Volume 36
February 2016

CONSULTING ECOLOGY

ECA
ECOLOGICAL
CONSULTANTS
ASSOCIATION
of NSW Inc

www.ecansw.org.au
ISSN 1836-6813

Newsletter of the Ecological Consultants Association of NSW

ECA ECOLOGICAL CONSULTANTS ASSOCIATION of NSW Inc

VOLUME 36 **February 2016**

INSIDE THIS ISSUE!

Editor: ***Jason Berrigan***

Design and Layout: ***Amy Rowles***

Front Cover Photo: Tawny Frogmouth. *Photo Courtesy and Copyright of Natalie Parker.*

Message from the President

Dear members,

It has been a long road to establish the Certification Scheme for Ecological Consultants. Representatives (Liz Ashby and myself) from the Ecological Consultants Association of NSW were part the Accreditation Scheme Working Group established by the Department of Environment and Conservation (now OEH) in 2006. From a series of meetings came a discussion paper titled "*Accreditation Scheme for Individuals Involved in Threatened Species & Biodiversity Survey & Assessment - Draft for Comment*". This quietly disappeared as it presented a relatively complex scheme with too many options for it to be workable.

By 2009 the ECA had formed an accreditation sub-committee to consider the development of a scheme that would respond to the 2007 amendments to the NSW Threatened Species Conservation Act i.e. "The Director-General may institute arrangements for the accreditation of suitably qualified and experienced persons to undertake and prepare surveys and assessments …." In 2010 the sub-committee had presented a draft outline of the scheme to the AGM. Since that time there has been a slow development of a Certification Scheme that is now ready to be utilized by ECA members.

We developed the scheme from scratch - well not really: some of our rules and guidelines were stolen from the British Institute of Ecology and Environmental Management and their Chartered Environmental Status process (my cousin is a member in the UK and trades as Denny Ecology). The Institute has a series of Professional Issues that cover disciplinary and complaints procedures that were also useful. However, overall, our scheme came together with input from many members of the ECA. In particular, Rebecca Hayes, Mark Couston, Belinda Pellow and Alison Hunt have generously contributed. Throughout its development, we have communicated with OEH and they have given us direct and informal support. In 2012, in support for our scheme, OEH funded the ECA to produce a business plan for the implementation of the certification scheme.

Now that the scheme has gone through extensive reviews and has been accepted by the members, we now have a Certification Scheme for Ecological Consultants that can be accessed through our web site. There are several background papers on our web site that explain the role we are planning to take. In a similar manner to that currently used to assess Biobanking Assessors, our scheme requires the creation of a panel to assess those consultants applying for certification. The panel will consist of five members and we are currently establishing representatives from different organisations as well as individuals. The panel will comprise a member and the President from the ECA, as well as three independent persons.

The idea is to have people on board who are able to assess the capabilities of ecological consultants but be independent from the ECA. Our search for appropriate panel members has been wide. We have an academic (Assoc. Professor E. Charles Morris, University of Western Sydney) as a panel member and are currently following up a representative from local government.

The Environmental Defenders Office has given us great support and have reviewed the scheme and given comments. Initially they were happy to provide a panel member but realised that there could be a conflict of interest if someone certified by the panel was involved in legal issues with the EDO. Similarly, another academic happy to assist needed to decline as he was associated with the Land and Environment Court. Some legal representatives have declined as they felt that they would not be sufficiently knowledgeable about ecological consulting. However, they may assist if legal matters are to be discussed.

Considering the close association between the ECA and OEH (we are on their Biobanking Assessor Panel), it was disappointing that they declined to offer someone to go on the panel. There seems to be a mistaken idea that ecological consulting deals only with Biobanking or Offsetting issues, whereas the major part of our profession is dealing with smaller projects at a local government level, and it is that area where there is the greatest need for accreditation of suitably qualified and experienced persons. We will continue to follow up on our relationship with OEH and hopefully be able to explain our role in more detail. The release of the new biodiversity regulations may affect how the certification scheme is run in the future.

A number of the ECA Councillors will start to apply for Certification to assist in picking up and correcting any small hiccups that are inevitable, and hopefully many more members will join the rush to be Certified Practicing Ecological Consultants (CPECs).

Martin Denny

The ECA Council meet every three months to discuss and deal with any current business of the association. The last meeting took place on the 15th of June and the next meeting is planned for the 28th of September 2015. Any member who wishes to view the minutes from any of the ECA council meetings may do so by contacting the Administration Assistant Amy Rowles admin@ecansw.org.au

PHOTO COMPETITION

Congratulations! to ***Natalie Parker*** for winning the last photo competition with her photograph featured on the front cover of a Tawny Frogmouth

Thank you to everyone who entered our photo competition. All entries have been included in the ECA Photo Gallery on the back cover and central pages of the newsletter.

Email your favourite flora or fauna photo to admin@ecansw.org.au to enter a competition and have your photo on the cover of the next ECA newsletter. Win your choice of one year free membership or free entry into the next ECA annual conference. The winner will be selected by the ECA council. Runners up will be printed in the photo gallery

Photos entered in the competition may also be used on the ECA website

EUROKY

Euroky***: ability of an organism to adapt to changes in the environment***

If you have any interesting observations or useful hints and information that you would like to share in the euroky column, please forward them to the newsletter editor or administration assistant to be included in the next edition.

PROPOSED BOW FISHING TRIAL AND POTENTIAL BOW FISHERY FOR CARP IN INLAND NSW: HOW WILL THIS IMPACT WILDLIFE?

Dr Tom Grant

The DPI are proposing to trial bow 'fishing' for carp in inland waters of NSW, with a view to opening up a larger recreational 'fishery'.

It was only recently brought to my notice and I view it with considerable concern. I have included a short submission that I have sent off to Mark Speakman, the Environment Minister, who is also my local member outlining my concerns and asking for a meeting to discuss the issue with him.

Personally I am edgy about any activity that brings hunters into even indirect contact with wildlife but this proposal is of greater concern, as it narrows the focus of the hunting down to inland waters, including small streams, where numbers of wildlife species, such as the platypus, are often in small populations. The recommended move of the platypus, for example, from 'least concern' status to 'near threatened' has been mainly due to the documented reduction in local population numbers (Woinarski *et al*, 2014 see references in submission). Also, few, if any of these bowfishers will be eating their 'catch' and so it comes down simply to the joy of killing something alive and moving. From the aspect of wildlife conservation, this is really a very bad idea, not impacting significantly on the carp populations, and inevitably resulting in wildlife mortalities.

Submission to the Hon. Mark Speakman, Member for Cronulla and Minister for the Environment

Re Trials and proposal for the introduction of carp (Cyprinus carpio) bowfishing in inland water of NSW

Dear Mr Speakman,

I write to you as my local member but also as the Minister for the Environment concerning the possible introduction of bowfishing for carp to inland water of NSW. As a biologist and strong advocate of wildlife conservation I have grave concerns relating to this proposed 'fishery'.

<u>Let me illustrate this concern</u>:

Is the animal in this picture a carp, platypus or perhaps a cormorant foraging near the surface with its neck underwater?

It is in fact a carp, but even with 40 years experience working with the platypus in the wild (Bino, Grant and Kingsford, 2015), I needed to spend some time on the water body with binoculars to determine that this was the case. It is almost certain that a bowfisher would not expend the same amount of effort before firing off an arrow. In this instance the result would have been a dead or wounded carp but it is of great concern to me that there will also be a significant mortality of wildlife species associated with this proposed recreational 'fishery' because of the difficulty of clearly distinguishing a number of wildlife species, including the platypus, native water rat, water dragon, various turtle species and a several diving birds from a carp moving near the surface of the water.

I am aware that the trial, due to begin in a number of areas this month, should enable any introduction of the 'fishery' to be refined. However, no trial can show the number of wildlife 'by-catch' mortalities resulting from incorrect identification, and it seems very unlikely that bowfishers, wanting to have this fishery continue, will record a dead wildlife species in their "catch report using the online Bowfishing Portal" as required by the permit to participate in the trial (DPI Prime Fact November 2015).

One of the rationales given for the considered introduction of this 'fishery' is that it will contribute to the control of this pest species. The NSW DPI itself in 2010 reported that:

"Traditional methods of controlling carp have involved mainly physical removal, for example through netting or angling. However, these generally have little long-term impact on the carp population, as carp are prolific breeders with strong migratory behaviour and can quickly repopulate areas where their numbers have been depleted."

Consequently it seems illogical that a trial and possible establishment of such a recreational 'fishery' is being considered, given that it will not help control carp populations and instead will risk a significant mortality of wildlife species using inland waters. Unlike the carp, some of these wildlife species are iconic, reproduce slowly and are threatened or near threatened.

The platypus, for example produces only 1-3 young (usually 1 or 2) in each annual breeding season. Not all females breed every year and do not start to breed until they are more than two years old (Grant, 2007). Recently the conservation status of this species has been recommended to be downgraded from 'least concern' to 'near threatened', mainly due to documented declines in local populations, especially in smaller rivers and catchments (Woinarski, Burbidge and Harrison, 2014). As the Minister for the Environment this should be of concern to you and I urge you to consider reassessment of this proposal with your ministerial colleagues and the NSW Parliament.

Dr. Tom Grant
Adjunct Senior Lecturer
School of Biological, Earth and Environmental Sciences
University of NSW

<u>References</u>:

Bino, G., Grant, T.R. and Kingsford, R.T. 2015. Life history and dynamics of a platypus (*Ornithorhynchus anatinus*) population: Four decades of mark-recapture surveys. *Science Reports*. 2015 Nov 5;5:16073. doi: 10.1038/srep16073

Grant, T. (2007). *Platypus*. 4th Edition. CSIRO Publishing. Collingwood, Victoria.

NSW Department of Primary Industries . 2010. Control Plan for the noxious fish carp *Cyprinus carpio*. Aquatic Biosecurity & Risk Management Unit, Industry & Investment NSW. Orange, November 2010.

Woinarski, J.C.Z., Burbidge, A.A. and Harrison, P.L. 2014. *The Action Plan for Australian Mammals. 2012.* CSIRO Publishing. Collingwood. Victoria.

....

It seems that the bowfishing trial is to continue until the middle of next year at the 33 sites specified on the DPI Bowfishing Portal and they expect it to be extended to other areas after the results of this 'trial' are assessed. I had a meeting with Speakman and two representatives from DPI and have written the summary below. I stress that these are my own recollections of the meeting and it is not a word for word transcript but the message is pretty clear.

One of the two DPI people alone contributed to almost all of the discussion (the "he" in the paragraphs below)

• *He didn't agree that the information in the press release and information presented on the various DPI website entries spruiked the idea that carp control was presented as a major rationale for the trial. Rather, he indicated that a large number (didn't specify the actual number) of submissions were made to the review of recreational fishing regulations in 2013 asking for the introduction of a bow fishery. As a result DPI decided it was worth being trialled, having the spin off of getting rid of a few feral fish.*

• *He indicated that non-target species would be considered in the trial but had to admit that this concern/risk had not been listed as an outcome of the trial in the DPI online document (final paragraph) "Bowfishing for Carp – How the program will be evaluated" (<u>www.dpi.nsw.gov.au/hunting/bowfishing-for-carp</u>).*

• *He did not agree that self-reporting by the bowfishers was an inadequate way to assess the extent of non-target mortality, stressing that hunters were licensed, experienced and responsible and that there would be close scrutiny of the activity by DPI field staff.*

• *He indicated that DPI field staff are very good at assessing* *compliance (e.g. regular inspection visits, setting up covert observations and quizzing locals). In answer to my direct question as to whether there were enough personnel, resources and funding to adequately assess compliance with the regulations and reporting he gave a definite "yes" answer several times.*

- *He indicated that, in its considerations of the trial, it was assumed the risk of non-target mortality would be low. I mentioned the regulations banning yabby traps from eastern NSW, which he agreed was a good initiative on the part of his department. I reminded him that it took 3 years of assembling more data (still almost certainly just the tip of the iceberg) before DPI finally accepted that there was a problem, and its long-held view that drowning of platypuses in yabby traps was only happening very occasionally, was wrong. The new regulations banning traps from east of the Newell Highway was put in place in 2003. We began the process of gathering data and lobbying at the end of 1999.*

- *He suggested that an attempt had been made to select sites to avoid overlapping wildlife species ranges, particularly the platypus. I informed him that 5 of the 33 sites (15%) were within the definite known platypus distribution and another 8 (in the western part of the Reverina and Central West and one in the lower Murray) were at the western edge of the species' historical/current distribution, and that 100% of the sites overlapped water rat and turtle distributions.*

- *Speakman asked which of these were threatened species and we had the usual discussion about high profile species, like the platypus, and that others were still wildlife, protected species and part of the stream ecosystem, whether they were threatened or not. I also reminded them of the 2014 recommendation to downgrade the platypus status to 'near threatened'. I also noted that the water rat was largely a species that was data deficient and certainly a concern to the Australian Platypus Conservancy, which collected data on the species, particularly in Victoria.*

- *The DPI guy asked me to forward to him a list of the trial sites in relation to wildlife distributions, especially the platypus. I have done this.*

- *He indicated that his department expected that bowfishing would be expanded to more areas following the analysis of the trial, ending in June 2017.*

- *He would not commit to the results of the trial being made public and/or if there would be further public consultation before bowfishing was expanded to other areas.*

- *He did suggest that myself and others (e.g. David Goldney) could be asked to be involved in "refining" the proposed areas to minimise possible overlap with wildlife species*

I have decided to approach it again after the trial, including getting the data from the trial (such as it will be seeing all of it is from reporting by the bow fishers themselves) released and hopefully being able to collect other information that might lead to a strong case to abandon it or certainly not to expand it.

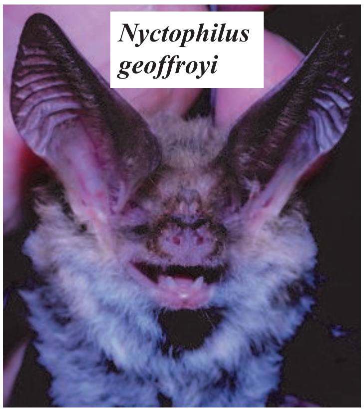
If any members come across bowfishing activities in any areas they are working, it would be beneficial to let me know, so that we could follow up after the end of the trial.

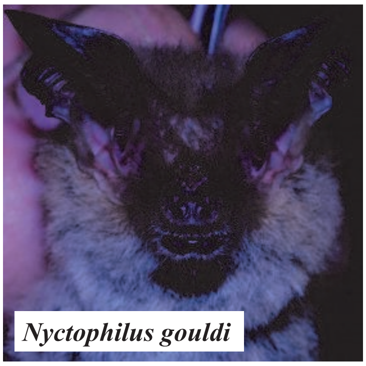
A COMPARISON OF NYCTOPHILUS POST-NASAL RIDGES.

David Milledge

Landmark Ecological Services Pty Ltd

These *Nyctophilus* close-ups are of animals resident in my study sites on the NSW Far North Coast, Tablelands and Western Slopes and show the diagnostic post-nasal ridges.





UPCOMING ECA EVENTS IN 2016

Business Development and Practices Workshop

Date: 29th April 2016

Location: Oatlands Golf Course, Western Sydney, near Parramatta.

Cost: $90 Members; $120 Non-members

Details: Page 7 or www.ecansw.org.au

ECA ANNUAL CONFERENCE, 2016

Date: Monday 25th July 2016

Theme: New Insights in Ecology

Location: Briars, Bowral, Southern Highlands

Cost: Earlybird registration - $120 Members;
$150 Non-members;
$80 Students

Details: Page 8 or www.ecansw.org.au

PROPOSED ECA WORKSHOPS 2016 / 2017

- **Invertebrates**
- **Experimental Design**
- **Statistics for Ecological Consultants**

The dates and venues for these workshops are yet to be determined. You may register your interest in any of these workshops by emailing admin@ecansw.org.au.

Non ECA Events

- **Rehabilitation of Mined Land Conference**

Date: 7th April 2016

Location: Singleton, NSW

Theme: the role of soil symbiotic microbes in a successful rehabilitation process, final voids in the Hunter, along with a broad range of presentations on the business of ecological rehabilitation of mined lands.

