Technical Guidance

Sampling methods for Terrestrial vertebrate fauna

The content of this Guidance has not yet been updated to reflect the EPA's framework for environmental considerations in environmental impact assessment

Environmental Protection Authority

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GOVERNMENT OF WESTERN AUSTRALIA

Department of Environment and Conservation

Technical Guide - Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment

Technical report of the Environmental Protection Authority and the Department of Environment and Conservation




Edited by B.M. Hyder, J. Dell and M.A. Cowan

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Front cover-left to right
Kultarr (*Antechinomys laniger*) – Mark Cowan
Western Bluetongue (*Tiliqua occipitalis*) – Gary Porter
Splendid Tree Frog (*Litoria splendida*) – Mark Cowan
Red-eared Firetail (*Stagonopleura oculata*) – Gary Porter

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Pit trap-line at Lorna Glen – Mark Cowan

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1.0 Introduction

1.1 Background and objectives

Protection of biological diversity is a key environmental factor for the Environmental Protection Authority (EPA) when assessing proposals. The purpose of this guide is to ensure adequate data of a high standard is obtained for environmental impact assessment. This guide provides greater detail on: the EPA and Department of Environment and Conservation's (DEC's) expectations for undertaking the different levels of survey (Level 1 and Level 2) outlined in Guidance Statement No. 56 (EPA 2004); fauna survey protocols; methodology; analysis and reporting. However, it is recognised that surveys need to be conducted by practitioners with the appropriate level of expertise to conduct an acceptable survey.

This guide provides advice on fauna sampling techniques and methodologies for different regions of the State and the analysis, interpretation and reporting requirements for EIA. It draws on the wealth of knowledge of biological surveys by personnel from government departments, consultants and academia. It should be read in conjunction with EPA Guidance Statement No. 56 (EPA 2004) and any subsequent revision.

1.2 Application of this guide

This guide is intended for use when planning and undertaking terrestrial vertebrate fauna surveys for assessment of the impacts of development generally (including new infrastructure, mining and native vegetation clearing) rather than just the projects that are submitted for formal assessment under Part IV of the *Environmental Protection Act, 1986*. This guide provides detail on the different levels of terrestrial vertebrate fauna surveys. Where a proposal is part of an EPA assessment the Office of the Environmental Protection Authority (OEPA) should be the primary decision making contact, for other assessments the DEC is the primary contact.

This guide is specific to terrestrial vertebrate fauna. Other faunal groups are covered by other statements including:

- EPA Guidance Statement No. 54 *Guidance for the Assessment of Environmental Factors – Consideration of Subterranean Fauna in Groundwater and Caves* (EPA 2003);

- EPA Guidance Statement No. 54a (Technical Appendix to Guidance Statement No. 54) *Sampling Methods and Survey Considerations for Subterranean Fauna in WA* (EPA 2007) deals specifically with stygofauna and troglofauna; and

- EPA Guidance Statement No. 20 *Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA 2009).

2.0 Protocols prior to survey

Prior to undertaking a fauna survey, consideration needs to be given to obtaining land access and formal approvals required to conduct the survey. These are discussed below. It is assumed that proponents will consider occupational health and safety issues when undertaking field work which is often conducted in remote and difficult terrain.

Fauna surveys should be coordinated by fauna specialists experienced in the region being surveyed. Survey personnel must have appropriate skills and experience in survey techniques and the identification of fauna species. Team members who are less experienced in fauna surveys should be supervised by an experienced specialist. Each survey should include at least one person experienced in each of the groups being surveyed, this includes the experience to recognise when a species is new or outside its normal range.

2.1 Access to land

Approval to access land needs to be sought from the land owner or manager. For example when surveys are to be undertaken on lands managed under the Conservation and Land Management Act (e.g. National Park, Nature Reserve, Conservation Park) a Regulation 4 (*Conservation and Land Management Regulations 2002*) authority needs to be obtained from DEC prior to commencement of a survey. Permission to access lands vested in Aboriginal Land Councils, pastoral lease or freehold land must be obtained from the leaseholders or owners before entering land within their boundaries.

There is a legislative obligation (in the form of licence conditions) for survey practitioners to inform the relevant DEC Regional or District Office if survey and vouchering are to be undertaken in their region.

2.2 Legislation

When undertaking fauna survey all relevant legislation and/or agreements must be complied with. A range of legislation and agreements relevant to biodiversity conservation in Western Australia should be consulted including:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- *Wildlife Conservation Act 1950*;
- *Conservation and Land Management Act 1984*;
- *Environmental Protection Act 1986* (EP Act);
- *Animal Welfare Act 2002*;
- *The Convention on Wetlands of International Importance* especially as waterfowl habitat (Ramsar Convention) 1971;
- *Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment* (Japan-Australia Migratory Bird Agreement – JAMBA published as “Australian Treaty Series 1981 No. 6” by the Australian Government Publishing Service, Canberra, 1995);
- *Convention on the Conservation of Migratory Species of Wild Animals* (the Bonn Convention, 1979) published October 2003;
- *Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment* (China-Australia Migratory Bird Agreement – CAMBA published as “Australian Treaty Series 1988 No. 22” by the Australian Government Publishing Service, Canberra, 1995); and
- *Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds* (Republic of Korea-Australia Migratory Bird Agreement – RoKAMBA published as “Australian Treaty Series 2007 ATS 24” by the Australian Government Publishing Service, Canberra, 2007).

2.3 Licences and ethics

Licences are required to trap or collect fauna, including the taking of voucher specimens. Licences are also required in order to gain access to the lands or waters managed by the DEC. Additionally, all levels of survey will require consideration of animal ethics.

2.3.1 Fauna permits and vouchering

All survey personnel involved in the taking of fauna must hold a current and applicable Regulation 17 "Licence to Take Fauna for Scientific Purposes" from the DEC prior to commencement of each fauna survey. The Department's Nature Protection Branch is responsible for administering fauna licences in accordance with the *Wildlife Conservation Act 1950*.

Applications for Regulation 17 licences will take time to process, especially if insufficient information is provided initially. Ensure that adequate time is allocated to obtaining the licence prior to commencing field surveys. Surveys must be carried out in accordance with the conditions attached to the licence. Any vouchered specimens must be lodged with the Western Australian Museum. Advice on specimen submissions and requests for identification is available on the Museum website.

Fauna should be vouchered if:

- they have been specifically requested during discussion with the Western Australian Museum;
- they cannot be identified with confidence in the field (this should not be taken as an invitation to allow inexperienced field staff to undertake surveys and then rely on the WA Museum to confirm the identification of fauna collected); or
- they exhibit a significant range extension.

The number of specimens vouchered should be kept to a minimum while still achieving the objectives of the survey. In some cases, photographs, audio recordings or hair samples may be an effective and less invasive method of validating identification. These data should be lodged with the State's collections housed at the WA Museum for permanent reference. It is important to recognize that diagnostics are different for each taxonomic group, be it genus or family, and suitable field guides need to be checked or appropriate expert advice sought regarding which types of fauna are suitable for identification from photographic images.

A DEC licence, either Regulation 17 or Regulation 23 (Licence to take and mark fauna for research purposes), is required to operate mist nets for birds or bats.

2.3.2 Animal ethics considerations

Welfare of the animals (both target species and by-catch) should be of primary concern during fauna surveys. The provisions of the *Animal Welfare Act 2002* apply and should be adhered to when undertaking fauna surveys. The *Animal Welfare Act 2002* prohibits cruelty to and other inhumane or improper treatment of animals (fauna) and reflects the community's expectation that people who are in charge of animals will ensure that they are properly treated and cared for.

Any person catching or handling wildlife for 'scientific purposes' also requires a licence issued under the provisions of the *Animal Welfare Regulations (Scientific Purposes) Regulations 2003*. These licences can be obtained from the Department of Local Government.

In addition, Section 5 of the *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes* (NHMRC, 2004) details animal ethics requirements for wildlife studies and these should be adhered to at all times.

If an animal is in ill health or badly injured, it may be necessary to euthanase using methods approved in the *Australian Code of Practice for the Care and Use of Animals* (2004) (http://www.nhmrc.gov.au/publications/synopses/eA16syn.htm). The Australian and New Zealand Council for the Care of Animals in Research and Teaching has guidelines *Euthanasia of Animals for Scientific Purposes* (ANZCCART, 2001) that detail methods of euthanasia which conform to the Australian Code of Practice, and highlight methods that are not acceptable.

Ways of reducing the impact of survey activities on the welfare of animals are also referred to below in Section 4.0 Sampling techniques.

2.3.3 Wildlife disease considerations

Diseases borne by wild animals can be transferred between animal populations and humans via contaminated traps, holding bags, waders, boots, nets and temporary housing/caging. As a precautionary principle effective hygiene should be adopted to minimise the risk.

Bats have the potential to carry Lyssavirus, a genus of viruses closely related to the Rabies virus. For this reason it is essential that anyone handling bats is vaccinated against Rabies. Since this does not guarantee immunity it is essential to take the utmost care to avoid bites or scratches when handling bats and if these do occur, medical advice should be sought.

For information on the risks associated with working with wildlife and the steps necessary to minimise the risks to staff and wildlife see Chapman *et al*. (2008).

3.0 Guide to levels of survey

A critical first step before commencing a survey for an environmental impact assessment is to determine the purpose and outcomes of the study. EPA Position Statement No. 3 (EPA 2002) and Guidance Statement No. 56 (EPA 2004) outline two levels of survey required for EIA (Level 1 and Level 2) depending on the requirements of the individual situation. A decision on the level of survey required should be determined using Guidance Statement No. 56 (EPA 2004) and in consultation with the OEPA (EPA assessments) or DEC (other assessments) where appropriate.

This guide discusses sampling techniques for baseline terrestrial vertebrate fauna surveys and cover an array of methods for most terrestrial vertebrate faunal groups. In situations where a targeted survey rather than a detailed survey is considered appropriate, surveyors should consult with the OEPA or DEC (see above) and provide justification for methods proposed.

3.1 Level 1 survey

A Level 1 survey consists of a desktop study and basic ground truthing through a reconnaissance survey.

The purpose of the desktop study is to gather background information on the project area by searching literature and data sources and map-based information.

The reconnaissance survey should verify the accuracy of the desktop study, delineate and characterise the fauna and faunal assemblages present in the project area, and identify potential impacts. This involves a site visit by suitably qualified personnel to provide habitat descriptions and habitat maps of the project area and undertake selective, low intensity sampling of the fauna and faunal assemblages. The information collected will help determine if a Level 2 survey will be required and/or whether it will target a particular species or group of species.

