poorly-surveyed areas additional information may be obtained by requesting searches from the WAM fauna databases directly. For areas near the border of Western Australia, the government biodiversity databases of the Northern Territory and/or South Australia should be searched.

2.2.2 Literature review

A literature review captures species records not available through databases, identifies the habitats that may be present and contributes to an overall understanding of the area and its regional context. The extent of a review will depend on the type and availability of information for the area.

Literature reviews should include, but not be limited to, previous survey reports, unpublished survey datasets, locally-held records (e.g. registers kept at mine sites) and any major regional survey reports or papers (e.g. Appendix A). Scientific literature, including the Species Profile and Threats Database (SPRAT), Conservation Advice, threatened species recovery plans and peer-reviewed journal articles and research are useful for providing information on a species status, biology and ecology.

Records incorporated into the literature review should represent observations from original sources, rather than records that were extrapolated or cited from derived sources. If information in a previous desktop study is relevant, the underlying original data should be included in the review rather than the previous desktop study itself.

2.3 Significant species and habitats

A detailed evaluation of significant fauna and habitats should be completed, based on the fauna and habitat inventories. For each significant species or habitat this should include discussion of:

- its conservation status or the other reasons for its significance
- for a species, its known distribution and habitat preferences
- for a habitat type, its known extent and attributes that are important to fauna
- its likelihood of occurrence in the study area, accounting for local environment, age and location of records, ecological knowledge and regional context
- any ecological traits or attributes relevant to EIA, such as vulnerabilities to specific impacts.

3 Determining survey type

This guidance outlines three survey types: basic, detailed and targeted. The type of survey required should be determined based on the survey objectives, existing available data, information required and the scale and nature of the potential impacts of the proposal. These aspects should be considered in the context of the information acquired by the desktop study.

An appropriate survey type should provide adequate information to determine impacts, conditions, offsets and an analysis of the cumulative impacts. Determining the type of survey requires consideration of the characteristics of the proposal and the scale and nature of the impact.

Areas that intersect or may otherwise impact national parks, nature reserves or other parts of the conservation reserve system, including areas that are not yet formally protected but have been recommended for protection for a conservation purpose, require a detailed survey as a minimum. For other areas, aspects to be considered when determining the type of survey required include the:

- level of existing regional knowledge
- type and comprehensiveness of recent local surveys
- degree of existing disturbance or fragmentation at the regional scale
- extent, distribution and significance of habitats
- significance of species likely to be present
- sensitivity of the environment to the proposed activities
- scale and nature of impact.

Small-scale impacts may not negate the need for a detailed or targeted survey. For example, in regions where there is a high degree of existing habitat fragmentation, small-scale impacts to remnant habitats may be significant and multiple activities in the local area or region may contribute to cumulative impacts. Therefore, detailed and/or targeted surveys may be required to better predict the residual impact to fauna. The type of survey required may vary both within and between regions, in response to regional characteristics such as landscape heterogeneity, the extents of geology and vegetation types, the degree of existing disturbance and the level of biodiversity knowledge.

The Swan Coastal Plain and Jarrah Forest bioregions have a high degree of existing impact and remnant areas can be of considerable importance to fauna. However, the fauna of these bioregions is well understood and comprehensive long-term data is available to inform and predict the significance of impacts. Therefore, basic and targeted surveys usually suffice in these bioregions.

Elsewhere in Western Australia, proposals generally require detailed and targeted surveys because of the scarcity of local-level data. Surveys should be consistent with the standards outlined in this document, as well as any environmental scoping document instructions.

4 Survey types

4.1 Basic

A basic survey is a low-intensity survey, conducted at the local scale to gather broad fauna and habitat information. The primary objectives are to verify the overall adequacy of the desktop study, and to map and describe habitats. A basic survey can also be used to identify future survey site locations and determine site logistics and access. The results from the basic survey are used to determine whether a detailed and/or targeted survey is required.

A basic survey should include habitat assessment, photography and mapping. These activities can also be undertaken as part of a detailed survey, in cases where a basic survey is bypassed. During a basic survey, opportunistic fauna observations should be made and low-intensity sampling can be used to gather data on the general faunal assemblages present.

4.2 Detailed

The purpose of a detailed survey is to gather quantitative data on species, assemblages and habitats in an area. A detailed survey requires comprehensive survey design and should include at least two survey phases appropriate to the biogeographic region (bioregion). Surveys should be undertaken during the seasons of maximum activity of the relevant fauna and techniques should be selected to maximise the likelihood that the survey will detect most of the species that occur. Techniques should be quantitative and standardised, with at least one trapping site established in each habitat type, to allow analysis and comparison of data.

4.3 Targeted

A targeted survey is used to gather information on significant fauna and/or habitats, or to collect data where a desktop study or field survey has identified knowledge gaps. Examples of where targeted surveys are appropriate include, but are not limited to:

- confirming the presence of a significant species likely to occur within the proposal area
- determining distribution and abundance of specific significant species
- determining fauna movement and habitat use
- describing and mapping habitats or features that are important to significant fauna or faunal assemblages, such as for breeding, foraging or dispersal
- monitoring significant species, assemblages or habitats.

Because impacts must be placed into context, targeted surveys are not necessarily confined to potential impact areas. For example, if a significant habitat will be impacted in a proposal area but its extent outside of the area is unknown, a targeted survey to obtain contextual data may be required in the surrounding region.

A targeted survey usually requires one or more site visits to detect and record significant fauna and habitats. For areas with multiple significant species there may not be a single time of year suitable to detect all species. In these cases, multiple visits, each targeting different species or groups, should be conducted.

5 Preparation for survey

All surveys should be coordinated and led by zoologists experienced in systematic fauna surveys and fauna identification. It is essential that surveys, and individual teams in the case of large surveys, are led by zoologists with extensive knowledge and experience of the fauna of the bioregion to be surveyed.

Survey leaders should have experience in the identification and ecology of the fauna expected to occur, and the ability to deal with taxonomic uncertainty. This includes the requisite skills to appropriately voucher specimens, sample and store tissue and/or accurately document and photograph key diagnostic characters. The survey leader should ideally oversee the survey from beginning to end, including the analysis, reporting and review. Team members who are less experienced should be trained and supervised by an experienced zoologist.

Appropriate licences must be obtained to take, i.e. trap, collect and/or disturb, fauna. Permission must also be obtained from landholders or managers to access or undertake surveys on their land.

Surveys are often conducted in remote and difficult terrain, and health and safety issues must be planned for. Survey-specific safety procedures are often needed to ensure that work can be safely undertaken. For example, night or cave work safety requirements should be identified early in planning.

Animal welfare and biosecurity should also be considered during survey planning. This includes management of risks associated with disease transfer, which may be animal-to-human (e.g. human contraction of Australian Bat Lyssavirus), animal-to-animal (e.g. from poor trap hygiene), or to soil and vegetation (e.g. spread of *Phytophthora* dieback). Refer to Section 8.5 for more details on animal welfare requirements.

6 Habitat assessment

Habitat assessment is used to identify fauna habitat types and quantify their extents within the study area. In documenting the habitats and habitat features, a habitat assessment should incorporate information obtained through the desktop study, e.g. vegetation and geological information, as well as information obtained through a field survey, e.g. habitat boundaries and physical characteristics.

Unique habitats can be identified based on their combinations of landforms, soil and vegetation, which determine their ability to support specific fauna assemblages or significant fauna. The history of an area may also need to be considered, e.g. an area may be treated differently if it was recently burnt or is long unburnt.

Significant habitats include rare or isolated habitats and habitat features, such as rock piles, caves, gullies, significant trees, drainage lines, waterholes, damplands and springs, and those that are likely to provide special resources to fauna. Other important habitats include ecological linkages and migration pathways, refugia, islands, areas that support large or seasonal aggregations of fauna and areas that are important to significant fauna, e.g. for breeding, roosting or foraging.

6.1 Habitat mapping

Preliminary habitat maps should be based on existing vegetation data, geological and geographical data, e.g. topography, soil and land systems, and aerial imagery. Information available from modelling or remote sensing datasets can also be incorporated. The scale at which habitat types are defined will depend on proposal-specific factors, such as the bioregion, the fauna assemblages expected, the size of the proposal, the degree of existing habitat fragmentation and the proximity of habitats to predicted impacts.

Preliminary habitat maps should be verified through field observations conducted as part of the survey. The habitats should be considered when planning the locations of any survey sites. Habitat maps should be refined as new field observations are made.

The final habitat map and underlying electronic dataset should be suitable for spatial analyses. These include the calculation of areas of habitat likely to be impacted and the correlation of fauna records with habitats.

6.2 Habitat observations

Comprehensive habitat observations should be made at locations representative of each habitat type and at each survey site. Key attributes to consider when making habitat observations include:

- soil type and characteristics
- extent and type of ground surfaces and landforms
- height, cover and dominant flora within each vegetation stratum
- presence of specific flora or vegetation of known importance to fauna
- evidence of fire history including, where possible, estimates of time since fire
- evidence and degree of other disturbance or threats, e.g. feral species
- presence of microhabitats and significant habitat features, such as coarse woody debris, rocky outcrops, tree hollows, water sources and caves
- evidence of potential to support significant fauna
- function of the habitat as a fauna refuge or part of an ecological linkage.

The resulting data should be used to validate habitat maps, determine the extent and condition of each habitat type and produce detailed habitat descriptions.

Habitat observations should be undertaken systematically, such as at defined points within fixed areas or along transects. The use of unmanned aerial vehicles may be useful in areas with limited access, very large areas or when mapping linear corridors, but data obtained in this way should only be considered supplementary to direct habitat observations.

High-resolution, good-quality digital photographs should be taken of each habitat type. Enough photographs should be taken to ensure accurate representation of the habitat and capture any variation that exists or significant features.

7 Survey techniques

A wide variety of detection techniques are used in fauna surveys. The suitability of each depends on the expected species or assemblages, the nature of the environment, weather conditions and the purpose of the overall study.

This guide discusses the key sampling techniques used for fauna surveys and covers a range of techniques for different fauna groups. This guidance is not prescriptive about the use of any particular technique, but highlights the benefits and limitations of the different techniques to help zoologists in making appropriate choices.

A list of primary and supplementary techniques is provided in Table 1 and outlined below. This list is not exhaustive and other techniques may be suitable. Primary techniques are those known to efficiently deliver presence and abundance data. Surveys for EIA should use primary techniques to develop species inventories. Supplementary techniques can then be used to build on and refine results as necessary.

Special-purpose techniques, for particular species or circumstances, should be used where necessary. The DBCA website contains survey guidelines for a selection of Western Australian significant species. For species listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*, the Australian Government has published a series of general survey guidelines (DSEWPaC 2011a, DEWHA 2010a, DSEWPaC 2011b, DEWHA 2010b, DSEWPaC 2011c, DEWHA 2010c); the Species Profiles and Threats Database should also be checked for species-specific survey guidelines. If necessary, DBCA should be consulted regarding survey techniques and design when targeting particular species.

Regardless of the survey techniques used, impacts to habitats due to survey activities should be minimised. Disturbed sites should be returned to their original condition, e.g. by backfilling of soil, at the end of the survey.

Table 1: Key techniques for detecting broad fauna groups in EIA surveys

Primary detection techniques are denoted by X, supplementary techniques are denoted by S. The matrix should be considered indicative only.

Group	Pit traps	Funnel traps	Small-medium aluminium box traps	Large aluminium box traps	Cage traps	Spot lighting from vehicle	Spot lighting and head-torching on foot	Observation (e.g. bird surveys, active searching, opportunistic)	Searching for tracks and other signs	Acoustic surveys – audible calls	Acoustic surveys – ultrasonic calls	Camera traps
Small mammals < 30g (e.g. *Sminthopsis* spp.)	X		X				S		S			S
Medium mammals < 2500g (e.g. *Isoodon* spp.)			X	X	X	S	S		X			X
Large mammals > 2500g (e.g. *Petrogale* spp.)					S	X	X	X	X			X
Phytophagic bats (e.g. *Pteropus* spp.)								X		S		
Zoophagic bats (e.g. *Taphozous* spp.)											X	
Birds						S	S	X		X		S
Small snakes < 45cm (e.g. *Parasuta* spp.)	X	X				S	X	X				
Medium-large Snakes > 45cm (e.g. *Demansia* spp.)		X				X	X	X	S			
Small–medium lizards < 150 mm (e.g. *Pogona* spp.)	X	X	S			S	X	X				
Large lizards > 150 mm (e.g. *Varanus* spp.)	S	X		S	S	S	S	X	X			
Frogs	X	S				S	X	X		X		

7.1 General techniques

7.1.1 Pit traps

Pit trapping is particularly productive for sampling small to medium-sized reptiles and mammals. A standardised design, in terms of trap configuration and timing, allows more robust data analyses than less quantitative survey techniques such as active searching.

Pit traps usually comprise a plastic bucket or PVC pipe buried with the open top flush with the ground. The trap captures unsuspecting animals that fall in and inquisitive animals that deliberately enter. Pit traps vary in depth and diameter, but typical sizes effective for surveys are 20 litre plastic buckets (45 cm deep x 30 cm wide) and PVC pipes (60 cm deep x 15 cm wide).

In general, the wider a pit the more effective it is at initial captures, and the deeper it is the better overall retention of those captures. Therefore, buckets tend to have significantly higher captures than narrow 15 cm PVC pipe (Cowan 2004), but the increased depth of PVC pipe (60 cm) is advantageous in retaining some species that are able to escape by jumping. For example, 60 cm deep pits have been specified for capturing agile species such as hopping mice (Moseby and Read 2001) and pit traps 55 to 60 cm deep are considered essential for sandhill dunnarts (*Sminthopsis psammophila*; Churchill 2001). The incorporation of funnel inserts can be used to enhance the effectiveness of shallow pits as this restricts the aperture through which animals can escape.

Pit traps should be used in conjunction with drift fences that direct animal movement towards pits and increase the likelihood of capture (e.g. Moseby and Read 2001). A drift fence consists of flywire, or some similar barrier, running over, or in line with, the centre of a pit, linking together a number of equidistantly spaced pits (Webb 1999). Drift fences are set at 20 to 30 cm high and buried at the base using local substrate. The base substrate should be flush with the pit opening to ensure there are no gaps that would divert fauna from the pit.