Details: www.tomfarrellinstitute.org

- **Island Biology Conference**

Date: 18th-22nd July 2016

Location: Terceira Island, Azores

Details: http://www.islandbiology2016.uac.pt/

- **Ecological Society of Australia 2016 Conference**

Date: 28th November - 3rd December 2016

Location: Fremantle, WA

Details: www.esa2016.org.au

- **Conservation Through Sustainable Use of Wildlife**

Date: 30th August - 1st September 2016

Location: Pullman, Brisbane

Details: http://event.icebergevents.com.au/sustainable-use-2016/

- **The 12th International Mammalogical Congress**

Date: 9th-14th July 2017

Location: Perth, WA

Details: http://www.promaco.com.au/IMC12/

Members may email any ideas for future ECA workshop topics or conference themes to Amy Rowles admin@ecansw.org.au

Ecological Consulting: Business Development and Practices

Oatlands Golf Club, *94 Bettington Rd, Oatlands*

Friday 29th April 2016   9am -5pm

Presenters:

Danny Wotherspoon (Abel Ecology)

John Travers (Travers Bushfire & Ecology)

$ 90 Members

$120 Non-members

(limit 10 people)

WORKSHOP for those who are new to managing an ecological consultancy or those considering the change from employment to self-employment.

- Business structure (sole trader, trust, incorporated company, registered business name)
- Minimum legal requirements for quoting (fees, scope of works, limitations, disclosures)
- Marketing (holding out, accreditation, qualifications, value for money, networking)
- Tendering processes and skills
- Client management and communication
- Fee collection and delinquent accounts
- The role and value of an accountant
- Document systems, records and management
- Financial issues (tax, superannuation, records, profit and viability)
- Employee support and management issues
- Role of your local Chamber of Commerce
- Intellectual property, security and copyright
- Use of copyright materials (LPMA topo maps, Nearmap, Google Maps)

Registration Details

On-line

www.ecansw.org.au

For more information contact admin@ecansw.org.au

New Insights in Ecology

Monday 25th July, Bowral 9am - 5.30pm


Photo courtesy of Rebecca Hogan

The 2016 ECA Conference encompasses a broad range of subject areas from fire to the marine environment. This years conference aims to bring new understanding in ecology to ecological consultants, environmental practitioners, regulators and managers. Scientific thinking is the main plank in our profession and every year researchers work to understand the mechanisms that support ecology, practically and theoretically. Experts in their field, this years conference speakers, will provide food for thought and discussion on ways our profession can identify flaws in current practice and more importantly improve upon it in a tangible way. This year we will also hear from our first two research grant recipients.

Registration

Includes Morning Tea, Lunch and Afternoon Tea

Early Bird Registration	**$120 Members** **$150 Non-members** **$80 Students**
Late Registration (after 30th June)	**$130 Members** **$160 Non-members** **$90 Students**

Registration closes 20th July

Dinner & Trivia

6 - 9pm

$55 pp

Gourmet cocktail dinner, Trivia Quiz & Prizes, Tea & Coffee , bar facilities available to buy your own drinks


Photo Courtesy of Ted Smith

Venue

Briars,

653 Mossvale Rd,
Bowral

Ecological Consultants Association of NSW

Annual Conference 2016

Contact:
Amy Rowles
0418 451 488
admin@ecansw.org.au

February 2016 ECA Membership Report

Amy Rowles
ECA administrative assistant

In total we have 182 members, comprised of 136 Practising Ecological Consultants, 5 Associate (Consultants), 22 Associate (Government Ecological/ Environment Officer), 8 Associate (Non-practising), 2 Associate (Subscriber) and 9 Students. We have had 5 new members and two current applicants over the last six months. The new members are introduced below:

- Nicholas Everitt (Practising)
- Sonja Elwood (Associate government)
- David Carr (Practising)
- Daniel McDonald (Practising)
- Will Brown (Associate consultant)

Recent Literature and New Publications

Recent Journal Articles / Literature

Mutze G., Cooke B. and Jennings S. (2016) **Estimating density-dependent impacts of European rabbits on Australian tree ans shrub populations**. *Australian Journal of Botany* - http://dx.doi.org/10.1071/BT15208

Prior B., Booth D. and Limpus C. (2016) **Investigating diet and diet switching in green turtles (Chelonia mydas)**. *Australian Journal of Zoology* **63(6)** 365-375 http://dx.doi.org/10.1071/ZO15063

Diete R. *et al* (2016) **Best bait for your buck: bait preference for camera trapping north Australian mammals.** *Australian Journal of Zoology* **63(6)** 376-382 http://dx.doi.org/10.1071/ZO15050

Taggart D. *et al* (2016) **Reintroduction methods and a review of mortality in the brush-tailed rock-wallaby, Grampians National Park, Australia.** *Australian Journal of Zoology* **63(6)** 383-397 http://dx.doi.org/10.1071/ZO15029

Kortner G.. *et al* (2016) **Home range and activity patterns measured with GPS collars in spotted-tailed quolls.** *Australian Journal of Zoology* **63(6)** 424-431 http://dx.doi.org/10.1071/ZO16002

Hillman A. and Thompson A. *et al* (2016) **Interactions between humans and urban-adapted marsupials on private properties in the greater Perth region.** *Australian Mammalogy* - http://dx.doi.org/10.1071/AM15045

Sprent J. and Nicol S. *et al* (2016) **Diet of the short-beaked echidna (Tachyglossus aculeatus) in the Tasmanian Southern Midlands.** *Australian Mammalogy* - http://dx.doi.org/10.1071/AM15023

Phillips S. **Aversive behaviour by koalas (Phascolarctos cinereus) during the course of a music festival in northern New South Wales, Australia.** *Australian Mammalogy* - http://dx.doi.org/10.1071/AM15006

Claridge A., Paull D. and Cunningham R. (2015) **Oils ain't oils: can truffle-infused food additives improve detection of rare and cryptic mycophagous mammals?** *Australian Mammalogy* **38(1)** 12-20 http://dx.doi.org/10.1071/AM15015

Lunney D. et al (2015) **Interpreting patterns of population change in koalas from long-term datasets in Coffs Harbour on the north coast of New South Wales.** *Australian Mammalogy* **38(1)** 29-43 http://dx.doi.org/10.1071/AM15019

Meek P. and Vernes K. (2015) **Can camera trapping be used to accurately survey and monitor the Hastings River mouse (Pseudomys oralis)?** *Australian Mammalogy* **38(1)** 44-51 http://dx.doi.org/10.1071/AM15016

Connolly J. (2015) **Distribution and characteristics of the platypus (Ornithorhynchus anatinus) in the Murrumbidgee catchment.** *Australian Mammalogy* **38(1)** 58-67 http://dx.doi.org/10.1071/AM14039

Mathews A. etal (2016) **Movement patterns of koalas in remnant forest after fire.** *Australian Mammalogy* **38(1)** 91-104 http://dx.doi.org/10.1071/AM14010

Davis N. and Coulson G. (2016) **Habitat-specific and season-specific faecal pellet decay rates for five mammalian herbivores in south-eastern Australia**. *Australian Mammalogy* **38(1)** 105-116 http://dx.doi.org/10.1071/AM15007

Dhanjal-Adams K. *et al* (2016) **The distribution and protection of intertidal habitats in Australia.** *Emu* - http://dx.doi.org/10.1071/MU15046

Clemens R. et al (2016) **Continental-scale decreases in shorebird populations in Australia.** *Emu* - http://dx.doi.org/10.1071/MU15056

Sarker S. et al (2015) **Forensic genetic evidence of beak and feather disease virus infection in a Powerful Owl, *Ninox strenua*.** *Emu* **116(1)** 71-74 http://dx.doi.org/10.1071/MU15063

Fairman T., Nitschke C. and Bennett L. (2015) **Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests.** *International Journal of Wildland Fire* - http://dx.doi.org/10.1071/WF15010

Raoult V., Peddemors V. and Williamson J. (2016) **Biology of angel sharks (*Squatina sp.)* and sawsharks (*Pristiophorus sp.*) caught in south-eastern Australian trawl fisheries and the New South Wales shark-meshing (bather-protection) program**. *Marine and Freshwater Research* - http://dx.doi.org/10.1071/MF15369

Lintermans M. (2015) **Finding the needle in the haystack: comparing sampling methods for detecting an endangered freshwater fish.** *Marine and Freshwater Research* - http://dx.doi.org/10.1071/MF14346

Cotsell N. and Vernes K. (2016) **Camera traps in the canopy: surveying wildlife at tree hollow entrances.** *Pacific Conservation Biology* - http://dx.doi.org/10.1071/PC15030

Hunter J. and Hunter V. (2016) **Tussock and sod tussock grasslands of the New England Tablelands Bioregion of eastern Australia.** *Pacific Conservation Biology* - http://dx.doi.org/10.1071/PC15037

Lindenmayer D. *et al* (2015) **Ignoring the science in failing to conserve a faunal icon – major political, policy and management problems in preventing the extinction of Leadbeater's possum.** *Pacific Conservation Biology* **21(4)** 257-265 http://dx.doi.org/10.1071/PC15022

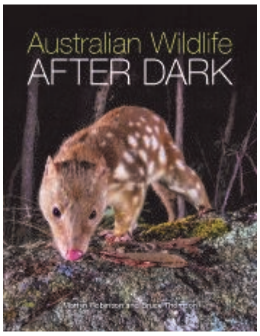
Lindenmayer D. *et al* (2015) **The need for a comprehensive reassessment of the Regional Forest Agreements in Australia.** *Pacific Conservation Biology* **21(4)** 266-270 http://dx.doi.org/10.1071/PC15042

Glass R. et al (2015) **Precision, accuracy and bias of walked line-transect distance sampling to estimate eastern grey kangaroo population size.** *Wildlife Research* **42(8)** 633-641 http://dx.doi.org/10.1071/WR15029

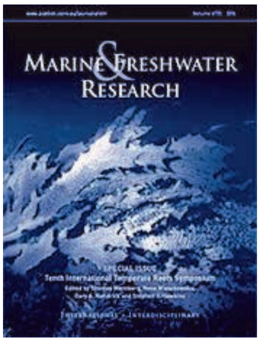
Recent Book Releases

Information Source: CSIRO Publishing
Website http://www.publish.csiro.au

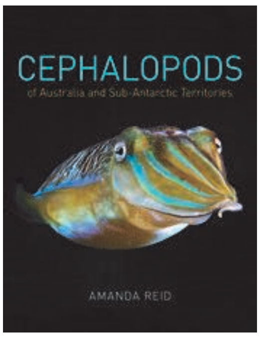
Title: Australian Wildlife After Dark
Author: M. Robinson and B. Thomson
RRP: $35
No. Pages:160
Publisher: CSIRO Publishing
Date: April 2016



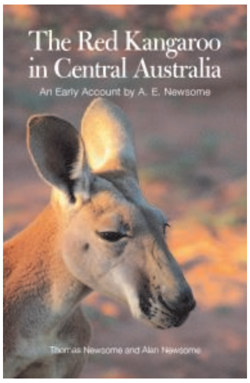
Title: Tenth International Temperate Reefs Symposium: Marine and Freshwater Research Special Issue 67(1)
Author: Ed. Wernberg T. *et al*
RRP: $75
No. Pages:161
Publisher: CSIRO Publishing
Date: April 2016



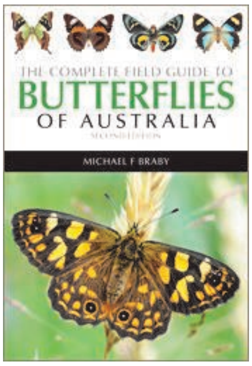
Title: Cephalopods of Australia and Sub-Antarctic Territories
Author: A. Reid
RRP: $280
No. Pages:472
Publisher: CSIRO Publishing
Date: July 2016



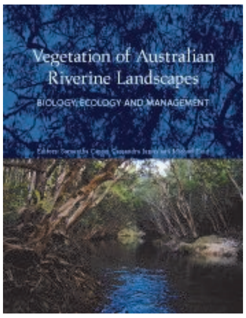
Title: The Red Kangaroo in Central Australia
Author: Newsome T. and Newsome A.
RRP: $39.95
No. Pages:176
Publisher: CSIRO Publishing
Date: July 2016



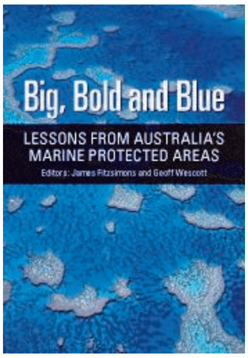
Title: Butterflies of Australia
Author: Michael Braby
RRP: $49.95
No. Pages:400
Publisher: CSIRO Publishing
Date: April 2016



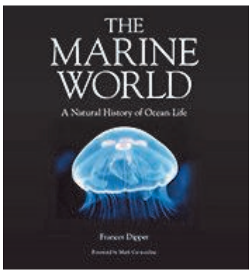
Title: Vegetation of Australian Riverine Landscapes: Biology, Ecology and Management
Author: S. Capon, C. James and M Reid
RRP: $140
No. Pages:440
Publisher: CSIRO Publishing
Date: April 2016



Title: Big, Bold and Blue: Lessons from Australia's Marine Protected Areas
Author: Ed by J Fitzsimons and G Wescott
RRP: $89.95
No. Pages:432
Publisher: CSIRO Publishing
Date: July 2016



Title: The Marine World: A Natural History of Ocean Life
Author: F. Dipper
RRP: $89.95
No. Pages: 544
Publisher: CSIRO Publishing
Date: August 2016



REPLICATING TREE HOLLOWS BY INSTALLING HABITAT STAGS: Promoting new pruning practices in Greater Sydney to help address a housing shortage

Jenny Schabel
Senior Local Land Services Officer

Greater Sydney Local Land Services (GS LLS) is leading the way in introducing habitat stag chainsaw techniques on the Cumberland Plain.

In a landscape that has seen tens of thousands of trees disappear due to new housing developments and heightened public safety concerns, GS LLS is raising awareness of the value and importance of tree hollows to native wildlife.

A combination of Sydney Growth Areas, Bell-miner associated dieback, the Rural Fire Service 10/50 Vegetation Clearing Scheme and NSW public school tree maintenance programs has intensified a critical housing shortage for more than 150 hollow-dependent native NSW species including about 40 that are vulnerable or endangered. So when we talk about a chronic housing shortage in Sydney we should spare a thought for our native wildlife as well.

GS LLS is taking a proactive approach to breaking the cycle of blanket tree clearing by demonstrating that in many cases, trees can be rendered safe while retaining and enhancing habitat values. Pruning a tree and installing habitat homes can cost about the same as removing a tree and grinding the stump.

A number of Sydney media outlets recently picked up the news story about making dangerous trees safer for the community while creating homes for local wildlife. Sydney Arbor Trees arborist Michael Sullings who has been helping GS LLS with chainsaw demonstrations in Council reserves has been widely quoted as saying

"Alive or dead, trees containing hollows are habitat for all manner of organisms. It is time for us to rethink our approach, not all trees are hazardous."

GS LLS is working with five Western Sydney Councils to promote these new pruning practices to a wide range of practitioners as well as the general public. These events followed on from the success of a *Hollows for Habitat* forum at Newington Armory hosted by GS LLS in May. Partnering with Sydney Olympic Park Authority, GS LLS brought together 200 delegates from state and local government, arborist, bush regeneration and ecological consultancies, universities, Bushcare groups, and wildlife carer groups from across Greater Sydney to show the value of enhancing hollow habitat. Recognised early innovator arborists Pat and Ben Kenyon from Victoria demonstrated chainsaw techniques.

In recent months we have seen steady growth in interest across Sydney to trial new techniques to augment hollow habitat for wildlife, from hollow logs to fish crates to new nest box designs to habitat stags, and to incorporate them in to bushland management programs and funding applications.

Another opportunity for using habitat stags is the common requirement of nest boxes in development consent conditions to offset tree hollow loss. Nest boxes incur issues including longevity, tree attachment and maintenance. Habitat stags may be worth considering as an alternative in these cases as they are likely to have lower maintenance requirements. As they more closely replicate natural tree hollows they may well have better thermal insulation properties too.

GS LLS is scheduling a number of hollow habitat events for 2016 including a Hollows for Habitat Forum with the University of Newcastle in Ourimbah (9 Feb), and habitat stag demonstrations in Winston Hills (13 Feb) and Plumpton (24 Feb). For more details visit http://greatersydney.lls.nsw.gov.au/resource-hub/events

Proceedings from the Hollows for Habitat Forum in May 2015 can also be downloaded at http://greatersydney.lls.nsw.gov.au/__data/assets/pdf_file/0005/566627/hollows-for-habitat-proceedings.pdf

These initiatives have been supported through funding from the NSW and Australian governments

The first habitat stags installed in Western Sydney were carved into this large dead tree in Belgenny Park, Camden. A large bird box and bat flat were installed after the canopy was pruned back.

