Innovative eDNA citizen science for biodiversity conservation in agricultural landscapes

Helen Barclay [1] , Josh Griffiths [1] , Sue vern Song [1] , Peter Ronalds [2] , Philip Darton [3] , Terry McPhee [4]

1. *EnviroDNA, Brunswick, VIC, Australia, info@envirodna.com*
2. *Western Port Catchment Landcare Network, Koo Wee Rup, VIC, Australia, peter@wpcln.org.au*
3. *Neerim District Landcare Network, Neerim, VIC, Australia, darton@dcsi.net.au*
4. *Tarago Catchment Healthy Farms Project (supported by Melbourne Water) Neerim, VIC, Australia, terrymcp45@gmail.com*

Key Points

- eDNA is an exciting opportunity for the everyday person to use a molecular wildlife survey tool.
- Citizen scientists gather extensive amounts of wildlife biodiversity data in farm dams and waterways adjacent to private properties.
- Farm dams in agricultural landscapes can be important to supporting biodiversity and for engaging landholders in conservation actions.
- Typical agricultural operations threaten biodiversity and thus landholder engagement in conservation is important but not easy – innovative approaches need to be considered.

Abstract

Agricultural operations have a significant impact on waterway health in Australia. Conservation interventions typically involve funding for management strategies like fencing, nutrient management, weeding and revegetation, as well as a focus on water quality insights. Relatively new in the toolkit of environmental scientists, environmental DNA (eDNA) analysis of freshwater samples has been used since the early 2000s (Ficetola *et al,* 2008) as a tool for species detection. eDNA sampling provides an exciting collaborative opportunity to engage landholders as citizen scientists generating unprecedented amounts of biodiversity data. Citizen science provides a generational opportunity to inspire broader engagement and deeper connection to nature in waterways, thus encouraging better management. This paper explores the results of two eDNA citizen science projects run with Landcare groups in West Gippsland, Victoria, that have successfully engaged private landholders in this innovative way. Farmers and other landholders investigated wildlife biodiversity in and around waterways such as tributaries and farm dams. In undertaking eDNA sampling citizen scientists were empowered to access a molecular wildlife survey tool. For a National Landcare Funded project, efforts resulted in over 60 wildlife species detected from taxonomic groups like fish, frogs, birds, turtles, and crustaceans, including some threatened or cryptic species that were unknown to participating citizen scientists. Macroinvertebrate communities, which can be important bioindicators of environmental health, were also surveyed in one of the projects, and 38 macroinvertebrate families were detected. The innovative projects attracted high levels of community involvement, including many new Landcare participants. Participant feedback highlighted that new wildlife and biodiversity knowledge was acquired by all respondents with many showing intentions for further biodiversity conservation actions. With engagement being the first step to behaviour change, it's hoped these example projects inspire further innovative citizen science approaches for biodiversity conservation with landholders in agricultural landscapes.

Keywords

Citizen science, farm dams, agriculture, eDNA, biodiversity conservation

Introduction

This is a professional paper written for environmental practitioners and community members who want to learn more about the merits of an innovative citizen science approach for biodiversity conservation. Innovation aside, the premise of such approaches is to educate the public about biodiversity and in turn lead to changes in individuals' behaviour.

The example this paper focuses on involves Environmental DNA (eDNA) metabarcoding, which puts a molecular wildlife survey tool into the hands of lay people. eDNA refers to the genetic material that organisms leave behind in the environment through shedding things like skin cells, hair, mucous and faeces. Analysis of eDNA is a relatively new, cheap, time-efficient and non-invasive method for detecting single species or, more recently, entire taxonomic groups (McColl-Gausden *et al.* 2019; Rees *et al.* 2014; Thomsen & Willerslev 2015).

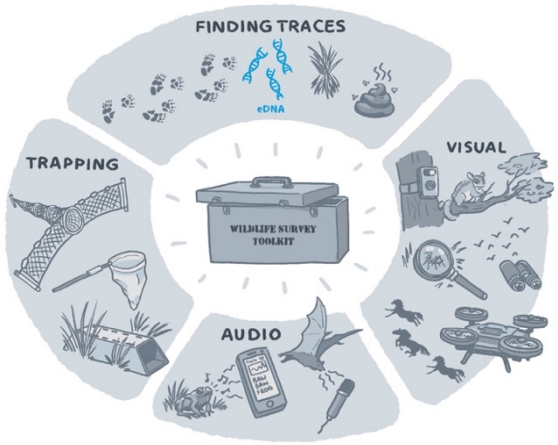

Figure 1: visual highlighting how eDNA can now be part of a wildlife survey toolkit (Illustrator: Sally Barclay)