Desktop study

A thorough desktop study is fundamental to a well planned on-ground survey that maximises outcomes in the time available. Information collected as part of a desktop study will help determine the level of survey necessary. Desktop studies should cover:

- Information collected from databases (for example Naturemap http://naturemap.dec.wa.gov.au/default.aspx or Birds Australia) should be searched and reported on, including an indication of the likelihood of each species occurring based on the presence of suitable habitat;

- The characteristics of all elements of the proposal including: a detailed description of the location and scope of the proposal and the intensity, scale and duration of potential direct and indirect impacts;

- The nature of the environment including: background information on the project area and the surrounding region; a comprehensive listing of species that are known from or likely to occur based on habitats present; and species of conservation significance, habitats, ecosystems or communities of conservation significance which may occur in the area. This information should be put into a regional context;

- Where major surveys have previously been undertaken within the relevant region information derived from these should be used to put the proposal area into a regional context. Appendix 1 has a selection of references for the different regions of Western Australia. DEC and the WA Museum library catalogues are available on the web:
  http://www.dpaw.wa.gov.au/about-us/science-and-research/publications-resources/110-conservation-library
  http://www.museum.wa.gov.au/collections/library/library.asp; and

- A summary of the potential direct and indirect impacts of the proposal.

Reconnaissance survey

Methods adopted for reconnaissance surveys will differ according to the types of habitats present and the faunal groups and conservation significant fauna that are likely to be present. Survey techniques for different fauna groups are described in Section 4. Advice on survey timing for targeted fauna species should be sought through consultation with relevant experts including the OEPA, DEC and the Western Australian Museum. If habitat suitable for conservation significant fauna is present, targeted searches will need to be conducted and information on the size and extent of the population obtained to determine any obvious threats as part of a Level 2 survey. Results from the reconnaissance survey should then be used to determine whether a targeted or comprehensive Level 2 survey is required.

3.2 Level 2 survey

If the Level 1 survey indicates the need for further work through a Level 2 survey it may range from a targeted survey of selected species to a comprehensive survey.

If a region is well surveyed but conservation significant fauna were identified during a Level 1 survey as possibly occurring then a targeted survey may be required for these species. The methods of survey and selection of groups identified for a targeted survey must be agreed upon by OEPA prior to the survey.

A Level 2 Survey provides information on the project area through one or more visit/s in each season appropriate to the bioregion and the faunal group being surveyed. Surveys should be conducted during the season of maximum activity of the targeted faunal group which will depend on the region as outlined in Section 5.2. Generally, comprehensive surveys will follow the season of maximum rainfall whilst targeted surveys will need to be timed according to seasonal activity patterns of the targeted faunal groups (e.g. amphibians are best sampled during wet conditions). The area of survey may need to be extended beyond the project area, where regional information is poor.

4.0 Sampling techniques

A wide variety of detection techniques and sampling designs are used in fauna surveys. The applicability of these varies in relation to the targeted species or assemblages, nature of the environment, weather conditions, and purpose of the overall study as outlined for reptiles and mammals by Garden *et al.* (2007).

This guide discusses sampling techniques for baseline terrestrial vertebrate fauna surveys and covers an array of methods for different terrestrial vertebrate groups. Where a targeted survey rather than a detailed survey is considered appropriate, surveyors should consult with the OEPA and provide justification for the methods proposed.

Some sampling techniques may be more productive than others. This guide is not prescriptive about the use of any particular technique but highlights the benefits and shortcomings of the different techniques to aid survey zoologists in making appropriate choices. Potential appropriate techniques for the recommended faunal groups are provided in Table 1 and outlined below.

Many of the trap types discussed below regularly capture venomous vertebrates and invertebrates and field practitioners need to exercise appropriate levels of caution when checking and clearing traps.

4.1 Pit traps

Pit trapping in various forms and configurations has been used for many years. It is particularly productive for sampling small to medium sized reptiles and mammals. Standardised design of trap configurations and survey timing permit more robust analyses of data than do less quantitative survey methods such as hand collecting. However, when pitfall trapping for reptiles at cooler times of the year is not particularly effective (see Figure 1) searching can produce good results, provided the practitioner is already competent in these techniques.

Pit traps are usually a form of plastic bucket or PVC pipe buried with the open top flush to the ground, thus providing a means of passively capturing either unsuspecting animals that fall in, or overly inquisitive animals that deliberately enter. They vary in depth and diameter but typical dimensions that are effective for general survey are 20L plastic buckets (450mm deep x 300mm wide) and PVC pipe (600mm deep x 150mm wide). A variety of modifications can be made, for example the incorporation of funnels, to enhance the effectiveness of shallow pits. This restricts the aperture through which animals can escape.

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 150 mm PVC Pipe (Cowan 2004), but the increased depth of PVC pipe (600 mm) is advantageous in retaining some species that are effective jumpers, for example, hopping-mice (*Notomys* spp.) and Mulgara (*Dasycercus cristicauda*) (M. Cowan unpublished). Providing elevated pit-trap covers to shield the bucket from rain or to prevent overheating of captured animals can also increase capture rates of some reptile species (Hobbs *et al*. 1999).

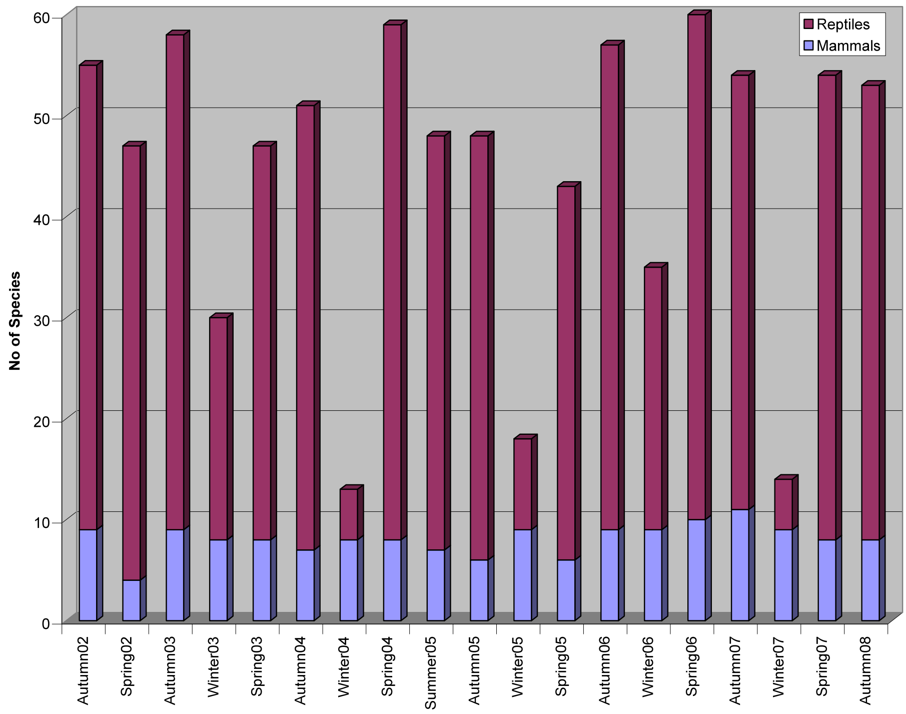


Figure 1. Richness of pit trapped vertebrates from a Goldfields study site (Lorna Glen Station) in different seasons and years (M. Cowan unpublished data).

Previously, pit traps were used without fences but it is now common practice and considerably more efficient to use "drift fences" of flywire, or some similar barrier, running over the centre of a pit and often linking together a number of equidistantly spaced pits (Webb 1999). These fences are buried at their base and are usually 20 to 30 cm in height. Drift fences direct animal movement towards the pits thus increasing the likelihood of capture. Moseby and Read (2001), in their study of chenopod shrublands in South Australia, found that capture rates where trap arrays incorporated fences were up to five times greater than those that did not.

The design of pit trap arrays has been assessed by a number of authors (Friend 1984; Friend *et al*. 1989; Hobbs *et al*. 1994; Morton *et al*. 1988; Rolfe and McKenzie 2000) and while it is recognised that traps are most effective when used in conjunction with a drift fence the configuration of pits along such a fence is still the subject of frequent debate. For example, should traps be positioned singly, in pairs or in larger numbers along a continuous fence line, and what spacing should exist between traps? There are some logical aspects to note in these design considerations that should help in devising a suitable trapping design.

If traps on a long drift fence line are positioned too close together they make each other partially redundant as an animal caught in one trap may otherwise have continued on and been captured in the next trap, had the first not been present. It may also be the case that if spacing between traps is too great, then some animals will turn away from a fence and not be captured at all. However, providing there are enough traps in the overall sampling design, this is not a significant issue as most of the effort in establishing a trapping grid, particularly in hard substrate, is usually invested in installing the pits rather than the fence. It is therefore important to ensure captures per trap are maximised and this is achieved by having an appropriate distance between traps (see section 5.5 below).

If a single trap is located in the centre of a drift fence it can be expected that at least 50% of animals coming into contact with the fence will miss the trap. If animals contact the fence to the left of the trap and continue to move left they will miss the trap and similarly if contact is to the right of the trap and they move right they will also avoid the trap.

It is advisable to check the area for ant foraging trails prior to installation of pit traps and practitioners must be prepared to close individual traps or entire lines should ants become unmanageable.

Overheating is also a potential problem in bucket-type pits, especially in northern latitudes in late spring-early summer, when the sun is at its highest; under these conditions, temperatures in uncovered buckets can reach 66^{o}C (Hobbs and James 1999). The pits themselves need to be shaded, or adequate amounts of shelter need to be placed within the pits, and it may be necessary to check pits more frequently than once a day, or to close them under really hot conditions. This is less of a problem with deep, narrow pits.

4.2 Funnel traps

Funnel traps have been utilised in various forms overseas for many years (Fitch 1951; Clark 1966; Hall 1967), although their common use in Australia has only occurred relatively recently. Funnel traps are generally made from some form of mesh (e.g. dense shade cloth) covering a wire framed rectangular prism with small opening funnels at either end. Laid parallel to a drift fence, animals may enter the internal space through either funnel but have difficulty in finding a way out.

Most survey work using funnels has involved the placement of pairs of funnels, one either side of a drift fence, alternating with pit traps along the fence. While there have been studies comparing effectiveness of funnels to pits (in North America e.g. Crosswhite *et al.* 1999 and Maritz *et al*. 2007; and in Australia Thompson and Thompson 2007a) the trap types have generally not had true independence from each other and therefore inferences as to the advantages and disadvantages of either type are somewhat clouded. What does appear to be the case though is that funnels are effective in capturing reptiles such as snakes and some larger varanids that readily escape from pit traps and there may be other reptile groups that they are at least as effective in capturing as are pits, although this is unclear at this stage. Funnels do not appear to be effective in capturing mammals. A significant advantage of funnels is their ease of deployment in sampling areas where the substrate precludes establishment of pit lines, such as on granites or other similarly hard surfaces.

As funnel traps are positioned on the surface they have even greater exposure to temperature variability and extremes than the bottom of pit traps, so their use in hot conditions should be considered very carefully or avoided. Where possible, and if the sampling design permits, they should be positioned under natural shade but failing this, adequate shade and insulation may be provided through covering the top with grass, Spinifex or leaves etc. If it is necessary to operate in extreme conditions (i.e. summer months through the semi-arid to arid parts of the state) and if adequate protection or insulation from radiant heat cannot be provided, then leaving the trap so it cannot catch animals following the morning check, and returning in the late afternoon to re-set the funnel, should be considered as death from exposure to daytime captures is almost certain.