Figure 7 – To begin the 'bat flats', a 'faceplate' is first removed from the outside of the stem.

Figure 8 – The bat flats, with the entry passage bored out.

Figure 9 – The bat flats, with the chambers bored out. The idea here is to provide areas of differing temperatures for the bats to move around in as their needs change across the seasons.

Figure 10 – The bat flats, with the faceplate reattached, showing both entry slots – vertical and horizontal.

The habitat stag work on this dead Blue Box along Cabramatta Creek was particularly interesting as there were hollows in the aerial termite mounds and branches already being used by birds including Sacred Kingfishers. Sydney Arbor Trees showcased how pruning could make the tree safe for users of the public cycleway below, while retaining hollow and perching habitat, and creating new homes for birds and microbats.

Resident Sacred Kingfisher and the inside of a hollow purpose-built for Kingfishers

PRODUCT REVIEW: STATISTIXL (UNIVERSITY OF WESTERN AUSTRALIA)

Stephen Ambrose

Director, Ambrose Ecological Services Pty Ltd

PO Box 246, Ryde, NSW, Australia 1680

Email: stephen@ambecol.com.au

Articles in *Consulting Ecology* are usually accustomed to reviewing items of field equipment or recently-released books that are useful for ecological consultants. But equally important are statistical software packages for analysing ecological data in ecological impact assessments that have an experimental field component.

Over the years, I've used a number of different statistical software packages, none of which I have found totally satisfactory. My main criticisms include:

- the high financial cost of the software;
- it can be cumbersome to use, especially if data have to be organised as text files or imported manually into the statistical software from other software packages;
- instruction manuals are too technical and often need to be supplemented with expensive workshops, online video tutorials or through the purchase of additional textbooks;
- a lot of analytical output of a performed analytical test is difficult for non-statisticians to understand and is not relevant to biological studies.

Therefore, it was refreshing to be introduced recently to *statistiXL™*, a user-friendly statistical software package developed within the Department of Zoology at the University of Western Australia, specifically for biologists.

statistiXL™ is a powerful data analysis package that runs as an add-in to Windows versions of Microsoft Excel™. Therefore, data stored in Excel™ don't have to be exported to the software package or converted to a text file. Output resulting from the statistical analyses is also displayed alongside the data in the same Excel™ document (Figure 1). In fact, if more than one statistical test is performed on the same set of data, the output of all the analyses appear in the same document as the data and the investigator can designate where in the document the outputs are displayed.

statistiXL™ has had a number of upgrades since it was first developed, the latest version (*v*1.11) being available at the time of writing this article (2 December 2015). It has a very simple, graphical user interface that provides access to the following range of statistical tools:

- **Analysis of Variance (ANOVA)**: Both univariate and multivariate ANOVA and ANCOVA. Full factorial and user specified models are supported as are fixed and random factors, nesting and repeated measures.
- **Clustering:** Hierarchical clustering of binomial, quantitative and mixed datasets is supported as is clustering based on a predetermined distance matrix. A wide variety of similarity/distance estimates and clustering methods are available, and the resultant clustering strategy can be graphically displayed as both a text based and/or graphical dendrogram.
- **Contingency Tables:** Both two-way and multi-way contingency data can be analysed.
- **Correlation:** Simple, Partial, Multiple and Canonical correlation is supported with graphs of Canonical Variates available for the latter.

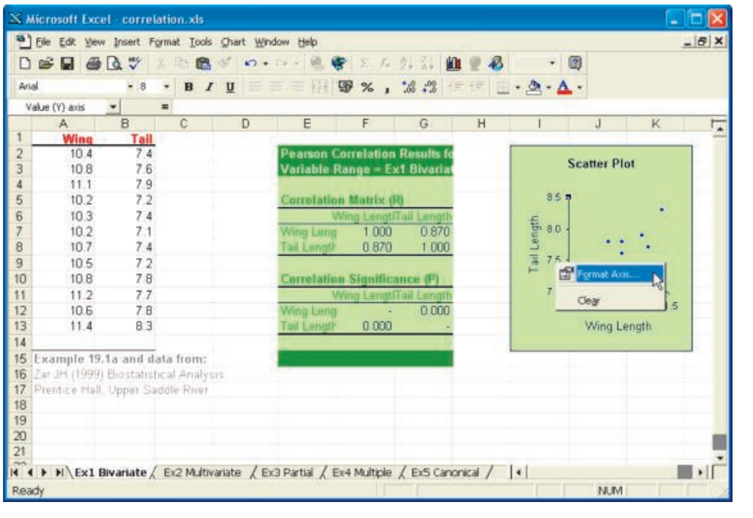


Figure 1 Example of a display of statistical information in ExcelTM after a Pearson Correlation analysis of data.

- **Descriptive Statistics**: Descriptive Statistics are available for both linear and circular data sets. Linear descriptives include a choice of 18 statistics such as Mean, Standard Error and Mode, as well providing Box and Whisker plots and Error Bar plots for a graphical representation of the data. Circular descriptives provide 9 statistics including Mean Angle Circular Variance and Angular Variance.

- **Discriminant Analysis:** Both Grouping and Classification methods of Discriminant Analysis are supported. For Grouping Discriminant Analysis, scatterplots of case scores can be produced for each pair of components. For Classification Discriminant Analysis, an alternate dataset can be classified based on the discriminant functions determined for the primary set.

- **Factor Analysis:** Factor Analysis can be performed on either the correlation or covariance matrix of the raw data set. A variety of component extraction and rotation methods are supported and both scree and scatterplots of case scores can be produced.

- **Goodness of Fit:** A wide variety of tests for the Goodness of Fit of datasets to theoretical distributions are provided including those for Binomial, Circular, Normal, Poisson and Uniform distributions. The level of fit to user specified distributions can also be calculated.

- **Linear Regression:** Simple and Multiple Linear Regression is supported. Plots of regression models and residuals can be produced.

- **Nonparametric Tests:** Numerous Nonparametric Tests are supported including Friedman, Kruskal-Wallis, Mann-Whitney, Mood's Median, Sign, Spearman, Wald-Wolfowitz and Wilcoxon Paired-Sample tests.

- **Principal Components:** Principal Component Analysis is provided as a means for the reduction of large multivariate data sets into simpler structures. Scree plots and Scatterplots of case scores can be produced.

- **t Tests:** One and two sample, univariate and multivariate *t* tests are supported.

There is no need to learn complicated command line procedures or to decipher multiple menu systems full of cryptic options. Popup help is available for every control within each of *statistiXL*'s modules and an indexed Help File contains explanations and examples. There are also online support forums, and the *statistiXL*™ support desk can also be contacted directly by email.

Therefore, this package offers most of the statistical tools that are used regularly by ecological consultants who engage in biostatical analysis. However, it does not have two tools that I rely on as a consultant: Analyses of Similarity (ANOSIM) (I use *Primer-E* software for this purpose) and non-metric multidimensional scaling (I use *Systat* software for this purpose) for treatment comparisons of community structures. It would be useful for future versions of *statistiXL*™ to include those tools.

For me, the biggest advantage of this software package, apart from its ease of use, is its low cost. It can be downloaded from the *statistiXL*™ website http://www.statistixl.com/default.aspx for a 30-day free trial period, with access to all the modules. After the trial period you have the option of purchasing a licenced copy. Two types of licence are available, both of which allow you to run *statistiXL*™ on a single PC at work and a single PC at home: a perpetual licence to run any version 1.x release of *statistiXL*™ that does not expire (US$75) or a renewable 12-month licence for US$40/year. This cost puts it within financial reach of tertiary education students, and for ecological consultants who do not want to pay hundreds or thousands of dollars for biostatistical support.

DESIGN OF FIELD EXPERIMENTS IN BIODIVERSITY IMPACT ASSESSMENT

Stephen Ambrose

Director, Ambrose Ecological Services Pty Ltd

PO Box 246, Ryde, NSW, Australia 1680

Email: stephen@ambecol.com.au

INTRODUCTION

In the last issue of *Consulting Ecology* I was critical of the shortage of field projects that had appropriate aims and experimental designs that assessed the impacts of development and other human activities on terrestrial biodiversity in NSW (Ambrose 2015).

I concluded that some of the blame for poorly-designed biodiversity monitoring lies with the expectations of the proponents of such projects. These proponents appear to have no or at most a poor understanding of experimental design, or have that knowledge and for one reason or another have decided not to use it in the workplace. Denny (2015) also directs some of the blame at government authorities who appear to be relaxing the regulatory need for comprehensive field studies in relation to proposed developments and activities. As ecological consultants, we have an obligation to encourage appropriate field survey design, timing and effort in biodiversity impact assessment, and congratulate proponents and regulatory authorities when they accept that advice. But we also need to ensure that they recognise good (and poor) experimental field survey designs, or at least have them accept the recommendations of appropriate expert advice. Admittedly, this is a significant challenge for both the individual consultant and an industry body such as the Ecological Consultants Association of NSW Inc. (ECA) because, although regulatory authorities in particular often seek advice, and promote the fact that they have consulted with relevant parties, that advice is often ignored by them.

The present article has been written at the invitation of the ECA Council in response to those criticisms. These are my own views and not necessarily those of the ECA Council. I adopt the viewpoint that scientifically -rigorous experimental designs should be employed in ecological- or biodiversity-impact assessment in consultancy projects where this opportunity occurs. It describes the components of field experimentation and analysis and how they can be applied to biodiversity impact assessment in the real world of ecological consultancy. The target readership consists of (a) proponents of development and major activities (our clients), (b) regulatory authorities who set the standards for biodiversity monitoring and impact assessment, and who ultimately review our flora and fauna impact assessment reports, and (c) the ecological consultant who is seeking to be reminded about cost-effective applied experimental design of ecological field projects.

COMPONENTS OF ECOLOGICAL RESEARCH AND IMPACT ASSESSMENT

Overview

Field *et al*. (2007) classify ecological field monitoring projects into three approaches: Ecological Field Experiments, Unscientific Monitoring and Inventories. These approaches are defined by funding, objectives and sampling design considerations. Denny (2010) added a fourth approach, Systematic Monitoring, to cater for projects that are financed and managed by private and public bodies that are responsible for developments and management actions that may have significant environmental impacts (Table 1). Denny explains that the overall aim of Systematic Monitoring is to collect field data in a systematic and repeatable manner that can be reported to and used by government agencies overseeing and managing impacts. Advice in the present article is relevant to biodiversity impact assessment projects that fall into one or more approaches associated with Ecological Field Monitoring and Systematic Monitoring.

Observations, Models and Hypotheses

A framework for conducting a field research project is described in detail by Underwood (1997 & 2009) and is summarised in Figure 1. While Underwood's papers focus on fundamental research, the same principles should be applied, where possible, to biodiversity impact assessment in ecological consultancy. In fact, many of the examples I have used in the present article illustrate sound field research designs in biodiversity impact assessment.

The project usually starts with field observations, i.e. observed ecological patterns in space and time. They are things that have been seen or are known. No one observes the world without being influenced by prior knowledge, so our observations may be incorrect as a result of observer bias. The purpose of the subsequent research is to determine why these observations have been made and if they are correct.

The next step is to propose potentially plausible explanations as to why these observations exist, i.e. processes that may account for the observations. These explanations are usually called models or theories. For instance, if there are more Brown Bulldog Ants *(Myrmecia pyriformis)* on 1 m^2 of ground surface in an unburnt habitat than in a recently-burnt nearby area of the same size in the same habitat type (the observation), then plausible explanations include: the unburnt area is more suitable as habitat, allowing greater densities of ants to occur; ants are more vulnerable to predators in unburnt areas, so avoid these areas or have experienced higher predation; there is more food in unburnt areas; there is less interspecific competition for resources, etc. (the model or theory). It should be noted that there could be more than one explanation for the observation, including interactive explanations. Explanatory models proposed by other ecologists are often found by consulting the scientific literature, the internet or colleagues. Therefore, models are derived from knowledge, past experience, inductive reasoning and inspired guesswork to explain why the observations were made. The explanatory model that we wish to investigate further is known as the hypothesis. Hypotheses are logically derived from models by deduction, i.e. they are predictions that can only be correct if the models from which they are derived are correct.

Proposed models often turn out to be incorrect or at least poorly supported by subsequent evidence. Therefore experimental procedures are needed to eliminate those that are incorrect. Consequently, instead of adopting the model as the hypothesis to be tested, we create a null hypothesis, consisting of all the possible logical alternatives to the hypothesis. If the null hypothesis is disproven by experimental data, the only alternative is the hypothesis. However, if the experimental data conform with the predictions in the null hypothesis, we can conclude that the original hypothesis is not supported.

Example

The overall distribution of the Brown Treecreeper *(Climacteris picumnus)* in NSW has not changed, but it is now extinct in parts of its range. Declines in populations have been recorded from the Cumberland Plain (Hoskin 1991, Keast 1995, Egan *et al*. 1997), the New England Tablelands (Barrett *et al*. 1994), the Inverell district (Baldwin 1975), from Munghorn Gap Nature Reserve near Mudgee (Scientific Committee 2001), and from travelling stock routes in the Parkes district (N. Schrader in Scientific Committee 2001). Reid (1999) identified the Brown Treecreeper as a 'decliner' in a review of bird species' status in the NSW sheep-wheatbelt.

Brown Treecreepers forage on tree trunks and on the ground among leaf litter and on fallen logs for ants, beetles and larvae (Noske 1979). Maron & Lill (2005) indicate that Brown Treecreepers prefer foraging on fallen timber that is close to the base of standing trees. Antos *et al*. (2008) found that Brown Treecreepers were more abundant in grassy woodland habitat that had native grass cover and a low incidence of exotic grasses and weeds.

Doer *et al*. (2010 & 2011) state that Brown Treecreepers disperse through areas where there are scattered trees, possibly in preference to more densely-vegetated corridors.

Bennett *et al*. (2013) found that Brown Treecreepers reintroduced into restored habitat areas chose sites with sparse ground cover because this allowed better access to food and better vigilance for predators.

Collectively, there is a mix of observations and models in the above-mentioned habitat studies of the Brown Treecreeper. The following pieces of information are observations about Brown Treecreepers:

1. they forage on tree trunks and on the ground among leaf litter and on fallen logs for ants, beetles and larvae;

2. they forage on fallen timber that is close to the base of standing trees;

3. they occur in grassy woodland habitat that has native grass cover and a low incidence of exotic grasses and weeds;

4. those reintroduced into restored habitat areas move to sites with sparse ground cover; and

5. they disperse through areas where there are scattered trees, fewer Brown Treecreepers have been observed in more densely-vegetated corridors.

Two potential explanatory models for these observations are:

1. Brown Treecreepers are found only in these microhabitats, or are more abundant in them, because they represent the appropriate habitat for this species.

2. Brown Treecreepers are restricted to or are more abundant in these microhabitats because of unsuitable or hostile features of other microhabitats.

Hypotheses must, at the very least, contain one or more overt or implied predictions. They need to be as explicit as possible so that expectations from field experiments can be clarified, data can be analysed statistically and interpretation of results is assisted.

For instance, if the first model is correct, the null hypothesis proposed could be that the Brown Treecreeper occurs in habitat areas other than those in which they have been observed, and at similar population densities.

If subsequent field data reject the hypotheses derived from the first model, then the second model could be investigated to consider components of the environment in other habitats within the range of the species that are causing Brown Treecreepers to stay where they are observed (e.g. shortage of resources, fragmentation and isolation of habitats, presence of predators and/or competitors, diseases, extreme harshness of the climate) would form the basis of alternative models about the negative nature of other habitats.

EXPERIMENTAL DESIGN

Overview

Excellent discussions of design of field experiments in ecology are provided by Hurlbert (1984), Hairston Snr (1989), Underwood (1990, 1997 & 2009) and Krebs (2014). Experiments are designed to test hypotheses. A *treatment* is a feature (i.e. an *experimental unit*) of the experiment that is manipulated by the researcher to determine how variables within the experimental system respond. The *experimental design* refers to the characteristics of the experimental units, the types of treatments applied to them, the numbers of units receiving each treatment, and how treatments are applied in space and time.