No particular configuration of pits along a fence is universally optimal (and there are various options, see Friend 1984, Friend et al. 1989, Hobbs et al. 1994, Morton et al. 1988, Rolfe and McKenzie 2000). However, pits positioned singly should generally be avoided in favour of pits positioned in pairs or in larger numbers along a continuous fence. Spacing between pits may vary. Configuration should reflect local conditions and survey objectives, but an appropriate overall level of trapping effort should be maintained (see Section 8.4).

7.1.2 Funnel traps

Funnel traps are usually made from mesh, such as shade cloth, covering a wire framed rectangular prism with small funnels opening at either end. Laid parallel to a drift fence, animals enter the trap through a funnel, but have difficulty in finding a way out.

Generally, funnel traps are used in pairs with one placed either side of a drift fence, alternating with pit traps along the fence. Because they are placed on the surface of the ground, funnel traps can also be readily used in areas where the substrate precludes establishment of pit lines, such as on granites or ironstone outcrops. Care should be taken to ensure that funnel traps are placed flush on the ground. In sandy habitats, the entrance to funnels can be partially buried, using soil to create a ramp that disguises the edge of the funnel.

Some studies have compared effectiveness of funnel traps to pits (in North America e.g. Crosswhite et al. 1999, Maritz et al. 2007, and in Australia e.g. Thompson and Thompson 2007), but the trap types have generally not had true independence from each other and the advantages and disadvantages of either trap type are difficult to determine. Funnel traps effectively capture reptiles that readily escape from pit traps, such as snakes and some larger varanids, but are ineffective in reliably capturing mammals. Independent trials conducted in Western Australia indicate that funnels should always be considered supplemental to pits, as pits are more effective overall (DBCA pers. comm. 17 May 2017).

7.1.3 Aluminium box traps

Aluminium box traps, e.g. Elliott and Sherman brand traps, operate using a trigger plate on the floor of the trap. This is set off by the animal when it enters and triggers a hinged door to close, trapping the animal inside. The size of the box trap used will depend on the species targeted or predicted to occur.

Animals are enticed into the traps by bait. A universal bait made from oats and peanut butter is suitable for most species, with other additives, e.g. bacon, sardines, fruit, honey or truffle oil, used to target specific species. Additives should be selected with care to minimise the risk of ant attack and bait spoiling (Petit and Waudby 2012).

Aluminium box traps are typically used in arrays or transects and are useful for capturing most rodent species and small to medium-sized mammals, e.g. quolls, mulgaras and bandicoots, using the appropriately sized trap. Aluminium box traps are not particularly effective for many small dasyurids and most reptiles, though they have worked for targeted collection of species including the kultarr (*Antechinomys laniger*), some skinks and some varanids.

Distance between aluminium box traps usually ranges from 10 to 20 m. The layout may incorporate a combination of different size traps.

Capture rates of aluminium box traps often improve after several days, perhaps because animals are initially wary of foreign objects. Therefore, it is essential to ensure that surveys are undertaken over sufficient time to account for this (James 1994, Moseby and Read 2001).

7.1.4 Cage traps

Cage traps made of wire mesh, e.g. Sheffield brand traps, are available in sizes ranging from those suitable for rodents, bandicoots and possums, to those suitable for wallabies. Soft-walled cage traps, made of shade-cloth or similar non-metal mesh material, are recommended for species that are prone to injure themselves when in traps. Cage traps operate via a treadle and wire link holding open a door. To access a bait the animal must cross the treadle, causing the trap door to be released and locked in the closed position, trapping the animal inside.

The bait used is usually the same as for aluminium box traps and depends on the species expected. Surveys targeting particular species, e.g. the carnivorous chuditch (*Dasyurus geoffroii*), can result in higher capture rates if the bait includes lure ingredients favoured by the target species but not by others (Wayne et al. 2008).

Rigid and collapsible type cage traps are available, the latter being particularly suitable for carrying over distance. Both types are relatively cumbersome to handle, transport and set out; consequently, if it is equally appropriate to trap for the expected species using aluminium box traps, these may be a better choice.

Cage traps may be used in isolation for targeted surveys or in conjunction with other trap types for detailed surveys, set along a transect or in an array or grid. The best arrangement and spacing of traps will depend on the target species, habitat characteristics and the data required, e.g. presence-absence or population density. For example, a study of chuditch successfully used transects with 200 m spacing between traps (Wayne et al. 2008), while studies of northern quoll (*Dasyurus hallucatus*) found that transects of 50 traps 50 m apart were appropriate in some areas but transects of 20 traps set 25 m apart were better in others (DPaW 2013, Morris et al. 2015.)

7.1.5 Spotlighting and headtorching

Spotlighting and headtorching are important survey techniques because much of Western Australia's fauna is nocturnal or crepuscular, particularly many threatened taxa. Many of these species are more often observed than trapped.

Spotlighting is a valuable technique for detecting mammals, nocturnal birds, geckos, snakes and frogs. However, when illuminated by a spotlight some species freeze and may be difficult to see, while others immediately flee and may be hard to identify. It is therefore essential to know what may be encountered beforehand and to have experienced individuals spotlighting.

Spotlighting can be done from a vehicle, to cover large distances along roads and tracks; with this method, the vehicle is driven at low speed on a predetermined transect, stopping as required. Portable spotlights can be used while walking to investigate at a finer scale, or in areas where vehicle access is not possible. Spotlighting on foot may be effective for cryptic species, e.g. quails, which may otherwise not be seen.

Headtorching is more useful than spotlighting for some fauna, such as geckos and frogs, due to the dimmer light and because having the light beam in the same plane as the observer's eyes improves detection of reflected eye shine. Headtorching is useful for inspecting discrete features, such as termite mounds, rocky outcrops and caves.

Spotlighting and headtorching are most productive for reptiles on warm evenings (Read and Moseby 2001), when they are more active. High humidity may also increase herpetofauna activity (e.g. Cowan 2016). However, cooler conditions should not necessarily negate undertaking night work. Headtorching for frogs is most successful following rain.

Spotlighting and headtorching should be conducted in a manner that minimises disturbance to fauna. For example, care should be taken with sensitive nocturnal bird species.

7.1.6 Observation - bird surveys

For birds, techniques for standardised site surveying include fixed time and position counts, transect searches and area searches (Bibby et al. 2000, Craig 2004, Craig and Roberts 2001, Gregory et al. 2004, Loyn 1986). These methods support both visual and acoustic detection of birds; additional information specific to acoustic surveys is contained in Section 7.1.10.

Bird surveys should occur during peak activity periods, typically after dawn and before dusk. Birds are less active in wet, windy and extremely hot conditions.

Birds can be recorded as present with or without an associated measure of abundance. Abundance data are harder to collect but can be useful for providing information on the relative importance of habitats, provided bias caused by detection differences between habitats is considered; however, it is often important to understand temporal variation in abundance before spatial variation can be interpreted (e.g. Ives and Klopfer 1997).

The best locations to survey birds may not correspond with those identified for trapping sites. Local terrain and conditions must be considered, and bird surveys should be conducted in the areas most likely to yield observations that accurately reflect the usage of given habitats by birds. For example, a stand of flowering grevilleas may yield additional bird species.

Bird survey results are highly observer-dependent and precautions should be taken to reduce bias. Sites should be surveyed more than once – at different times of day and on different days – in a consistent manner across sites. If multiple observers are used, they should be alternated when doing repeat surveys of individual sites. Multiple observers may also be used to survey the same site concurrently.

Area searches and point counts are commonly used for bird surveys. Area searches involve inspecting a designated area for a pre-determined period. A typical area search may cover a 1 to 3 ha plot area over 10 to 20 minutes (DEWHA 2010a), however the size of the plot and time spent should reflect local conditions and larger areas will be more appropriate in arid regions. Area searches are most suitable in open habitats. Point counts involve making observations from a designated series of points or habitats for a pre-determined period. For example, York et al. (1991) conducted 10 minute observations at five points, 100 m apart along a 500 m transect. Point counts are most suitable in dense habitat.

Determining the technique to use will depend on the survey objectives. An area search is more useful where the aim is to detect as many species as possible for an inventory, because small, cryptic species are more likely to be encountered and walking through the area increases the chance of flushing individuals.

Some bird groups may require specific search techniques. For example, raptors tend to use thermals on warm days and can be spotted from high ground.

The time spent surveying each site will depend on the habitat present. Diverse and structurally complex habitats are likely to have higher bird species richness, require more survey effort and contain more species that are difficult to detect. Dense vegetation may require more survey effort than open vegetation where species are easier to detect. Imitating calls will often entice birds in closer, allowing a visual identification.

All observations should be recorded, but care should be taken in assigning them to locations. To ensure peripheral habitats do not skew results, only those species using the habitat surveyed should be assigned to that habitat. For example, during a bird survey of a ridgetop habitat, species seen circling over a distant plain should not be included in the ridgetop habitat dataset, but should be recorded as opportunistic observations.

Large areas, particularly for shorebird surveys, may require aerial survey (for an overview of techniques see Kingsford et al. 2008). Shorebird identification is difficult, and surveyors should have specific experience in their identification and survey techniques. Australian shorebird survey reference information is available from the *Shorebirds 2020 Program*.

7.1.7 Observation - active searching

Active searching, primarily for herpetofauna, involves searching microhabitats. This includes digging up burrows, turning over rocks and logs, splitting fallen timber, raking soil and leaf litter, peeling off bark and searching soil cracks and holes in fence posts (Bush et al. 2007). Active searching complements trapping because it allows for hand-capture of species that have low capture rates in traps.

Active searching requires knowledge of the species that may occur and their habitat preferences. Species detection is correlated with observer experience and the amount of effort applied, so it is important that surveys are designed to ensure that effort is adequate and consistent across sites.

Timing of active searches is important. In hot and dry conditions reptiles are hard to detect and they are quick and elusive to capture. In such conditions, searching earlier in the day may be more productive. Impacts to habitat should be minimised, with all rocks, logs and debris being returned to their original location and orientation after searching. Care should also be taken to ensure that the disturbance associated with active searching does not impact any other surveys being conducted in the same area.

7.1.8 Observation - opportunistic

All vertebrate fauna detected while travelling between sites or undertaking other general tasks should be recorded. These opportunistic records can make a substantial contribution to overall species lists. It is important to record the location and habitat where the signs or species were observed, so that these records can be considered in the context of the proposal.

7.1.9 Searching for tracks and other signs

Searching for tracks, diggings, burrows, nests, scats and pellets, claw marks on tree trunks and other signs requires persistence, well-developed observation skills and knowledge of the natural history of the local fauna. This technique is useful for species that are not readily trapped because they are too large or avoid traps, or are at low densities in the area. Species with clumped distributions, e.g. the brush-tailed mulgara (*Dasycercus blythi*) and bilby (*Macrotis lagotis*), may be easier to detect by way of tracks and other signs because large areas of potential habitat can be assessed relatively quickly.

Sand is an ideal substrate for tracks, although wind and rain will mask them quickly. Early morning or late afternoon, when the sun is lowest in the sky, are optimal times for searching; these give the greatest amount of shadow within tracks, maximising their detectability and interpretation.

Diggings and burrows can last for long periods, even years, after an animal was present; for example, malleefowl (*Leipoa ocellata*) mounds and boodie (*Bettongia lesueur*) diggings. Therefore, diggings and burrows may only indicate historical usage of an area, and targeted trapping or other confirmation may be required to determine the contemporary presence of a species.

7.1.10 Acoustic surveys - audible calls

Many birds and frogs produce audible calls that allow identification to species level, and listening for or recording these will often supplement information gathered through other survey techniques for these groups. Acoustic surveys are especially useful as a non-invasive means of surveying for nocturnal, rare or cryptic species (e.g. Burbidge et al. 2007).

Detecting birds in an area by their call is an effective survey technique, particularly for passerines. Passerine call frequencies are usually greatest at dawn and dusk, and before or after periods of rain. Listening to the dawn chorus at a site will give an understanding of the bird species that have roosted in the area the preceding night and may identify cryptic species that are hard to detect visually.

Experienced observers are essential for correctly interpreting bird calls. Mimicry is common in songbirds (e.g. Chisholm 1932, Kelley et al. 2008, Igic and Magrath 2014), and call repertoires can differ by region, time of day, situation and life history stage. When recording bird calls, the call locations must be accurately assigned to habitats. For example, an observer on a plain who hears a sacred kingfisher (*Todiramphus sanctus*) in an adjacent drainage line should assign the record to the drainage line, not the plain.

Playing pre-recorded calls of target species, i.e. call playback, can improve the chance of detecting birds. Call playback should only be used with consideration of the animal welfare and ethics of the technique (see Birdlife Australia 2012).

Resources for bird call identification are available online, e.g. from xeno-canto, AVoCet, the Internet Bird Collection and the Macaulay Library, and as published materials (e.g. BOCA 2001, Simpson and Day 1999). Some field guide mobile applications also include calls.

Different frog species call in different seasons and survey timing should reflect this (Section 8). Most species call at night, often peaking a few hours after dusk. Frogs will also call from shaded and sheltered positions, dense vegetation or burrows during the day in overcast and warm weather periods.

If an unfamiliar call is heard the frog should be located and identified visually. This can be difficult, as resonance from the call may give the impression that the frog is somewhere other than its actual location. Hard-to-locate individuals can be found by triangulation; this involves two people standing at 90 to 180 degrees estimating the direction of the call from two different angles simultaneously, then focusing on where the calls intersect to forage for the frog by hand (Bush et al. 2007).

Resources for frog call identification are available online, e.g. through the Frog Watch and FrogID projects. Some field guide mobile applications also include calls.

Any calls that represent unusual, ambiguous or significant observations should be recorded. Recordings can yield additional species for an inventory when referred to an expert, or can provide unequivocal evidence supporting an otherwise contentious record. If a specific survey objective is to record calls then digital recorders and specialty microphones should be used, otherwise incidental recordings can be made using a smartphone.

Autonomous recording units (ARUs) designed for bioacoustics are useful for acoustic surveys (Burbidge 2016). They can be deployed for long periods in any terrain and under most conditions, and record following a program. Because of this they can provide temporal sequence data that are not logistically feasible to collect using manual observations alone.

ARUs may be custom made or off-the-shelf. ARUs should be deployed to avoid weather, fire and interference, targeting the correct habitats, and with correct orientation, microphones and programming. Data analysis may be manual, using spectrogram viewing software such as Song Scope (Wildlife Acoustics) or Raven (Cornell Lab of Ornithology), or automated in special cases such as targeted surveys.