The paper outlines a blueprint for eDNA citizen science projects through examples with farmers and other landholders within agricultural districts in West Gippsland, Victoria. Such environments are typically stripped of biodiversity and host farming practices that have ongoing negative impacts, particularly on waterway health and biodiversity. Thus, waterways and waterbodies that persist in agricultural landscapes serve as an important opportunity for conservation. While there are funded programs that support intervention actions and private investment from landholders themselves (e.g. fencing out stock from waterways), the first step to action is education and engagement. Citizen science biodiversity projects, where participants collect biodiversity data, provides an opportunity for this (Peter, Diekötter, Höffler & Kremerk, 2021).

Background

Importance of citizen science

According to the Australian Citizen Science Association, citizen science is public participation and collaboration in scientific research with the aim to increase scientific knowledge. In the context of biodiversity conservation it is also a means of community engagement for the purposes of building connection with nature and inspiring behaviours that conserve the environment (Peter, Diekötter, Höffler, & Kremerk, 2021).

The Aussie Backyard Bird Count is an example of one of Australia's largest and growing citizen science initiatives, with 108,000 participants and 4.6 million birds counted in its 2020 event. While it has limitations, it's an initiative that can help ecologists track large-scale biodiversity trends but also gives people the chance to connect with their natural environment and gain greater appreciation of the country's unique fauna (Birdlife Australia, 2021).

Importance of landholder engagement in agricultural landscapes for environmental outcomes

According to the International Union for Conservation of Nature (IUCN) freshwater species globally are going extinct more rapidly than terrestrial or marine species (International Union for Conservation of Nature, 2021). Waterway health and biodiversity can be severely impacted by agricultural practices such as erosion, poor soil health, nutrient run off, and habitat destruction. In Victoria, freehold agricultural land makes up 55% of land tenure (Agriculture Victoria, 2021). With such significant landholding it is vital to have the cooperation of farmers and other surrounding landholders in biodiversity conservation efforts on their private properties.

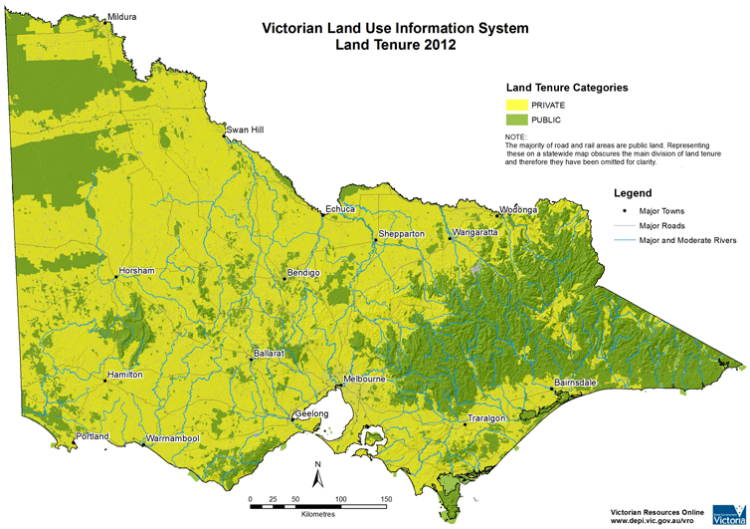

Figure 2 – Map of land tenure in Victoria demonstrating 62% private land and 38% public land (Agriculture Victoria, 2021)

There are a range of government and not for profit programs aimed at farmers to educate and support sustainable practices from water health and soil health through to emissions reduction. When it comes to waterways, typical programs support interventions like fencing out stock and revegetation activities such as riparian rehabilitation. Landcare groups in Australia are a leading example of not for profit and community driven efforts that enable people to actively care for the environment in their community – aiming for a balance between land practices and conservation. There are ~6,000 Landcare groups in Australia helping to facilitate community engagement and activities for this purpose. Along with common revegetation efforts Landcare groups often run other activities and provide resources in their local communities to help educate and upskill landholders. In terms of biodiversity citizen science efforts, bird counting, frog audio surveys, and platypus visual surveys are some common ways in which Landcare and other not for profit groups engage.

