The case for Sloane’s Froglet: Generating ecological knowledge with the intent to benefit biodiversity

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Certificate of Authorship

I hereby declare that this submission is my own work and to the best of my knowledge and belief, understand that it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Charles Sturt University or any other educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by colleagues with whom I have worked at Charles Sturt University or elsewhere during my candidature is fully acknowledged. I agree that this thesis be accessible for the purpose of study and research in accordance with normal conditions established by the Executive Director, Library Services, Charles Sturt University or nominee, for the care, loan and reproduction of thesis, subject to confidentiality provisions as approved by the University.

Name

Alexandra Knight

Signature

[Signature]

Date

26 March 2015
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Alexandra Ruth Derwent Knight, March 2015.
Abstract

Sloane’s Froglet, *Crinia sloanei*, is a threatened and little-known frog with a historical distribution in the Australian states of New South Wales (NSW) and Victoria (Vic). I investigated Sloane’s Froglet distribution and habitat (chapters 2, 3 and 4). As my intention was for the ecological knowledge generated to be applied, I undertook a transdisciplinary case study approach, and used social research methods to explore knowledge exchange between researchers and practitioners, and advocacy (chapters 5 and 6). I discuss the research approach in Chapter 7.

I undertook distribution studies from 2010 to 2013 and established the presence of an important extant population of Sloane’s Froglet in southern NSW and northern Vic, within a highly modified landscape that is quickly becoming more densely settled by humans. I investigated the habitat characteristics of waterbodies occupied by Sloane’s Froglet in winter, its peak breeding period, by comparing the physical and vegetation characteristics of 54 occupied and 40 unoccupied waterbodies. I determined a core calling period for Sloane’s Froglet and detection probabilities for the surveys undertaken. Sloane’s Froglet occupied both constructed and “natural” waterbodies with a variety of features, including differing hydroperiods and surrounding landuse. The waterbodies that Sloane’s Froglet occupied differed from unoccupied waterbodies by containing a greater percent cover of small stem-diameter emergent vegetation; often connecting with adjacent ephemeral shallow overflows; having gently sloping banks; and less bare ground on the banks within two metres of the waterbody. I explored the microhabitat and relative spatial positioning of Sloane’s Froglet within waterbodies by comparing the characteristics of 54 sites around individual male Sloane’s Froglet with 57 randomly selected unoccupied sites. Sloane’s Froglets were found to always call from within the waterbody rather than on the bank, distinguishing them from other sympatric *Crinia* species. Sloane’s Froglets occurred at sites with less of the site above the water level, and at significantly shallower water depths, than unoccupied sites. Sloane’s Froglets were closer to other Sloane’s Froglets and other calling male frogs at occupied sites, suggesting clustering behaviours.

Recommendations for applying this knowledge to benefit Sloane’s Froglet are included in chapters 2 to 4.
I used an autoethnographical approach to describe the advocacy I undertook during
the research process and to reflect on knowledge exchange between me as a
researcher-advocate, environmental practitioners and the broader community. I
further investigated the constraints and enablers of knowledge sharing and utilisation
by exploring the insights of 11 environmental practitioners whose work can benefit
water-dependent biodiversity. Exploration of the semi-structured interviews suggests
that exchange and utilisation of new knowledge is impacted by: how knowledge and
knowledge sharing processes are perceived; the media for knowledge communication;
continual learning and adaptive management; personal values and the role of
advocacy; and, external filters such as political will and institutional processes. The
transdisciplinary case study results suggest that my applied research will not be utilised
without an advocative approach, preferably with the support of an influential person
and validation of an established organisation. In addition, a collaborative research
approach or the coproduction of knowledge with practitioners will enable the
management application of the ecological research.

In Chapter 7 I present a framework that I call “intentional ecology” based in
conservation biology, systems and contemporary feminist theories to support the
transdisciplinary and applied research approach. Intentional ecology provides a
platform for the use of multiple methodologies and an imperative for action in which
knowledge exchange and advocacy are understood as implicit to ecological research
with management implications.
Chapter 1  General Introduction
1.1 INTRODUCTION

New knowledge of the distribution and habitat of the threatened Australian frog Sloane’s Froglet (*Crinia sloanei* Littlejohn 1958, Anura: Myobatrachidae) is presented in this thesis. The ways in which this type of knowledge regarding water-dependent threatened species influences environmental practice are then explored. The ecology of Sloane’s Froglet is researched including its distribution throughout Australia, and the habitat in which it occurs during peak calling periods. The habitat study is undertaken at two scales, the waterbody scale and the within-waterbody (microhabitat) scale. As very little was known about Sloane’s Froglet prior to the commencement of this research, the thesis presents vital and foundational knowledge of its ecology. The thesis then addresses the question of how this new knowledge has been exchanged with and used by environmental practitioners for the benefit of Sloane’s Froglet and what factors might enable and constrain future knowledge exchange. The research goes beyond the Sloane’s Froglet context to explore how knowledge exchange processes influence environmental practice in regional Australia.