Automated analyses require a pre-existing reference library of calls. After creating classification rules based on the library, software such as Kaleidoscope (Wildlife Acoustics) or SoundID (SoundID) can use the rules to analyse and categorise sound clusters, i.e. calls, which the software identifies. This is not necessarily straightforward; the reference library must be accurate and comprehensive, classification rules must be thoroughly validated and it may not be possible to automatically identify calls in complex datasets.

ARUs are not a replacement for observer-based methods in assemblage surveys, but they can be cost-effective and accurate for targeted surveys. Current examples of effective ARU use include threatened bird monitoring (e.g. Pinder 2012, DPaW 2014) and night parrot (*Pezoporus occidentalis*) surveys (Murphy 2014). Where custom-made ARU equipment is used, or if automated techniques and reference libraries are used for analysis, quantitative evidence of the effectiveness of these methods must accompany any results.

7.1.11 Acoustic surveys - ultrasonic calls

The detection and recording of ultrasonic calls is an important survey method for zoophagic bats, which hunt using ultrasonic echolocation calls that cannot be heard by humans. Most bats in Western Australia are zoophagic; if phytophagic species are expected, echolocation surveys can be augmented with visual, acoustic and trap-based surveys as necessary.

Echolocation can be detected in real-time with handheld heterodyne or full-spectrum detectors, which detect calls and replay them audibly or display them as spectrograms. Full-spectrum detectors are more versatile, but still require an operator with expert knowledge of calls to identify species. Some modern full-spectrum detectors have potential to identify species in real-time based on classification rules, but these require setup and validation.

ARUs – see Section 7.1.10 – can be very effective at detecting and recording ultrasonic calls (Burbidge 2016). The type of ARU dictates the available recording and analysis methods; therefore it is important to identify the survey objectives, and thus the required recording method, equipment and settings, prior to field work. The available technology changes rapidly, so this should be done in consultation with equipment manufacturers and experts on the expected bat fauna. The Song Meter (Wildlife Acoustics) and Anabat (Titley Electronics) platforms are commonly used ARUs in EIA surveys.

Zero-crossing and full-spectrum are common recording methods (e.g. see McKenzie and Bullen 2003, 2009, Agranat 2012). Zero-crossing recordings capture the frequency range, shape and duration of the strongest harmonic of the call, are simple to interpret and create relatively small files; however, they do not capture amplitude or harmonic information. This missing information can be important for differentiating species. Full-spectrum recordings capture all the available information and have a signal-to-noise ratio advantage, but create large files and require more analysis effort. The additional amplitude information can also be sensitive to interference. Full-spectrum recordings can be converted to zero-crossing, and data storage is declining in price, so full-spectrum recording is likely to be the best choice in most cases. Zoologists must ensure that the chosen recording method is appropriate based on the location and objectives of the survey.

ARUs, even those with omnidirectional microphones, must be placed appropriately with respect to habitats, interference, fire, weather and other local constraints. Good site choices include water sources, drainage lines, wooded areas, flyways along landscape features and potential roost caves. With long deployments, regular equipment checks and data downloads should be conducted. ARUs in some habitats may require protection from fauna gnawing on cables and microphones. A minimum of three complete recording nights should occur at each site during the warmer part of the year, and this should be during good weather (Australasian Bat Society 2006).

Analysis of bat echolocation recordings may be manual or automatic, and requires access to a call reference library (e.g. see McKenzie and Bullen 2009, 2012). Automated analyses are subject to limitations and may not be possible in many situations (see Section 7.1.10).

If bats have been identified from echolocation calls, the report should cite the reference library used and present example graphs of time versus frequency for each identified species (based on actual field data; Australasian Bat Society 2006). The method used to discriminate between species with similar calls should be described and the proportion of calls that could be identified out of the total number processed should be stated (Australasian Bat Society 2006).

7.1.12 Camera traps

A camera trap is a digital camera that captures an image or video using an infrared sensor when an animal moves into a detection zone. Most camera traps used in wildlife surveys are off-the-shelf units, from manufacturers such as Reconyx and Bushnell, but they can also be custom-built. Cameras can be left to operate for many days through to months, depending on power source and image storage, providing information beyond what is attainable by human observers during a field survey.

Camera traps are usually triggered by a passive infrared sensor detecting the movement of a heat signature, i.e. movement of an object with a different temperature to its surrounds. The camera then uses an infrared or white flash to take a greyscale or colour image, respectively, and stores the file internally or wirelessly transmits files back to the user.

Despite their advantages, camera traps are not suitable in all situations (e.g. see Richardson et al. 2017). Camera trapping is useful for medium-to-large, distinctive mammals (e.g. DPaW 2013, Cramer et al. 2016), and to a lesser extent birds, due to the likelihood they will trigger a sensor with their heat signature. Camera traps may also work for small mammal surveys (e.g. De Bondi et al. 2010). However, in areas where multiple similar species exist, they can be hard to differentiate – particularly if the images are of low resolution and/or there is no reference scale included in the image detection zone.

For some species, camera traps can be used to estimate density and abundance. This requires traps to be deployed according to a robust experimental design, incorporating known detection rates (e.g. Howe et al. 2017). If the objective is only to determine species presence, camera trap placement should target areas of activity including tracks and runways, burrow entrances or areas with foraging evidence.

Camera traps should be tailored to the survey requirements. Camera settings – particularly those relating to image quality and resolution, but also those for detection zone, trigger time and recovery time – should reflect the survey objectives, expected fauna, environmental conditions and specifications of the particular traps (Meek and Pittet 2012, Rovero et al. 2013, Meek et al. 2014, Gillespie et al. 2015 and Meek et al. 2015).

Baits may be used to attract fauna to camera traps, such as universal bait, a bait targeting a particular species (e.g. Wayne et al. 2008, Austin et al. 2016), or a bait station or scent lure designed for long-term use (e.g. Meek et al. 2014, Gillespie et al. 2015). Using bait stations of a known size, or installing an object for scale, is useful for identifying fauna. Baits should not be used where they could attract predators to locations critical for fauna. For example, baits should not be used outside bilby burrows or at malleefowl mounds.

Camera traps should be tested prior to being taken into the field, including ensuring time and date settings are correct, and after their initial setup. Camera traps deployed for extended periods should be inspected and have data downloaded regularly. Images and accompanying metadata should be stored following a systematic procedure (Gillespie et al. 2015).

7.2 Special-purpose techniques

7.2.1 Faecal DNA analysis

Population size and demography can be estimated by genotyping individuals from faecal DNA. The technique is useful for rare or cryptic fauna (Piggott and Taylor 2003), and is being increasingly adopted (e.g. Alacs et al. 2003, Piggott et al. 2006, Marks et al. 2009, Ruibal et al. 2009). In arid Western Australia, a protocol has been developed to survey for bilbies by identifying individuals from scats (Dziminski and Carpenter 2014, DPaW 2016).

Faecal DNA analysis requires protocols to be developed for each species. The relevant research institution or analytical laboratory should be consulted for specimen collection requirements. Environmental conditions, scat age and preservation techniques all have the potential to influence results (Panasci et al. 2011, Carpenter and Dziminski 2016), so appropriate precautions and pilot studies are required (Piggott and Taylor 2003).

7.2.2 Trapping for bats

Trapping for bats is required when it is necessary for them to be physically handled, e.g. for mark-recapture and tracking, and can also be used in areas where echolocation surveys may fail to detect or are unable to distinguish between species. Such situations are only occasionally encountered in an EIA context in Western Australia.

Bat trapping methods include the use of mist nets and harp traps (Jones et al. 1996). A mist net is a net that is stretched across a flyway and entangles bats. Harp traps, also set in flyways, comprise a series of vertical wires that deflect flying bats into a pocket below.

The technique used should be guided by the survey objectives, expected bat assemblage and site conditions (Thomas and West 1989, Jones et al. 1996, Flaquer et al. 2007). For procedure overviews, see Jones et al 1996, Murray et al. 2002, DEWHA 2010b and FUA 2015.

7.2.3 Hair tubes

Hair tubes collect hair samples for species identification using physiological or genetic analysis (Brunner and Coman 1974, Suckling 1978, Brunner and Triggs 2002). A hair tube is a tube or funnel, lined with adhesive tape, that captures hair when an animal enters the trap in response to a bait (e.g. Scotts and Craig 1988). Hair tubes are low-impact and can be set for long periods. However, they can be less effective than other techniques used for mammals (Catling et al. 1997), and their efficacy varies with design, geographic location and taxa present. Consequently, hair tubes are best used for targeted surveys.

Hair tubes should be placed where animals are likely to be active or to concentrate, such as runnels in dense vegetation. To avoid bycatch, e.g. small reptiles, adhesive should only be used on the upper sides and top of a hair tube, not the bottom or lower sides.

7.2.4 Checking scat and pellet contents

Bone and hair samples can be collected from owl pellets or carnivore scats and used to identify species (e.g. Huebschman et al. 2000, Bilney et al. 2010, Bilney 2014). Results must be interpreted carefully, as birds and large predators can forage over large distances, and the technique is time-consuming and not always conclusive.

Samples are best found below the nests or perches of raptors, along breakaways, under rock overhangs and in cave entrances. Scats of larger predators such as quolls and dingo (*Canis familiaris*) may be found in the open. Remains may also be found in middens under ghost bat (*Macroderma gigas*) feeding perches.

7.2.5 Examination of feral predator gut contents

Feral predators such as cats and foxes feed on native fauna (e.g. Martin et al. 1996, Risbey et al. 1999). The gut contents from specimens collected as road kill or predators that have been euthanased can be examined and any remains identified.

8 Survey design

Appropriate survey design is pivotal in EIA, and is determined by factors including the survey type, the objectives of the survey, the scale of the proposal, the local environment and the faunal assemblages expected. Survey design, including the level of effort applied, requires careful consideration and should reflect local and regional conditions (How 1998, Rolfe and McKenzie 2000, Berry et al. 1991).

Adequate effort must be applied during surveys to enable the assessment of impacts of the proposal on fauna and habitats. Survey adequacy is a function of techniques, site selection, seasonality and timing and survey duration. Parameters including the types and numbers of traps, their layout and the number of days over which they are operated will also determine adequacy. The rationale for the chosen survey design should be clear.

8.1 Site selection

The number of sites required will vary depending on the habitat characteristics of the study area and its surrounds, such as the type and variety of substrates, vegetation, topography, and the number of discrete habitats or degree of similarity between habitats within an area. Sites should be selected according to geographic extent and variation in these attributes, with an attempt made to survey across the entire range of variability.

For detailed surveys, trapping sites should be established in each habitat type. It is recommended that replicate trapping sites are established within each habitat type; the degree of such replication should reflect the extent and significance of habitats, the confidence that individual sites will adequately document assemblages, the data analyses required and the amount of existing knowledge for the study area. Replicated sites may result in additional species being captured as species are unlikely to be distributed equally within a habitat type.

Sites should generally be positioned within habitat types rather than on their peripheries – as this will reduce edge effects on results – unless surveying ecotones is important for the survey. Sites should be positioned to achieve adequate geographic spread throughout the study area.

Site selection should consider the size, shape and location of the proposed activities, and the scale and nature of the impacts of the proposal, where known. Survey sites should be established both inside and outside potential impact areas, to provide sufficient data to identify potential impacts and place these into context.

8.2 Seasonality and timing

Western Australia can be divided into three broad climatic regions – Southern, Eremaean and Northern – based on Beard's (1980) botanical provinces (Figure 1). Fauna activity is closely linked with the seasons in each of these regions.

Surveys must consider seasonality and timing of peak fauna activity by region, particularly for herpetofauna. Peak activity can coincide with conditions that preclude survey from logistical or animal welfare perspectives. In such cases, a compromise that is close to desired timing but also meets logistical and ethical requirements would be expected.

Recommended survey timing for different fauna groups in each region is given in Table 2. Timing should be further refined per the geography, expected weather conditions and actual weather over preceding months in the study area.

Repeated surveys yield more comprehensive species inventories than single surveys and account for temporal differences in activity patterns (Moseby and Read 2001, How and Cooper 2002, Cowan and How 2004). For EIA, a detailed survey should therefore include at least two complementary survey phases, based on seasons and fauna activity patterns (Table 2).

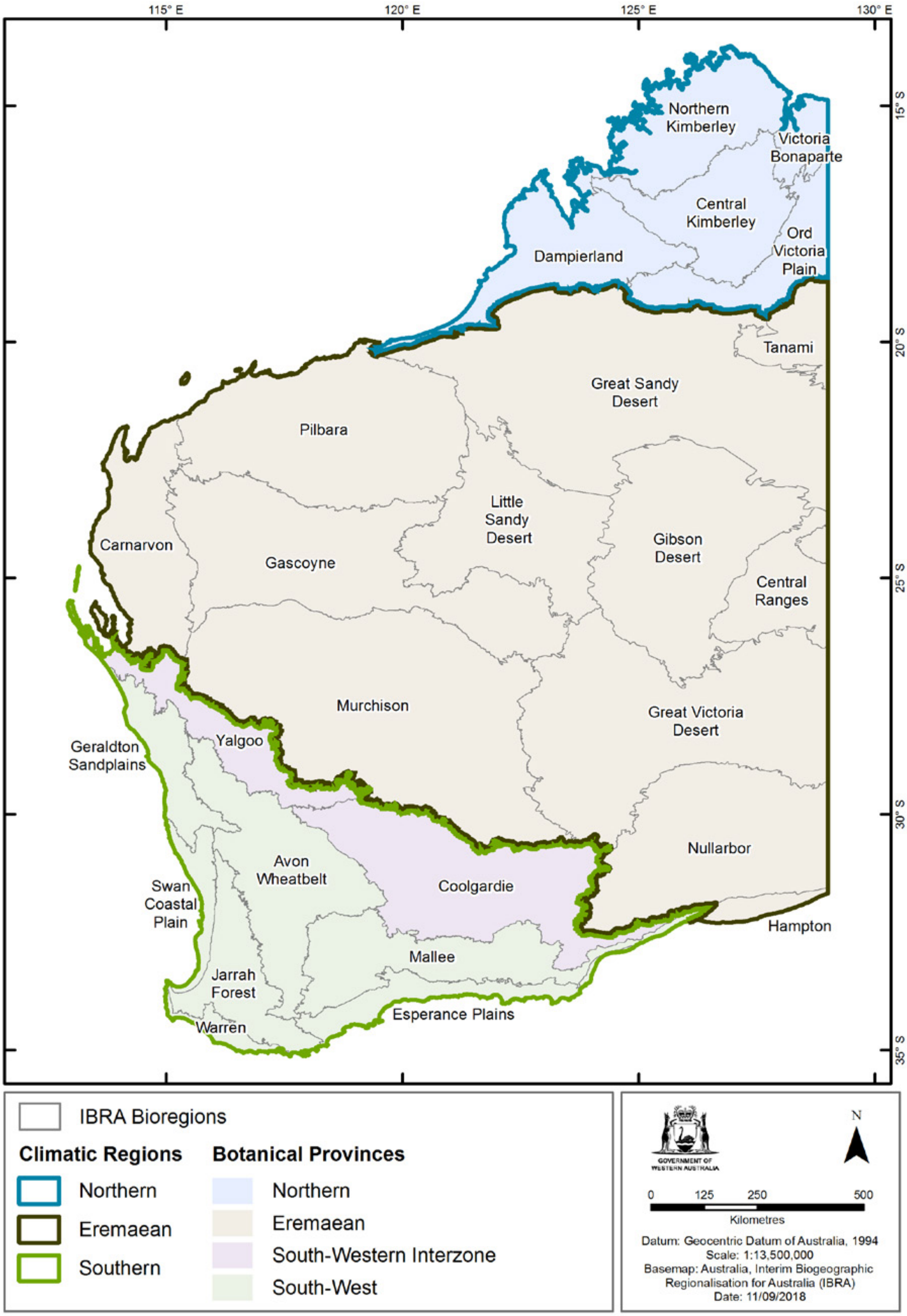


Figure 1: Broad climatic regions of Western Australia

Based on botanical provinces (Beard 1980, modified following Desmond and Chant 2003). Bioregions per IBRA.