The first challenge is capturing the attention and involvement of farmers and other landholders in these voluntary conservation programs. The second challenge is to ensure intervention action and ongoing management of such efforts. Raising awareness of what biodiversity is and its value is a first step to positive behaviour change around conserving the environment (Barker & Elliott, 2000; Navarro-Perez & Tidball, 2012). The hook to getting farmers involved is often highlighting the productivity benefits of such interventions, but this paper proposes that meaningful behaviour change for biodiversity outcomes needs innovative engagement approaches.

Innovative citizen science to detect biodiversity in & around waterways

Innovation is about doing something new and different – creating a change that adds value. In the context of innovating how communities in agricultural landscapes are engaged, as discussed in this paper, the intention is to inspire broader and more significant participation in biodiversity conservation.

While citizen science programs to survey for biodiversity are not uncommon amongst groups like Landcare, providing access to a molecular wildlife survey tool is innovative. In Victoria there have been several eDNA citizen science projects run with Landcare groups that have successfully engaged farmers and other landholders in agricultural landscapes with this innovative tool and in an innovative way. While molecular analysis

generally requires expertise to complete, the environmental sampling of eDNA can be relatively straight forward so that with the right direction anyone can undertake it, including children. Below we discuss two example projects that seek to highlight the potential of innovating how communities in agricultural regions are engaged for conservation outcomes.

At a high level, the eDNA citizen science process involved:

1. Learning about this innovative genetic method for surveying wildlife
2. Undertaking eDNA sampling themselves and visiting each other's properties
3. Seeing biodiversity results generated via individual reports and/or community seminars and discussing results
4. Learning about conservation interventions

PROJECT 1 - Farm dam biodiversity assessment with eDNA in west Gippsland, Victoria

Farm dams interrupt natural waterflows in a catchment and thus can be detrimental to waterway health. At the same time, farm dams can be important biodiversity assets in agricultural landscapes. For those farm dams that persist there is opportunity to educate landholders on the importance of and the opportunities for better managing farm dams for waterway health and biodiversity.

Undertaken in 2018 and 2019, this National Landcare funded project engaged farmers and other landholders in assessing biodiversity across 18 farm dams on working farms and hobby farms. These dams were located within a dairy and cattle farming region. The Tarago River flows through the region along with the Tarago Reservoir, which is situated mid catchment. There are also several tributaries that flow in and out of the reservoir and the river – most are through privately owned land.

Activity:

Collaboration across 2 x Landcare groups (Neerim District Landcare group and Jindivick Landcare group) including: 18 x farm dams assessed using eDNA metabarcoding and visual habitat condition assessment, as well as a selection of dams sampled for taxonomic and DNA identification of macroinvertebrates; 14 x private properties involved; 2 x eDNA sampling occasions (autumn & spring); 30 x citizen scientists collecting eDNA samples after being trained by EnviroDNA staff; 40 x people attending results reveal session and discussion; 21 x people attending a Landcare event for the first time; and numerous local newspaper articles.

Wildlife detection results

110 x eDNA water samples collected by citizen scientists and analysed by molecular scientists at EnviroDNA, 60 x species detected including 41 x native species 13 x invasive, 4 x livestock & 2 x domestic species; 38 families of macro invertebrates. Birds, mammals, frogs and crustaceans were detected. Such an extensive list of wildlife detection data would not have been feasible without eDNA. See supplementary material for list of species.

Feedback from participant:

A follow up survey was delivered via a paper form and via a Survey Monkey questionnaire. 62.5% of survey respondents indicated a positive response when asked if they were inspired to take action beyond the project to investigate and better manage their farm dams for biodiversity, with remainder of respondents either skipping the question or noting they didn't have a dam. 100% of respondents noted they had learned something when it came to farm dam wildlife and biodiversity. When responding to what they most enjoyed during their participation, one example of a participant comment particularly highlights how such a program can inspire conservation action: "Being involved in the process of capturing the data in the dams & the results – I loved knowing what's living in the dam - motivating to finish off the fencing". During the results reveal event, many participants were also noting their surprise with the diversity of species identified (including the endangered blue billed duck).