Hurlbert (1984) identifies two classes of experiment: mensurative and manipulative experiments.

Mensurative experiments involve collecting data at one or more points in space and time, with space or time as the only experimental variable or treatment. For instance, the number of birds flying between suitable habitats on either side of a point along a busy highway may be recorded at different points in time (time is the experimental variable). Alternatively, the number of bird crossings may be recorded at several locations (crossing points) along the highway, at one point in time, with all crossing points as identical as possible (space is the experimental variable).

A *manipulative experiment* always involves two or more variables or "treatments", and has as its goal the making of one or more comparisons. For instance, the number of Superb Fairy-wrens (*Malurus cyaneus*), a weak flier, crossing a highway via a vegetated wildlife overpass may be compared with the numbers crossing the highway at locations where there is no overpass, and data are collected simultaneously at each location across a number of time periods. In this example, the treatments are the types of bird flyways across the highway (vegetated wildlife overpass or its absence), time and space.

A prediction (hypothesis) requires a clear statement of the conditions that must exist for it to be confirmed. To carry out a satisfactory experiment one must have full knowledge of the conditions existing before the experiment begins (Hairston Snr 1998). Therefore, the sampling or experimentation must include replication so that the estimates of ecological parameters from samples can be compared with the appropriate natural and sampling variation (Underwood 2009). Typical sources of variation in an ecological experiment and how they are reduced by experimental design are shown in Table 2.

Replication

Variability is all-pervasive in nature, so it is impossible to find identical locations for different treatments in a field experiment. Differences can also appear as a result of random errors in the measurement process. Care in choosing treatments and in taking measurements can minimise these sources of variability, but they cannot be eliminated completely. This variability, usually termed experimental error, can be measured if experimental units are *replicated*, i.e. several units are assigned to each treatment or condition.

A simple illustration of replication is the comparison of the numbers (densities) of adult Spotted Marsh Frogs (*Limnodynastes tasmaniensis*) in ponds where phosphorous fertiliser has been added (e.g. similar amounts of fertiliser runoff into separate ponds from surrounding urban landscapes and with other replicate pond variables being constant) with those in similar types of ponds containing no fertilisers. In this particular case, appropriate experimental units are entire ponds. Therefore, such an experiment must consist of two or more ponds treated with fertiliser and compared with two or more untreated ponds of similar type. The observations are that the numbers of adult Spotted Marsh Frogs vary from one pond to another and the model proposed is that a major contribution to this variation is the presence or absence of phosphorous fertiliser in the water. The hypothesis to be tested is that the number of adult frogs will, on average, be greater in ponds containing no fertiliser than in ponds where fertiliser has been added. The null hypothesis is that, on average, there will be no difference in numbers, or that there will be more adult frogs in ponds containing the fertiliser.

Proper replication requires that replicates be independent of each other, i.e. no measurement, count or other observation on a replicate should influence a similar observation of another replicate. Replication that violates this assumption is known as *pseudo-replication* (Hurlbert 1984). There are several forms of pseudo-replication:

Simple pseudo-replication involves taking multiple measurements of response variables within individual experimental units and analysing these measurements

Table 1 Schematic representation of approaches to ecological field monitoring in Australia (as modifed by Denny 2010)

Inventories	Unscientific Monitoring	Ecological Field Experiments	Systematic Monitoring
Short to long term, often in response to short-lived political pressures. Unlikely to be sufficiently spatially and temporally replicated for meaningful analysis	Short to medium term, discontinued due to lack of interest and focus on activities designed to attract and retain volunteers.	Short to medium term, often associated with terms of students' projects or grants.	Medium to long term, mainly associated with regulatory and other obligations (e.g. Conditions of Consent, control programs)
Aim to gather snapshot inventories of particular locations. Usually lack rigorous scientific design and produce datasets that are unusable or have low statistical power.	Aim to gather snapshot inventories of particular locations of interest to volunteers, or which support specific objectives. Usually lack rigorous scientific design and produce datasets that are unusable or with low statistical power.	Aim to collect information on specific ecological characteristics of target organisms. Adhere to rigorous scientific design, but abundance and distribution usually measured incidentally.	Aim to collect information in a systematic and repeatable manner. Abundance and distribution usually measured. Able to undertake rigorous scientific analysis and relate to environmental changes.
Poor to medium quality data, systematically archived but usually inaccessible to outsiders.	Poor to medium quality data, unlikely to be systematically archived except by largest and best-funded organisations.	Medium to high quality data, but rarely sufficiently long-term to permit demonstration of trends.	Medium to high quality data, major restrictions of quality are funding, ability of monitoring body and conditions imposed by the regulator.

Table 2 Sources of data variability and how they are reduced by experimental design.

Source of Variability	Reduction by Experimental Design
Variability among experimental units.	Replication, interspersion and simultaneous measurement.
Random error in measurement of response variables.	Replication.
Change in conditions over time.	Controls.
Unsuspected side-effects of treatment procedures.	Controls.
Bias of investigator.	Randomised assignment of treatments to experimental units.
Chance influences on experiment in progress.	Replications and interspersion.

as if they came from different experimental units. For instance, in our Spotted Marsh Frog example, fertiliser being added to a single pond only, and the densities of adult frogs and other variables are measured in several locations (plots) within that pond is pseudo-replication because the measurements in each plot are not independent of each other. In this instance, pseudo -replication would be avoided by increasing the number of ponds or accepting that the results apply not to ponds in general, but only to those being studied.

Temporal pseudo-replication occurs when measurements are taken within the same experimental unit at different times are treated as coming from separate experimental units. Therefore, pooling counts of adult frogs from surveys conducted at different times to calculate average numbers is temporal pseudo-replication because the responses of measured variables to the treatment in any one survey period would be influenced by those measured in previous survey periods.

Sacrificial pseudo-replication occurs when an experimental design involves true replication of treatments, but the data for replicates are pooled prior to statistical analysis, or where two or more samples or measurements from each experimental unit are treated as independent replicates. Information on the variation among treatment replicates exists in the original data, but is ignored or "sacrificed" when the samples from the two or more replicates are pooled (Hurlbert 1984). In our frog example, if phosphorous fertiliser is added to three different ponds, and three other ponds were not fertilised, and the abundance of frogs in each pond was measured on six separate occasions, then there would be a total of 36 measures of frog abundance (18 in fertilised ponds, 18 in unfertilised ponds). A simple comparison of the effect of fertilisation on frog abundance, using 34 (36 minus 2) degrees of freedom in a statistical test, is an example of sacrificial pseudo-replication. In this case, a nested analysis of variance could be used to partition variability in frog abundance within ponds, among ponds of similar treatment (e.g. survey times), and between fertilised and unfertilised ponds. The appropriate test of influence of fertilisation on frog abundance would have 4 (6 minus 2) error degrees of freedom. However, Hurlbert (1984) cautions that in a field situation this form of statistical analysis is inappropriate because the replicate plots or ponds in each treatment are not identical.

Controls

In manipulative experiments, *controls* are experimental units that are identical to those receiving manipulative treatments except in the critical treatment factor. Almost any measurement or manipulation involves incidental impacts of the researcher on data collection (e.g. observer bias, responses of animals to the presence of the observer), which can be accounted for by the establishment of controls. Controls can also reveal whether or not some change through time is tending to occur in the plots because of factors the researcher cannot hold constant, such as seasonal changes in resources (e.g. food resources), climate, day length and composition of communities. Therefore, controls are essential for ecological field experiments, because it can rarely be assumed that conditions in nature will remain constant for any substantial time, and because almost any measurement or manipulation involves incidental impacts of the researcher.

It is important to note the difference between carrying out experiments in the field and under more controlled conditions in the laboratory. In the laboratory, all extraneous variables are kept constant (e.g. temperature. humidity, light regime), except one, which is the factor identified in the hypothesis. In the field, none of the extraneous variables can be controlled and thus vary over the course of the experiment, and only a single variable is under control – the one thought to be essential to the hypothesis. However, it does mean that even when one gets the expected answer, there are "*n minus 1*" other possible interpretations of the result, where n is the number of uncontrolled environmental variables.

Example: Road-crossing Behaviour of Squirrel Gliders Petaurus norfolcensis along the Hume Highway (van der Ree et al. 2010).

van der Ree *et al*. (2010) examined the road-crossing behaviour of 47 Squirrel Gliders resident in woodland adjacent to a section of the Hume Highway using radio-tracking. The traffic volume (highway vs. secondary road), presence or absence of tall trees in the centre median, and the sex of the glider were investigated as potential factors influencing crossing rates.

To ensure that the rate of crossing by Squirrel Gliders at the highway was due to the road and high traffic volumes, and not an artifact of habitat geometry, the researchers also selected intersections between two secondary (single-lane) roads to act as control or reference sites. These were located 6.5 km (Control-1) and 9.7 km (Control-2) from the Hume Highway and had a canopy gap < 9 m. The traffic volume was < 50 and 50 – 150 vehicles per day (vpd) on the two roads at Control-1, and < 50 vpd on both roads at Control-2.

The proportion of gliders crossing the road at control sites (77%) was similar to the proportion that crossed one or both roadways at the highway with trees in the median (67%), whereas only a single male (6%) crossed the highway where trees were absent from the median. The frequency of crossing for each individual was also similar at control sites and highway sites with trees in the median. The almost complete lack of crossing at sites where trees were absent from the median was attributed to the wider gap in canopy (50–64 m vs. 5–13 m at sites with trees in the median). This suggests that traffic volume, up to 5,000 vehicles per day on each roadway, and the other characteristics of the highway that were studied are not in themselves complete deterrents to road crossing by Squirrel Gliders. This study demonstrates that retaining and facilitating the growth of tall trees in the centre median of two-way roads may mitigate the barrier effect of roads on gliders, thus contributing positively to mobility and potentially to connectivity.

Randomisation and Interspersion

In manipulative experiments, the researcher may create replicated experimental units, some serving as controls and some as treatments. These must be interspersed in space or time so that, on average, the different sets of units experience the same environmental conditions. Treatments and controls can be assigned to experimental units randomly. If the number of replicates is large, a random assignment procedure serves well, since it is very unlikely that, for instance, all controls would end up clustered in one location and all treatment units clustered in another.

However, in ecological field experiments, the number of replicates is often small, out of necessity. If a researcher sets up trapping grids to determine the effect of adding different types of hollow logs on the abundance of small mammals in habitat restoration areas, the effort and large area required for each experimental unit probably limit the number of experimental units per treatment to three or four. If control or supplementary hollow log status were assigned to grids randomly, it is very possible that control grids would by chance be clustered in one part of the study site and treatment grids in another. Such an arrangement increases the chance of systematic influence operating differentially on one part of the area in which the grids are located. For example, predators might enter the grid area more frequently from one side than from the other, or vegetation density might change gradually from one side to the other. Without interspersion, such differences might exert a bias on responses of control or treatment plots. Hurlbert (1984) terms such an influence a "non-demonic intrusion".

Where such a possibility exists, *semi-systematic* or *systematic interspersion* of experimental units is desirable. Control and treatment units can be alternated, or arranged in checkerboard fashion. A *randomised block design* (Figure 2), which combines randomisation and systematic interspersion, is a frequently used procedure, where the total number of experimental units is divided into sets known as *blocks* (plots). Each block consists of a number of experimental units equal to the number of different types of treatments (including control). In this example, the treatments are different types of hollow logs, including no supplementary logs (the control). Within each block, treatments are then assigned randomly to the experimental units. A *latin square design* (Figure 2) is even more systematic in arrangement, having treatments assigned so that a given treatment occurs only once in each row or column.

Before-Impact-Control-Impact (BACI) Design

Ecological consultants work on many field projects where experimental design and analysis is possible, but where replication is impossible or impractical. Examples of such projects include assessing the ecological impacts of dams or water extraction for mining or agriculture on aquatic ecosystems, underground mining on above-ground terrestrial and aquatic systems, creation of new wetland habitat for foraging and roosting shorebirds, construction or significant modification of major transport routes (e.g. highways and railways) on the composition of ecological communities and movements of individuals within them.

Although these are, in a sense, giant experiments, in that they are planned ahead of time and their location selected, they are single "treatments" that do not permit an experimental assessment of general treatment effects. It may be possible, however, to test whether or not the specific project causes a significant change in conditions that prevailed before it was

Figure 1 A framework for conducting a field research project (from Underwood 1997)

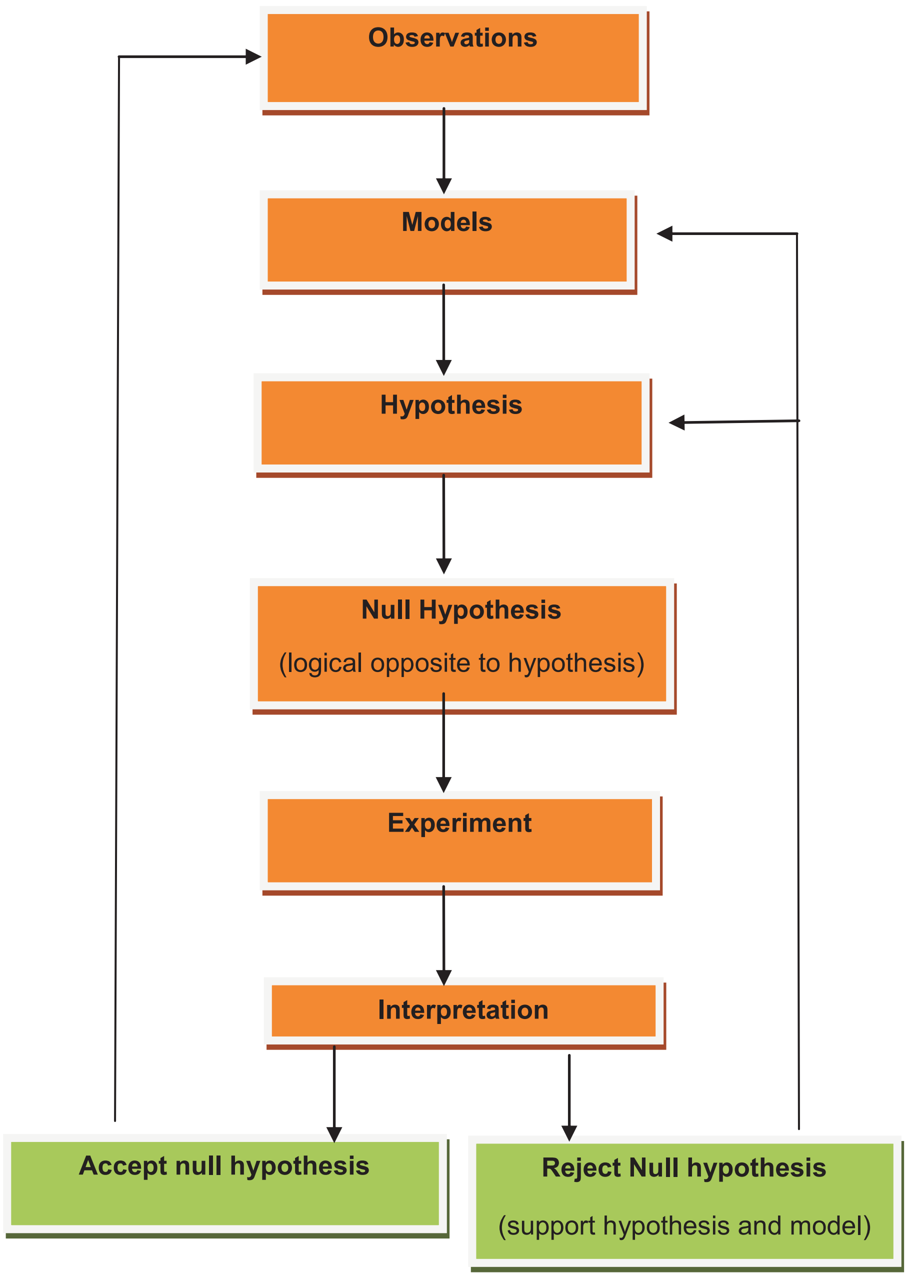
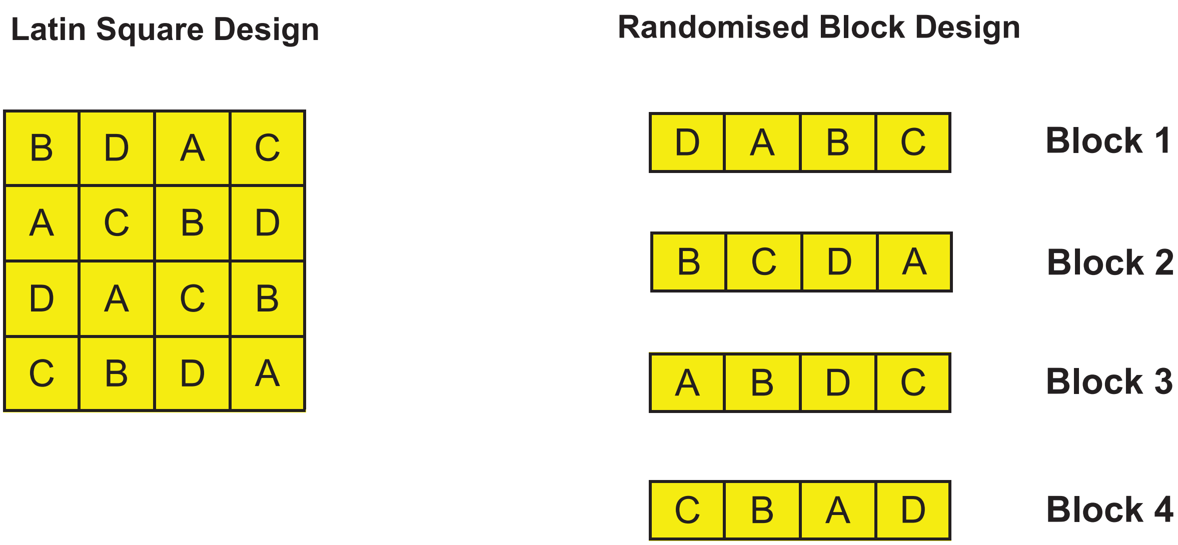


Figure 2 Schematic representation of a plot layout for experiments with a latin square design and randomised block design. The letters A, B, C and D represent four different treatments.



constructed.