Table 2: Recommended timing for vertebrate fauna assemblage surveys

Recommended timing differs between the Southern, Eremaean and Northern broad climatic regions (Figure 1). A detailed survey should include at least two complementary survey phases, based on the approximate seasons and fauna activity patterns outlined below.

A: Southern

Fauna Group	Survey timing	Rationale
Reptiles	October-December (primary survey) February-March (secondary survey)	Reptiles typically become active with rising temperatures in spring, when they commence breeding. Then there is generally a less active period in summer, after which hatchlings appear in late summer/ early autumn. Surveys should occur in spring to early summer and in late summer to autumn to coincide with peak activity (see How 1998). On the south coast, spring surveys may need to be later in the season due to generally lower temperatures. Local temperature records should be consulted prior to surveys.
Amphibians	May-August (autumn-winter breeders) November-December (summer breeders)	Burrowing frogs, e.g. *Heleioporus* and *Neobatrachus* spp., begin calling with autumn-winter rains. The coldest, wettest part of winter is peak breeding time for winter breeders, e.g. *Crinia* and *Geocrinia* spp. Summer breeders, e.g. *Litoria* spp., commence their main calling as the weather heats up in late spring to early summer.
Birds	September-December (most bush birds) November-March (migratory birds)	The main breeding period for most bush birds is spring, sometimes extending into early summer depending on local conditions. Most species have established breeding territories by this time, resulting in maximum vocalisation and activity. The main period when migrating shore birds are present in wetlands is between November and March.
Mammals	September-December	As mammals are homeothermic, survey timing is not constrained as it is for reptiles. For efficiency mammal surveys can be concurrent with reptile surveys.

B: Eremean

Temperatures increase along a northward latitudinal gradient. Rainfall is summer-dominated in the north and more evenly spread across the year in the south. Episodic summer thunderstorms and rain-bearing depressions are key bioclimatic activators and hence drive vertebrate activity. Working around these events is ideal, but difficult to plan and implement.

Faunal Group	Survey timing	Rationale
Reptiles	September-April	Reptiles are most active between September and April when higher temperatures are experienced. There is generally little activity during 'winter'. Surveys should therefore coincide with peak activity (see How et al. 1992, How and Dell 2004, Thompson and Thompson 2005).
Amphibians	Immediately after significant rain events.	Most frog species aestivate during dry periods and are activated by heavy rain. Breeding activity peaks after rain and tadpoles complete their metamorphosis cycle before water dries up. Episodic rain events generally occur in summer and autumn.
Birds	Immediately after rain events.	Prolific seeding after heavy rains activates breeding by most granivores, which declines to lower levels in periods of drought. In contrast, non-granivores do not concentrate spatially or temporally to the same extent (Berry et al. 1991, How et al. 1992), and survey timing for non-granivores is less constrained. Episodic rain generally occurs in summer and autumn. In times of drought breeding by both granivores and non-granivores is curtailed, and birds are less vocal and more difficult to observe.
Mammals	No preferred time (see rationale)	As mammals are homeothermic, survey timing is not constrained as it is for reptiles. For efficiency, mammal surveys can be concurrent with reptile surveys. Mammals can have differing population cycles, with carnivore and granivore populations peaking at different times. This often relates to rainfall (e.g. Cooper et al. 2006). In such cases, repeat surveys may need to occur at different times to reptile surveys.

C: Northern

Fauna Group	Survey timing	Rationale
All groups	December-March (planned based on local weather) April to August (prior to conditions becoming too dry)	The wet season is the peak activity period for vertebrates and, access permitting, the primary survey should coincide with this. A second survey should occur during the dry season.

8.3 Duration

The duration of survey is important, with the number of species captured usually increasing over time. If the survey is too short, it considerably reduces the amount of data available for analysis and interpretation. When undertaking detailed surveys, a minimum of at least seven nights of trapping is recommended per phase, per method used. This duration reduces the potential for adverse weather conditions (e.g. extreme hot, cold or wet periods) to dominate the survey period that may cause suboptimal trapping conditions (e.g. Moseby and Read 2001). Surveys may need to be extended or repeated where adverse weather conditions result in poor capture rates or reduced trapping days. It is inappropriate to increase the number of traps to compensate for reduced duration, as this would not give an equivalent sampling effort.

8.4 Trapping design for non-volant mammals and herpetofauna

There is no single trapping design that is universally suitable for EIA in Western Australia, but there are several design elements that are commonly used and are known to be widely effective. A typical trapping grid for a detailed survey will include pit traps, funnel traps, aluminum box traps and cage traps. This is outlined below and should be considered a starting point for trapping design.

Pit trapping effort will vary with the habitats being surveyed, their extent and the species targeted. Based on previous studies, 10 to 12 pit traps should be used per site for detailed surveys. However, trap numbers will also depend on site characteristics. For example, pit trap placement may be difficult in hard substrates and the numbers of other trap types may need to be increased to compensate.

A combination of trap types can be used, for example deep PVC pipes (600 mm deep x 150 mm diameter) with 20 L buckets (400 mm deep x 300 mm diameter). Alternatively, 20 L buckets may be used on their own, where pipes would offer no clear advantage given the expected fauna. Pipes are efficient in capturing species that escape from buckets, e.g. hopping mice, but 150 mm pipes should not be used alone because they are not as effective as buckets and do not maximise efficiency, which is critical in short-duration surveys. Drift fences are essential to most pit trapping designs. Seven or more metres between pits is beneficial (Friend et al. 1989), but excessive distances are probably not helpful. Approximately 10 metre spacing is typical and is recommended.

Single pits centred in fences may be less effective than long fences with numerous pits. Therefore, the overall trapping effort (i.e. number of traps or trapping duration) may need to be increased if using single pits. Fences with single pits should be a minimum of 10 metres in length.

If the different habitats are extensive it may be desirable to replicate trap lines or, where conditions permit, it can be beneficial to split the trap line, i.e. install two lines of five pits or even three lines of four, rather than one line of 10 or 12. This can capture additional species, as assemblages are unlikely to be distributed evenly throughout a habitat. Replicated or split lines should be a minimum of 50 to 100 m apart to ensure some independence between sections. This gives good spatial representation at the site level and enables analysis of similarity within and between sites.

Funnel traps should be deployed in conjunction with pit trap lines to augment overall captures at a site. In general they should be used in pairs, placed on either side of a drift fence in alternation with pits, although they may be set in other configurations provided a drift fence is used. On granite and other impenetrable surfaces, where it is not possible to use pit traps, funnel traps can be used without pits. In these cases, the trapping design and effort should be similar to that for pit trap lines.

Aluminium box traps should be positioned systematically and at a consistent distance from pits.

Grids may be less effective than linear arrangements (Read et al. 1988). Optimal spacing varies with environment. When targeting small mammals, Read et al. (1988) concluded that 10 m spacing was better than 20 m. Because of their greater home range size, spacing between traps for larger species may be increased.

Aluminium box traps should be set some distance from other trap types, but still in the same habitat, to increase the area covered and maximise captures. It is recommended that a grid or transect of 20 medium box traps is laid, with an extra five large box traps where larger species are expected.

Cage traps should be set following the same principles as for aluminium box traps. The number used should reflect the attributes of local habitats and the expected density of target species, but for general applications two to four cage traps per trapping grid is sufficient.

8.5 Animal welfare

Welfare of fauna – both target species and bycatch – should be a primary concern during surveys, and all team members should be trained to recognise, mitigate and report welfare risks and issues. Techniques used to interact with, capture, handle or disturb fauna must comply with the *Animal Welfare Act 2002* (WA), the *Australian Code for the Care and Use of Animals for Scientific Purposes* (NHMRC 2013), the conditions of any survey-specific licences and permits and any other relevant legislation or policies.

The EPA expects that proponents and survey personnel will adhere to these animal welfare requirements when planning and implementing surveys. Consideration for animal welfare includes, but is not limited to:

- checking traps at appropriate times of day and at adequate frequencies
- the management of ants around traps
- ensuring appropriate thermal conditions in traps
- responding appropriately to unexpected rainfall, changes in weather or weather extremes
- maintaining trap hygiene and biosecurity protocols
- using tools like call playback responsibly
- avoiding disturbance to breeding and similarly vulnerable individuals.

Animal welfare considerations related to specific techniques and issues, e.g. sample collection, first aid, disease risk management and euthanasia, are documented in DBCA’s Standard Operating Procedures, and euthanasia principles and methods have been documented by the Australian and New Zealand Council for the Care of Animals in Research and Teaching (ANZCCART 2001). These references are not exhaustive and it is the survey team’s responsibility to be aware of contemporary best practice.

9 Specimens

9.1 Identification

Selected texts and resources for fauna identification are listed in Appendix B. However, as taxonomy changes regularly, zoologists must keep up-to-date with the relevant primary literature.

Where zoologists are unfamiliar with a species likely to be encountered on a survey they should contact WAM to view available specimens before commencing fieldwork. If identification of a specimen to species level is not possible in the field, further information can be gathered by capturing digital images, taking standardised measurements, collecting genetic material or vouchering the specimen for later identification by an expert.

9.2 Nomenclature

Nomenclature and organisation of species lists should follow recognised checklists. Names and sequences used in reports and datasets should follow the Checklist of the Terrestrial Vertebrate Fauna of Western Australia for mammals and herpetofauna, and the Australian Faunal Directory for birds.

9.3 Vouchering

Vouchering of specimens improves biodiversity knowledge and validates species identification, and is particularly important for EIA surveys in poorly-studied areas. To prevent unnecessary collection, however, WAM and DBCA should be consulted during survey planning regarding the necessity of vouchering or tissue collection. Fauna specimens should be vouchered if they:

- have been specifically requested during pre-survey discussions with WAM or DBCA
- represent a substantial range extension or other significant record
- potentially represent an undescribed species.

Vouchering is not a substitute for having qualified and experienced zoologists make in-field identifications. The number of specimens vouchered should be kept to a minimum and based on advice from WAM or DBCA. Advice on specimen submission is available from WAM.

Photographs, recordings, tissue samples and hair samples may be an effective and less invasive means of verifying species identification. Diagnostic characters differ among taxonomic groups, and appropriate guides or experts should be consulted regarding the types of fauna that can be identified using these methods.

10 Data analysis

Considering data analysis prior to conducting field surveys will aid in development of an appropriate survey design. It is important to ensure that the analyses and data presentation:

- are commensurate with the type of survey or study
- provide evidence that the work was conducted in accordance with EPA guidance
- are sufficient to allow robust assessment of the impacts.

The types of analyses should be appropriate for the data available. For example, desktop studies may simply include species lists, whereas reports for detailed surveys may include species-by-site and species-by-habitat matrices. Analyses should incorporate abundance information whenever suitable data have been collected. Summary statistics can include species richness and/or diversity and similarity matrices. Care should be taken to ensure that the underlying assumptions of analyses are valid.

This guidance does not cover all possible analyses for the range of survey types used in EIA. Ecological data analysis methods evolve continuously and it is the survey leader's responsibility to ensure that the analyses are suitable. Involving biostatisticians in the design and analysis of surveys and monitoring programs can be beneficial.

The following sections outline steps expected in the treatment and analysis of data. Depending on the survey, these steps may be adequate as analyses in their own right or they may be precursors to more detailed analyses (Green et al. 2009 gives a useful review of methods).

10.1 Assessment of the reliability and veracity of data

The reliability of data should be critically evaluated. For example, an absence of records of a species does not necessarily indicate the absence of that species, and may instead be due to information gaps. Information gaps may be:

- spatial – if some areas have been better surveyed than others (e.g. due to access restrictions);
- taxonomic – if surveys focused on specific groups or their methodologies were not suitable for detecting all species present;
- ecological – if surveys omitted some habitat types or failed to account for species rarity or temporal variation in abundance; or
- topographic – if surveys focused on some features to the exclusion of others (e.g. survey only on ridge tops).

Checking data for errors such as misspellings of species names, incorrect identifications and erroneous data entry is essential before analysis. In addition, prior to grouping or presenting data for significant species, their current listing statuses should be checked.

10.2 Basic interpretation of data

Most surveys do not result in complete species inventories, so the choice of analyses depends on the amount of data collected. Analyses are also constrained by survey design; if data are not collected systematically, diversity measures cannot be compared and may be misleading.

Diversity information should be separated according to the major faunal groups – reptiles, frogs, birds and mammals. Diversity indices should be compared spatially, i.e. between sites and habitats; and temporally, i.e. between surveys and seasons, provided that data have been obtained using equal effort or that any variation in effort is accounted for in the analysis.

Different data types require different indices, and the overall analysis should give an indication of species that are common or restricted to specific sites or habitats. The inclusion of similarity matrices provides more interpretable and better comparative data. Useful indices include Jaccard's coefficient of community for binary data, i.e. presence-absence, and the Bray-Curtis coefficient for abundance data (see Legendre and Legendre 1998).

Abundance data should be incorporated into comparisons between sites, areas and habitats because variation in abundance is ecologically meaningful. This is especially important when many or all species are shared between sites.