4.3 Aluminium box traps

Elliott and Sherman traps are brands of collapsible aluminium box traps. Aluminium box traps are available in a variety of sizes ranging from 8 x 9 x 32 cm to 15 x 15.5 x 46 cm. They all operate by means of a trigger plate on the floor of the trap, which is set off when the animal enters, allowing a hinged door to flick up into the closed position. Animals are enticed into the traps through use of bait, usually a ball of oats and peanut butter but sometimes with other additives such as bacon, sardines, fruit, honey, truffle oil, etc, depending on the target species.

A number of important considerations should be taken into account when using bait in traps. Firstly, some additives may increase the likelihood of ants being attracted to the trap thus increasing the risk of ant attack on captured vertebrates. Secondly, the inclusion of sardines or other fish can pose a health risk to animals if they have "gone off" prior to ingestion. Therefore it is essential to replace bait daily where these ingredients are used.

Aluminium box traps are typically used in arrays or along transects and are useful in capturing most rodent species (larger rodents e.g. *Rattus fuscipes* may eat their way out) and larger marsupials including quolls, Mulgara, bandicoots and possums, providing the appropriate sized traps are used for the expected fauna. Aluminium box traps do not appear to be particularly effective for many small dasyurids or most reptile species although they have worked for targeted collection of certain species including the Kultarr (*Antechinomys laniger*), skinks (e.g. *Ctenotus inornatus, C. leonhardii*) and some varanids (e.g. *Varanus acanthurus*). Captures of a variety of other reptile species may occur occasionally, but not reliably.

A number of important issues require consideration when using aluminium box traps. Traps should be located to avoid large numbers of ants and daily observations are required to ensure that ants are not becoming a potential animal welfare risk (see Section 2.3 Licences and ethics). Traps should be stable when deployed and checked to ensure they are working well. Both cold and hot conditions may also present problems for animal welfare as aluminium is an excellent thermal conductor.

Where possible, traps should always be placed to take advantage of natural cover and insulation so that the trap does not get over-heated prior to being checked in the morning. Traps should be checked more regularly or closed if there is a risk of animals overheating. Where overnight conditions may be very cold, some form of insulative material should be placed in the trap to form a barrier between the animal and the aluminium surface. If wet conditions are expected, through rain or condensation, traps can be inserted in sturdy plastic bags such as those used by the mining industry for soil samples.

Distance between individual traps usually ranges from 10 to 20 metres and the overall layout may incorporate a combination of different size aluminium box traps.

Experience in a number of regions has shown that capture rates in aluminium box traps often improve after several days, perhaps because animals are initially wary of alien objects with shiny metallic surfaces or unfamiliar scents. Whatever the reason, it is essential to not only consider adequate effort in terms of trap numbers but also to ensure that survey work is undertaken over a sufficient number of days to give the best chance of detecting species (James 1994; Moseby and Read 2001).

4.4 Cage traps

Cage traps made of wire mesh are available in a variety of sizes ranging from those suitable for rodents, bandicoots and possums up to sizes large enough for rock wallabies. They operate through a treadle and wire link holding open a door. To access the bait the animal must cross a treadle, at the back of the trap, which causes the trap door to be released and locked in a closed position. Traps are available in a rigid or collapsible form, the latter being particularly suitable where large numbers require transportation or carrying any distance. However, even the collapsible type are quite cumbersome to handle, transport and set out, so if the expected species all fall within the size range that aluminium box traps are effective for, or are known to be readily captured in, they may be a preferable alternative. Traps made out of fabric have disadvantages as animals have been known to eat their way in or out of the trap.

Cage traps are used for larger mammal species such as Quokka (*Setonix brachyurus*), Water-rats (*Hydromys chrysogaster*) and Chuditch (*Dasyurus geoffroii*). As mammals of this size range are now predominantly confined to the South West and the Kimberley regions of WA the value of this type of trap through much of WA's more arid regions is often rather limited, and therefore not essential as a standard trapping method. However they are used in the arid zone for species such as the Bilby (*Macrotis lagotis*).

Cage traps may be used as the sole trap type, usually for species-specific projects, or in combination with other types such as aluminium box traps for more general survey and where larger mammal species are expected to occur. As with other trapping designs, the layout of such traps may be along a transect, or as part of an array or grid design. When cage traps are used they can be placed considerably further apart than aluminium box traps as the target species are usually larger and have greater home ranges. A study of Chuditch by Wayne *et al.* (2008) showed that the most efficient trap densities for this species was a spacing of 200 metres between traps along transects.

Similarly to aluminium box traps, cage traps require careful placement to minimise exposure to the elements. Additional protection may be provided by placing a hessian sack, calico bag or other insulative material over the traps. This also aids in keeping captured animals calm when the traps are approached for inspection, thus minimising the risk of injury to the animals. Occasionally animals suffer abrasion to snouts and limbs trying to escape through the wire, this should be carefully monitored.

The type of bait used is generally the same as for aluminium box traps and will depend on the species targeted or expected to occur. Surveys targeting particular species, e.g. the carnivorous Chuditch can result in higher capture rates if bait type includes lures favoured by the target species but not favoured by other species (Wayne *et al.* 2008). Care should be taken with bait to minimise the risk of ant attack and bait going off.

4.5 Observation

There are a number of observational activities that are usually required for effective fauna survey, as trapping and other techniques alone are unlikely to maximise detection of species present in an area. These techniques may include:

- Spotlighting/headtorching;
- Active searching;
- Searching for tracks and other signs;
- Bird observation; or
- Bird or frog calls (including recording).

Each of these techniques is relevant to specific faunal groups and requires some degree of expertise to maximise the information gained for the effort undertaken. Less experienced individuals will invariably detect fewer species than those who are more experienced; as a result consideration should be given to how equal and adequate effort is applied to each site. A good summary of the use of these techniques for herpetofauna survey can be found in Bush *et al.* (2007).

It is also important to record all vertebrate fauna while travelling between sites in the survey area as additional species may be encountered that are not recorded from actual survey sites.

4.5.1 Spotlighting/headtorching

Spotlighting and headtorching at night from vehicles and on foot are important survey techniques as much of our fauna is nocturnal or crepuscular, particularly many threatened taxa, and many of these are more often observed than trapped. Undertaking night work is currently outside the safety guidelines of many industries. Night survey work needs to be incorporated into safety guidelines to ensure night time work can be undertaken. Otherwise survey work at night may be limited and consequently this will affect the quality and comprehensiveness of data provided for assessment.

Spotlighting may be useful for a variety of species including mammals, nocturnal birds, geckoes, snakes and frogs. Spotlighting can be done from a vehicle which covers large distances along roads and tracks. Portable spotlights can be used while walking to investigate at a finer scale or in areas where vehicle access is not possible.

Some species will remain motionless when caught in the high intensity beam of a spotlight and may be difficult to see, e.g. quails, while others will immediately take flight and be difficult to identify. It is therefore essential that some idea of what may be encountered is known beforehand and that experienced individuals are involved in the exercise. Spotlighting on foot may be effective for cryptic species such as button-quails which may otherwise be unseen. Some nocturnal bird species are sensitive to disturbance, for example, Grass Owls and Masked Owls are particularly sensitive during the breeding season and Bush Stone-curlews will abandon nests if repeatedly disturbed (DEC NSW 2004).

Spotlighting from a vehicle may involve a number of people searching with a spotlight, recording and catching fauna as required. Fauna observations are made as the vehicle is driven at low speed, along a predetermined transect. Where fauna cannot be immediately identified it may be necessary to stop the vehicle so the surveyor can collect/observe fauna. When spotlighting from a vehicle, consideration should be given to preparing operating procedures to ensure the safety of the personnel participating in the spotlighting.

The dimmer light (compared with spotlights) makes headtorching a more useful method for detecting the eye shine of vertebrates like geckoes and frogs. In general, the light colour from incandescent lights is better than that from the newer LED torches, particularly for seeing reflected eye shine, but this is somewhat of a personal preference.

Both spotlighting and headtorching are most productive for reptiles on warm evenings (Read and Moseby 2001) when activity for many species becomes elevated. However, cooler conditions should not necessarily negate undertaking night work. Headtorching for frogs is most successful after rains.

4.5.2 Active searching

Active foraging for reptiles and amphibians will involve searching particular microhabitats and may include digging up burrows, turning over rocks and logs, splitting fallen timber, raking soil and leaf litter, peeling off bark and searching soil cracks around water bodies and holes in fence posts. Effective active searching requires some knowledge of which species could be present in an area and their specific habitat preferences. Active searching can be physically demanding, particularly in warm conditions. Timing is important as in hot and dry conditions reptiles are hard to detect and with high body temperatures they may also be very quick and elusive. Therefore, in hot conditions searching early in the day may yield the best results. This method frequently provides considerable supplementary information to trapping programs as many species that may have low capture rates in traps, may be readily caught by hand, for example when trapping reptiles at cooler times of the year (see Figure 1). It is important to minimise impact on habitat and all rocks, logs and debris should be returned to their original location and orientation where possible.

4.5.3 Searching for tracks and other signs

Searching for tracks, diggings, nests, scats, claw marks on tree trunks and other signs requires persistence, well developed observational skills and knowledge of the natural history of the local fauna. These activities are well suited to detecting species that are not readily trapped because they are either too large (e.g. some varanids), avoid traps (e.g. arboreal species) or are at low densities (e.g. some snakes). Species with clumped distributions, for example Mulgaras (*Dasycercus cristicauda*) or Bilbies (*Macrotis lagotis*), are often difficult to detect with standardised trapping regimes but may be readily detectable through observation as much larger areas can be assessed than just the specific trapping locations.

Sand is an ideal substrate for looking for tracks although wind and rain will often mask these quite quickly, particularly for small animals that only make shallow impressions. Diggings often occur in a variety of substrates and can last for quite some time, often many months or even years after an animal has been present, so detection of these may only indicate general or historical usage of an area but not necessarily presence at the time of observation. Therefore it is often desirable to undertake targeted trapping or some other form of confirmation to be certain of correct identification and determine the continued presence of a species of interest.

4.5.4 Bird observation

Birds are one of the more readily observable faunal groups and there have been a wide variety of methods proposed for standard site assessment (Bibby *et al*. 2000; Craig 2004; Craig and Roberts 2001; Gregory *et al.* 2004; Loyn 1986). These may incorporate fixed time and position counts; transect searches, area searches or variations and modifications to any of these techniques.

Bird surveys should be conducted in the period of optimal activity. Typically this may be post-dawn and before dusk, but in hot climates in very open habitats, such as low sparse samphire, survey may need to begin before dawn, as the dawn chorus might be the only time that some species can be readily detected. Bird activity is lower in wet, windy or extremely hot conditions.

Birds can be recorded in terms of presence/absence or a measure of abundance. It takes much more effort to get abundance data compared to presence/absence data. Abundance data can be important in providing information on the comparative importance of different habitats, provided allowance is made for bias caused by visibility differences between habitats. In addition, it is often important to understand temporal variation in abundances before spatial variation in abundance can be interpreted (e.g. Ives and Klopfer 1997).

Birds often respond to different components of the environment compared with terrestrial species, and ideal locations for trapping grids may not represent the ideal location for conducting bird surveys. Therefore the location of trapping grids will not always be the optimum location for bird survey. For example a stand of flowering grevilleas is likely to yield additional bird species.