Suggested designs for evaluating such a perturbation are the Before-After Control-Impact (BACI) Method (Stewart-Oaten *et al*. 1992) (e.g. road construction or implementation of mitigation strategies) and a modification of BACI involving the use of multiple control sites (Underwood 1994). These techniques involve simultaneously measuring response variables at impact (treatment) and control sites on a series of occasions before the structure is constructed and on a series of occasions afterwards.

The control site or sites must be nearby and similar to the impact site, so that it can reasonably be assumed that without the impact the sites would change through time in parallel fashion (the validity of the technique depends on this assumption being fulfilled!). Intervals between measurements must also be long enough that the values obtained are statistically independent. The differences between measurements at control and impact sites can then be compared for the before and after periods by an appropriate statistical test.

van der Ree *et al*. (2015) discuss modifications to the basic BACI design, including assessment of ecological impacts:

1. before, during and after construction or activity, at control and impact sites (BDACI);

2. before, during and after construction or activity at impact site only (BDA);

3. control-impact (CI), where measurements are taken before construction (Control 1), after construction without mitigation (Control 2), and after mitigation measures have been implemented (impact).

The principles behind each of these variations of the BACI design in relation to testing the effectiveness of a road mitigation measure (road overpass for wildlife) are illustrated in Figure 3.

USE OF BIODIVERSITY SURROGATES

As ecological consultants we are often required to monitor impacts of development or other human activity on biodiversity. This involves the assumption that biodiversity can be measured, but ecosystems are too complex to allow comprehensive mapping of their specific or genetic diversity (Scheffers *et al*. 2012). Our ability to measure "total biodiversity" is dependent on surrogates, in practice, a small number of frequently-studied taxa (Westgate 2015) and typically with an emphasis on vertebrates and vascular plants (Westgate *et al.* 2014).

Therefore, a significant consideration of any experimental design aimed at documenting biodiversity impacts (experimental responses) to development or other human activities (treatments) is to choose the most appropriate biodiversity surrogates (experimental units). The surrogates (e.g. vertebrates, threatened species) are often chosen by our clients or government authorities, but there are sometimes opportunities for us to advise them which taxa are best to study. The challenge is to choose surrogates that are easy and cost-effective to study or manipulate experimentally, and that can be studied at the most appropriate environmental scale in relation to the nature and extent of the impacts. Examples of surrogates used in ecological, conservation and environmental management studies are shown in Table 3.

Example of Appropriate Use of Biodiversity Surrogates

Invertebrates are ideal biodiversity surrogates in many ecosystems (Samways *et al*. 2010; Gerlach *et al.* 2013) because:

1. many taxa are easy to survey, thus providing a cost-effective option for gathering biodiversity data;

2. invertebrates are small in size and occupy a wide range of niches, thus being highly sensitive to localised changes in the environment;

3. they are highly mobile and capable of colonising new habitat quickly;

4. their short generation times and their abundance allows them to be "numerically responsive" to habitat change; and

5. they are highly diverse in their biology and ecology, with different species or taxa capable of being linked to specific environmental parameters.

The richness and abundance of insect taxa (especially butterflies, beetles and ants) also correlate with these parameters for other animal taxa at higher trophic levels (e.g. Oliver & Beattie 1996; Lawton *et al*. 1998; Andersen *et al*. 2004; Billeter *et al*. 2008; Vandewalle *et al*. 2010).

Figure 3 **Three possible BACI designs for assessing the ecological effectiveness of a road mitigation strategy (road overpass) (reproduced from van der Ree *et al*. 2015; original source is Roedenbeck *et al*. 2007).**

Legend: **BDACI:** Before (-During)-After-Control-Impact; **BDA**: Before-During-After; **CI:** Control-Impact. The dots and orange arrows symbolise animals moving in the landscape and across the over-pass, respectively.

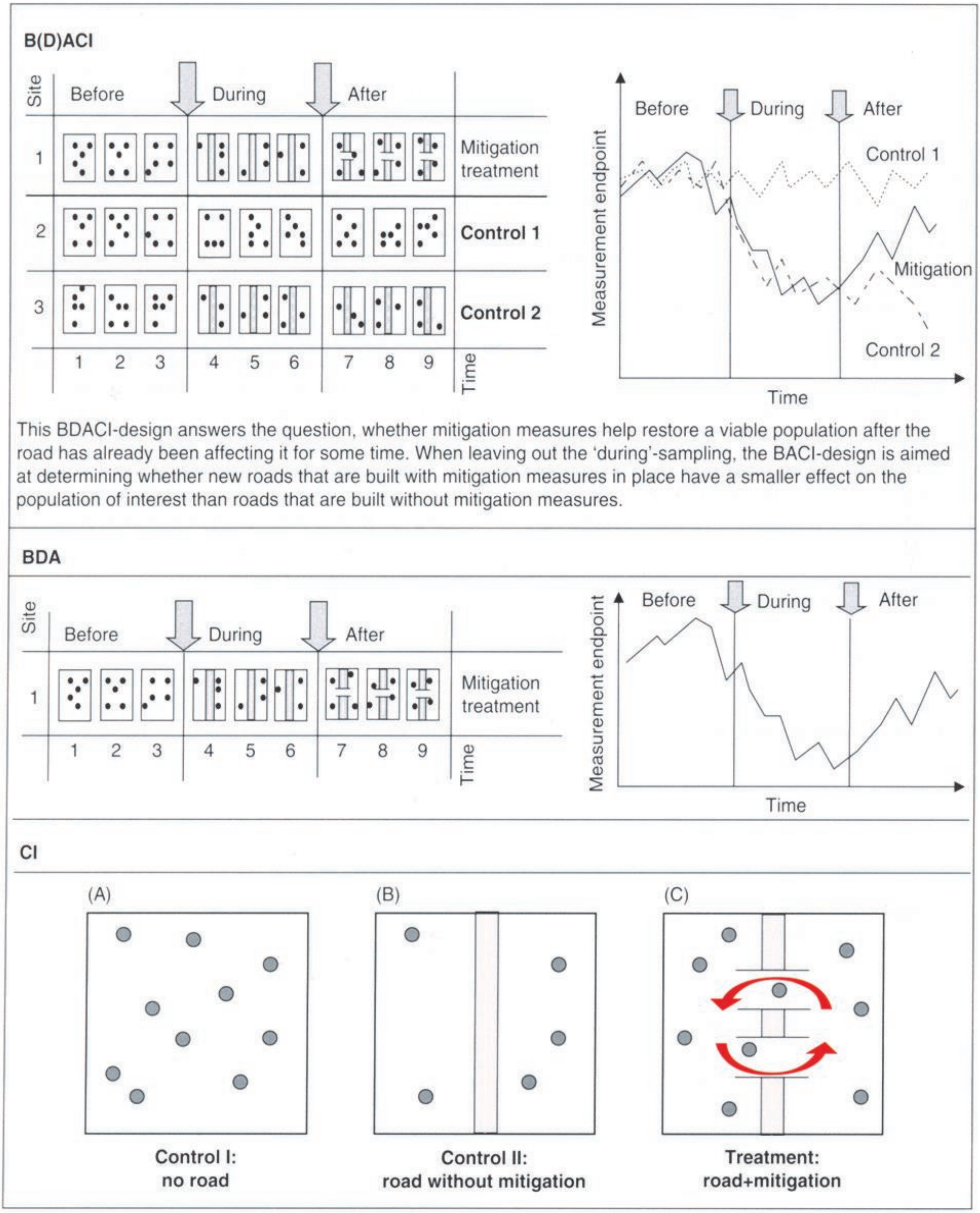


Table 3 Examples of the use of biodiversity surrogates and indicator species in ecological, conservation and environmental management studies (from Lindenmayer *et al.* 2015 and modified by adding more taxa and references).

Field	Examples
Restoration ecology	Collembola (Zeppelini *et al*. 2009); ants (Andersen & Sparling 1997, Andersen & Majer 2004, Andersen *et al.* 2004, Fagan *et al*. 2010, Majer 1983, Majer & Nichols 1998, Majer *et al*. 2007 & 2013); dung beetles (Gollan *et al*. 2011); spiders (Brennan *et al*. 2003); plant-dwelling arthropods (Barton *et al*. 2013, Moir *et al*. 2005, 2010 & 2011; Woodcock *et al.* 2008)); plant pollinators (Forup & Memmott 2005); terrestrial invertebrates (Oliver & Beattie 1996); McGeoch 1998); soil invertebrates (Riggins *et al.* 2009).
Agri-ecological conservation	Vascular plants, birds and arthropods (Billeter *et al.* 2008); grass-land plants (Kaiser *et al.* 2010).
Forest ecology and management	Woodpeckers (Drever *et al*. 2008); owls (Martin *et al.* 2015); grass-hoppers (Saha & Halder 2009).
Plantation tree management	Endemic and endangered species (Roundtable for Sustainable Palm Oil 2007); bryophytes, vascular plants, spiders, hoverflies and birds (Smith *et al.* 2008).
Pollution ecology	Diatoms (Dixit *et al.* 2002; Herring *et al.* 2006); macrophytes (Hering *et al.* 2006), aquatic macroinvertebrates (Hering *et al*. 2006, Menezes *et al.* 2010); freshwater fish (Karr 1981, Hering *et al*. 2006, Hitt & Angermeier 2011, Jackson *et al*. 2001); *Calluna vulgaris* (Fam. Ericaceae) (Edmondson *et al.* 2010); mosses (Salo 2015); lichens (Branquinho *et al*. 2015); Diamondback Terrapins (Basile *et al.* 2011); coral reefs (Beger 2015); Giant Squid (Guerra *et al*. 2011).
Pest management	Mites (Bernard *et al.* 2010).
Conservation planning	Ants (Mitrovich *et al.* 2010), butterflies (Maes & Van Dyck 2005); birds (Gardner *et al.* 2008, Vidal *et al.* 2013, Moran & Catterall 2014, Peck *et al*. 2014).
Rare and threatened species management	Indicator threatened fish species (Wenger 2008), apex predators (e.g. Letnic *et al.* 2009).
Climate Change	Epiphytes (Ellis *et al.* 2009); birds, butterflies and vascular plants (Pearman *et al*. 2011).
Ecological Monitoring	Forest stand structure and composition, state & volume of dead wood, tree regeneration, composition of ground vegetation (Cantarello & Newton 2008).

Majer *et al*. (2007) summarise the findings of a series of ground-breaking studies, running for more than 30 years, of invertebrate responses to habitat restoration of 30 bauxite mines, in comparison with responses to natural processes in three unmined forest control sites, in the Darling Range of Western Australia.

Majer *et al.* (2007) explain that the Jarrah (*Eucalyptus marginata*) forest surrounding the former mine sites contain a rich diversity of terrestrial invertebrates. To re-establish a self-sustaining ecosystem at restored sites, one must re-establish the full range of ecosystem functions and processes. Therefore it is important to re -establish all components of biota. They argue that, although microorganisms, plants, and vertebrates are of unquestionable importance, invertebrates feature prominently as drivers of ecosystem functions and processes. Therefore, the outcome of restoration attempts is influenced profoundly by the presence or absence of some of these animals. Mining companies should therefore revegetate areas in a manner that maximizes the return of the full range of biodiversity.

Consequently, the studies have monitored the species or morphospecies richness and abundance of invertebrates in the soil and litter layers (earthworms and other soil invertebrates, collembola, mites, termites and ants) on understorey plants and trees (e.g. beetles, bugs, butterflies, moths and ants) and predatory arthropods (e.g. scorpions and spiders) in the mine restoration sites (treatment sites) and the uncleared forest sites (control sites) (Figure 4). Therefore, invertebrate responses to habitat restoration and to natural environmental processes were adequately sampled by selecting a broad range of indicator species across a broad range of ecological niches. Other environmental variables (treatments) measured at each site in each sampling period were soil moisture, litter depth litter cover (% ground cover), shrub cover (% foliage cover), tree cover (% canopy cover), plant species richness and time since restoration.

This experimental design and ongoing monitoring has been able to document the role of ants as seed predators and as indicators of ecosystem health. Successional data for other groups, when measured as species richness (ants, spiders and hemipterans) and composition (ants and spiders) show reassembly trajectories tracking toward those found at the forest control sites.