10.3 Assessment of survey effectiveness

Plotting the cumulative number of species encountered against effort, either as trapping effort or cumulative individuals, provides a species accumulation curve. Species accumulation curves can be useful in estimating total species richness and the proportion of species caught during a survey. As effort increases, an under-surveyed assemblage will continue to show a rapid rise in the number of species, while a well-surveyed assemblage will have fewer new species added and the curve will begin to level out.

Randomised species accumulation curves should be calculated for the major fauna groups in the habitats surveyed. Where there is no evidence of a plateau additional survey effort may be necessary to better define the assemblages.

Programs used to create species accumulation curves can also estimate total species richness. These are based variously on the functions of the number of species in only one or two samples, e.g. Chao 2 and Jackknife, the number of species with only one or two individuals across all samples, e.g. Chao 1, or the proportions of samples that contain each species, e.g. Bootstrap (Chao et al. 2005, Green et al. 2009, Magurran 2004).

10.4 Data retention

All raw data collected during surveys, e.g. dates, locations, fauna records, habitat details, etc., should be retained in the form it was originally collected. Derived datasets and analysis outputs should also be retained. This ensures that subsequent surveys can be adequately designed, survey limitations are transparent to data users and the surveys themselves are verifiable and auditable.

11 Mapping

All reports should contain maps that adequately illustrate the existing environment and key field data, and support the interpretations and conclusions of the studies and surveys. Maps should be used, as relevant, to illustrate:

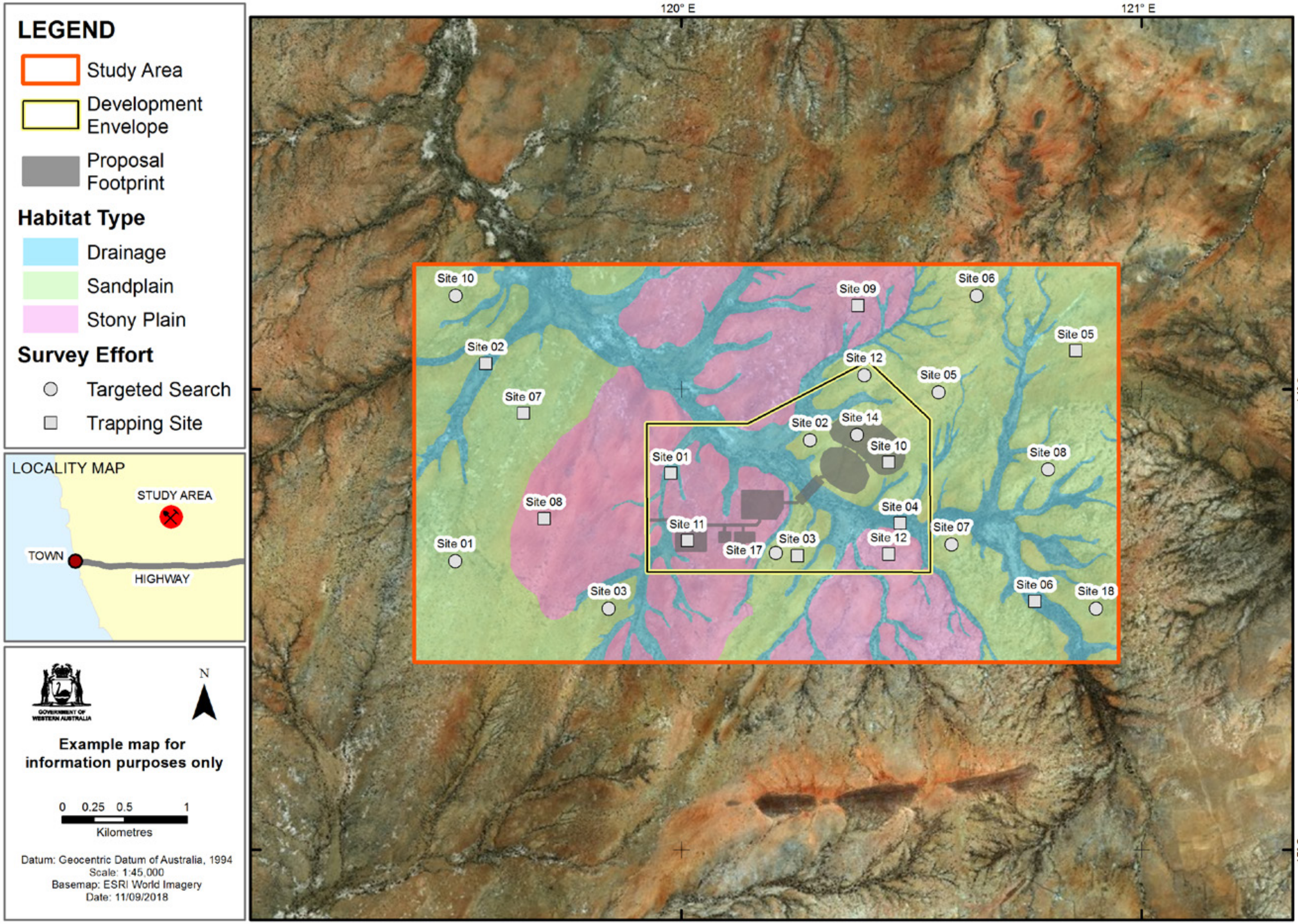
- extent of the study area in a regional context (e.g. major towns, roads, rail and Local Government Area boundaries)
- IBRA bioregions and subregions, land systems, vegetation, soils and geology
- extents of the desktop study database search areas, and the locations of previous surveys included in the literature review or otherwise discussed
- locations of significant fauna records in the region acquired during the desktop study, relative to the proposal area
- extents of fauna habitats within the study area, including any significant habitat features
- locations of current survey sites, in relation to fauna habitats and the proposal
- locations of significant fauna records from the current survey, in relation to fauna habitats and the proposal.

Maps should be legible and include the most current information. Aerial imagery should be the base layer for most maps, with the subject of the map overlaid using transparent colours and labelled features. Colours of features and/or shapes of symbols should be readily distinguishable from one another. The colours or textures used to indicate recurring features, e.g. impact footprint, should be consistent for all maps within the survey report.

As a minimum, all maps should include an explanatory title, legend or labels, scale bar, north point, grid or graticules, coordinate system identification, figure number and date or version (Figure 2). Maps should be north-oriented, use the GDA94 datum and be projected into the appropriate Map Grid of Australia zone, unless this is unsuitable for the scale. Map scale will vary depending on the size of the study area, spatial heterogeneity of data layers and overall amount of information that needs to be displayed.

Large map sets, especially those for linear corridors, should include an overview map for orientation and reference. For maps depicting only part of the study area, an inset illustrating the map extent relative to the whole area should be included. Insets can also be used to focus on areas with high numbers of records, to improve clarity or highlight important areas.

Figure 2: Example map showing minimum expected elements



12 Reporting

The structure, content and detail of the survey report should be based on the objectives of the survey. The report should accurately reflect the information obtained through the survey, include a rational interpretation of the results and demonstrate that contemporary techniques and guidance have been used.

Reports should be comprehensive, contain all relevant data and stand alone as the definitive source of information for a given survey. They should be written by a zoologist involved in conducting the survey, and any significant changes made to the report by those who were not involved in the survey should be justified.

12.1 Executive summary and introduction

The executive summary should be a succinct overview of the survey objectives, techniques, key results and conclusions. The introduction should state the survey objectives and summarise the relevant background information, including the nature of the proposal and key contextual data from the desktop study.

12.2 Methods

Reports should contain a section outlining the scope, techniques used and limitations of the survey. Justification of the type of survey conducted and the survey design, including any deviation from this guidance, should be provided.

The reports, publications, databases and other sources used for the desktop study should be stated. Documentation of the survey methods should include, but not be limited to, the survey dates and phases, survey level, rationale for survey design and site selection, weather prior to and during the survey, techniques used and survey effort. The survey effort should be broken down by technique and habitat, and should use meaningful units (i.e. person-hours or trap-nights). The methods and literature used for identifying fauna should be cited. Detailed descriptions of the data analysis methods should be provided.

The personnel involved in the survey should be listed and their roles, survey licence details, qualifications and experience should be outlined. If third parties contributed to the report or analyses, e.g. expert advice for a fauna group, their details and roles should also be included.

Any limitations of the survey should be outlined. These may include:

- availability of data and information
- competency/experience of the survey team, including experience in the bioregion surveyed
- scope of the survey, e.g. where faunal groups were excluded from the survey
- timing, weather and season
- disturbance that may have affected results, e.g. fire, flood
- the proportion of fauna identified, recorded or collected
- adequacy of the survey intensity and proportion of survey achieved, e.g. the extent to which the area was surveyed
- access problems
- problems with data and analysis, including sampling biases.

12.3 Results

Survey results should be presented in text and tabular format summarising relevant fauna and habitat values within the study area. The results from the desktop study and surveys should be collated.

Fauna data should be presented quantitatively wherever possible. Reports may contain observational notes and qualitative data, but raw data supporting key conclusions should always be presented, either in the report or as appendices.

Survey results should include tables and figures summarising the survey effort, weather records before and during the survey and observations and captures (by site and habitat, including geographic coordinates and survey techniques used). Data collected during the survey should be clearly differentiated from data gathered from the desktop study, and sources of information used should be clearly referenced in the report.

Information on fauna habitat should be presented. Each habitat type should be described in detail, including the key characteristics of the habitat (not just vegetation), how fauna may use it and the significant species likely to occur, and accompanied by photographs and maps. Each description should be based on the habitat assessment and desktop study. Any information regarding the sensitivity of the habitat to specific impacts should be included.

Species recorded should be discussed in a regional context, including the presence of regional endemics or species for which the project area is at the limits of the known range, or where the record is an extension of the previously known range. The main body of the report may present fauna assemblage data in summary, but should present records of significant species in detail.

Results for significant species should be detailed in a standalone section devoted specifically to significant species and their habitats. The information presented should include their conservation statuses, distributions, locations recorded and habitats occupied.

Identification results, including the relevant field specimen, voucher specimen or WAM lodgement numbers, should be included in the report where appropriate. This will enable identifications to be verified.

12.4 Discussion

The discussion should provide a summary of the fauna, assemblage and habitat values of the study area, and their significance in relation to the proposal and regional context. The scales defining local and regional contexts are different for every survey, and may even differ between fauna or habitats within a survey. For example, the local and regional contexts for migratory fauna will be quite different to those for a reptile endemic to a single salt lake.

The discussion should consider the adequacy of the survey and state whether the studies and surveys meet EPA guidance. To demonstrate the veracity of the field survey, the comprehensiveness of the overall species inventory should be discussed using quantitative data. This should include:

- tabulation of the survey effectiveness, based on the number of individuals captured and survey effort expended
- limitations of the inventory as demonstrated by species accumulation curves
- the use and relevance of diversity indices, estimates of species richness, measures of evenness and differences in the faunal assemblages among habitat types
- other analyses of fauna data, taking into account any effects of bias.

Where significant species were identified through the desktop study as potentially occurring in the study area but were not found, the report should discuss possible reasons for the difference. In such cases the need for additional surveys should be evaluated.

12.5 Conclusions

The survey report should conclude with a summary of the key findings of the survey and any recommendations. All conclusions should be substantiated by the data and/or reference to the literature. The influence of survey limitations on the results should also be noted. It is particularly important to highlight fauna issues to be mitigated in planning a proposal, or where further survey work is required to inform an assessment.

12.6 Appendices

Appendices containing species lists should be presented in tabular format, organised taxonomically and grouped by class and family, with significant and introduced species identified accordingly. At minimum, appendices should include:

- an inventory of all species recorded during the field survey, with abundance summarised according to site, habitat and broad detection technique (e.g. trapped, observed or secondary evidence)
- an inventory listing all species potentially present in the study area, noting whether they were recorded by each of the different databases and literature sources, and/or the field survey
- individual records for each significant species observed, including habitat, precise location, abundance and detection method (as well as lodgement details if any specimens were vouchered).

Appendices should be prepared and submitted per the guidelines for reporting above. All data sources should be cited and attributed to the original author, including maps, spatial data, figures and tables copied or adapted from other sources.

If a report relies substantially on information contained within another document – for example species identification reports or genetic analysis and results – then that document should be provided as an appendix. Any other substantial information that supports the main report or results should be appended.

12.7 Provision of electronic datasets

To support assessments, raw data should be supplied electronically. All reports containing field survey results should be accompanied by an electronic data package prepared according to the IBSA data standards and submitted through the IBSA data portal.

13 References

Agranat, I (2012). *Bat Species Identification from Zero Crossing and Full Spectrum Echolocation Calls using HMMs, Fisher Scores, Unsupervised Clustering and Balanced Winnow Pairwise Classifiers*, unpublished report prepared for Wildlife Acoustics.

Alacs, E, Alpers, D, de Tores, PJ, Dillon, M and Spencer, PBS (2003). Identifying the presence of quokkas (*Setonix brachyurus*) and other macropods using cytochrome *b* analyses from faeces, *Wildlife Research* 30: 41–47.

ANZCCART (2001). *Euthanasia of animals used for scientific purposes* 2nd edn JS Reilly (ed), Australian and New Zealand Council for the Care of Animals in Research and Teaching, Adelaide.

Austin, C, Tuft, K, Ramp, D, Cremona, T and Webb, JK (2016). Bait preference for remote camera trap studies of the endangered northern quoll (*Dasyurus hallucatus*), *Australian Mammalogy* 39: 72–77.

Australasian Bat Society (2006). Recommendations of the Australasian Bat Society Inc for reporting standards for insectivorous bat surveys using bat detectors, *Australasian Bat Society Newsletter* 27: 6–9.

Beard, JS (1980). A new phytogeographic map of Western Australia, *Western Australian Herbarium Research Notes* 3: 37–58.

Berry, PF, Tinley, KL, How, RA, Dell, J, Cooper, NK, Harvey, MS and Waldock, JM (1991). Ecological Survey of the Abydos-Woodstock Reserve, Western Australia, *Records of the Western Australian Museum* S37: 1–145.

Bibby, CJ, Burgess, ND, Hill, DA and Mustoe, SH (2000). *Bird Census Techniques* 2nd edn, Academic Press, London.

Bilney, RJ (2014). Poor historical data drive conservation complacency: the case of mammal decline in south-eastern Australian forests, *Austral Ecology* 39: 875–886.