All of these methods are highly observer dependent and different individuals will have varying degrees of success. To reduce these biases it is important to record sites a number of times and, where multiple observers are involved, ensure that each site is not consistently assessed by the one observer who may be more or less skilled than others on the project, i.e. rotate the skill levels across all sites to ensure some degree of consistency. Alternatively two or more observers may work at the same site concurrently. Imitating the calls of a bird will frequently entice a variety of species in close so as to allow a visual identification.

Two common methods for bird surveys are area searches and point counts. Area searches involve walking around a designated area for a pre-determined period of time. The Birds Australia Atlas project uses 20 minute surveys where an experienced ornithologist records numbers of each species seen while actively searching a 2 ha area. Area searches can be used for either density estimates (especially in open habitats) or for species richness studies. Larger areas (e.g. 16 ha) will be more appropriate in arid regions. Point count methods involve making observations from a pre-determined series of points or habitats for a pre-determined period of time. For example, York *et al.* (1991) conducted a series of 10 minute observations at five points, 100 m apart along a 500 m transect. Such methods are most appropriate for population density estimates in dense habitats.

Both area searches and point counts have advantages and disadvantages, and the choice of technique will depend on the objectives of the survey. If the aim of the survey is to record a species inventory and obtain the most species in the shortest amount of time, an area search has a slightly higher chance of recording small cryptic species. Walking through the habitat also increases the chance of flushing more cryptic species. Some species may require specific search techniques. For example, raptors tend to use thermals on warm days and can be spotted from high ground overlooking the canopy.

The timing of surveys should take into account seasonal migrants e.g. waders (especially as many of these are listed in International Agreements), cuckoos and some nectarivores. If appropriate habitat is present for internationally listed migratory species then a survey must be conducted during the appropriate season when maximum numbers of these migratory species are likely to be present. A number of other species also have smaller seasonal migrations within WA (e.g. some insectivores, nectarivores and raptors) and need to be recognised. If surveys cannot be conducted in the correct season this should be listed as a limitation in the report.

The amount of time spent surveying each site will depend on the nature of the habitat. Complex habitats are likely to have higher species richness. Dense vegetation may require more survey effort than open vegetation where species are easier to detect. Some species such as quail-thrushes and fieldwrens can be difficult to detect in dense habitats.

The area and habitat being assessed should be accurately defined. Only the species observed within the defined area should be assigned to that site, as the inclusion of species from peripheral areas or habitat types may lead to erroneous interpretation of site results. However, all observations during a survey should be recorded but particular care should be taken as to what habitat they are assigned.

The identification of waterbirds especially migratory shorebirds can be particularly difficult compared to other birds (observed from great distances e.g. mud flats, middle of lake;

different stages of moult affecting plumage colour and presence of vagrants) and it is important that surveyors have experience in their identification and survey techniques. Survey for migratory shorebirds will be necessary at sites where no suitable survey records exist, records are too old to be considered reliable, or the site characteristics have changed since previous surveys were conducted (DEWHA 2009).

Count surveys are the preferred technique for migratory shorebirds. However, when it is not possible to survey the site during the appropriate time, and good regional information is available, a thorough habitat assessment will identify potential habitat. The characteristics of the site (landform, hydrology, flood levels, etc.) should be assessed and used to predict the extent of migratory shorebird habitat. Where possible, survey methodologies should be consistent to allow comparison between data sets. Methods for counting migratory shorebirds are outlined by DEWHA (2009).

Many non-tidal areas used by migratory shorebirds are ephemeral. Surveys of non-tidal wetlands may be more difficult than coastal tidal wetlands as roosting and foraging behaviour is less predictable. Survey should include consideration of the area covered, timing, tidal and weather conditions. For example, surveys should not be undertaken during periods of high rainfall, strong wind or when activities causing disturbance to the birds are underway. Survey coverage should include all habitat thought to be used by the same population of shorebirds and the entire area of contiguous habitat where shorebirds may occur. Survey timing must include the time when the majority of migratory shorebirds are present. Peak numbers may occur during the northward or southward migration (this is usually the best period in northern WA).

Tidal area surveys for roosting shorebirds should be conducted as close to the time of high tide as practicable, while surveys for foraging shorebirds should be conducted as close to the time of low tide as practicable and no more than two hours either side. For non-tidal areas survey conditions are most suitable for migratory shorebirds when water is present with a minimally vegetated exposed margin.

Sampling large wetlands can be difficult due to variability between counts, even within one day, depending on tidal conditions either within the wetland, or at nearby wetlands. For example, there is intra-day movement of birds between Lake McLarty (non-tidal) and the nearby Peel system, partly related to small tidal effects. This is partly related to human disturbance (M. Bamford pers. com.). Some large wetlands are more effectively counted from the air. Estimates of numbers need to be quick and only a few species can be identified during surveys. Helicopters are preferable to fixed-wing aircraft. Aerial survey needs to be augmented with ground-based counts for cryptic species such as crakes, rails and bitterns. Surveys on high spring tides are preferable to avoid the times when foraging birds are dispersed and hard to see. The use of a telescope is necessary to count birds from the ground. Best results are achieved at high tide but low tide should also be checked as birds may occupy different areas. Consideration should be given to survey at spring versus neap tides. Greater amplitude of spring tides concentrates roosting birds but allows feeding birds to disperse widely. Big flocks may need to be estimated by counting area subsets and estimating the proportion of each species from a part count.

Survey timing for waterfowl needs to consider a variety of variables. For example, species such as Banded Stilts are seasonal and a site that is important for them may be dry most of the time. Many ducks and swans concentrate in autumn as wetlands dry out, but are dispersed for breeding in spring (breeding wetlands may be missed by autumn surveys). To determine wetland usage by waterfowl it is necessary to count at high water levels and also at declining water levels. Ducks are best counted at a time when the light is good, but crakes and rails are more active around dusk. In some wetlands, this must be done from the water, as the surrounding vegetation can block views of the appropriate habitat. Bitterns are most effectively counted by aural surveys.

Survey effort will depend on many variables. It is recommended that at least two people undertake the counts and surveys are replicated during the period when survey is undertaken. For detail on recommended survey effort see DEWHA (2009). Further information is available on the Birds Australia website http://birdlife.org.au/projects/shorebirds-2020

4.5.5 Bird and frog calls

Birds and frogs produce audible calls and recording of these will often produce information in addition to that gathered through other survey techniques.

The optimum time for listening for bird calls is at dawn and over the following few hours, particularly on still mornings. However, birds may call at all times of the day and even the night so it is important to always be listening while in the field. Listening for calls at night is a useful way to detect presence of many nocturnal species, at least in the breeding season. Bird calls may vary throughout the day as well as across a species geographic range. There are a number of resources for assisting in song identification such as the CD set produced by the Bird Observers Club of Australia (BOCA 2001).

As with visual observation for birds, it is important to accurately record the location of individuals of interest to ensure they are assigned the actual habitat in which they occurred. For example records from a wooded drainage tract adjacent to a site with quite different habitat characteristics should not be assigned to that site without reference to the actual location and habitat attributes.

Different frog species call in different seasons, therefore survey timing needs to reflect this. It is only the male that calls and this is primarily during the breeding season. Calling in the south west is mainly during rains in the late autumn and winter months, for the Kimberley during the wet season, and over most of the arid zone following heavy rainfall (see Table 2). Dusk and the early part of the night are the best times to listen for calls. Where surveyors are not familiar with calls they should locate and identify the calling animal or record the sound for later identification. A range of frog calls from across Western Australia can be heard on the Western Australian Museum Frogwatch website: http://frogwatch.museum.wa.gov.au.

Calling frogs can be difficult to locate as the resonance from the call may give the impression that the animal is somewhere else other than its true location. Experience in knowing preferred calling locations will help. Individuals which are hard to locate can be found by triangulation. This is often easier with two people, enabling the direction of the call to be determined from two positions simultaneously (Bush *et al*. 2007).

Playing pre-recorded calls of target species through amplification (call playback) will improve the chances of locating bird and frog species. In a study on a number of nocturnal bird species, Kavanagh and Peake (1993) found that call playback more than doubled detection rates of all species. Call playback for nocturnal birds provides better results in the early evening or before dawn. Further information on call playback techniques is available in DEC NSW (2004).

4.6 Bat detector surveys

Bats constitute a significant proportion of mammal richness across Australia. There are two basic groupings, primarily insectivorous species that use high frequency echolocation to find and catch their prey, and primarily frugivorous species that do not. Bat survey is often more problematic than for other vertebrate groups. Bat detection devices, such as the Anabat system (Titley Electronics, Ballina, New South Wales) or the range of systems available from Pettersson Electronik (Sweden) or a number of other manufacturers, have become important tools in detection and identification of these species. These systems work through converting ultrasonic frequencies into audible signals that can be recorded on a tape, minidisk, compact flash or directly to a computer hard disk. Analysis of the call structure can then be undertaken on a computer with appropriate software. This system can be used in conjunction with a visual/aural based survey for the non-echolocating large fruit-bats (e.g. *Pteropus* spp.) and a net/trap based survey for the small non-echolocating nectivorous species (e.g. *Macroglossus minimus*).

Identifying echolocation calls is a difficult task as bat call structure is complex and not all species can be easily distinguished from one another this way (O'Farrell *et al.* 1999). A number of good quality call recordings are often needed to confirm the presence of particular species. There are four basic methods for analysing these call recordings. All require access to a library of reference calls from the bats of the study region to enable comparison of the features of the recorded calls.

Heterodyning method

The simplest method for analysing call recordings is the Heterodyning method (Het). This can provide a sensitive detection system for species with known frequency characteristics. The user manually tunes the detector to a target frequency and the detector makes bat calls at this frequency audible. The advantage of this system is that the detectors can provide a higher level of sensitivity for the targeting of particular species. The disadvantage is that heterodyning is a totally manual system that will pick up calls from all species that sweep through the tuned frequency. For survey, this system should only be used for identification of species where subsequent visual identifying is possible.

Frequency division method

The second level is the basic time-history comparison technique using "frequency division" (FD) methods combined with zero crossing analysis. Cost-effective FD detectors, such as Anabat, convert the original high frequency call in real time and divide by a user-selected ratio to give an output that is in the normal hearing range of frequencies. This can be analysed using software such as Analook for Anabat systems from Titley Electronics, Ballina N.S.W. This technique requires that a comparison be made of the frequency range, shape and duration of the recorded call's fundamental harmonic with the reference calls. Advantages of this system include simplicity of use, the ability of the proprietary software to select calls for analysis and the ability to leave systems in the field for significant periods of time. The disadvantages of this system are twofold. There are a number of echolocating species, up to a third depending upon the region under survey, with very similar calls that have characteristics that cannot be distinguished using this method. All FD systems are only capable of tracking the strongest harmonic, usually the fundamental one, and it is therefore not possible to perform any analysis of higher harmonics.