Examples of Inappropriate Use of Biodiversity Surrogates (from Ambrose 2015)

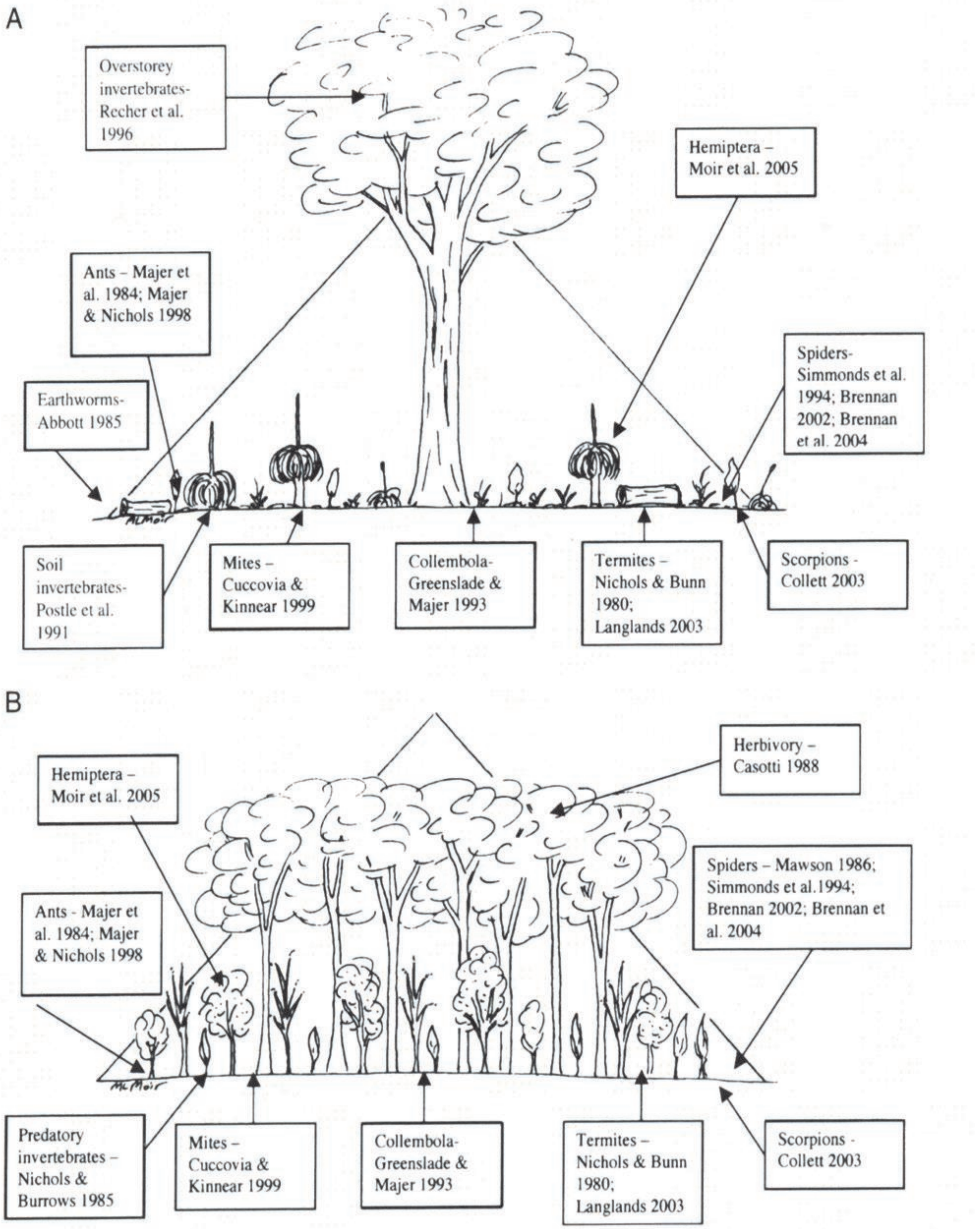
A local council in Sydney's metropolitan area has developed bushfire management plans for reserves under its management. In 2015 it called for tenders for a baseline vertebrate survey of two adjoining urban bushland reserves as a first step in the process of assessing the impacts of mosaic patch burning on their values as a biobanked site. Collectively, these two reserves are about 94 ha in area and, on average, about one hectare would be patch-burned in a given year. Control-burning would not occur every year at these reserves, the first two patches (both less than 0.5 ha in area) were burned in mid-2015, but the next patch is not due to be control-burned until the 5th year, and the entire control-burn cycle of the forest's edges would take 37 years to complete if there are no wildfires. Although the 37-year cycle would result in most of the smaller reserve being fire-managed, control-burning would be restricted to the northern end of the larger reserve, and most of this latter reserve would be untouched.

The richness and diversity of vertebrates have been documented in previous studies of these two reserves. Threatened fauna species that have been recorded in them include the Gang-gang Cockatoo (*Callocephalum fimbriatum*), Powerful Owl (*Ninox strenua*), Grey-headed Flying-fox (*Pteropus policephalus*), Eastern Bentwing-bat (*Miniopterus schreibersii oceanensis*), East Coast Freetail-bat (*Mormopterus norfolkensis*) and Yellow-bellied Freetail-bat (*Saccolaimus flaviventris*), all of which have home ranges that would extend well beyond the reserves' boundaries. Other vertebrate species recorded in the reserves have a widespread distribution within the Sydney Basin Bioregion. The high mobility of vertebrates within the reserves, and between the reserves and habitat areas elsewhere in the locality, in comparison with the relatively small areas that would be burned, gives these species little value as measures of the impacts of control-burning on the reserves' biodiversity values. Most notably:

1. the absence or reduced abundance of a vertebrate species or guild within the reserves or bushfire management zone during a fauna survey period may be due to:

    a. individuals using parts of their home range that are outside the reserves or management zone at the times of the surveys; or

Figure 4 Invertebrate sampling described by Majer *et al.* (2007) at restored former mine sites (upper diagram) and forest control sites (lower diagram).



b. local populations of vertebrates (e.g. migratory populations) being impacted by a wide range of detrimental environmental conditions away from the reserves.

Therefore, a measure of vertebrate richness and abundance in the reserves may lead to misleading information about vertebrate responses to bushfire management; and

2. vertebrate populations may be unresponsive or less responsive (in terms of changes in distribution and abundance) in comparison with other biodiversity that are affected by environmental changes in the reserves.

More appropriate biodiversity surrogates for this project would have been invertebrates as in the project described by Majer *et al*. (2007) and for the reasons provided in the previous section of the present article. Other potentially suitable indicators include plant species composition and richness (including the identification of plant species that are particularly useful as habitat for fauna species of special consideration) and microhabitat variables (soil moisture, litter depth, litter cover, shrub cover and tree cover).

In other studies, Weinberg *et al*. (2008) demonstrated that desktop biodiversity toolkits (such as the BioBanking credit calculator, which relies on a range of key vegetation and landscape attributes) were good at predicting some fauna assemblages, but not others, on sites. For instance, toolkits are better at predicting the presence of fauna groups that are dependent on structurally complex vegetation (e.g. woodland-dependent birds, arboreal mammals and reptiles), but not bats and non-woodland-dependent birds. Similarly, Cristecu *et al*. (2013) found that flora criteria used in assessment of habitat restoration success of former mine sites in eastern Australia did not accurately predict the presence or extent of recolonisation by the Koala (*Phascolarctos cinereus*), a threatened species, on restoration sites. Therefore, great care must be exercised in the choice of biodiversity surrogates.

ANALYSIS AND INTERPRETATION OF DATA

Ecological measurements are variable, and therefore data usually require statistical analyses. The general principles in using inferential statistics are summarised in Figure 5.

Hypothesis testing examines the likelihood of a null hypothesis being true (and therefore accepted) or, conversely, false (and therefore rejected). Wheater *et al.* (2011) state that such tests involve the calculation of a test statistic that summarises the comparison (e.g. difference, relationship or association), and has known characteristics that depend on the size of the dataset. The size of the dataset and this test statistic can be used to obtain the probability of the difference between sets of data occurring by chance. If the resulting probability is below the critical value of 0.05 (5%), then we can reject the null hypothesis of no significant difference, relationship or association. However, if the resulting probability is equal to or higher than 0.05, then we cannot reject the null hypothesis and must conclude that there is no significant difference, relationship or association. Although it is still worth remembering that when the probability (P) is equal to 0.05, there is still a one in 20 chance that the difference observed has happened by chance.

The choices of what statistical tests are most appropriate for analysing your field data can be quite complex, it is not discussed here, and you are advised to seek expert advice from a statistician. However as a field ecologist and ecological consultant, I have also found McCune & Grace (2002), Manly (2005), Zuur *et al*. (2007) and Quinn & Keough (2010) particularly useful in assisting me to choose the most appropriate statistical tests for analysing field data, and for understanding the assumptions and limitations of these tests.

In conducting statistical analyses, it is worth remembering the following advice from Underwood (2009): If a hypothesis predicts that some quantity is of different magnitude under different controlled conditions, it is more likely that the difference will be seen in the experimental data if:

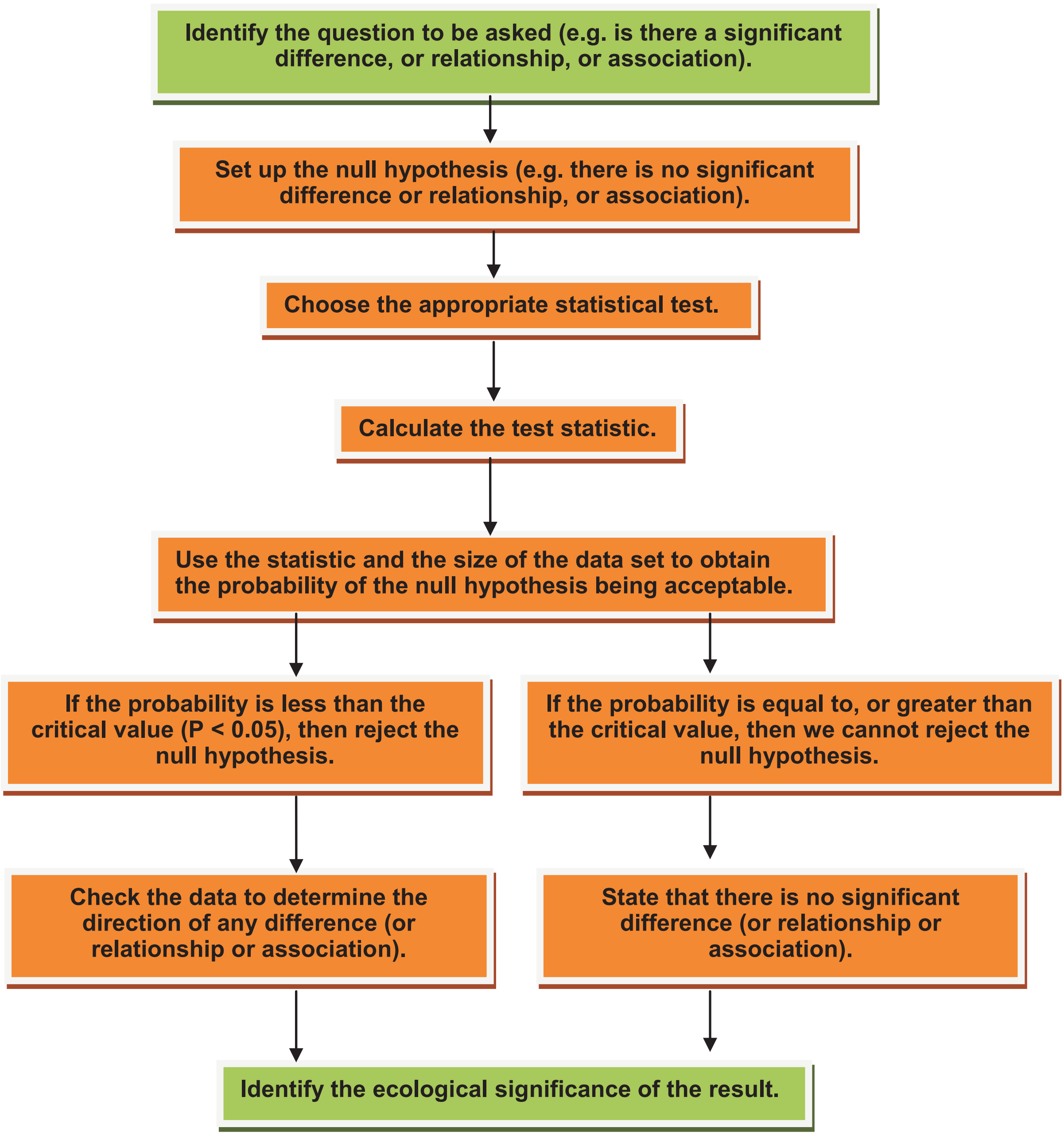
1. measures are made on more, rather than fewer, experimental units (i.e. samples are large);

2. the intrinsic variability in the measures from one experimental unit to another (i.e. the variance of the measures being made) is relatively small; and

3. the predicted difference(s) between (among) treatments are relatively large.

Therefore, it is important for your field experiment to be designed and that you choose the statistical test(s) that promote these three principles.

Figure 5 Stages in using inferential statistics (from Wheater *et al*. 2011)



Statistical tests of data are usually performed using computer software. There are many statistical software packages suitable for analysing ecological data; the types and complexity of analyses, personal preference, availability in the workplace, and to some extent the size of your budget, will determine which ones you will use. Software packages that I use regularly are Primer-E (for analyses of similarity, ANOSIM, between the structures of community groups or the same community group at different time periods), Systat (Systat Software Inc.) and statistiXL (University of Western Australia) for a broader range of statistical analyses. I have found the latter package particularly useful from the perspective that data can be statistically analysed while still stored in Excel, i.e. without the need to convert the dataset to a text file or manually importing it into the statistical software.

The final part of the study is presenting the data and discussing the ecological significance of the results. This should always be done in the context of the ecological findings of related studies. Recommendations from your study should be realistic; for instance, even though there may be significant statistical differences between data sets in the study, it is important to weigh up the cost-effectiveness of implementing suitable mitigation or conservation measures. In other words, what is an acceptable ecological impact and are the potential mitigation strategies arising from the study financially and environmentally viable? That is a whole new topic worthy of discussion at another time.

THE PUBLICATION DILEMMA

As ecological consultants we are practitioners of ecological impact assessment and management. Those of us who sometimes work on large projects usually collect data that have wider scientific and conservation value, as well as having practical importance to the client. This is particularly relevant to projects that have an experimental field component. Yet the results of such studies are seldom published in the broader scientific literature unless they have been conducted by university or government researchers. Reasons for this include:

1. Written confidentiality agreements between client and consultant, precluding information about the project from being communicated outside the usual development application or environmental management processes.

2. Data and reports are usually the intellectual property of the client.

3. Ecological consultants earn an income primarily by conducting field investigations, desktop assessments and writing reports for clients. Diversion from this process to publish the results of studies in the scientific literature, in the event of clients giving permission to publish their results, usually cuts into a consultant's income-earning time. Few consultants want or are able to reduce their income-earning abilities, especially in an industry as competitive as ours. The administrative side of running a business, which seems to have become more demanding over time, also competes for non-income-earning time in the workplace. (Of course there are, on rare occasions, notable exceptions. Dr Stephen Debus, a well-known ornithological consultant, was awarded the D.L. Serventy Medal by Birdlife Australia recently for his lifetime contribution to the Australian ornithological literature. In accepting his medal at the Australasian Ornithological Conference in Adelaide in November 2015, Stephen gave some insight on how he has lived frugally for a significant part of his working life so that he could conduct independent bird research and publish his findings!)

This is a dilemma because important scientific and conservation findings can be buried in the "grey literature" (e.g. environmental impact statements, ecological management plans and biodiversity monitoring reports) and are often overlooked by university and government researchers, environmental managers, regulatory authorities and even other consultants. Consultants are also criticised unfairly by their scientific colleagues in universities and government for not publishing their work in scientific journals, often without looking into or appreciating the reasons why.

Unless clients are prepared to pay consultants for their time in preparing scientific papers for publication, it is unlikely that large numbers of papers from ecological consultancy studies will be published. But is it ethical to expect clients to pay for these costs, especially once the services that we have provided are completed? Some clients may fund such ventures if it has a public relations benefit, but few would do it as a philanthropic gesture. Many clients also have tight budgets and simply cannot afford to fund the preparation of scientific publications.

There is no easy solution to this problem. On occasions, industry groups and societies have considered inviting their members to competitively tender for a one-off grant to write and publish a paper of scientific importance based on consultancy work. But, understandably, such considerations have never advanced beyond the initial idea. There are usually two reasonable challenges to this concept:

1. If funds are available to assist in the publication of scientific papers, should they not be granted to students as part of their career development and who, arguably, have much lower incomes than most consultants?

2. Members of industry groups (e.g. the ECA) work together to develop and promote standards in their industry, communicate new ideas, and provide training. But outside the industry group, in the workplace, we are competitors. Is it possible for peers to award grants objectively for the publication of papers that could give the recipients a competitive advantage in the market place?

Realistically, the solution to the publication dilemma probably comes down to a bit of give-and-take by all parties involved. Perhaps as consultants we should be prepared to devote a bit more of our work-time publishing our results in journals. Perhaps there are ways of passing some of these costs to clients in situations where it is ethical. For instance, there may be an opportunity for us to negotiate a 'scientific publication fee" at the start of a contract, though I can't see that being successful in most situations. Perhaps industry groups and societies should revisit the idea of a special grants scheme. Perhaps governments should institute a regulatory requirement for scientific publication of work resulting from government contracts, where there is scientific merit in doing so.

CONCLUSION

In summary, the following is a checklist of procedures for ecological consultants conducting experimental field studies for biodiversity impact assessment:

1. Consult with the client (and the relevant government authorities) to ensure all parties are in agreement with the project objectives and timetable.

2. Undertake a desktop review (online database and literature research) of previous studies of the immediate area within which the site is located to provide background knowledge on flora and fauna issues related to the proposed development or activity.

3. Make an initial visit to the site to be surveyed and assessed so that you are familiar with the range and condition of habitats and the context of the site within the broader locality, to obtain a snapshot of community types and assemblages (observations), and to develop further opinions of issues that need to be investigated as part of the impact assessment (models).

4. Identify the null hypothesis or hypotheses to be tested. In the case of biodiversity impact assessment, they need to address the brief provided by the client and potential impacts that may arise from the development, human activity or mitigation strategy that is/are being considered in the investigation.