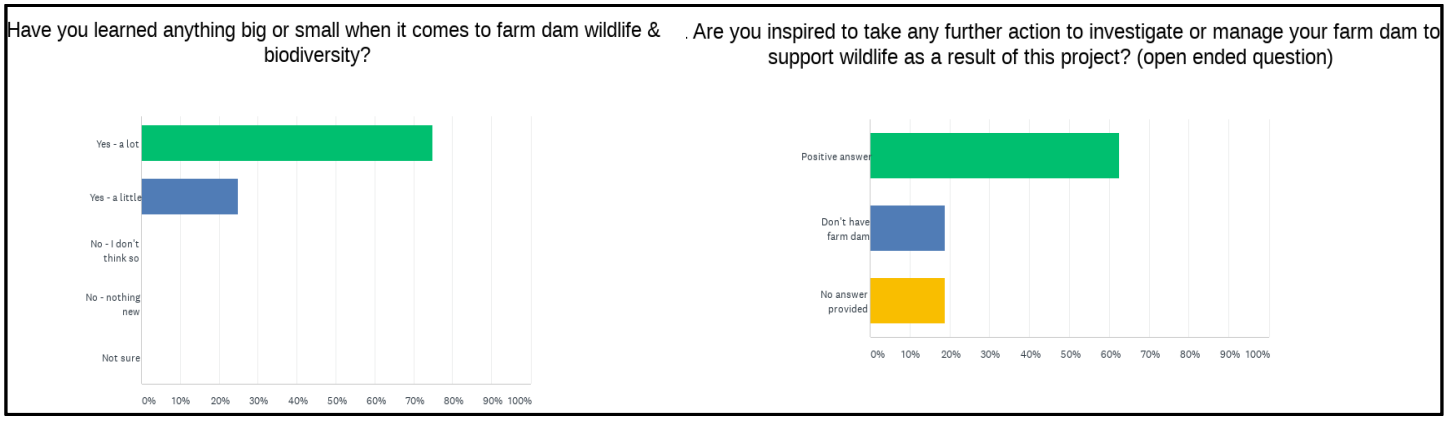

Figure 3 – summary of responses to two questions asked in the project follow up survey to citizen scientists and other local community members who got involved. ~50% survey response rate.

PROJECT 2 Biodiversity assessment of tributaries flowing into the Tarago reservoir, Victoria

Tributaries flowing through and adjacent to private properties can become sinks of high nutrient load and degradation from farming practices. These issues impact tributaries, causing flow on effects further downstream, and in this case could adversely affect the water health of the Tarago reservoir, one of Melbourne's key water resources.

Undertaken in 2019 this citizen science program assessed vertebrate and decapod biodiversity of some tributaries that run through and adjacent to privately owned farmland and into the Tarago reservoir. This project was initiated by the Tarago Healthy Farms Project delivered by Neerim District Landcare and funded by Melbourne Water that assists landholders with land and waterway management interventions within the Tarago Reservoir catchment. The intention was to take an innovative approach to engaging with landholders. Whether they participated in the project directly or not, the opportunity to learn about the wildlife in these waterways was something new in comparison to other engagement programs. It was intended to inspire an appreciation for nature and importance of conservation actions by landholders.

The project also involved two primary schools (Neerim South and Jindivick Primary schools), where students got to meet a scientist, and become scientists themselves by sampling artificial ponds on school grounds.

Activity

Collaboration across two Landcare groups (Neerim District Landcare group and Jindivick Landcare group) including: 2 x tributaries from 2 x catchment areas and several private properties assessed, as well as ponds from two primary schools in the region; 1 x sampling occasions (spring in 2019); 19 citizen scientists collecting eDNA samples after being trained by EnviroDNA staff plus school age children; >40 x people attending results reveal session and discussion; 6 people attending a Landcare event for the first time in the local area. No participant follow up has occurred yet for this project.

Wildlife detection results

There were 30 eDNA water samples taken by citizen scientists and analysed by molecular scientists at EnviroDNA. For the 2 tributaries surveyed there were 9 sampling sites and the wildlife species detected included 4 frogs, 25 birds (1-2 invasive), 13 mammals (4-5 invasive), 5 fish (1 invasive), 2 reptiles, and 6 decapods (burrowing crayfish, yabbie and a shrimp). Several species were listed on Victorian or national threatened species lists.

Project design: A blueprint for eDNA citizen science projects

Example design that the above-mentioned projects followed: 6-12 month duration.

Month 1

1. Sign up landholders who are willing to put forward their farm dams or waterways for biodiversity assessment.
    - Optional – undertake vegetation/condition/habitat assessments of farm dams and other waterways to assist with future analysis and insights.
2. Determine sampling design e.g. how many dams or waterways, sampling sites and timing.