Continuous recording of ultrasonic signals

This technique uses continuous recording of ultrasonic signals that are subsequently analysed in frequency domain. This technique uses FD detectors such as Anabat feeding quality digital recorders or laptop computers with adequate analogue to digital cards installed to provide a recording of all the ultrasound generated at the survey site. The signal is then checked for bat calls in the spectrographic display of conventional sound analysis software. This display allows good-quality search phase echolocation calls to be selected, and these are measured using a fast-Fourier Transform (FFT), either individually or in sequences. The results are displayed in a 'frequency analysis' window in terms of the number of cycles at each frequency, and the measurements made in this frequency domain can be used to identify species. It should be noted that the apparent harmonics displayed in these windows are an artefact of the FFT analysis process and need to be ignored (McKenzie and Bullen 2003, 2009). The majority of WA's echolocating bat species can be determined from the differences in their calls in frequency domain, and, being continuously recorded, all bat calls no matter how short are captured by the recorder for subsequent analysis.

Recordings are best stored on a quality digital recorder as stereo 16 bit 'Windows PCM wave' files with a audio sampling rate of 44.1 kHz or better'. Mp3 files at this sampling rate are adequate, and even minidisc storage is sufficient if set to 'mono SP' mode (146 kbits/s at a bit depth of 16 = 9.1 kHz sampling rate) provided the input signal from the detector has been divided by a factor of 16 or more. According to the Nyquist Theorem, these minidisc settings should accurately reproduce audio to a maximum frequency of 73 kHz (0.5 x the sampling rate of 9.1 x the division factor of 16). In WA, only three species (the 3 horseshoe bats) have the strongest harmonic in their search mode call at frequencies higher than 73 kHz, and their call frequencies are so separated that high audio precision is not required for species recognition (*Hipposideros stenotis* 89 – 105 kHz, *Rhinonicteris aurantia* 108 – 128 kHz, and *Hipposideros ater* 150 – 160 kHz). For the last species (*H. ater*), the Anabat detector must be set to a frequency division factor of 32, prior to recording. Also, the downloaded mp3 files should not be re-saved because audio quality degrades each time.

Time expansion

Time Expansion (TE) is a technique that converts the recording of the original broadband calls, including original signal strength and harmonics, and plays them back at slower speeds allowing full analysis of all call parameters commonly used in species identification. The primary disadvantage of this system is that it does not sample new signals during playback. Using a typical expansion factor of 10, systems sample only approximately 9% of available time, which can result in missed species if bat activity is particularly high.

To overcome the various shortcomings in the methods available, the Australasian Bat Society Inc. (2006) makes recommendations on surveying effort and methods for echolocation based surveys. It is recommended that reports include a description of the reference library used for identification and that a sample graph of time versus frequency for each identified species be included. Reporting should document the effort undertaken (i.e. hours per habitat, number of nights and times). It is recommended that a minimum of three complete nights of survey be conducted in each habitat type during the warmer part of the year and this should be during good weather conditions. Careful consideration should be given to the placement of recording devices.

Due to the uncertainty in identification and detection of all species present at a site through call analysis, supplementary techniques including observation and trapping may also be required.

4.7 Bat surveys using mist nets, harp traps and trip lines

As with all traps mist nets, harp traps and trip lines should only be used by experienced operators with the appropriate permits. These trap types are effective in the capture of the smaller low flying bat species although they have very different modes of operation. In addition, use of these devices can occasionally be the preferred way to sample the presence of particular species such as the non-echolocating nectarivorous blossom bats.

Mist nets are constructed from a mesh of thin fibres which are difficult for bats to detect. When unfurled and tensioned properly mist nets have four or five horizontal pockets spaced evenly across the height of the net. When a bat flies into the net it generally drops into the pocket below, where it becomes entangled in the mesh.

Harp traps have a series of vertical tensioned nylon wires spaced evenly along a rectangular frame with a canvas bag positioned directly below. The nylon wires are difficult for bats to detect and they fly into the wires getting caught between them and subsequently drop down into the canvas bag. The bag has clear plastic flaps on the inside that restrict the bat from climbing out.

Harp traps have a distinct advantage over mist nets in that they do not require an operator to be continuously present and can just be checked for captures early the following morning. While mist nets are a far more effective method for capturing bats (Jones *et al.* 1996), they need to be constantly monitored so captures can be immediately disentangled. Mist nets are also relatively cheap, easy to set up and can be used under a wide variety of conditions.

Trip lines consist of a grid of fine fishing lines set over small water bodies. When bats fly in to drink they hit the lines and fall into the water then swim to the edge where they are collected. Water bodies with trip lines must be monitored constantly from dusk to dawn. Larger waterbodies may require more than one person to collect the bats, which should be allowed to dry before being released. The technique is best used on bodies of water with surface dimensions less than 50m across (University of Ballarat n.d.).

Positioning of mist nets, harp traps and trip lines is critical to success and consideration should be given to locations that intersect foraging, drinking and commuting pathways or are adjacent to roosting sites. These areas may include caves, creek lines, and the periphery of dense vegetation or over pools of water. Often an early evening observation will assist in assessing the potential of a specific location.

Trip lines can be useful for the capture of bat species not normally captured in harp traps (Helman and Churchill 1986) or where a dam is not suitable for mist netting. When installed over dams and small water bodies in warm weather, they can assist in capturing high flying species such as freetail bats (*Mormopterus* spp.). Like mist nets, trip lines are labour intensive, require constant supervision and are suitable at relatively limited sites and in suitable weather periods. They may be utilised, however, when conditions are suitable as they assist in obtaining individuals of species not readily captured by other methods (Murray *et al*. 2002).

Performing bat surveys using these types of nets and traps have a number of disadvantages compared with ultrasonic detector based surveys. The five most important of these to take into account when designing a survey are:

- mist nets and harp traps can only sample an extremely small area relative to that used by free-flying bats and so site selection is extremely important;
- mist nets and trip lines must be monitored continuously;
- bats left in harp traps overnight can be attacked by terrestrial predators or succumb to exposure;
- trapping will under-represent high-flying species and very low/slow flying gleaning species; and
- traps can be detected by bats, so equipment is more effective if it is positioned in situations where the bats are surprised, deceived or cornered. Bats also have a good capacity for learning, so traps are less effective on subsequent nights, unless shifted, and for some considerable time after sampling at a location.

Working with bats can pose potential health risks (see Section 2.3.3) and handling bats needs to be undertaken carefully.

4.8 Supplementary techniques

Supplementary techniques may not result in the capture or sighting of an animal but may provide evidence of species present on the site that were not recorded by the primary detection techniques.

4.8.1 Remote cameras

Remote digital cameras triggered by infrared movement sensors are readily available. Cameras are particularly useful for many of the larger and distinctive mammals although the definition and detail of images is not always ideal, particularly where an animal is distant or relatively small, or where cameras have infrared filters.

Motion sensors are set so that they only activate the camera when an animal is in the field of view and close to the camera. Cameras can be left to operate for many days through to months, depending on batteries, and therefore provide information beyond what is attainable while in the field. Locations that are suitable for camera use include along tracks and runways where there are signs of activity, focused on burrow entrances or on some form of lure or bait.

4.8.2 Hair tubes

Hair sampling and analysis is a technique for mammal survey that has been developed over the last 30 years in Australia, initially with the publication of a mammal hair identification guide (Brunner and Coman 1974) followed by a hair tube sampling technique (Suckling 1978). There has since been experimentation both in design of hair tubes (Scotts and Craig 1988) and efficacy in sampling (Lindenmayer *et al.* 1999; Lindenmayer *et al*. 1996; Mills *et al.* 2002; Nelson 2006) as well as further refinement in hair identification (Brunner and Triggs 2002). In a comparative study of trapping techniques for mammals in north-eastern forests of New South Wales, Catling *et al.* (1997) found hair tubes to be one of the least effective techniques. Therefore, hair tubes should be considered as a supplementary rather than a primary technique.

Hair tubes are designed either as a tube through which the target animal can fit or as a funnel in which just the head of the animal will fit. Within the tube or funnel there is some form of adhesive tape exposed, usually on the top and sides, on which a sample of hair is caught. Avoiding placing tape on the bottom minimises the chance of bycatch (e.g. small reptiles). Animals are enticed to enter through baiting within the tube or at the narrow end of the funnel. A range of tube and funnel sizes should be used to maximise the likelihood of species detection.

Hair tubes can be easily positioned in a variety of habitats, including on trees for arboreal species, and have the advantage over conventional trapping that they can be left on site for considerable lengths of time without the need for daily checking and allow broad areas to be examined. Hair tubes should be located where animal movement is concentrated such as in runnels in dense vegetation. Studies show considerable variation in the effectiveness of hair tubes and funnels for different taxa and geographic locations (Lindenmayer *et al.* 1999; Mills *et al.* 2002) and may not reveal the presence of all mammals present. They do not provide information on abundance, unless genetic analysis of samples is undertaken.

4.8.3 Sand pads

Sand pads may be a useful way of detecting the presence of certain species although the reliability is very dependent on the observer's skills and knowledge of animal tracks.

Pads can be small grids of approximately one square metre of smoothed sand or larger areas which are "brushed" along a sand track or fire break, often prepared using a chain dragged behind a vehicle. If sand must be transported to the site it is important that the sand is declared pathogen free. Where small pads are established they generally rely on the use of bait to entice animals to cross the sand while long "drags" rely on covering large areas thus increasing the likelihood that animals may cross.

These techniques are most useful for targeted species assessment rather than as a general survey methodology, as there is often a high degree of uncertainty with smaller animals about the species identification. Sand pad data can be used reliably as an indication of presence and activity levels, but is less useful for estimates of abundance.

4.8.4 Checking scat and pellet contents

Bones and hair samples collected from owl pellets or the scats of carnivorous mammals can provide valuable additional information on the presence of other vertebrate species. The best locations for finding material are below the nests or perches of raptors, along breakaways, under rock overhangs or in cave entrances although scats of mammal predators such as Quolls and Dingoes may be found out in the open. The positive identification of bone and tooth fragments collected this way can be problematic and may require the expertise of a palaeontologist. Hair samples may be able to be identified through the use of an electronic key (Brunner and Triggs 2002) through reference collections or comparative material in museum collections. The collection of material from a specific location does not mean that it is the origin of the remains as birds and large predators can forage over large distances.

4.8.5 Examination of feral predator gut contents

Feral predators such as cats and foxes are known to feed on a variety of native vertebrate fauna (Martin *et al.* 1996; Risbey *et al.* 1999). Therefore the examination of the gut content of feral predators can provide valuable records on the presence of other vertebrate species not obtained using primary survey techniques. For example, during fauna surveys of the Diamantina Shire and the Mount Moffatt Section of Carnarvon National Park, Queensland, the gut content of feral cats was the only source of records of particular species e.g. *Limnodynastes fletcheri* (Long-thumbed Frog) and *Acrobates pygmaeus* (Feathertailed Glider) respectively (G. Porter pers. com.). Examining the gut content of feral predators obtained for example, as road kill or by shooting or trapping, can be useful in establishing additional species occuring in the vicinity.

5.0 Survey design

Some designs may be more effective than others and even suboptimal ones may provide sufficient data for a particular purpose given adequate effort in terms of number of traps and/or time spent sampling. The designs outlined below highlight the benefits and shortcomings of different design to assist survey zoologists when designing surveys to meet environmental impact assessment requirements.