The thesis is presented as applied research and a transdisciplinary case study, where the “case” is considered as “a specific, a complex, functioning thing” (Stake, 1995, p.2). While ecological research has previously been situated as being best understood as case study work (Shrader-Frechette & McCoy, 1993), autoecological research is not usually described as case study research. As such, and because the work is transdisciplinary, I do not situate this thesis within an established discipline at the outset, rather I explore the challenge associated with presenting research that is not easily situated within traditional disciplinary understanding.

Multiple disciplinary approaches are now often recommended in environmental studies which research complex social-ecological systems (Klein, 2010; Pooley, 2013) and may include multidisciplinary, interdisciplin ary and transdisciplinary approaches (Pooley, 2013). While discussion continues regarding the definition for transdisciplinary studies (Zscheischler & Rogga, 2014), the concept commonly accepted involves not only embracing learning from differing natural science disciplines but includes natural and social sciences as well as the humanities (Schroll & Staerdahl, 2001). It involves using multiple methodologies based on different epistemologies. In addition, the concept of “transdisciplinary” enables the inclusion of
practice: this takes the approach across from the realm of science into that of society (Zscheischler & Rogga, 2014), and enables engagement with policy and management (Schroll & Staerdahl, 2001). Integral to this is the notion that non-academics will be involved in the process (Zscheischler & Rogga, 2014). A transdisciplinary approach, then, integrates “academic researchers from unrelated disciplines, and non-academic participants, in pursuing a common goal, and creating new knowledge and theory” (Pooley, 2012, p. 22). Three core feature of transdisciplinary research common to the literature are: (i) complex real-world problems or a problem focus, (ii) collaborations, and (iii) evolving methodologies. (van Kerkhoff, 2014 p. 149; Zscheischler & Rogga, 2014, p. 5).

Transdisciplinary studies may result in “new conceptual frameworks” (Rosenfield, 1992, p. 1345). More recently Zscheischler & Rogga (2014) also recognise this as a core feature of transdisciplinarity in their description and discussion of “[E]volving methodology” (p. 5). In grasping complexity (Pohl, 2008) as transdisciplinary research aims to do, different perspectives may not be simply added up, but perspectives interrelate in different ways (Pohl, 2008) and so a synthetic approach, which tries to make a whole of differing parts is not always appropriate.

In Chapter 7, rather than presenting a traditional synthesis as might be developed, for instance, for a study sited within one discipline such as ecology, I develop a conceptual framework to underpin and frame my entire work. In doing so, I call upon theoretical guidance from the disciplines of conservation biology, systems theory, environmental philosophy and contemporary feminist theory and introduce literature from these disciplines to build the conceptual applied transdisciplinary framework that is presented as “intentional ecology”. In presenting intentional ecology I argue for: the overt recognition of the importance of social and moral questions and actions within research and practice; the need to reflect upon boundaries; the need to act, and to be explicit about researchers’ values and intentions, as well as; the importance of harnessing emotions associated with care. In chapter 7 I also review the thesis, in light of the original conceptual framework, calling upon the need for reflexivity (van Kerkhoff, 2013) as my transdisciplinary approach “fundamentally rejects [this] linear process as a basis for research design and practice; we, as researchers, are embedded within the systems we are examining and seeking to understand and act within, and so
must be prepared to react and respond to our emergent findings in nonlinear ways” (van Kerkhoff, 2013, p. 145).

My research was motivated by the listing of Sloane’s Froglet at a threatened species in 2008 in one state of Australia under the New South Wales Threatened Species Conservation Act 1995 (NSW), and my professional awareness as a practising biodiversity officer that very little was known about the species. As a practitioner I was cognizant that research outputs may be overlooked and I felt an imperative to advocate for this little-known species. As a researcher I felt that work on Sloane’s Froglet could also provide important insight into the relationship between knowledge generation and practise. Throughout, my work has been informed by my academic background in environmental philosophy which has provided an ethical framework guiding my research approach.