Month 2

3. Select a date for eDNA sampling event, invite landholders and broader community.
    - Consider undertaking more than one sampling occasions for the same waterways/waterbodies across different seasons. For example, Spring and Autumn. To help increase chances of detecting different species that may only become present at certain times of the year.
4. Run eDNA sampling morning/citizen science day
    - Meet at a convenient location (ideally somewhere near a water body such as a dam)
    - Introduce group to eDNA and provide training and demonstration on undertaking eDNA water sampling.
    - Form groups and visit different farms to take eDNA water samples. Consider how many dams and/or waterways can be sampled in what timeframe.
    - Regroup for lunch, all samples gathered, and invite discussion about the process.
    - Consider option for guest speaker to talk about wetland/farm dam rehabilitation.

Month 3/4

5. eDNA analysis to detect wildlife
    - Conducted by molecular laboratories with eDNA wildlife detection abilities.
    - Ideally undertaking vertebrate analysis to provide a broad scope of species (such as birds, mammals, fish, frogs). Other analysis options could include decapods (crustaceans). In the future macroinvertebrates will be an eDNA analysis option.

Month 5/6

6. Results reveal session
    - Locals in region invited including those who participated in samples.
    - Results shared – consider presentation and high level report designed for the public. Ensure opportunity for questions and discussion.
    - Consider guest speaker to provide advice on rehabilitating waterways e.g. revegetation advice, creating habitat for wildlife advice.
    - Consider providing take home resources regarding managing waterways such as farm dams and tributaries for conservation outcomes.
    - Consider providing supper or snacks for all to encourage community connection.

To align with best practice citizen science, it's valuable to consider how the data will be made publicly available for example in a repository like Atlas of Living Australia.

Images: Citizen scientists take eDNA water samples themselves, preparing to unleash an exciting amount of biodiversity data (first image credit – Hamish Brooks).

Conclusion

Taking an innovative citizen science approach using eDNA to engage farmers and other landholders in agricultural communities can be useful to getting more people involved in learning about biodiversity and conservation. As our first project example highlighted, 21 participants were new to the Landcare groups. It was one of the most involved and participated Landcare projects in the local region, with multiple sampling days at 14 properties undertaken by 30 local citizen scientists across two Landcare groups. All participants who completed the follow up survey said that had learned something new with majority noting they were inspired to learn more or take further action for biodiversity conservation.

eDNA is an innovative tool for citizen science engagement, not to mention for environmental professionals. Waterway biodiversity assessments using eDNA metabarcoding generated extensive lists of wildlife detection data that would not have been feasible with traditional survey efforts. With more data comes more power to unveil species of interest such as threatened or invasive species. The threatened blue billed duck is an example of a threatened species detected that many citizen scientists didn't realise persisted on their properties. Another example highlighted the sensitivity of eDNA to pick up cryptic species like burrowing crayfish. These species are very rarely seen and difficult to survey so to identify at least four different species is an exciting outcome for the citizen scientists.

Education and engagement programs like this one, are the start of positive behaviour change and conservation efforts by individuals. A worthy next step for these two projects would be to revisit the farmers and other landholders involved to determine resulting conservation actions.

Acknowledgments

Thanks to: National Landcare Program; Tarago Healthy Farms Project; Melbourne Water; Jindivick Landcare; Neerim District Landcare Group; GHD for assisting with the macroinvertebrate survey; participating landholders and citizen scientists; and all dedicated scientists who have passionately pursued refining eDNA as a wildlife detection technique.

References

Barker, S., & Elliott, P. (2000). Planning a skills-based resource for biodiversity education. *Journal of Biological Education, 34*(3), 123-127.

Ficetola, G.F., Miaud, Claude., Pompanon, Francois., Taberlet, Pierre. (2008). Species detection using environmental DNA from water samples. Biol. Lett., 4423–425.

McColl-Gausden, E. F., Weeks, A. R. & Tingley, R. (2019). A field ecologist's guide to environmental DNA sampling in freshwater environments. *Australian Zoologist*, *40*(4), 641-651.

Peter, M., Diekötter, T., Höffler, T., & Kremerk, K. (2021). Biodiversity citizen science: Outcomes for the participating citizens. *People and Nature, 3*(2), 294-311.

Rees, H. C., Maddison, B, C., Middleditch, D, J., Patmore, J., & Gough, K, C. (2014). The detection of aquatic animal species using environmental DNA – a review of eDNA as a survey tool in ecology. *Journal of Applied Ecology, 51*(5), 1450-1459.

Thomsen, P. F. & Willerslev, E. (2015). Environmental DNA – An emerging tool in conservation for monitoring past and present biodiversity. *Biological Conservation*, *183*, 4-18.