Survey design will vary with the nature of the environment being investigated, its spatial extent, and the species targeted. Detection of a threatened species may only require a limited number of techniques such as ground searching for signs of presence, followed by targeted trapping. Cryptic species may require a more systematic approach which may include targeting known habitats with appropriate trap types or recording devices. Documentation of assemblages or species richness will generally require a more comprehensive approach incorporating a number of techniques applied with consistent and adequate effort. Factors such as survey timing and duration, and the number, type and layout of traps, are key elements.

There will be an expectation that a minimum effort is achieved and that some general design parameters are met. The parameters that need to be considered will include numbers and types of traps, their layout and the number of days over which they are operated. The following sections provide guidance on survey design. Survey zoologists will need to provide a rationale for the survey design that has been selected for a specific project.

5.1 Site selection and sampling effort

The number of sites required for an environmental impact assessment survey will vary with each survey and is dependent upon aspects such as the type and variety of substrates, vegetation and topography within the project area, and its surrounds. Sites should be selected with consideration for the geographic extent and habitat variation in these attributes and should attempt to sample this range. In systematic survey the sites should generally be positioned well within the habitat type rather than on the periphery, as this will remove edge effects in sampling. However, there may also be occasions where the sampling of ecotones is desirable. In either case this information should be documented.

The sampling effort required for terrestrial vertebrate fauna surveys will depend on the state of knowledge of the area being surveyed. In poorly surveyed areas such as much of the arid zone, pastoral zone and Kimberley, a baseline survey with an array of survey techniques may be needed to account for the possibility of unexpected species or conservation significant populations. These species may include range extensions or previously unknown isolated populations. In better known areas such as the Swan Coastal Plain and much of the South West, the likelihood of recording unexpected species is low and a more targeted survey to determine the presence of conservation significant species may be appropriate.

The sampling effort (in terms of design, duration, timing and sampling technique) is critical when assessing the environmental impacts of a proposal. Practitioners must demonstrate that adequate sampling effort (see Section 4 and 5.2 - 5.5) has been used to enable assessment of any impacts of the proposal on terrestrial vertebrate fauna.

5.2 Timing

Western Australia can be divided into three broad climatic regions based on Beard's (1980) Northern, Eremaean and South West Botanical Provinces (Figure 2). A Level Two survey when undertaken in any of these regions must consider both seasonality and the timing of peak activity, particularly for herpetofauna or other species with temporal variability in activity. It is recognised that periods of peak activity can coincide with conditions that may preclude survey from a logistical point of view and/or from an animal welfare perspective. In these instances a compromise that most closely coincides with desired timing while meeting logistical and ethical issues would be expected. The most opportune time to detect certain taxa, or undertake hand searching and observation techniques, may vary from overall peak activity. A survey can be undertaken at an alternate time if appropriate, provided it is justified. Table 2 summarises recommended timing for surveys of different fauna groups within each province. The best time for survey within each province should be assessed in relation to the geography of the survey area, expected climatic conditions and type of weather over the preceding months. For example, pit trapping for reptiles along the south coast would usually be most effective in late spring or early summer, rather than early spring due to cooler temperatures when compared with the northern extent of the South West Province (e.g. How 1998).

When planning the timing of fauna survey, animal ethics must be considered to ensure that animals that are breeding, lactating or have dependent young are not unduly stressed.

5.3 Duration

A reasonable sampling effort is required for trapping duration, as it is for other aspects such as trap type and numbers (see Section 5.5). If the survey duration is too short it considerably restricts the amount of data available for analysis and interpretation. Whilst there are specific analyses that can be undertaken to establish whether survey effort has been adequate (see Section 6.1), these are typically carried out-post survey providing guidance in respect of future survey requirements. Establishing whether adequate survey duration has been achieved is often unrealistic, therefore the EPA has recommended a *reasonable* survey duration. In general, seven nights or more is the recommended effort for any particular sampling period when undertaking general inventory surveys (Moseby and Read 2001). A minimum of seven days reduces the potential for adverse weather conditions (e.g. cold or wet periods) to dominate a survey period, which might result in suboptimal trapping conditions. The duration of sampling is important and longer sampling times often produce additional species. It is therefore not appropriate to increase the number of traps while decreasing the number of trap days, as this would not give an equivalent sampling effort.

5.4 Seasonal or repeat surveys

The activity patterns of fauna are often closely linked with seasons and sampling across these will produce a more comprehensive understanding than can be obtained from just one season. For example, in the South West Province most reptile species breed in mid to late spring when many species are particularly active and readily caught. However late summer to autumn is when the offspring emerge and are readily trapped.

Repeated surveys will generally yield higher numbers of species than single surveys, and will account for temporal differences in activity patterns (Cowan and How 2004; How and Cooper 2002; Moseby and Read 2001).

5.5 Trapping design for terrestrial mammals and herpetofauna

Prescriptive design assumes that optimal trapping design and techniques are known. Trapping methods and design have evolved over several decades to include the use of fences with pit traps, wider diameter and deeper pits and funnel traps. Had a single prescription been adopted in the past we may not be aware of the benefits of these more recent designs and techniques. To enable the continued evolution and refinement of sampling design this section avoids prescriptive trapping design, rather it provides examples of techniques that can be used.

Historically both biological survey work and environmental impact assessment have used varying numbers of pit traps per site. For example, the Biological Surveys Committee (1984) used between 6 and 10 PVC pipes; McKenzie *et al*. (2000) 12 PVC pipes and four 20 L buckets; Burbidge *et al*. (2000) a minimum of 12 PVC pipes; Cowan and How (2004) twelve 20 L buckets; Biota (2007) ten 20 L buckets; and Ecologia (2007) a combination of twenty PVC pipes and 20 L buckets. It is generally accepted that drift fences are an essential part of any pit trapping program. Spacing of traps along drift fences has also been variable within the studies referenced, ranging from five to ten metres. It is beneficial to have a distance of seven metres or upwards between pits (Friend 1989) although excessive

Table 1: Species group and major survey detection methods.

Primary detection methods are denoted by X, supplementary methods are denoted by S.

Group	Pit traps	Funnel Traps	Medium Aluminium Box	Large Aluminium Box	Cage	Spot-lighting from vehicle	Spot-lighting on foot	Head torching	Diurnal Observation / Active Searching	Searching for tracks & signs etc	Sound/ calls	Recording Techniques including Anabat	Mist netting	Harp traps	Trip lines	Remote camera	Hair tubes
Small Mammals < 30g (eg *Sminthopsis*)	X		X			S	S			S						S	S
Medium Mammals <2500g (eg *Isoodon*)	S		X	X	X	X	S			X						S	S
Large Mammals >2500g (eg *Petrogale*)				X	X	X	S	S	X	X						S	S
Bats (Megachiroptera)									X				X		X		
Bats (Microchiroptera)							S	S	X			X	X	X	X		
Birds						S	S		X	S	X	S	S				
Small snakes <45cm(eg *Parasuta*)	X	X				X	X	X	X								
Medium-Large Snakes> 45cm (*Demansia*)		X				X	X	X	X	S							
Small –medium Lizards <150mm(eg *Pogona*)	X	X	S			S	S	X	X								
Large lizards>150mm (*Varanus*)	S	X		S	S	S	S	S	X	X							
Frogs	X	S				S	S	X	X	S	X	X					

distances are probably of no advantage. Approximately ten metres spacing is known to be effective and is commonly used. Single pits in the centre of a fence may be less efficient than a continuous fence with numerous pits, therefore the overall trapping effort (i.e. number of traps or trapping duration) may need to be increased. Fences used with single pits should be a minimum of seven metres and preferably ten metres in length.

Survey design will vary with the nature of the environment under investigation, its spatial extent, and the species targeted. Based on previous studies it is expected that generally 10 to 12 pit traps should be used for each site during inventory surveys. However, trap numbers are dependent on site characteristics, for example in hard substrates pit trap placement may be difficult and other trap types may need to be increased. Where less than 10 pit traps are used, the rationale should be provided.

A combination of trap types can be used for example deep PVC (600mm depth x 150mm diameter) pipes and 20 L buckets (400mm depth x 300mm diameter); or 20 L buckets on their own. Narrow diameter (150mm) PVC pipes are not recommended for use alone as they are not as efficient for small vertebrate captures as 20 L buckets and do not maximise sampling efficiency which is critical in relatively short duration surveys. Deep narrow PVC pipes may be efficient in capturing some rodent species e.g. hopping mice which are known to jump out of 20L buckets.

If the different habitats are extensive it may be desirable to replicate trap lines. This may result in additional species being captured as species are unlikely to be distributed equally within a habitat. Replicates should be set a minimum of 50 to 100m apart to ensure some level of capture independence along each line. The advantages of this include good spatial representation at the site level as well as enabling analysis of similarity within and between sites.

The overall value of funnel traps remains unclear but where they are used as an alternative to pit traps, for example on granite or other hard substrates, the design and effort can be similar to that of pit trap lines as outlined above. This requires funnels to be used in pairs, one either side of a drift fence, although a single funnel can be placed at either end of a fence. Although there is no requirement for funnels to be used as a standard method at the current time, they may be deployed in conjunction with pit trap lines to augment overall captures at a site.

Elliott traps are often incorporated in trapping grid design as they form one of the primary techniques for capturing small to medium sized mammals. They are often used in standard arrays positioned in a particular pattern in relation to, and a certain distance, from pit lines. However, some studies suggest that trap layout in a grid is less effective in capturing diversity than linear arrangements of traps (Read *et al*. 1988). While recognising that additional work is required to determine optimal spacing between traps, particularly in differing environments, Read *et al.'s* study concluded that 10m spacing was better than 20m spacing when the target group was small sized mammals. Because of increases in home range size with larger size species, it is reasonable to conclude that the spacing between larger traps could be greater.

Elliott traps should be set some distance away from other trap types to increase the area of survey and maximise capture rates, while still in the same habitat. A common design is to establish a grid or transects with 20 size A Elliotts, or where larger species are targeted the addition of a further 5 large Elliotts.