Bilney, RJ, Cooke, R and White, JG (2010). Underestimated and severe: small mammal decline from the forests of south-eastern Australia since European settlement, as revealed by a top-order predator, *Biological Conservation* 143: 52–59.

Birdlife Australia (2012). *Ethical Birding Guidelines*, unpublished report.

BOCA (2001). *A Field Guide to Australian Birdsong (CD Audio)*, Bird Observers Club of Australia, Nunawading.

De Bondi, N, White, JG, Stevens, M and Cooke, R (2010). A comparison of the effectiveness of camera trapping and live trapping for sampling terrestrial small-mammal communities, *Wildlife Research* 37: 456–465.

Brunner, H and Coman, BJ (1974). *The Identification of Mammalian Hair*, Inkata Press, Melbourne.

Brunner, H and Triggs, BE (2002). *Hair ID: An Interactive Tool for Identifying Australian Mammalian Hair* (CD-ROM), CSIRO Publishing, Melbourne.

Burbidge, A (2016). Use of sound recording devices in wildlife survey, in *EIANZ and ECA WA: Best Practice for Fauna Impact Assessment Workshop*, Perth.

Burbidge, AH, Rolfe, J, McNee, S, Newbey, B and Williams, M (2007). Monitoring population change in the cryptic and threatened Western Ground Parrot in relation to fire, *Emu* 107: 79–88.

Bush, B, Maryan, B, Browne-Cooper, R and Robinson, D (2007). *Reptiles and Frogs in the Bush: Southwestern Australia*, UWA Press, Crawley.

Carpenter, FM and Dziminski, MA (2016). Breaking down scats : degradation of DNA from greater bilby (Macrotis lagotis) faecal pellets, *Australian Mammalogy* 39: 197–204.

Catling, P, Burt, RJ and Kooyman, R (1997). A comparison of techniques used in a survey of the ground-dwelling and arboreal mammals in forests in north-eastern New South Wales, *Wildlife Research* 24: 417–432.

Chao, A, Chazdon, RL, Colwell, RK and Shen, T-J (2005). A new statistical approach for assessing similarity of species composition with incidence and abundance data, *Ecology Letters* 8: 148–159.

Chisholm, AH (1932). Vocal mimicry among Australian birds, *Ibis* 74: 605–624.

Churchill, S (2001). *Recovery Plan for the Sandhill Dunnart (*Sminthopsis psammophila*)*, Biodiversity Conservation Program, Department for Environment and Heritage, Adelaide.

Cooper, NK, Teale, RJ and Kendrick, PG (2006). A recently observed increase in distribution of the Desert Mouse, *Pseudomys desertor*, in Western Australia, *Western Australian Naturalist* 25: 169–186.

Cowan, MA (2004). *Preliminary Analysis of Fauna Sampling for CALM's Feral Cat Research Program at Lorna Glen*, unpublished report prepared for the Department of Conservation and Land Management.

Cowan, MA (2016). Terrestrial vertebrate surveys – some design and analysis considerations, in *EIANZ and ECA WA: Best Practice for Fauna Impact Assessment Workshop*, Perth.

Cowan, MA and How, RA (2004). Comparisons of ground vertebrate assemblages in arid Western Australia in different seasons and decades, *Records of the Western Australian Museum* 22: 91–100.

Craig, MD (2004). A comparison of species counts and density estimates derived from area searches, line transects and point counts in the Jarrah forest of south-western Australia, *Corella* 28: 55–59.

Craig, MD and Roberts, JD (2001). Evaluation of the impact of time of day, weather, vegetation density and bird movements on outcomes of area searches for birds in eucalypt forests of south-western Australia, *Wildlife Research* 28: 33–39.

Cramer, VA, Dziminski, MA, Southgate, R, Carpenter, FM, Ellis, RJ and van Leeuwen, S (2016). A conceptual framework for habitat use and research priorities for the greater bilby (*Macrotis lagotis*) in the north of Western Australia, *Australian Mammalogy* 39: 137–151.

Crosswhite, DL, Fox, SF and Thill, RE (1999). Comparison of methods for monitoring reptiles and amphibians in upland forest of the Ouachita Mountains, *Proceedings of the Oklahoma Academy of Science* 79: 45–50.

Desmond, A and Chant, A (2003). Yalgoo (Yal), in JE May & NL McKenzie (eds), *A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions in 2002*, Department of Conservation and Land Management, Perth, 656–667.

DEWHA (2010a). *Survey Guidelines for Australia's Threatened Birds*, Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (2010b). *Survey Guidelines for Australia's Threatened Bats*, Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (2010c). *Survey Guidelines for Australia's Threatened Frogs*, Department of the Environment, Water, Heritage and the Arts, Canberra.

DPaW (2013). *Pilbara Northern Quoll Regional Monitoring Guidelines*, Department of Parks and Wildlife, Perth.

DPaW (2014). *South Coast Threatened Birds Recovery Plan*, Western Australian Wildlife Management Program, Department of Parks and Wildlife, Perth.

DPaW (2016). *The Conservation and Management of the Bilby (*Macrotis lagotis*) in the Pilbara - Progress Report 2016*, Department of Parks and Wildlife, Perth.

DSEWPaC (2011a). *Survey Guidelines for Australia's Threatened Mammals*, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

DSEWPaC (2011b). *Survey Guidelines for Australia's Threatened Reptiles*, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

DSEWPaC (2011c). *Survey Guidelines for Australia's Threatened Fish*, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Dziminski, MA and Carpenter, F (2014). *The Conservation and Management of the Bilby (Macrotis lagotis) in the Pilbara - Annual Report 2013-2014*, Department of Parks and Wildlife, Perth.

Flaquer, C, Torre, I and Arrizabalaga, A (2007). Comparison of sampling methods for inventory of bat communities, *Journal of Mammalogy* 88: 526–533.

Friend, GR (1984). Relative efficiency of two pitfall-drift fence systems for sampling small vertebrates, *The Australian Zoologist* 21: 423–433.

Friend, GR, Smith, GT, Mitchell, DS and Dickman, CR (1989). Influence of pitfall and drift fence design on capture rates of small vertebrates in semi-arid habitats of Western Australia, *Wildlife Research* 16: 1–10.

FUA (2015). *General Guidelines for Wildlife Capture and Handling*, Centre for Environmental Management, Federation University Australia, Ballarat.

Gillespie, GR, Brennan, K, Gentles, T, Hill, B, Low Choy, J, Mahney, T, Stevens, A and Stokeld, D (2015). *A Guide for the Use of Remote Cameras for Wildlife Survey in Northern Australia*, Charles Darwin University, Darwin.

Green, MJB, How, R, Padmalal, UKGK and Dissanayake, SRB (2009). The importance of monitoring biological diversity and its application in Sri Lanka, *Tropical Ecology* 50: 41–56.

Gregory, RD, Gibbons, DW and Donald, PF (2004). Bird census and survey techniques, in WJ Sutherland, I Newton, & R Green (eds), *Bird Ecology and Conservation: A Handbook of Techniques*, Oxford University Press, Oxford, 17–55.

Hobbs, TJ, Morton, SR, Masters, P and Jones, KR (1994). Influence of pit-trap design on sampling of reptiles in arid spinifex grasslands, *Wildlife Research* 21: 483–490.

How, RA (1998). Long-term sampling of a herpetofaunal assemblage on an isolated urban bushland remnant, Bold Park, Perth, *Journal of the Royal Society of Western Australia* 81: 143–148.

How, RA and Cooper, NK (2002). Terrestrial small mammals of the Abydos Plain in the north-eastern Pilbara, Western Australia, *Journal of the Royal Society of Western Australia* 85: 71–82.

How, RA and Dell, J (2004). Reptile assemblage of the Abydos plain, north-eastern Pilbara, Western Australia, *Journal of the Royal Society of Western Australia* 87: 85–95.

How, RA, Milewski, A V, Keighery, GJ and Dell, J (1992). The biological survey of the Eastern Goldfields of Western Australia. 7. Duketon-Sir Samuel Study Area, *Records of the Western Australian Museum* S40: 69–131.

Howe, EJ, Buckland, ST, Després-Einspenner, M-L and Kühl, HS (2017). Distance sampling with camera traps, *Methods in Ecology and Evolution* 8: 1558–1565.

Huebschman, JJ, Freeman, PW, Genoways, HH and Gubanyi, JA (2000). Observations on small mammals recovered from owl pellets from Nebraska, *The Prairie Naturalist* 32: 209–215.

Igic, B and Magrath, RD (2014). A songbird mimics different heterospecific alarm calls in response to different types of threat, *Behavioral Ecology* 25: 538–548.

Ives, AR and Klopfer, ED (1997). Spatial variation in abundance created by stochastic temporal variation, *Ecology* 78: 1907–1913.

James, CD (1994). Spatial and temporal variation in structure of a diverse lizard assemblage in arid Australia, in LJ Vitt & ER Pianka (eds), *Lizard Ecology*, Princeton University Press, New Jersey, 287–318.

Jones, C, McShea, WJ, Conroy, MJ and Kunz, TH (1996). Capturing Mammals, in DE Wilson, RF Cole, JD Nichols, R Rudran, & MS Foster (eds), *Measuring and Monitoring Biological Diversity: Standard Methods for Mammals*, Smithsonian Institution Press, Washington, 115–155.

Kelley, LA, Coe, RL, Madden, JR and Healy, SD (2008). Vocal mimicry in songbirds, *Animal Behaviour* 76: 521–528.

Kingsford, RT, Halse, SA and Porter, JL (2008). *Aerial surveys of waterbirds – assessing wetland condition*, unpublished report prepared for the National Land and Water Resources Audit.

Legendre, P and Legendre, L (1998). *Numerical Ecology* 2nd edn, Elsevier Science, Amsterdam.

Loyn, RH (1986). The 20 minute search - a simple method for counting forest birds, *Corella* 10: 58–60.

Magurran, AE (2004). *Measuring Biological Diversity*, Blackwell Science, Malden.

Maritz, B, Masterson, G, Mackay, D and Alexander, G (2007). The effect of funnel trap type and size of pitfall trap on trap success: implications for ecological field studies, *Amphibia-Reptilia* 28: 321–328.

Marks, CA, Gigliotti, F, McPhee, S, Piggott, MP, Taylor, A and Glen, AS (2009). DNA genotypes reveal red fox (*Vulpes vulpes*) abundance, response to lethal control and limitations of contemporary survey techniques, *Wildlife Research* 36: 647–658.

Martin, GR, Twigg, LE and Robinson, DJ (1996). Comparison of the diet of feral cats from rural and pastoral Western Australia, *Wildlife Research* 23: 475–484.

McKenzie, NL and Bullen, RD (2003). Identifying Little Sandy Desert bat species from their echolocation calls, *Australian Mammalogy* 25: 73–80.

McKenzie, NL and Bullen, RD (2009). The echolocation calls, habitat relationships, foraging niches and communities of Pilbara microbats, *Records of the Western Australian Museum* S78: 123–155.

McKenzie, NL and Bullen, RD (2012). An acoustic survey of zoophagic bats on islands in the Kimberley, Western Australia, including data on the echolocation ecology, organisation and habitat relationships of regional communities, *Records of the Western Australian Museum* S81: 67–108.

Meek, P, Fleming, P, Ballard, G, Banks, P, Claridge, A, Sanderson, J and Swann, D (eds) (2014). *Camera Trapping: Wildlife Management and Research*, CSIRO Publishing, Clayton.

Meek, PD, Ballard, GA and Fleming, PJS (2015). The pitfalls of wildlife camera trapping as a survey tool in Australia, *Australian Mammalogy* 37: 13–22.

Meek, PD and Pittet, A (2012). Use-based design specifications for the ultimate camera trap for wildlife research, *Wildlife Research* 39: 649–660.

Morris, K, Cowan, M, Angus, J, Anderson, H, Garretson, S, Algar, D, Moro, D and Williams, M (2015). *The Northern Quoll Cat Bait Uptake and Survivorship Study, Yarraloola Land Management Area, Pilbara Region, WA*, Department of Parks and Wildlife report prepared for the Yandicoogina JSW and Oxbow Project Threatened Species Offset Plan.

Morton, SR, Gillam, MW, Jones, KR and Fleming, MR (1988). Relative efficiency of different pit-trap systems for sampling reptiles in spinifex grasslands, *Wildlife Research* 15: 571–577.

Moseby, KE and Read, JL (2001). Factors affecting pitfall capture rates of small ground vertebrates in arid South Australia. II. Optimal pitfall trapping effort, *Wildlife Research* 28: 61–71.

Murphy, SA (2014). *Night Parrot (*Pezoporus occidentalis*) Research Plan*, unpublished report prepared for Fortescue Metals Group.

Murray, M, Bell, S and Hoye, G (2002). *Flora and Fauna Survey Guidelines: Lower Hunter Central Coast Region*, Lower Hunter Central Coast Regional Environmental Management Strategy, Cessnock.

NHMRC (2013). *Australian Code for the Care and Use of Animals for Scientific Purposes* 8th edn, National Health and Medical Research Council, Canberra.

Panasci, M, Ballard, WB, Breck, S, Rodriguez, D, Densmore, LD, Wester, DB and Baker, RJ (2011). Evaluation of fecal DNA preservation techniques and effects of sample age and diet on genotyping success, *The Journal of Wildlife Management* 75: 1616–1624.

Petit, S and Waudby, HP (2012). Standard operating procedures for aluminium box, wire cage, and pitfall trapping, handling, and temporary housing of small wild rodents and marsupials, *Australian Journal of Zoology* 60: 392–401.

Piggott, MP, Banks, SC, Stone, N, Banffy, C and Taylor, AC (2006). Estimating population size of endangered brush-tailed rock-wallaby (*Petrogale penicillata*) colonies using faecal DNA, *Molecular Ecology* 15: 81–91.

Piggott, MP and Taylor, AC (2003). Remote collection of animal DNA and its applications in conservation management and understanding the population biology of rare and cryptic species, *Wildlife Research* 30: 1–13.

Pinder, J (2012). Breakthrough for Western Ground Parrot Survey, *Western Australian Bird Notes* 143: 12.

Read, JL and Moseby, KE (2001). Factors affecting pitfall capture rates of small ground vertebrates in arid South Australia. I. The influence of weather and moon phase on capture rates of reptiles, *Wildlife Research* 28: 53–60.

Read, KT, Malafant, KWJ and Myers, K (1988). A comparison of grid and index-line trapping methods for small mammal surveys, *Australian Wildlife Research* 15: 673–687.