2020 Aussie Backyard Bird Count results, retrieval date 2 May 2021, *Birdlife Australia*, https://aussiebirdcount.org.au/2020-results/

Freshwater biodiversity, retrieval date 5 May 2021, *International Union for Conservation of Nature*, https://www.iucn.org/theme/species/our-work/freshwater-biodiversity#

Agriculture Victoria, retrieval date 26 June 2021 http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/landuse-home

Supplementary material

Example list of species detected by eDNA metabarcoding. In this case the list reflects overall species detected across 18 farm dams in Neerim district and Jindivick, Victoria, over two sampling occasions.

Birds
27 species

Species name	Common name
Acanthiza pusilla	Brown thornbill
Ardea novaehollandiae	White faced heron
Ardea species	Heron or egret species
Chenonetta jubata	Australian wood duck
Colluricincla harmonica	Grey shrikethrush
Corvus coronoides	Australian raven
Cygnus atratus	Black swan*
Fulica atra	Common coot
Gallinula chloropus	Common moorhen
Gymnorhina tibicen	Australian magpie
Malurus cyaneus	Multiple sp Superb fairy wren
Malurus species	Fairy wrens
Manorina melanocephala	Noisy miner
Microcarbo melanoleucos	Little pied cormorant
Oxyura australis	Blue billed duck - Endangered
Phaps chalcoptera	Common bronzewing
Platycercus eximius	Eastern rosella
Porphyrio porphyrio	Purple swamphen
Ptilonorhynchus violaceus	Satin bowerbird
Tachybaptus novaehollandiae	Australian grebe
Tadorna species	Shelduck
Todiramphus sanctus	Sacred kingfisher
Acridotheres tristis	Common mynah - Invasive
Anas platyrhynchos	Mallard - Invasive**
Sturnus vulgaris	Common starling - Invasive
Turdus merula	Common blackbird - Invasive
Turdus philomelos	Song thrush - Invasive

*Black swan could also be goose.
**Mallard could also be the native Pacific black duck.

Mammals
13 species

Species name	Common name
Mormopterus planiceps	Southeastern free tailed bat
Hydromys chrysogaster	Rakali (water rat)
Ornithorhynchus anatinus	Platypus
Rattus fuscipes	Bush rat
Petaurus breviceps	Sugar glider
Pseudocheirus peregrinus	Common ringtail possum
Trichosurus vulpecula	Brushtail possum
Vombatus ursinus	Common wombat
Mus musculus	House mouse - Invasive
Oryctolagus cuniculus	Rabbit - Invasive
Rattus rattus	Black rat - Invasive
Rusa unicolor	Sambar Deer - Invasive
Vulpes vulpes	Fox - Invasive

Decapods
2 species

Species name	Common name
Euastacus species	Spiny crayfish
Paratya australiensis	Australian glass shrimp

Fish
7 species

Species name	Common name
Anguilla australis	Short finned eel
Macquaria ambigua	Golden perch
Nannoperca species	Pygmy perch species
Percalates novemaculeata	Australian bass
Gambusia holbrooki	Eastern mosquitofish - Invasive
Perca fluviatilis	Redfin perch - Invasive
Salmo trutta	Brown trout - Invasive

Frogs
4 species

Species name	Common name
Crinia signifera	Eastern common froglet
Limnodynastes peronii	Striped marsh frog
Limnodynastes tasmaniensis	Spotted marsh frog
Litoria species	Southern brown tree frog and/or another Litoria frog species

Reptile
1 species

Species name	Common name
Chelodina longicollis	Eastern long necked turtle

Domestic & Livestock
6 species

Species name	Common name
Bos taurus	Cow
Gallus gallus	Chicken
Ovis aries	Sheep
Sus scrofa	Pig
Canis lupus	Dog
Felis catus	Cat

Wildlife detections – insect sampling & DNA

Macro invertebrates
38 families

Acarina
Aeshnidae
Ancylidae
Atyidae
Baetidae
Belostomatidae
Calamoceratidae
Calocidae
Ceratopogonidae
Chiltoniidae (formally Ceinidae)
Chironominae
Coenagrionidae
Corduliidae
Corixidae
Dixidae
Dugesiidae
Dytiscidae
Glossiphoniidae
Haliplidae
Hydrometridae
Leptoplebiidae
Lestidae
Libellulidae
Lymnaeidae
Mesoveliidae
Naucoridae
Notonectidae
Notonemouridae
Odonotoceridae
Oligochaeta
Orthocladiinae
Physidae
Planoribiidae
Pleidae
Scirtidae
Sphaeriidae
Tanypodinae
Veliidae