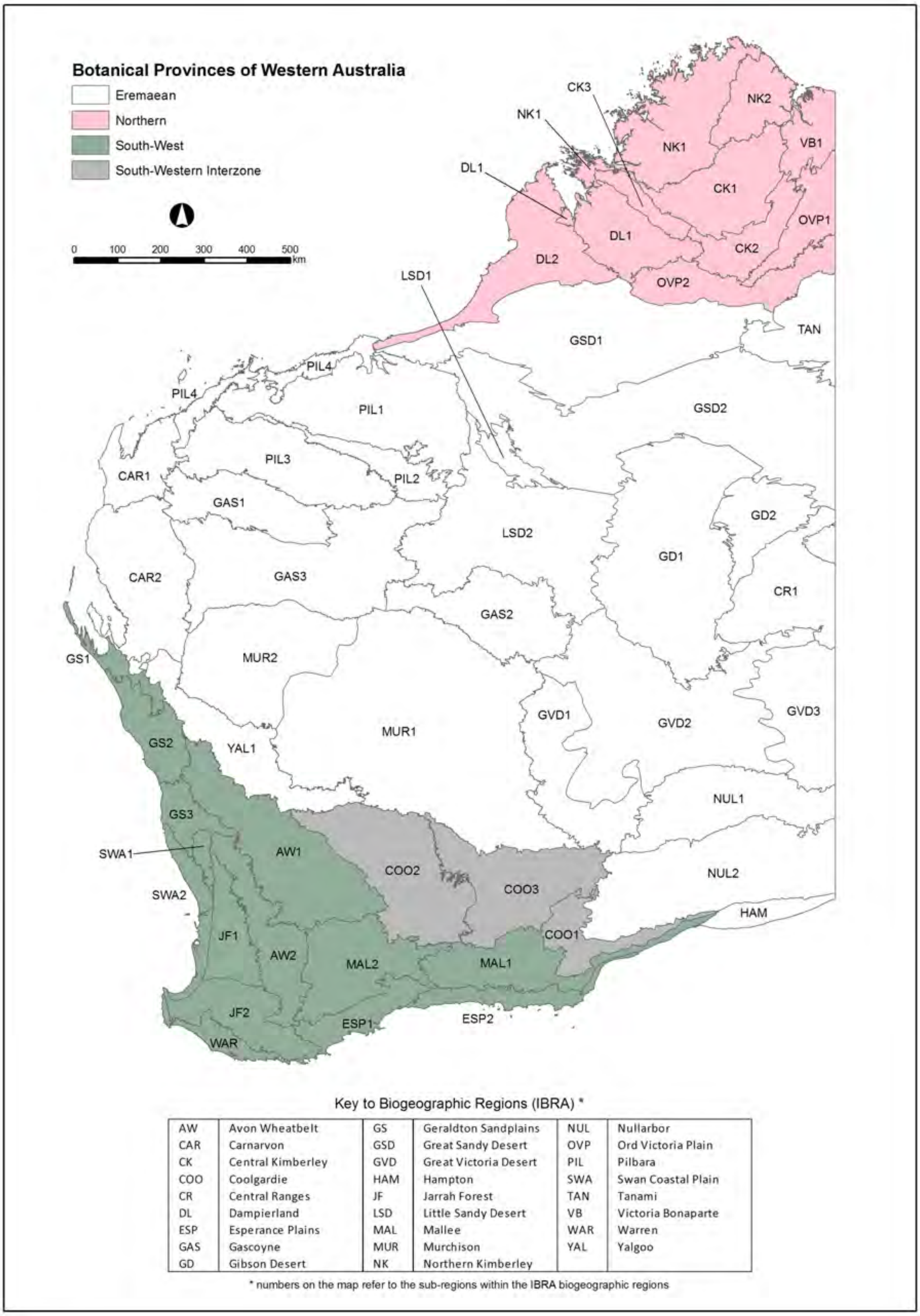


Figure 2. The Botanical Provinces of Beard (1980) and the Interim Biogeographic Sub regionalisation for Western Australia (Thackway and Cresswell 1995)

Table 2: Recommended timing for vertebrate fauna assemblage surveys for the South-West Botanical Province/South-Western Interzone, Eremaean Botanical Province and Northern Botanical Province (Beard 1980), see Figure 2. A Level 2 Survey should include two surveys based on the seasons outlined below.

A: SOUTH-WEST PROVINCE AND SOUTH-WESTERN INTERZONE

Faunal Group	Survey timing	Rationale
Reptiles	October-December (primary survey) February-March (secondary survey)	Typically reptiles become active with rising temperatures in spring when they commence their breeding activity. Generally there is then a less active period during summer before hatchlings start appearing in late summer/early autumn. Sampling should be concentrated in spring to early summer (October - December) and late summer to autumn (February - April) to coincide with peak activity times (see studies by How 1998). Note: because of lower temperatures in south coastal regions spring surveys will need to be considered later in the season. Monthly temperature means should be consulted.
Amphibians	May-June July-August November-December	Burrowing frogs (*Heleioporus* and *Neobatrachus*) begin calling with autumn winter rains. The coldest wettest part of winter is peak breeding season for winter breeding species (*Crinia* and *Geocrinia*). Summer breeding species commence main calling (*Litoria*).
Birds	September-December November-March	Main breeding period for most bush birds. Most species have established breeding territories resulting in maximum vocalisation and activity. The main period when migrating shore birds are present in wetlands is between November and March. For migratory wader surveys see Section 4.5.4.
Mammals	September-December	As mammals are homeothermic survey timing is not constrained as it is for reptiles. For efficiency mammal survey can be concurrent with reptile survey.

B: EREMAEAN PROVINCE

Temperatures increase through a latitudinal gradient northwards. 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 drivers for vertebrate activity. The opportunity to work around these events can be useful, although difficult to plan and implement. Planning spring surveys earlier in the north and later in the south may be advantageous.

Faunal Group	Survey timing	Rationale
Reptiles	September-April	Being ectotherms reptiles are most active during higher temperatures between September and April. Generally there is little activity during winter. Sampling should be concentrated in September to April to coincide with peak activity times (see studies by How and Dell 1992, 2004; Thompson and Thompson 2005).
Amphibians	Immediately after rain events. Episodic rain events generally occur in summer and autumn.	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.
Birds	Ideal timing is immediately after rain events. Episodic rain events generally occur in summer and autumn.	Prolific seeding following heavy rains activates breeding by most granivorous species. Granivore populations decline to low levels in periods of drought. In contrast non-granivores do not concentrate either spatially or temporally to the same extent (How *et al*. 1991; How and Dell 1992) therefore survey timing is less constrained. During times of drought breeding by both granivores and non-granivores will be curtailed and birds will be less vocal and more difficult to observe. For migratory wader surveys see Section 4.5.4.
Mammals	No preferred time (see rationale)	As mammals are homeothermic survey timing is not constrained as it is for reptiles. For efficiency mammal survey can be concurrent with reptile survey. However, mammal species have differing population cycles (for example carnivore and granivore populations peak at different times) which are often related to episodic rainfall. Repeat surveys may need to be undertaken at a different time to reptile surveys.

C: NORTHERN PROVINCE

Faunal Group	Survey timing	Rationale
Reptiles **Amphibians** **Birds** **Mammals**	Wet season: December - March. (Providing the wet season has begun) Dry season: April to August	The wet season is the period of highest vertebrate activity and planning should coincide with this period, or as soon after as practicable. The wet season may begin as early as November or December but as late as February. Conditions in the latter half of the year are very dry with temperatures ranging from moderate to hot. A second survey should be undertaken prior to conditions becoming too hot and dry. For migratory wader surveys see Section 4.5.4.

5.6 Field identification texts

All reports should reference the literature used for identification of fauna. Where consultants are not familiar with a species, prior to going on site they should contact the WA Museum and view any specimens to assist with field identification. A selection of texts for field identification of vertebrate fauna can be found in Appendix 2.

6.0 Analysis

The objectives of the study should determine the methodologies used and the type of data collected and available for analysis. Analysis should be appropriate to the data available, to ensure that data are not used beyond capacity. Data can be treated in various ways. Desktop reviews may simply require incorporation of species lists but more detailed analysis may for example include species/site matrices (presence/absence data, abundance data), summary statistics can include species richness and/or diversity and similarity matrices.

This document does not cover all types of analyses available to practitioners across the range of survey types undertaken for environmental impact assessment. The following sections provide guidance as to treatment and analyses of data from typical inventory surveys. However there are a number of key issues that need to be considered prior to analysis: including reliability and veracity of data including checking for recording and/or entry errors; treatment/ analysis of data; assessment of the effectiveness of sampling; and assessment using species diversity measures (see Green *et al.* 2009 for a review of current methodologies).

6.1 Assessing the reliability and veracity of data

When reviewing the data it is important to consider the reliability of the data used in making interpretations. For example, the absence of records of a species does not necessarily mean that the species is not present within the area but may represent information gaps. Gaps in information include: spatial (e.g. restricted access due to tenure) gaps where some areas are better surveyed than others; taxonomic gaps (previous surveys may have focused on particular taxonomic groups); ecological gaps where some habitat types have been omitted from previous surveys; and topographic gaps where previous surveys may have focused, for example, on ridge tops, ignoring other topographic features. Gaps in the literature can also highlight areas where more information needs to be collected and can be informative when designing the survey (How and Cowan 2006).

Checking all data for errors such as misspellings of species names, incorrect recording numbers and erroneous data entry is essential before any analysis is undertaken.

6.2 Treatment of data

Most surveys do not provide full species inventories, therefore data analysis will depend on the amount of data collected. Also if data have not been collected in a systematic manner diversity measures cannot be compared and may result in misleading interpretation.

Diversity and/or richness information should be separated between the major vertebrate taxonomic groups - reptiles, frogs, birds and mammals. Comparison between sites based on diversity indices alone is of more use when comparison is made between sites or habitats, provided samples are of equal effort. Interpretation of data is of limited meaning unless there is some indication of species that are shared or limited to specific sites in each major taxonomic group. Inclusion of similarity matrices provides more interpretable and better comparative data between sites. The choice of index for data analysis is important as different indices are required to present different data types. Indexes such as Jaccard are useful for binary (presence/absence) data analysis while Bray-Curtis is useful for comparing abundance data. Useful general texts such as Legendre and Legendre (1998) give numerous examples of different analysis techniques.

Sampling over more than one season in a year can provide useful abundance data provided there is equal effort between sites and/or sampling sessions. Abundance data should be incorporated in comparisons between sites or areas as the variation in numbers is ecologically meaningful, even where all species are shared between sites. Figure 3 provides a hypothetical example of three sites with the same suite of species, but in different abundances. Presence/absence analysis would indicate that the sites are identical. Clearly they are not, when abundance information is considered.

The hypothetical example (Figure 3) has additional limitations. Differences between sites could be consequences of random processes rather than actual differences; small numbers of individuals sampled (32 in each) indicate sites are likely to be under sampled. This highlights the importance of having adequate survey effort.

When comparing sites/areas population abundance also needs to be considered as this may be highly variable through time, e.g. rodents (Cooper *et. al*. 2006). Different species will have different population cycles in relation to time and environmental conditions and site similarities can be temporally highly dynamic. How and Cooper (2002) concluded that dasyurid carnivores did not show large population fluctuations following major rainfall. In comparison they showed that some rodent granivores had major fluctuations after rain. Peak capture rates for some species did not occur until 18 months after major rainfall with one species having capture rates 50 times greater between years.