5. Choose the most appropriate experimental field design for testing the null hypotheses, ensuring that the treatments chosen are relevant to the hypotheses being tested, there are adequate replicates and controls for environmental variation, experimental error and observer bias, and that data can be collected in a systematic way that enable them to be analysed statistically. This includes a design that allows equal and simultaneous effort of discreet data collection across all treatments and controls. It is recommended that you consult a statistician during this phase of the project to ensure that the experimental field design is amenable to the most appropriate forms of statistical analysis.

6. If biodiversity surrogates are used in the field study, ensure that they are ecologically-appropriate surrogates for the hypotheses being tested and that they can be studied in a cost-effective and timely manner.

7. Collect the field data using the methods prescribed in Point 5, noting any variations in the design of the project or extraneous variables that may affect the quality of data and/or conclusions that may arise from subsequent analyses.

8. Analyse and interpret data using statistical tests most appropriate for testing your null hypotheses. Ensure that you are aware of the limitations and assumptions of the statistical tests, and the levels of certainty in interpreting the conclusions that arise from testing your data. These limitations need to be identified in the report that is produced for the client and the people in the government agencies who assess it. The conclusions must also be discussed

in the environmental context of similar or related studies.

9. Although the field data may have been collected in an experimental or systematic manner, the results, conclusions and recommendations must be presented in a way that is meaningful to all who are involved in the development application or impact assessment process. Therefore, the resulting report should not be so technical that it is understood only by expert ecologists, because it is meant to be informative to a broader audience. However, it should demonstrate the extent of scientific rigour involved in the design of the project, and the collection, analysis and interpretation of the data. Recommendations that arise from the study should be realistic; for instance, it is important to weigh up the cost-effectiveness of implementing suitable mitigation or conservation measures.

10. Where possible, publish in the mainstream scientific literature those findings from your field study that have scientific and/or conservation merit. This is subject to the client providing you with permission to do this and that you have the resources (e.g. time and the financial capacity) to complete the task.

ACKNOWLEDGEMENTS

I thank Martin Denny and Alison Hunt (ECA Council) and Don Bradshaw (University of WA) for their comments on an earlier draft of this paper. Their comments helped greatly to improve its structure and content. Discussions with a number of colleagues (especially Liz Ashby, Peter Banks, Don Bradshaw, Martin Denny, Daryl Jones, Brad Law, Dan Lunney, Tom Newsome, Martin Predavec, Kevin Roberts, David Sharpe, Josie Stokes, John Travers and Rodney van der Ree), prior to or during the preparation of this article, assisted in the identification of issues and the practicalities that the article needed to address. Ambrose Ecological Services Pty Ltd provided financial resources for the purchase of references that were accessed online during the preparation of the paper. I also thank my wife, Michele, for tolerating my researching and writing of this article when we could have been enjoying more leisurely and social activities outside the work environment.

REFERENCES

Ambrose, S.J. (2015). Biodiversity impact assessment: the good, the bad and the ugly of experimental design. *Consulting Ecology* 35:19-21

Andersen, A.N, Fisher, A., Hoffman, B.D., Read, J.L. and Richards, R. (2004). Use of terrestrial invertebrates for biodiversity monitoring in Australian rangelands, with particular reference to ants. *Austral Ecology* 29: 87-92.

Andersen, A.N. and Majer, J.D. (2004). Ants show the way Down Under: invertebrates as bioindicators in land management. *Frontiers in Ecology and Environment* 2: 291-298.

Andersen, A.N. and Sparling, G.P. (1997). Ants as indicators of restoration success: relationship with soil microbial biomass in the Australian seasonal tropics. Restoration *Ecology* 5: 109-114.

Antos. M.J., Bennett, A.F. and White, J.G. (2008). Where exactly do ground-foraging woodland birds forage? Foraging sites and microhabitat selection in temperate woodlands of southern Australia. *Emu*. 108: 201-211.

Baldwin, M. (1975). Birds of the Inverell District, NSW. *Emu* 75: 113-120.

Barrett, G.W., Ford, H.A. and Recher, H.F. (1994). Conservation of woodland birds in a fragmented rural landscape. *Pacific Conservation Biology* 1: 245-256.

Barton, P.S., Colloff, M.J., Pullen, K.R. and Cunningham, S.A. (2013). Arthropod assemblages in a focal tree species (*Eucalyptus microcarpa*) depends on the species mix in restoration plantings. *Biodiversity and Conservation* 22: 2091-2110.

Basile, E.R., Avery, H.W., Bien, W.F. and Keller, J.M. (2011). Diamondback terrapins as indicator species of persistent organic pollutants: using Barnegat Bay, New Jersey as a case study. *Chemosphere* 82: 137-144.

Beger, M. (2015). Surrogates for coral reef ecosystem health and evaluating management success. Pp. 113-123. In: Lindenmayer, D., Barton, P. and Pierson, J. (eds). *Indicators and Surrogates of Biodiversity and Environmental Change*. 203 pp. (CSIRO Publishing, Clayton South).

Bennett, V.A., Doerr, V.A.J, Doerr, E.D., Manning A..D., Lindenmayer, D.B. & Yoon, Y-J. (2013). Habitat selection and behaviour of a reintroduced passerine: linking experimental restoration, behaviour and habitat ecology. http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0054539.

Bernard, M.B., Cole, P., Kobelt, A., Horne, P.A., Altmann, J., Wratten, S.D. (2010). Reducing the impact of pesticides on biological control in Australian vineyards: pesticide mortality and fecundity effects on an indicator species, the predatory mite Euseius victoriensis (Acari: Phytoseiidae). *Ecotoxicology (London, England)* 103: 2061-2071.

Billeter, R., Liira J., Bailey, D., Bugter, R., Arens, P., Augenstein, I., Aviron, S., Baudry, J., Bukacek, R., Burel, F., Cerny, M., De Blust, G., De Cock, R., Diekotter, T., Dietz, H., Dirksen, J., Dormann, C., Durka, W., Frenzel, M., Hamersky, R., Hendrick, F., Herzog, F., Klotz, S., Koolstra, B., Lausch, A., Le Coeur, D., Maelfait ,J.P., Opdam, P., Roubalova, M., Schermann, A., Schermann, N., Schmidt, T., Schweiger, O., Smulders,M.J.M, Speelmans, M., Simova, P., Verboom, J., van Wingerden, W.K.R.E, Zobel, M. and Edwards, P.J. (2008). Indicators for biodiversity in agricultural landscapes: a pan-European study. *Journal of Applied Ecology* 45: 141–150.

Branquinho, C., Matos, P. and Pinho, P. (2015). Lichens as ecological indicators to track atmospheric changes: future challenges. Pp. 77-90. In: Lindenmayer, D., Barton, P. and Pierson, J. (eds). *Indicators and Surrogates of Biodiversity and Environmental Change*. 203 pp. (CSIRO Publishing, Clayton South).

Brennan, K., Majer, J. and Koch, A. (2003). Using fire to facilitate faunal colonization following mining: an assessment using spiders in Western Australia jarrah forest. *Ecological Management and Restoration* 2: 145-147.

Cantarello, E. and Newton, A.C. (2008). Identifying cost-effective indicators to assess the conservation status of forested habitats in Natura 2000 sites. *Forest Ecology and Management* 256: 1209-1221.

Cristecu, R.H., Rhodes, J., Frere, C and Banks, P.B. (2013). Is restoring flora the same as restoring fauna? Lessons learned from koalas and mining rehabilitation. *Journal of Applied Ecology* 50: 423-431.

Denny, M. (2010). Then and now – fauna monitoring within the Sydney Basin. Pp. 90-101. In: Lunney, D., Hutchings, P. and Hochuli, D. (eds). *The Natural History of Sydney* (Royal Zoological Society of NSW, Mosman, NSW).

Denny, M. (2015). Message from the President. *Consulting Ecology* 34: 2-3.

Dixit, S.S., Smol, J.P., Kingston, J.C. and Charles, D.F. (1992). Diatoms – powerful indicators of environmental change. *Environmental Science and Technology* 26: 22-33.

Doerr, V.A.J., Doerr, E.D. and Davies, M.J. (2010). Does structural connectivity facilitate the dispersal of native species in Australia's fragmented terrestrial landscapes? *Systematic Review No. 44, Collaboration for Environmental Evidence* (CSIRO Sustainable Ecosystems, Gungahlin, ACT.

Doerr, V.A.J., Doerr, E.D. & Davies, M.J. (2011). Dispersal behavior of Brown Treecreepers predicts functional connectivity for several other woodland birds. *Emu* 2011: 71 -83.

Drever, M.C., Aitken, K.E.,, Norris, A.R. and Martin, K. (2008). Woodpeckers as reliable indicators of bird richness, forest health and harvest. *Biological Conservation* 141: 624-634.

Edmondson, J.L., Carroll, J.A., Price, E.A. and Caporn, S.J. (2010). Bio-indicators of nitrogen pollution in heather moorland. *The Science of the Total Environment* 408: 6202-6209.

Egan, K., Farrell, J. and Pepper-Edward, D. (1997). Historical and seasonal changes in the community of forest birds at Longneck Lagoon Nature Reserve, Scheyville, New South Wales. Corella. 21: 1-16.

Ellis, C.J., Yahr, R. and Coppins, B.J. (2009). Local extent of old-growth woodland modifies epiphyte response to climate change. *Journal of Biogeography* 36: 302-313.

Fagan, K.C., Pywell, R.F., Bullock, J.M. and Marrs, R.H. (2010). Are ants useful indicators of restoration success in temperate grasslands? Restoration Ecology 18: 373-379.

Field, S.A., O'Connor, P.J., Tyre, A.J. and Possingham, H.P. (2007). Making monitoring meaningful. *Austral Ecology* 32: 485-491.

Forup. M.L. and Memmott. J. (2005). The restoration of plant-pollinator interactions in hay meadows. *Restoration Ecology* 13: 265-274.

Gardner, T.A., Barlow, J., Araujo, I.S., Avila-Pires, T.C., Bonaldo, A.B, Costa, J.E., Esposito, M.C., Ferreira, L.C., Hawes, J., Hernandez, M.I.M., Hoogmoed, M.S., Leite, R.N., Lo-Man-Hung, N.F., Malcolm, J.R., Martins, M.B., Mestre, L.A.M., Miranda-Santos, R., Overal, W.L., Parry, L., Peters, S.L., Ribero-Junior, M.A., Da Silva, M.N.F., Da Silva Motta, C. and Peres, C.A. (2008). The cost-effectiveness of biodiversity surveys in tropical forests. *Ecology Letters* 11: 139-150.

Gollan, J.R., Reid, C.A.M., Barnes, P.B. and Wilkie, L. (2011). The ratio of exotic-to-native dung beetles can indicate habitat quality in riparian restoration. *Insect Conservation and Diversity* 4: 123-131.

Guerra, A., Gonzalez, A.F., Pascual, S. and Dawe, E.G. (2011). The giant squid *Architeuthis*: an emblematic invertebrate that can represent concern for the conservation of marine biodiversity. *Biological Conservation* 144: 1989-1997.

Hairston Snr, N.G. (1996). *Ecological Experiments: Purpose, Design and Execution*. 370 pp. (Cambridge University Press, Cambridge).

Hering, D., Johnson, R.K., Kramm, S., Schmutz, S., Szoskkiewitz, K. and Verdonschot, P.F.M. (2006). Assessment of European streams with diatoms, macrophytes, macroinvertebrates and fish: a comparative metric-based analysis of organism response to stress. *Freshwater Biology* 51: 1757-1785.

Hitt, N.P. and Angermeier, P.L. (2011). Fish community and bioassessment responses to stream network location. *Journal of the North American Benthological Society* 30: 296-309.

Hoskin, E. (1991). *Birds of Sydney 1770-1989* (Surrey Beatty and Sons: Sydney).

Hurlbert, S.H. (1984). Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54: 187-211.

Jackson, D.A., Peres-Neto, P.R. and Olden, J.D. (2001). What controls who is where in freshwater fish communities – the roles of biotic, abiotic and spatial factors. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 157-170.

Kaiser, T., Rohner, M-S, Matzdorf, B. and Keisel, J. (2010). Validation of grassland indicator species selected for result-orientated agri-environmental schemes. Biodiversity and Conservation 19: 1297-1314.

Karr. J.R. (1981). Assessment of biotic integrity using fish communities. *Fisheries (Bethesda, Md.)* 6: 21-27.

Keast, A. (1995). Habitat loss and species loss: the birds of Sydney 50 years ago and now. Australian Zoologist. 30: 3-25.

Krebs, C.J. (2014). Ecological Methodology. 3rd ed. 624 pp. (Addison-Wesley Educational Publishers Inc., Boston).

Lawton, J.H., Bignell, D.E., Bolton, B., Bloemers, G.F., Eggleton, P., Hammond, P.M., Hodda, M., Holt, R.D., Larson, T.B., Mawdsley, M.A., Stork, N.E., Srivastava, D. and Watt, A.D. (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature* 391: 72-76.

Letnic, M., Koch, F., Gordon, C., Crowther, M.S. and Dickman, C.R. (2009). Keystone effects of an alien top-predator stem extinctions of native mammals. *Proceedings of the Royal Society of London, Biological Sciences* 276: 3249-3256

Lindenmayer, D., Barton, P., Westgate, M., Lane, P. and Pierson, J. (2015). Pp. 15-24. In: Lindenmayer, D., Barton, P. and Pierson, J. (eds). *Indicators and Surrogates of Biodiversity and Environmental Change*. 203 pp. (CSIRO Publishing, Clayton South).

Maes, D. and Van Dyck, H. (2005). Habitat quality and biodiversity indicator performances of a threatened butterfly versus a multispecies group for wetlands in Belgium. *Biological Conservation* 123: 177-187.

Majer, J.D. (1983). Ants: bio-indicators of minesite rehabilitation land-use and land conservation. *Environmental Management* 7: 375-383.

Majer, J.D. and Nichols, O.G. (1998). Long-term recolonization patterns of ants in Western Australian rehabilitated bauxite mines with reference to their use as indicators of restoration success. *Journal of Applied Ecology* 35: 161-182.

Majer, J.D., Brennan, K.E.C. and Moir, M.L. (2007). Invertebrates and the restoration of a forest ecosystem: 30 years of research following bauxite mining in Western Australia. *Restoration Ecology* 15: S104-S115.

Majer, J.D., Heterick, B., Gohr, T., Hughes, E., Mounsaher, L. and Grigg, A. (2013). Is thirty-seven years sufficient for full return of ant biota following restoration? *Ecological Processes* 2: 19.

Manly, B.J.F. (2005). *Multivariate Statistical Methods: A Primer.* 3rd ed. 214 pp. (Chapman & Hall/CRC Press Co., Boca Raton, Florida).

Martin, K., Ibarra, J.T. and Drever, M. (2015). Avian surrogates in terrestrial ecosystems: theory and practice. Pp. 33-44. In: Lindenmayer, D., Barton, P. and Pierson, J. (eds). *Indicators and Surrogates of Biodiversity and Environmental Change*. 203 pp. (CSIRO Publishing, Clayton South).

Maron, M. and Lill, A. (2005). The influence of livestock grazing and weed invasion on habitat use by birds in grassy woodland remnants. *Biological Conservation* 124: 439-450.

McCune, B. and Grace, J.B. (2002). *Analysis of Ecological Communities.* 300 pp. (MJM Software Design, Oregon).

McGeoch, M.A. (1998). The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews of the Cambridge Philosophical Society* 73: 181-201.

Menezes, S., Baird, D.J. and Soares, A.M.V.M. (2010). Beyond taxonomy: a review of macroinvertebrate trait-based community descriptors as tools for freshwater biomonitoring. *Journal of Applied Ecology* 47: 711-719.

Mitrovich, M.J., Matsuda, T., Pease, K.H. and Fisher, R.N. (2010). Ants as a measure of effectiveness of habitat conservation planning in southern California. *Conservation Biology* 24: 1239-1248.

Moir. M.L., Brennan, K.E.C., Koch, J.M., Majer, J.D. and Fletcher, M.J. (2005). Restoration of a forest ecosystem: the effects of vegetation and dispersal capabilities on the reassembly of plant-dwelling arthropods. *Forest Ecology and Management* 217: 294-316.

Moir. M.L., Brennan, K.E.C., Koch, J.M., Majer, J.D. and Fletcher, M.J. (2010). Plant species redundancy and the restoration of fauna habitat: lessons from plant-dwelling bugs. *Restoration Ecology* 18: 136-147.