Richardson, E, Nimmo, DG, Avitabile, S, Tworkowski, L, Watson, SJ, Welbourne, D and Leonard, SWJ (2017). Camera traps and pitfalls: an evaluation of two methods for surveying reptiles in a semiarid ecosystem, *Wildlife Research* 44: 637–647.

Risbey, DA, Calver, MC and Short, J (1999). The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. I. Exploring potential impact using diet analysis, *Wildlife Research* 26: 621–630.

Rolfe, JK and McKenzie, NL (2000). Comparison of methods used to capture herpetofauna: an example from the Carnarvon basin, *Records of the Western Australian Museum* S61: 361–370.

Rovero, F, Zimmermann, F, Berzi, D and Meek, PD (2013). 'Which camera trap type and how many do I need?' A review of camera features and study designs for a range of wildlife research applications, *Hystrix* 24: 148–156.

Ruibal, M, Peakall, R, Claridge, A and Firestone, K (2009). Field-based evaluation of scat DNA methods to estimate population abundance of the spotted-tailed quoll (*Dasyurus maculatus*), a rare Australian marsupial, *Wildlife Research* 36: 721–736.

Scotts, DJ and Craig, SA (1988). Improved hair-sampling tube for the detection of rare mammals, *Australian Wildlife Research* 15: 469–472.

Simpson, K and Day, N (1999). *CD Birds of Australia 5.0*, Natural Learning, Sydney.

Suckling, GC (1978). A hair sampling tube for the detection of small mammals in trees, *Australian Wildlife Research* 5: 249–252.

Thomas, DW and West, SD (1989). Sampling Methods for Bats, in AB Carey & LF Ruggiero (eds), *Wildlife-Habitat Relationships - Sampling Procedures for Pacific Northwest Vertebrates*, USDA Forest Service, Portland.

Thompson, GG and Thompson, SA (2007). Usefulness of funnel traps in catching small reptiles and mammals, with comments on the effectiveness of the alternatives, *Wildlife Research* 34: 491–497.

Thompson, SA and Thompson, GG (2005). Temporal variations in reptile assemblages in the Goldfields of Western Australia, *Journal of the Royal Society of Western Australia* 88: 25–36.

Wayne, AF, Rooney, J, Morris, KD and Johnson, B (2008). Improved bait and trapping techniques for chuditch (*Dasyurus geoffroii*): overcoming reduced trap availability due to increased densities of other native fauna, *Conservation Science Western Australia* 7: 49–56.

Webb, GA (1999). Effectiveness of pitfall/drift-fence systems for sampling small ground-dwelling lizards and frogs in southeastern Australian forests, *Australian Zoologist* 31: 118–126.

York, A, Binns, D and Shields, J (1991). *Flora and fauna assessment in NSW state forests: survey guidelines and procedures for sampling flora and fauna for environmental impact statements*, Forestry Commission of NSW, Beecroft.

Appendix A:
A list of selected vertebrate fauna survey data reports

A: 'Southern' broad climatic region

Burbidge, A.A., Hall, N.J., G.J. Keighery and McKenzie, N.L. (eds) (1995). A biological survey of the eastern Goldfields of Western Australia. Part 12. The Barlee-Menzies study area. *Records of the Western Australian Museum* Supplement No. 49: 169-312.

Chapman, A., Dell, J., Kitchener, D.J. and Muir, B.G. (1978) *Biological survey of the Western Australian wheatbelt. Part 5. Dongolocking Nature Reserve.* Records of the Western Australian Museum Supplement No. 6: 1-80.

Chapman, A., Dell, J., Johnstone, R.E. and Kitchener, D.J. (1977) A Vertebrate Survey of Cockleshell Gully Reserve, Western Australia. *Records of the Western Australian Museum* Supplement No. 4: 1-87.

Chapman, A., Dell, J., Kitchener, D.J. and Muir, B.G. (1981) Biological survey of the Western Australian Wheatbelt Part 13: Billyacatting Hill Nature Reserves. *Records of the Western Australian Museum* Supplement No. 13: 5-54.

Chapman, A., Dell, J., Kitchener, D.J. and Muir, B.G. (1980) Biological survey of the Western Australian wheatbelt. Part 11, Yorkrakine Rock, East Yorkrakine and North Bungulla Nature Reserves. *Records of the Western Australian Museum* Supplement No. 12: 3-76.

Dell, J. and Hyder, B. (2009) *An Assessment of the Avifauna of the Area Between Dawesville and Binningup, Southern Swan Coastal Plain*. Report to the Environmental Protection Authority.

Dell, J., Chapman, A., Kitchener, D.J., McGauran, D.J. and Muir, B.G. (1981) Biological survey of the Western Australian Wheatbelt Part 14: East Yuna and Bindoo Hill Nature Reserves. *Records of the Western Australian Museum* Supplement No. 13: 7-105.

Dell, J., Chapman, A., Kitchener, D.J. and Muir, B.G. (1979) Biological survey of the Western Australian Wheatbelt Part 8: Wilroy Nature Reserves. *Records of the Western Australian Museum* Supplement No. 8: 5-54.

Dell, J., Chapman, A., Kitchener, D.J. and Muir, B.G. (1979) Biological survey of the Western Australian Wheatbelt Part 9: Marchagee Nature Reserves. *Records of the Western Australian Museum* Supplement No. 8: 5-50.

Dell, J., Harold, G., Kitchener, D.J., Morris, K.D. and Muir, B.G. (1979) Biological survey of the Western Australian Wheatbelt Part 7: Yornaning Nature Reserves. *Records of the Western Australian Museum* Supplement No. 8: 3-48.

Dell, J., How, R.A, Newbey, K.R. and Hnatiuk, R.J. (1985) The biological survey of the Eastern Goldfields of Western Australia. Part 3, Jackson-Kalgoorlie study area. *Records of the Western Australian Museum* Supplement No. 23: 1-168.

Hall, N.J. and McKenzie, N.L. (eds) (1993) The biological survey of the Eastern Goldfields of Western Australia. Part 9, Norseman-Balladonia study area. *Records of the Western Australian Museum* Supplement No. 42: 1-138.

Harvey, M.S., Dell, J., How, R.A., and Waldock, J.M. (1997) *Ground Fauna of Bushland Remnants on the Ridge Hill Shelf and Pinjarra Plain Landforms, Perth.* Report to the Australian Heritage Commission. NEP Grant N95/49. 56 pp.

How, R. A. (1998) Long-term sampling of a herpetofaunal assemblage on an isolated urban bushland remnant, Bold Park, Perth. *Journal of the Royal Society of Western Australia* 81: 143-148.

How, R.A. (ed.) (1978) *Faunal Studies of the Northern Swan Coastal Plain. A Consideration of Past and Future Changes.* Unpublished report for the Department of Conservation and Environment.

How, R.A. and Dell, J. (2000) Ground vertebrate fauna of Perth's vegetation remnants: impact of 170 years of urbanisation. *Pacific Conservation Biology* 6: 198-217.

How, R.A. and Dell, J. (1993) Vertebrate fauna of the Perth metropolitan region: consequences of a modified environment. pp 28-47. *In*: Hipkins M (ed.) *Urban Bush Management*. Australian Institute of Urban Studies, Perth, Western Australia.

How, R. A., Dell, J. and Humphreys, W. F. (1987) The ground vertebrate fauna of coastal areas between Busselton and Albany, Western Australia. *Records of the Western Australian Museum* 13: 553-574.

How, R.A., Harvey, M.S., Dell, J. and Waldock, J. (1996) *Ground Fauna of Urban Bushland Remnants in Perth.* Report N93/04 to the Australian Heritage Commission, 103pp.

How, R. A., Maryan, B. and Stevenson, C. A. (2009) *An Assessment of Herpetofauna on Near-coastal Landforms Between Dawesville and Binningup*, Southern Swan Coastal Plain. Report to the Environmental Protection Authority.

How, R.A, Newbey, K.R., Dell, J., Muir, B.G. and Hnatiuk, R.J. (1988) The biological survey of the Eastern Goldfields of Western Australia. Part 4, Lake Johnston-Hyden study area. *Records of the Western Australian Museum* Supplement No. 30: 1-233.

Keighery, G.J., Halse, S.A., McKenzie, N.L. and Harvey, M.S. (eds) (2004) A biodiversity survey of the Western Australian agricultural zone. *Records of the Western Australian Museum* Supplement No. 67: 1-384.

Keighery, G.J., McKenzie, N.L. and Hall, N.J. (eds) (1995). A biological survey of the eastern Goldfields of Western Australia. Part 11. The Boorabbin-Southern Cross Study Area. *Records of the Western Australian Museum* Supplement No. 49, 1-167.

Kitchener, D.J., Chapman, A. and Dell, J. (1975) A biological survey of Cape Le Grand National Park. *Records of the Western Australian Museum* Supplement No.1: 1-38.

Kitchener, D.J., Chapman, A., Dell, J., Johnstone, R.E, Muir, B.G. and Smith, L.A. (1976) Biological survey of the Western Australian Wheatbelt preface to the series and Part 1: Tarin Rock and North Tarin Rock Reserves. *Records of the Western Australian Museum* Supplement No. 2: 1-87.

Kitchener, D.J., Chapman, A., Dell, J. and Muir, B.G. (1977) Biological survey of the Western Australian Wheatbelt Part 3: Vertebrate fauna of Bendering and West Bendering Nature Reserves. *Records of the Western Australian Museum* Supplement No. 5: 1-58.

Kitchener, D.J., Chapman, A., Dell, J. and Muir, B.G. (1979) Biological survey of the Western Australian Wheatbelt Part 10: Buntine, Nugadong and East Nugadong Nature Reserves and Nugadong Forest Reserve. *Records of the Western Australian Museum* Supplement No. 9: 1-127.

Kitchener, D.J., Dell, J., Muir, B.G. and Palmer, M. Birds of Western Australian Wheatbelt Reserves - Implications for Conservation. *Biological Conservation* 22: 127-163.

McKenzie, N.L., Rolfe, J.K. and Youngson, W.K. (1993) The biological survey of the Eastern Goldfields of Western Australia. Part 10, Sandstone-Sir Samuel and Leonora-Laverton study areas. *Records of the Western Australian Museum* Supplement No. 47: 1-166.

Muir, B.G., Chapman, A., Dell, J. and Kitchener, D.J. (1978) Biological survey of the Western Australian wheatbelt. Part 6. Durokoppin and Kodj Kodjin Nature Reserves. *Records of the Western Australian Museum* Supplement No. 7: 3-77.

Muir, B.G., Chapman, A., Dell, J. and Kitchener, D.J. (1980) Biological survey of the Western Australian wheatbelt. Part 12, Badjaling Nature Reserve, South Badjaling Nature Reserve, Yoting Town Reserve, Yoting Water Reserve. *Records of the Western Australian Museum* Supplement No. 12: 3-65.

Newbey, K.R., Dell, J., How, R.A, and Hnatiuk, R.J. (1984) The biological survey of the Eastern Goldfields of Western Australia. Part 2, Widgiemooltha-Zanthus study area. *Records of the Western Australian Museum* Supplement No. 18: 21-158.

Storr, G.M. (1991) Birds of the South-West Division of Western Australia. *Records of the Western Australian Museum* Supplement No. 35: 1-150

Storr, G.M. and Johnstone, R.E. (1988) Birds of the Swan Coastal Plain and adjacent seas and islands. *Records of the Western Australian Museum,* Supplement No. 28: 1-76.

B: 'Eremaean' broad climatic region

Berry, P.F., Tinley, K.L., How, R.A., Dell, J., Cooper, N.K., Harvey, M.S. and Waldock, J.M. (1991) Ecological survey of Abydos-Woodstock Reserve, Western Australia. *Records of the Western Australian Museum* Supplement No. 37: 1-145.

Burbidge, A. *et al.* (1976) The wildlife of some existing and proposed reserves in the Great Victoria and Gibson Deserts, Western Australia. *Wildlife Research Bulletin Western Australia* 5: 1-16.

Burbidge, A.A., Hall, N.J., G.J. Keighery and McKenzie, N.L. (eds) (1995). A biological survey of the eastern Goldfields of Western Australia. Part 12. The Barlee-Menzies study area. *Records of the Western Australian Museum* Supplement No. 49, 169-312.

Burbidge, A. H., Johnstone, R. E. and Pearson, D. J. (2010) Birds in a vast arid upland: avian biogeographical patterns in the Pilbara region of Western Australia. *Records of the Western Australian Museum* Supplement No. 78: 247-270.

Burbidge, A.A. and McKenzie, N.L. (eds) (1983). Wildlife of the Great Sandy Desert. *Wildlife Research Bulletin Western Australia* No. 12, 1-127. Department of Fisheries and Wildlife, Perth.

Burbidge, A.H., Harvey, M.S. and McKenzie, N.L, (eds) (2000) Biodiversity of the southern Carnarvon Basin. *Records of the Western Australian Museum* Supplement No. 61: 1-595.

Cowan, M. (2015) *Terrestrial Vertebrate Fauna of the Katjarra Area of the Birriliburu IPA*. Report to the Birriliburu Native Title Holders and Central Desert Native Title Services.

Cowan, M., Bray, R. and Paltridge, R. (2015) *Kiwirrkurra Indigenous Protected Area BushBlitz Survey: Survey of Mammals and Reptiles*. Report to the Kiwirkurra Indigenous Protected Area.

Cowan M.A. and How R.A. (2004) Comparisons of ground vertebrate assemblages in arid Western Australia in different seasons and different decades. *Records of the Western Australian Museum* 22, 91-100.

Cowan, M. A., Edinger, D. and Coate, K. (2017) Biodiversity in the southern rangelands: variation in biota over time and space on the Black Range and Lake Mason stations, Murchison Bioregion, Western Australia. *Conservation Science Western Australia* 12: 1 [online].

Dell, J., How, R.A, Milewski, A.V. and Keighery, G.J. (1988) The biological survey of the Eastern Goldfields of Western Australia. Part 5, Edjudina-Menzies study area. *Records of the Western Australian Museum* Supplement No. 31: 1-137.

Dell, J., How, R.A, and Milewski, A.V. (1992) The biological survey of the Eastern Goldfields of Western Australia. Part 6, Youanmi-Leonora study area. *Records of the Western Australian Museum* Supplement No. 40: 1-63.

Doughty, P. et al. (2011) Herpetological assemblages of the Pilbara biogeographic region, Western Australia: ecological associations, biogeographic patterns and conservation. *Records of the Western Australian Museum* Supplement No. 78: 315-341.