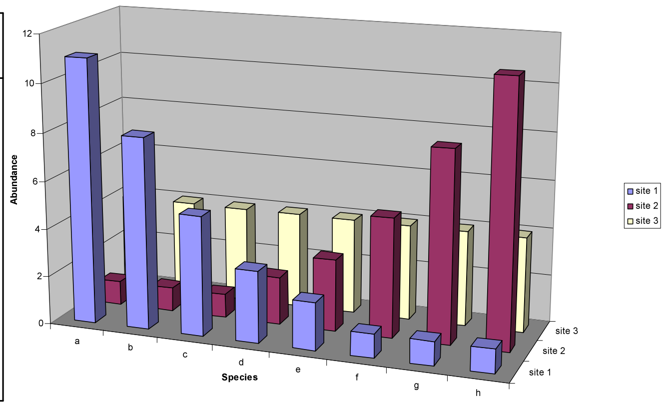
6.3 Effectiveness of sampling

A graph of the cumulative number of species encountered plotted against effort in terms of cumulative individuals or trap days/nights provides a species accumulation curve. Generally, under-sampled assemblages will continue to show a rapid rise in the number of species encountered as sampling effort increases, while a well sampled assemblage will

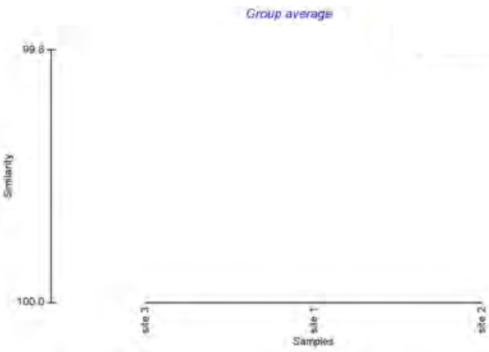
A

species	site 1	site 2	site 3
a	11	1	4
b	8	1	4
c	5	1	4
d	3	2	4
e	2	3	4
f	1	5	4
g	1	8	4
h	1	11	4

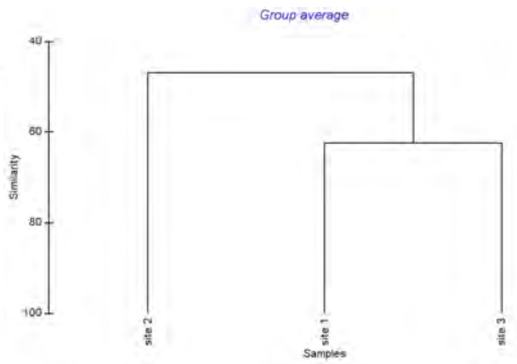
B



C



D



E

Sample	S	N	H'(loge)	D
site 1	8	32	1.724	0.2207
site 2	8	32	1.724	0.2207
site 3	8	32	2.079	0.1250

Figure 3. A hypothetical example of similarity of abundance and presence/absence data from three sites with the same species but different abundances.

A = the data table for each species at each site, B = graph of abundance data for each species at each site, C = similarity (S17 Bray Curtis) assessment of presence absence data for each site, D = similarity (S17 Bray Curtis) assessment using abundance data from each site, and E = two diversity measures, H' (Shannon index) and D (Simpson's index) for each site.

have new species added less frequently and thus the graph will begin to level out. Where there is no evidence of any plateau in the cumulative number of species, further sampling may be necessary to better determine the assemblage. If this is not possible it is important that the inadequacy of the sampling is highlighted in all analyses and reports (Green *et al.* 2009).

Species accumulation curves can be useful in estimating total species richness and the proportion of species caught during the fauna survey. Common animals are readily caught in trapping programs but greater trapping effort will usually be required to catch rare/cryptic species (Thompson *et al.* 2003). Thompson and Withers (2003) suggest that the shape of a species accumulation curve will alter with species richness and evenness. They suggest that much greater trapping effort will be required at sites that have a few abundant species and a high proportion of rarely sampled species, while sites with a large proportion of common or easily sampled species will require relatively little trapping effort to obtain an accurate estimate of species richness.

When species accumulation curves are used as a tool to predict species richness and estimate trapping effort required to catch a nominated proportion of species in an area, then 'distortions' to the shape of the curve attributable to environmental variables and sampling error need to be minimized (Thompson and Thompson 2007b).

Average randomised species accumulation curves should be calculated for the different faunal groups (avifauna, mammals, herpetofauna) within each of the habitats surveyed. The number of individuals recorded or the number of replicate samples should be plotted on the x-axis, with the number of species plotted on the y-axis.

There are a variety of programs used to calculate the species accumulation curves which will also provide an estimate of total species richness. These are based variously on the functions of the number of species seen in only one or two samples (Chao 2, Jacknife), the number of species that have only one or two individuals in the entire pool of samples (Chao 1), or the proportions of samples that contain each species (Bootstrap) (Chao *et al.* 2005, Green *et al.* 2009). These techniques can be used to indicate the number of species likely to occur in that habitat. The reliability of this estimate will be dependent on how close the species accumulation curve is to the asymptote.

Green *et al.* (2009) indicate that the value of species inventories is proportional to their completeness and accuracy, and that this together with a statement of methods employed, is essential for their assessment and interpretation. Species inventories can be enhanced when greater emphasis is given to improving identification skills and the quality of data presented for interpretation. Species inventories are decidedly more informative if accompanied by quantitative data on species abundance, since this permits a more accurate and enhanced level of assessment of both the methodology and comprehensiveness of the inventories.

7.0 Reporting

The report introduction should contain a clear statement of the objectives of the survey in addition to the background information gathered during the desktop study. This includes scope of the proposal, and climate, land systems and biogeography of the region. All reports should contain a section outlining the methods used and any limitations of the survey. This will assist in the assessment of proposals and allow easier comparison between surveys.

Justification of the level of survey conducted (Level 1 or 2) and the sampling design and timing should be provided. Survey methodology should include but not be limited to descriptions of site selection, timing of the survey, prevailing weather conditions prior to and during the survey, sampling techniques, and sampling effort. A map of survey sites and a diagram showing the survey design/layout of traps within these sites should be provided.

Each person's role should be outlined, for example, species identification, faunal group specialist, species verification, compilation, or report writing. The number of person/survey days should also be included. Details of the licences held by relevant survey members and the qualifications and experience of all personnel involved should be included.

Survey results should include a table summarising the survey effort, a table of weather records for the period during and immediately preceding the fauna survey, a table of observations and captures (both species and number of individuals of each species) by specific sites with geographic coordinates and observation/sampling methods used, and a description of the fauna assemblage including whether target species may require additional trapping effort.

In a desktop survey the results of searches of databases, reports, publications and legislation should be reported on, including an indication of the likelihood of each species occurring based on the presence of suitable habitat. The fauna identified during the survey should also be reported on, including detailed information on conservation significant fauna recorded. Detailed information on each species should include their conservation status, distribution, location within the study area and habitat occupied within the study area.

When reporting on survey data it is important to consider a number of factors including:

- reasons for selection of methods used and divergence from the methodology contained in this document and Guidance Statement No. 56 (EPA 2004) with a justification of any divergence;
- presentation of data in a quantitative form wherever possible. Survey data should be clearly differentiated from data gathered from published sources;
- tabulation of the effectiveness of sampling based on survey effort: this should be based on the number of individuals captured and effort expended for survey (see table in Porter (2007) and in How and Dell (2004));
- survey limitations of accessibility to different habitats, season, and previous and current weather conditions; for more detail see Guidance Statement No. 56 (EPA 2004);
- limitations of the inventory through species accumulation curves and assessments using Chao, Jacknife, Bootstrap or similar estimators (see Section 6.3 above);
- the use and relevance of diversity indices, estimates of species richness, measures of evenness and differences in the faunal assemblages among habitat types; and
- analysis of faunal data taking into account the effect of sampling bias.

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 for which the record is an extension of the previously known range. The report should refer to any likely threats and their potential impacts on both species and assemblages, and should also indicate which expected species, if any, appear to be missing from the site. A summary of the fauna values of the area and potential direct and indirect impacts on them should be given. The nature, extent, frequency, timing and duration of impacts should be considered, as well as the possible cumulative impacts of other projects. A recommendation for any further investigations should be included.

Reports must include a range of maps (e.g. showing habitat with aerial photography and the survey/sampling locations), glossary of the terms and acronyms used, and a comprehensive list of references and appendices. Appendices should include a complete list of all species recorded during the survey, grouped by family and following the taxonomic system used in the WA Museum checklists and Christidis and Boles (2008) for birds and the habitats in which they were found; a list of all specimens lodged with the Western Australian Museum including the field voucher identification numbers, the museum reference number and the collecting location; and a complete list of all species (grouped by family) previously collected or recorded within the region, obtained from previous surveys, database searches and museum records.

7.1 Nomenclature

Nomenclature and sequence of names should follow recognised lists. Bird names should follow Christidis and Boles (2008); mammal, reptile, and amphibian names should follow the *Western Australian Museum Checklist of the Vertebrates of Western Australia*. This can be found on the Museum website:
www.museum.wa.gov.au/research/departments.terrestrial-zoology/checklist-terrestrial-vertebrate-fauna-western-australia

The sequence of species names in reports should also follow the sequence in the WA Museum checklist or Christidis and Boles (2008) for birds. This will enable consistent nomenclature across environmental impact assessment reports for ease of comparison between surveys.

8.0 Acknowledgements

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Appendix 1

A list of selected regional vertebrate fauna survey data reports

A: SOUTH-WEST PROVINCE AND SOUTH-WESTERN INTERZONE

Burbidge, A.A., Hall, N.J., Keighery, G.J. 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.

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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., 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.

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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. (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.

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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.

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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.

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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.

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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.A., Hall, N.J., Keighery, G.J. 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.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.

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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.

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.

Johnstone, 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.

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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.

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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.

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.

C: NORTHERN PROVINCE

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.

Johnstone, 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., 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.

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 2

A selection of currently available field identification texts

ALCOA Frogwatch. (2006) *Frog Calls of Southwest Australia*. The Southwest Australia Frog Call CD. Western Australian Museum, Perth, WA.

Aplin, K.P. and Smith, L.A. (2001) Checklist of the Frogs and Reptiles of Western Australia. *Records of the Western Australian Museum* Supplement No. 63: 51-74.

Bush, B., Maryan, B., Browne-Cooper, R. and Robinson, D. (1995) *A Guide to the Reptiles and Frogs of the Perth Region.* University of Western Australian Press.

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

Churchill, S. (2008) *Australian Bats*. 2nd ed. Allen and Unwin, Crows Nest, NSW.

Cogger, H.G. (2000) *Reptiles and Amphibians of Australia* (6th Ed.) New Holland Publishers (Australia) Pty Ltd, Sydney.

Higgins, P. J., *et al.* (Eds) (1993-2006) *Handbook of Australian, New Zealand and Antarctic Birds*. Volumes 1 to 7. Oxford University Press: South Melbourne.

How, R.A., Cooper, N.K. and Bannister, J.L. (2001) Checklist of the Mammals of Western Australia. *Records of the Western Australian Museum* Supplement No. 63.

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

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Menkhorst, P. and Knight, F. (2004) *A Field Guide to the Mammals of Australia*. Oxford University Press, South Melbourne.

Morcombe, M. (2003) *Field Guide to Australian Birds*. Steve Parish Publishing, Archerfield.

Pizzey, G., and Knight, F. (2003) *The Field Guide to the Birds of Australia*. Harper Collins, Sydney.

Simpson, K. and Day, N. (2004) *Field Guide to the Birds of Australia*. Penguin Books Australia Ltd, Melbourne.

Slater, P., Slater, P., and Slater, R. (2003) *The Slater Field Guide to Australian Birds*. New Holland Publishers, Frenchs Forest.

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

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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.* rev. ed. Western Australian Museum, Perth.

Strahan, R. (2000). *The Mammals of Australia*. Reed Books, Sydney.

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