Moir. M.L., Brennan, K.E.C., Koch, J.M., Majer, J.D. and Fletcher, M.J. (2011). Multi-scale patterns in the host specificity of plant-dwelling arthropods: the influence of host plant and temporal variation on species richness and assemblage composition of true bugs (Hemiptera). *Journal of Natural History* 45: 2577-2604.

Moran, C. and Catterall, C.P. (2014). Responses of seed-dispersing birds to amount of rainforest in the landscape around fragments. *Conservation Biology* 28: 551-560.

Noske, R.A. (1979). Co-existence of three species of treecreepers in north-eastern New South Wales. Emu. 79: 120-128.

Oliver, I. and Beattie, A.J. (1996). Designing a cost-effective invertebrate survey: a test for methods of rapid assessment of biodiversity. *Ecological Applications* 6: 594-607.

Pearman, P.B., Fuisan, A. and Zimmermann, N.E. (2011). Impacts of climate change on Swiss biodiversity: an indicator taxa approach. *Biological Conservation* 144: 866-875.

Peck, M.R., Maddock, S.T., Morales, J.N., Ornate, H., Mafla-Endara, P., Penafiel, V.A., Torres-Carvajal, O., Pozo-Rivera, W.E., Cueva-Arroyo, X.A. and Tolhurst, B.A. (2014). Cost-effectiveness of using small vertebrates as indicators of disturbance. *Conservation Biology* 28: 982-991.

Quinn, P. and Keough, M.J. (2010). *Experimental Design and Data Analysis for Biologists* 537 pp. (Cambridge University Press, Cambridge).

Reid, J.R.W. (1999). Threatened and Declining Birds in the New South Wales Sheep-Wheat Belt: 1. Diagnosis, Characteristics and Management. Consultancy Report to NSW National Parks and Wildlife Service (CSIRO Wildlife and Ecology, Canberra).

Riggins, J.J., Davis, C.A. and Hoback, W.W. (2009). Biodiversity of belowground invertebrates as an indicator of wet meadow restoration success (Platte River, Nebraska). *Restoration Ecology* 17: 495-505.

Roedenbeck, I.A., Fahrig, L., Findlay, C.S., Houlahan, J.E., Jaeger, A.G., Klar, N., Kramer-Schadt, S. and van der Grift, E.A. (2007). The Rauischolzhausen agenda for road ecology. Ecology and Society 12(1): 11. http://www.ecologyandsociety.org/vol12/iss1/art11/.

Roundtable for Sustainable Palm Oil (2007). *Principles and Criteria for Sustainable Palm Oil Production* (RSPO, Kuala Lumpur, Malaysia).

Saha, J.J. and Haldar, P. (2009). Acridids as indicators of disturbance in dry deciduous forest of West Bengal in India. *Biodiversity and Conservation* 18: 2343-2350.

Salo, H. (2015). Mosses as passive and active indicator surrogates for investigations of atmospheric pollution and quality. Pp. 69-76. In: Lindenmayer, D., Barton, P. and Pierson, J. (eds). *Indicators and Surrogates of Biodiversity and Environmental Change*. 203 pp. (CSIRO Publishing, Clayton South).

Scheffers, B.R., Joppa, L.N., Pimm, S.L. and Laurance, W.F. (2012). What we know and don't know about earth's missing biodiversity. Trends in Ecology and Evolution 27: 501-510.

Scientific Committee (2001). Final Determination for the Brown Treecreeper Climacteris picumnus victoriae (eastern subspecies), 28 February 2011.

Smith, G.F., Gittings, T., Wilson, M., French, L., Oxbrough, A., O'Donoghue, S. O'Halloran, J., Kelly, D.L., Mitchell, F.J.G., Kelly, T., Iremonger, S., McKee, A-M., and Giller, P. (2008). Identifying practical indicators of biodiversity for stand-level management of plantation forests. *Biodiversity and Conservation* 17: 991-1015.

Stewart-Oaten, A., Bence. J.R. and Osenberg, C.W. (1992). Assessing effects of unreplicated perturbations: no simple solutions. *Ecology* 73: 1396-1404.

Underwood, A.J. (1990). Experiments in ecology and management: their logic, functions and interpretations. *Australian Journal of Ecology* 15: 365-389.

Underwood, A.J. (1992). Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology* 161: 145-178.

Underwood, A.J. (1997). *Experiments in Ecology: Their Logical Design and Interpretation Using Analysis of Variance* (Cambridge University Press, Cambridge).

Underwood, A.J. (2009). Components of design in ecological field experiments. *Ann. Zool. Fennici* 46: 93-111. http://www.annzool.net/PDF/anz46-free/anz46-093.pdf.

van der Ree, R., Cesarini, S., Sunnucks, P., Moore, J.L. and Taylor, A. (2010). Large gaps in canopy reduce road crossing by a gliding mammal. *Ecology and Society* 15(4): 35. http://www.ecologyandsociety.org/vol15/iss4/art35/

van der Ree, R., Jaeger, A.G., Rytwinski, T. and van der Grift, E.A. (2015). Good science and experimentation are needed in road ecology. Pp. 71-81. In: van der Ree, R., Smith, D.J. and Grilo, C. (eds). Handbook of Road Ecology. 522 pp. (John Wiley & Sons Ltd, Chichester, West Sussex, UK).

Vanderwalle, M., de Bello, Francesco, Berg, M.P., Bolger, T., Doldec, S., Dubs, F., Feld, C.K., Harrington, R., Harrison, P.A., Lavorel, S., Martins da Silva, P., Morettil, M., Niemela, J., Santos, P., Sattler, T., Sousa, J.P., Sykes, M.P., Vanbergen A.J. and Woodcock, B.A. (2010). Functional traits as indicators of biodiversity response to land use changes across ecosystems and organisms. *Biodiversity Conservation* 19: 2921-2947.

Vidal, M.M., Peres, M.M., Guimaraes, P.R., Jr. (2013). Large predators as the missing components of seed-dispersal networks. *Biological Conservation* 163: 42-48.

Weinberg, A.Z., Kavanagh, R.P., Law, B.S. and Penman, T.D. (2008). *Testing Biodiversity Toolkits – How Well do they Test Vertebrate Species Richness?* 92 pp. (Science & Research Division, NSW Department of Primary Industries, Beecroft).

Wheater, C.P., Bell, J.R. and Cook, P.A. (2011). *Practical Field Ecology: A Project Guide*. 362 pp. (John Wiley & Sons Ltd, Chichester, West Sussex, UK).

Woodcock, B.A., Edwards, A.R., Lawson, C.S., Westbury, D.A., Brook, A.J., Harris, S.J. Brown V.K. and Mortimer, S.R. (2008). Contrasting success in the restoration of plant and phytophagous beetle assemblages of species-rich mesotrophic grasslands. *Oecologia* 154: 773-783.

Westgate, M. (2015). Surrogates for the distribution and trajectory of biodiversity. Pp. 5-13. In: Lindenmayer, D., Barton, P. and Pierson, J. (eds). *Indicators and Surrogates of Biodiversity and Environmental Change*. 203 pp. (CSIRO Publishing, Clayton South).

Westgate, M.J., Barton, P.S., Lane, P.W. and Lindenmayer, D.B. (2014). Global meta-analysis reveals low consistency of biodiversity congruence relationships. *Nature Communications* 5: 3899.

Zeppelini, D., Bellini, B.C., Creao-Durate, A.J. and Hernandez, M. (2009). Collembola as bioindicators of restoration in mined sand dunes of northeastern Brazil. *Biodiversity and Conservation* 18: 1161-1170.

Zuur, A.F., Ieno, E.N. and Smith, G.M. (2007). *Analysing Ecological Data.* 672 pp. (Springer, New York).

From the Botany Desk

NOTES ON SEED PROVENANCE, RESTORATION AND PLANT ADAPTATION IN THE FACE OF CLIMATE CHANGE IN AUSTRALIA

Isaac Mamott

Sclerophyll Flora Surveys and Research Pty Ltd) isaac.mamott@sclerophyll.com.au

Those of us who undertake large scale restoration projects have had it drummed into us repeatedly to use 'local' seed provenance, with the reasoning that local seed and the plant it produces (which has adapted to suit the local environment regimes) will outperform those from a non-local or 'different' environment regimes, with environment defined coarsely as soil and geology type, temperature, rainfall and elevation. That is, we have been told that seed provenance can have a significant impact on restoration success, particularly where restoration strategies have become much more heavily (or solely) reliant on direct seeding methodologies typically as part of large or broad scale restoration of former agricultural lands (as a means of cost effective restoration relative to tubestock propagation and out-planting).

Well, surprise! Research undertaken on local and non-local provenances of *Eucalyptus leucoxylon* ssp. *leucoxylon* in the Mount Lofty Ranges of South Australia (which collected data on seedling survivorship, height, invertebrate herbivory and physiological stress) found that (in this instance) the local provenance was significantly outperformed by both non-local provenances for all measured attributes.

These research results are generally consistent with what I and others have often found on restoration projects in NSW where good quality seed collected from healthy non-local populations significantly outperformed local seed provenance, particularly where the local seed was sourced from relatively unhealthy or struggling plant populations. What the results show is that the use of local seed may not provide the best resilience to achieve plant population survival in a warming Australia; and that our seed collection strategies need to focus more on obtaining seed mixes from populations that are more likely to have adaptive plant traits to suit the changing climate. That is, resilience rather than 'local' must now govern seed collection and restoration.

With the federal government's 20 million trees program coupled with other State restoration initiatives, large areas of land earmarked for restoration in the coming decade will no doubt place added pressure on seed collection within a finite supply. These restoration projects will need to look locally and non-locally for the healthiest and best quality seed sources for their projects and include provenance that has the best ability to adapt to a warming climate. To this end, it is likely that seeds sourced from healthy populations from warm/hot and dry climatic regions will have a better chance at adapting to stress (ie. resilience) brought about by a warming climate and a predicted increase in the frequency (and duration) of drought periods.

Future restoration projects should have as a standard method an initial trial of different seed provenances under different environmental conditions, with performance indicators including seed viability, germination and survival. It may also become standard practice to undertake DNA testing of different provenances to identify genetic differentiation (adaptation). Optimal provenances can then be chosen for the site based on those populations that have the most suitable adaptive traits for the host site for a changing climate. Researchers are calling this a climate- adjusted provenancing approach to take advantage of or exploit the broad evolutionary traits of a species across its environmental gradients.

Many restoration projects often select as their target species, a large proportion of nitrogenous fixers (eg. peas and wattles) to kick start and enhance the degraded soil profile, and to mimic the natural processes of succession. Many nitrogenous fixers are widespread in their distribution and have large environmental gradients (eg. degrees of latitude, elevation) which can no doubt be exploited for increased resilience in large scale restoration. The key will be to choose provenances from the 'right' environmental gradients to suit the host site.

To assist restoration ecologists with this shift in seed collection strategy, we are very fortunate to draw upon the results from the research area called 'landscape genomics' which is yielding exciting new information on the most 'adaptive' genotypes available amongst different plant populations for several species of *Eucalyptus* and *Banksia*.

Essentially what researchers are doing is taking plant samples and seed from populations occurring across their full distributional range (incorporating its full spectrum of environmental gradients which in some cases can span several degrees of latitude and in excess of 1000m elevation, with varying degrees of mean rainfall and temperature), and subjecting the samples to DNA analysis to determine the level of genetic variation amongst populations at particular loci. Seeds from different populations are also tested for their ability to germinate over a range of incubation temperatures to determine particular 'thermal germination niches' between populations (ie. the temperature range or threshold which triggered seedling germination).

Not surprisingly, thermal germination niches varied significantly among populations, suggesting strong patterns of local adaptation. In other words, plant populations each favoured different temperature regimes for seed germination across their distribution range. Researchers have called this evidence 'adaptive genetic diversity', where plant populations have evolved over time to suit their respective thermal conditions (ie. temperature, rainfall). It is thought therefore that some plant populations should be able, to some extent, to further adapt under a changing (ie. warming) climate given their evolutionary adaptation potential. It is thought that restoration ecologists can then draw upon this data, where available, to collect seed from particular populations that exhibit the most suitable thermal germination niches for a particular host site. This would, invariably, include those populations that contain genotypes that are considered to be most adaptive for future climate change.

Who knows: in coming years this climate change provenancing approach may lead to restoration projects using genetically modified native seed mixes which contain alleles that plant geneticists deem to represent the best or optimal resilience for population survivorship in a changing climate. For example, for some species of *Banksia*, researchers have been able to identify genes involved in stress tolerance, regulation of stomatal opening, and closure and energy use.

Provenance is not the whole story though, to achieve restoration success. Often the way seeds are collected, handled, stored, processed and broadcast on the host site plays an equally important role in restoration success (a topic that I will address in a future botany desk article).

2016 Annual Subscription Is Now Due

Subscriptions unpaid by the **30th of April** will be cancelled. Membership may be reinstated at any-time, provided yearly subscription is paid in full.

If you did not receive your subscription renewal in the post please contact administration admin@ecansw.org.au

If you have 2nd hand ecological equipment that you would like to sell or would like to purchase you can place an ad in this newsletter. Free for members or $40 for non-members. Contact admin@ecansw.org.au.

Advertising Opportunities with the ECA

Website:

- $200 for a banner
- $300 for company name with some detail and a link
- $500 for company name within box, logo, details and web link

All website packages run for one financial year and include a small ad in any newsletter produced during the financial year.

Newsletter:

- $100 for a third of a page
- $250 for a half page
- $500 for a full page
- $1 / insert / pamphlet

Advertising is available to service providers of the Ecological Consulting industry. The ECA will not advertise a consultant or their consulting business.

If you wish to advertise, please contact the ECA administrative assistant on admin@ecansw.org.au.

"Non-ECA promotional material presented in the ECA Newsletter does not necessarily represent the views of the ECA or its members."

Contributions to the Newsletter, Volume 37

Contributions to the next newsletter should be forwarded to the administration assistant Amy Rowles admin@ecansw.org.au by the **15th of July 2016.**

- Articles may be emailed in WORD, with photos included or referenced in an attached file as a jpg.
- Please keep file size to a minimum, however there is no limit on article size (within reason)
- Ensure all photos are owned by you, or you have permission from the owner
- Ensure that any data presented is yours and you have permission from your client to refer to a specific site (if not please generalise the location).
- All articles will be reviewed by the editorial committee, and we reserve the right to request amendments to submitted articles or not to publish.
- Please avoid inflammatory comments about specific persons or entity

The following contributions are welcome and encouraged:

◊ Relevant articles
◊ Anecdotal ecological observations
◊ Hints and information
◊ Upcoming events
◊ Recent literature
◊ New publications (including reviews)
◊ Photographs

How to hold a quoll!

Photo courtesy of David Milledge.

ECA Photo Gallery

Photo Competition Entries

Top Left: Border Thick-tailed Gecko *Underwoodisaurus sphyrurus.* Photo courtesy of Narawan Williams.

Top Centre: Squirrel Glider on a Grass Tree. Photo courtesy of David Milledge

Top Right: Brown Tree Snake. Photo courtesy of David Milledge

Left: *Caleana major.* Photo courtesy of Isaac Mamott.

Right: Silvereye. Photo courtesy of Natalie Parker

Below Right: Eastern Bentwing Bat roosting in a tunnel. Photo courtesy of Narawan Williams

Above: Common Ringtail Possum. Photo courtesy of Narawan Williams.

Right: Waratah *Telopea speciosissima.* Photo courtesy of Isaac Mamott.

ECA Photo Gallery

Photo Competition Entries

Left: Brush-tailed Phascogale exiting a nest box. Photo courtesy of Michael Murray

Right: *Calochilus campestris.* Photo courtesy of Isaac Mamott

Left: *Caledenia porhyrea* at Norah Head. Photo courtesy of Bruce Hansen.

Right: Death Adder. Photo courtesy of Michael Murray.

Below Left: Northern Leaf-tailed Gecko *Saltuaris cornutus* at Atherton Tablelands, QLD. Photo courtesy of Anne Williams.

Below Centre: *Grevillea caylei.* Photo courtesy of Isaac Mamott

Right: *Nyctophilus bifax,* Atherton Tablelands QLD. Photo courtesy of Anne Williams

Below Right: Juvenile Lumholtz Tree Kangaroo. Photo courtesy of Narawan Williams.