Gibson, L.A. and McKenzie, N.L. (2009) Environmental associations of small land mammals in the Pilbara region, Western Australia. *Records of the Western Australian Museum* Supplement No. 78, 89-120.

Hall, N.J., Keighery, G.J., McKenzie, N.L., Milewski, A.V., Rolfe, J.K. and Youngson, W.K. (1994) The biological survey of the Eastern Goldfields of Western Australia. Part 10, Sandstone-Sir Samuel and Leonora-Laverton study areas. *Records of the Western Australian Museum* Supplement No. 47: 1-166.

How, R.A, Dell, J., Milewski, A.V. and Keighery, G.J. (1992) The biological survey of the Eastern Goldfields of Western Australia. Part 7, Duketon-Sir Samuel study area. *Records of the Western Australian Museum* Supplement No. 40: 69-131.

Humphreys, W.F. (ed.) (1993) Biogeography of Cape Range, Western Australia. *Records of the Western Australian Museum* Supplement No. 45: 1-248.

Jonstone, R. E. (1990) Mangroves and mangrove birds of Western Australia. *Records of the Western Australian Museum* Supplement No. 32: 1-120.

McKenzie, N.L. and Burbidge, A.A. (eds) (1979) The Wildlife of Some Existing and Proposed Nature Reserves in the Gibson, Little Sandy and Great Victoria Deserts, Western Australila. *Wildlife Research Bulletin Western Australia* No. 8, 1-36 Department of Fisheries and Wildlife, Perth.

McKenzie, N.L. and Robinson, A.C. (eds) (1987) *A biological survey of the Nullarbor Region, South and Western Australia in 1984*. Pp 1-413. S.A. Department of Environment and Planning, W.A. Department of Conservation and Land Management and Australian National Parks and Wildlife Service.

McKenzie, N.L. and Bullen, R.D. (2009) The echolocation calls, habitat relationships, foraging niches and communities of Pilbara microbats. *Records of the Western Australian Museum* Supplement No. 78, 121-153.

McKenzie, N.L. and Hall, N.J. (1992) A biological survey of the eastern Goldfields of Western Australia. Part 8. The Kurnalpi - Kalgoorlie Study Area. *Records of the Western Australian Museum* Supplement No. 41, 1-125.

McKenzie, N.L. and Hall, N.J. (1994) A biological survey of the eastern Goldfields of Western Australia. Part 10. The Sandstone - Sir Samuel and Laverton - Leonora Study Areas. *Records of the Western Australian Museum* Supplement No. 47, 1-166.

Milewski, A.V., McKenzie, N.L., Hall, N.J., Keighery, G.J., Rolfe, J.K., Hnatiuk, R.J. and Youngson, W.K. (1992) The biological survey of the Eastern Goldfields of Western Australia. Part 8, Kurnalpi-Kalgoorlie study area. *Records of the Western Australian Museum* Supplement No. 41: 1-125.

Newbey, K.R., Dell, J., How, R.A, and Hnatiuk, R.J. (1984) The biological survey of the Eastern Goldfields of Western Australia. Part 2, Widgiemooltha-Zanthus study area. *Records of the Western Australian Museum* Supplement No. 18: 21-158.

Pianka, E. R. (1969) Habitat specificity, speciation, and species density in Australian desert lizards. *Ecology* 50: 498-502.

Pianka, H. D. and Pianka, E. R. (1970) Bird censuses from desert localities in Western Australia. *The Emu* 70: 17-22.

Richards, J. D. et al. (2011) Small mammal and reptile assemblages of the semi-arid woodlands and *Acacia* sandplains in the southern rangelands of Western Australia. *Conservation Science Western Australia* 8: 1-10.

Richards, J. D. et al. (2011) Terrestrial bird assemblages of the semi-arid woodlands and *Acacia* sandplains in the southern rangelands of Western Australia. *Conservation Science Western Australia* 8: 11-21.

Richards, J.D. and Wilson, B. (eds) (2008) A biological survey of Faure Island, Shark Bay World Heritage property, Western Australia *Records of the Western Australian Museum* Supplement No. 75: 1-75.

Richardson, J. et al. (2007) The flora and fauna of Legendre Island. *Conservation Science Western Australia* 6: 97-108.

Richardson, J., Watson, G. and Kregor, G. (2006) The distribution of terrestrial vertebrate fauna in the Montebello Islands. *Conservation Science Western Australia* 5: 269-271.

Storr, G. M. (1984) Birds of the Pilbara Region, *Records of the Western Australian Museum* Supplement No. 16: 1- 63.

Storr, G. M. (1985) Birds of the Gascoyne Region, *Records of the Western Australian Museum* Supplement No. 21: 1- 66.

Storr, G. M. (1985) Birds of the Mid-eastern Interior of Western Australia, *Records of the Western Australian Museum* Supplement No. 22: 1- 45.

Storr, G. M. (1986) Birds of the South-eastern Interior of Western Australia, *Records of the Western Australian Museum* Supplement No. 26: 1- 60.

Storr, G. M. (1987) Birds of the Eucla division of Western Australia, *Records of the Western Australian Museum* Supplement No. 27: 1- 81.

Van Leeuwen S (ed.) (2002). Biological survey of the south-western Little Sandy Desert: National Reserve System Project N709: final report, June 2002. Department of Conservation and Land Management, 122 p.

Burbidge, A.A. and McKenzie, N.L. (eds) (1983). Wildlife of the Great Sandy Desert, Western Australia. *Wildlife Research Bulletin Western Australia* No. 12. Department of Fisheries and Wildlife, Western Australia, Perth.

C: 'Northern' broad climatic region

Bradley, A.J., Kemper, C.M, Kitchener, D.J., Humphreys, W.F. and How, R.A. (1987) Small Mammals of the Mitchell Plateau Region, Kimberley, Western Australia. *Australian Wildlife Research,* 1987, 14**,** 397-413.

Burbidge, A.A. and McKenzie, N.L. (eds) (1978) The islands of the north-west Kimberley Western Australia. *Wildlife Research Bulletin Western Australia* No. 7: 1-47. Department of Fisheries and Wildlife, Western Australia, Perth.

Doughty, P. et al. (2012) Biogeographic patterns of frogs of the Kimberley islands, Western Australia. *Records of the Western Australian Museum* Supplement No. 81: 109-124.

Gibson, L. A. and McKenzie, N. L. (2012) Occurrence of non-volant mammals on islands along the Kimberley coast of Western Australia. *Records of the Western Australian Museum* Supplement No. 81: 15-40.

How, R. *et al.* (2006) Appraising vertebrate diversity on Bonaparte Islands, Kimberley, Western Australia. *The Western Australian Naturalist* 25: 92-110.

Jonstone, R. E. (1990) Mangroves and mangrove birds of Western Australia. *Records of the Western Australian Museum* Supplement No. 32: 1-120.

Kabay, E.D. and Burbidge, A.A. (eds) (1977) A Biological survey of the Drysdale River National Park, North Kimberley, Western Australia, in August, 1975. *Wildlife Research Bulletin Western Australia* No. 6: 1-133. Department of Fisheries and Wildlife, Western Australia, Perth.

Kitchener, D.J., (1978) Mammals of the Ord River Area, Kimberley, Western Australia, *Records of the Western Australian Museum* Supplement No. 6: 189-219.

McKenzie, N.L. (ed.) (1981) Wildlife of the Edgar Ranges area, south-west Kimberley, Western Australia. *Wildlife Research Bulletin Western Australia* No. 10: 1-70. Department of Fisheries and Wildlife, Western Australia, Perth.

McKenzie, N.L. (ed.) (1983) Wildlife of the Dampier Peninsula, south-west Kimberley, Western Australia. *Wildlife Research Bulletin Western Australia* No. 11: 1-83. Department of Fisheries and Wildlife, Western Australia, Perth.

McKenzie, N. L. and Bullen, R. D. (2012) An acoustic survey of zoophagic bats on islands in the Kimberley, Western Australia, including data on the echolocation ecology, organisation and habitat relationships of regional communities. *Records of the Western Australian Museum* Supplement No. 81: 67-108.

McKenzie, N.L., Fontanini, L., Lindus, N.V. and Williams, M.R. (1995) Biological survey of Koolan Island, Western Australia. Part 2, Zoological notes. *Records of the Western Australian Museum* Supplement No. 17: 249-266.

McKenzie, N.L., Johnston, R.B. and Kendrick, P.G. (eds) (1991) *Kimberley Rainforests of Australia.* Surrey Beatty & Sons, Sydney. 490 p.

Miles, J,M. and Burbidge, A.A. (eds) (1975) A Biological survey of the Prince Regent River Reserve, north-west Kimberley, Western Australia, in August, 1974. *Wildlife Research Bulletin Western Australia* No. 3: 1-113. Department of Fisheries and Wildlife, Western Australia, Perth.

Minton, C. et al. (2013) Wader numbers and distribution on Eighty Mile Beach, north-west Australia: baseline counts for the period 1981-2003. *Conservation Science Western Australia* 8: 345-366.

Olds, L. G. M. et al. (2016) Small terrestrial mammals on Doongan Station, in the Northern Kimberley bioregion, Western Australia. *Australian Mammalogy* 38: 164-176.

Olds, L. G. M. et al. (2016) The occurrence and relative abundance of small terrestrial mammals on Theda Station in the Northern Kimberley, Western Australia. *Australian Mammalogy* 39: 78-91.

Palmer, R. et al. (2016) A survey for Wijingadda (northern quoll *Dasyurus hallucatus*) and other fauna on islands in Dambimangari country in Talbot Bay (Kimberley, Western Australia). *Conservation Science Western Australia* 9: 1-12.

Palmer, R. et al. (2013) Islands and scales: a biogeographic survey of reptiles on Kimberley islands, Western Australia. *Records of the Western Australian Museum* Supplement No. 81: 183-204.

Pearson, D. J., Cowan, M. A. and Caton, W. (2013) The avifauna of larger islands along the Kimberley coast, Western Australia. *Records of the Western Australian Museum* Supplement No. 81: 125-144.

Start, A. N. et al. (2012) The status of non-volant mammals along a rainfall gradient in the south-west Kimberley, Western Australia. *Australian Mammalogy* 34: 36-48.

Start, T. et al. (2007) The status of mammals in the North Kimberley, Western Australia. *Australian Mammalogy* 29: 1-16.

Storr, G. M. (1980) *Birds of the Kimberley Division, Western Australia*, Western Australian Museum Special Publication No. 11: 1- 117.

Western Australian Museum (1981) Biological survey of Mitchell Plateau and Admiralty Gulf, Kimberley, Western Australia. pp 1-274. Western Australian Museum, Perth.

Appendix B:
A list of selected vertebrate fauna identification texts

Anstis, M. (2013) *Tadpoles and Frogs of Australia*. New Holland, Sydney.

Bush, B., Maryan, B., Browne-Cooper, R. and Robinson, D. (2010) *Field Guide to Reptiles and Frogs of the Perth Region.* Western Australian Museum, Perth.

Bush, B., Maryan, B., Browne-Cooper, R. and Robinson, D. (2007) *Reptiles and Frogs in the Bush: Southwestern Australia.* University of Western Australian Press, Perth.

Bush, B. and Maryan, B. (2011) *Field Guide to Snakes of the Pilbara, Western Australia*. Western Australian Museum, Perth.

Churchill, S. (2009) *Australian Bats*. 2nd ed. Allen and Unwin, Sydney.

Cogger, H. G. (2014) *Reptiles and Amphibians of Australia*. 7th ed. CSIRO Publishing, Sydney.

Higgins, P. J., *et al.* (eds) (1990-2006) *Handbook of Australian, New Zealand and Antarctic Birds*. Volumes 1 to 7. Oxford University Press, Melbourne.

Johnstone, R. E. and Storr, G. M. (1998) *Handbook of Western Australian Birds: Volume 1 – Non-passerines*. Western Australian Museum, Perth.

Johnstone, R. E. and Storr, G. M. (2004) *Handbook of Western Australian Birds: Volume 2 – Passerines*. Western Australian Museum, Perth.

Menkhorst, P. and Knight, F. (2010) *A Field Guide to the Mammals of Australia*. 3rd ed. CSIRO Publishing, Sydney.

Menkhorst, P., Rogers, D., Clarke, R., Davies, J., Marsack, P. and Franklin, K. (2017) *The Australian Bird Guide*. CSIRO Publishing, Sydney.

Morcombe, M. (2004) *Field Guide to Australian Birds*. Revised ed. Steve Parish Publishing, Brisbane.
Note – a companion app for mobile devices is also available.

Moseby, K.E., Nano, T. and Southgate, R. (2009) *Tales in the Sand: A Guide to Identifying Arid Zone Fauna Using Spoor and Other Sign*. Ecological Horizons, Adelaide.

Pizzey, G., and Knight, F. (2012) *The Field Guide to the Birds of Australia*. 9th ed. Harper Collins, Sydney.
Note – a companion app for mobile devices is also available.

Simpson, K. and Day, N. (2010) *Field Guide to the Birds of Australia*. 8th ed. Viking, Melbourne.

Slater, P., Slater, P., and Slater, R. (2009) *The Slater Field Guide to Australian Birds*. 2nd ed. New Holland, Sydney.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1983) *Lizards of Western Australia. II. Dragons and Monitors*. Western Australian Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1986) *Snakes of Western Australia. Western Australian Museum*, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1990) *Lizards of Western Australia. III. Geckos and Pygopods*. Western Australian Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1999) *Lizards of Western Australia. I. Skinks.* Revised ed. Western Australian Museum, Perth.

Triggs, B. (2004). *Tracks, Scats and Other Traces: A Field Guide to Australian Mammals*. Revised ed. Oxford University Press, Melbourne.

Tyler, M.J. and Doughty, P. (2009) *Field Guide to Frogs of Western Australia*. 4th ed. Western Australian Museum, Perth.

Tyler, M.J. and Knight, F. (2011) *Field Guide to the Frogs of Australia.* CSIRO Publishing, Sydney.

van Dyck, S., Gynther, I. and Baker, A. (2013) *Field Companion to The Mammals of Australia*. New Holland, Sydney.

van Dyck, S. and Strahan, R. (editors) (2008) *The Mammals of Australia*. 3rd ed. Reed New Holland, Sydney.

Wilson, S. and Swan, G. (2017) *A Complete Guide to Reptiles of Australia*. 5th ed. New Holland, Sydney.

Environmental Protection Authority 2020, *Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment*, EPA, Western Australia.

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