This chapter provides context for the research with a brief overview of amphibian decline. Particular emphasis is placed on the role of habitat loss and modification in the decline of frogs and the possibilities of habitat management in their conservation. Detailed information about the state of existing knowledge of Sloane’s Froglet is provided, followed by a background to the relationship between environmental practice and new knowledge. In this context a brief overview of the discussions regarding: environmental knowledge exchange; the relationships between practitioners and researchers; advocacy within conservation biology; natural resource policy formation and integration; and, the relationship between best available science and adaptive management is provided. To conclude this chapter, I present my study aims and thesis structure.
1.2 AMPHIBIAN DECLINE

The worldwide decline in amphibians that was first noticed and discussed in the 1980s and 1990s (Barinaga, 1990; Blaustein & Wake, 1990) has now been confirmed, explored and well documented in a variety of contexts (e.g. Collins, Crump, & Lovejoy, 2009; Houlahan, Findlay, Schmidt, & Kuzmin, 2000; Stuart et al., 2004). This phenomenon has also occurred in Australia where “fifty of 216 amphibian species (23%) in Australia [are] now recognized as threatened or extinct” (Hero et al., 2006, p. 313). Gardner, Barlow, and Peres (2007) point out that “amphibians and reptiles have the highest threat status of all terrestrial vertebrates” (p.166).

Assessments to ascertain the causes of the threats to amphibians have been undertaken worldwide (e.g. Hobbs & Mooney, 1998; Nyström et al., 2007; Porej, Micacchion, & Hetherington, 2004). In Australia assessments of decline have been made for individual species such as the highly endangered Southern Corroboree Frog, *Pseudophryne corroboree*, (Hunter, 2000), the endangered Booroolong Frog, *Litoria booroolongensis* (Hunter & Smith, 2006), Green and Golden Bell Frog, *Litoria aurea* (Hazell, Cunningham, Lindenmayer, Mackey, & Osborne, 2001; Osborne, Patmore, Hunter, & Pietsch, 2008) and Southern Bell Frog, *Litoria raniformis* (Heard, Robertson, & Scroggie, 2004; Wassens, 2008). Reviews of the status and decline of groups of frog species including temperate riverine frogs (Gillespie & Hines, 1999), and frogs in the arid areas of NSW (Sadlier & Pressey, 1994) have also been undertaken.

Frog decline has been attributed to a number of threats including: predation by introduced species, the effects of agricultural chemicals, and UV-B radiation. Most emphasis in the scientific literature is placed upon two causative factors: habitat loss and modification, and susceptibility to disease, especially infection by chytridiomycosis (Gardner et al., 2007). In addition, climate change is viewed as a complicating factor.

As with terrestrial species, for amphibians the impacts of predation and pest species has been a focus for research, with particular attention paid to predation on frog eggs and tadpoles by both introduced and native fish. In Australia, emphasis has been placed upon the impact of the introduced fish *Gambusia holbrooki* (Morgan & Buttemer, 1996; Pyke & White, 2000; Reynolds, 2009). In their 2003 review, Kats and Ferrer assert that numerous studies undertaken in the prior 15 years have established the “direct affects of alien predators on amphibians” (p. 107). A particular research
emphasis has been on the role of fish as tadpole predators, for instance, in the eastern United States, G. R. Smith, Rettig, Mittelbach, Valiulis, and Schaack (1999) found that the Bluegill sunfish, *Lepomis macrochirus*, had a major impact on amphibian assemblages. Recent studies have shown that the affect of predators (both alien and native) on amphibian assemblages and abundances may also be linked to habitat features, such as the hydroperiod of frog breeding ponds (e.g. Arribas, Diaz-Paniagua, & Gomez-Mestre, 2014).

Frogs at all life stages are known to be affected by toxins in water. Pesticides, herbicides, surfactants, fertilisers and heavy metals are all contaminants that have potential risks for Australian frogs (Broomhall, 2004). Herbicides such as Atrazine (even in very low concentrations) have been proved to disrupt the endocrine system and alter the ability of frogs to reproduce by affecting their sexual development (Mann, Hyne, Choung, & Wilson, 2009). Glyphosate is a widely used chemical. Used on its own it may not represent a threat to frogs, however, it is most commonly mixed with a surfactant that incorporates POEA (polyoxyethylene tallowamine). When mixed this product has a relatively high toxicity for tadpoles (Mann et al., 2009).

Fertilisers may be a threat to frogs. A considerable amount of research about the effects of fertiliser has been undertaken in the northern hemisphere where researchers have found a relationship between frog declines and environmental increases in nitrites and ammonia (e.g. Shinn, Marco, & Serrano, 2008; Shinn, Marco, & Serrano, 2013). In Australia, the effect of agricultural chemicals on frog health and mortality has been researched but not widely acknowledged (e.g. Hyne et al., 2009; Mann & Bidwell, 2001; Mann et al., 2009).

In Australia, as elsewhere around the world, amphibian decline has been attributed to habitat destruction and modification (e.g. Hero et al., 2006). Gillespie et al. (2011) in their recent examination of the efficacy of conservation assessments showed habitat modification as the most “frequently identified threatening process across all species” (p. 1519). Habitat loss and modification is considered a threat in rural landscapes (e.g. Hazell, 2003; Hazell et al., 2001) as well as urban and peri-urban regions (e.g. Hamer & Organ, 2008; Smallbone, Luck, & Wassens, 2011).

Water is an essential component of frog habitat. Many frog species are reliant on water for part of their life cycle. Declining water quality and the introduction of toxins
into water are considered a major threat to amphibian species worldwide (Boyer & Grue, 1995). Alterations to water availability and regimes are also considered to have contributed to decline at a global scale (e.g. Euliss Jr & Mushet, 2004; Gamble & Mitsch, 2008; Paton & Crouch III, 2002; Snodgrass, Komoroski, Bryan Jr, & Burger, 2000). In Australia there has been a recent focus on water availability for amphibians, including the delivery of water in regulated systems, particularly within the Murray-Darling Basin (Wassens, Hall, Osborne, & Watts, 2010; Wassens & Maher, 2011).

Frog losses in areas considered by researchers to be “pristine” (Alford & Richards, 1999) such as national parks point to factors in decline beyond habitat, water condition and pest species, and both the effects of UV-B radiation (e.g. Searle et al., 2010) and disease, especially infection by chytridiomycosis, have been well researched. The pathogenic fungus *Batrachochytrium dendrobatidis* causes the disease chytridiomycosis in frogs and is now considered one of the major causal factors in global amphibian decline (Blaustein & Johnson, 2010; Skerratt et al., 2007). Hundreds of investigations have been undertaken into the disease since the 1990s including the effect of season and temperature on the spread of the disease (Berger et al., 2004) and latitudinal variation in its presence (Kriger, Pereoglou, & Hero, 2007). Models for interventions that may address the threat are currently being discussed (Scheele et al., 2014).

In Australia “mass mortality events due to chytridiomycosis resulting in catastrophic population declines in high altitude sites (that is > 400 m) have been observed” (Berger et al., 2004, p. 434). Both altitude and temperature have been shown to be linked with mortality of frogs from chytridiomycosis worldwide with low temperatures (e.g. Bradley, Rosen, Sredi, Jones, & Longcore, 2002) and higher altitudes increasing the likelihood. In Australia, heat and desiccation have been suggested as factors in limiting the spread and efficacy of chytridiomycosis (Berger et al., 2004).

Most recently, and as with assessments of other vertebrate groups (e.g. Pearson & Dawson, 2003), the effects of climate change on frogs is being considered (Corn, 2005) and modelling and discussion of predicted changes to habitat and water availability and consideration of subsequent effects has been undertaken (Lawler, Shafer, Bancroft, & Blaustein, 2010; Shoo et al., 2011). In south eastern Australia Mac Nally et al. (2009) and Mac Nally, Nerenberg, Thomson, Lada, and Clarke (2014) found that frog
declines continued in drying and warming climates even when weather patterns were broken by significantly wet periods.

In the following section I focus on amphibian habitat loss and modification and its relationship with environmental practice as it is the most “frequently identified threatening process” across all Australian amphibian species (Gillespie et al., 2011, p. 1519) and effective management relies on sound knowledge of habitat requirements (Begon, Townsend & Harper, 2009).

1.3 UNDERSTANDING AND CONSERVING AMPHIBIAN HABITAT

Informed and effective in-situ nature conservation management relies on sound information regarding species distribution, abundance and habitat requirements (Begon, Townsend, & Harper, 2009; Chapman & Reiss, 1999). Combating habitat loss and modification is a major goal of environmental research and practice (Fischer & Lindenmayer, 2007; Hails, 2008). The discipline of applied ecology has contributed in developing both specific knowledge of habitat and the means and processes for investigating and assessing species habitat needs and ecosystem and landscape processes (Begon et al., 2009). The more recent but well established discipline of conservation biology (as defined by Soulé, 1985) has contributed to the conservation effort by requiring researchers to undertake work that has direct links with management.

The importance of habitat studies for amphibians has been reasserted by Gardner et al. (2007) when comparing the available habitat studies worldwide for amphibians with those undertaken for birds and mammals. They state that

our failure to find more than 112 internationally published herpetological studies on the consequences of structural habitat change is cause for concern, suggesting that the level of threat associated with habitat change is not balanced by a proportional level of research effort (Gardner et al., 2007, p. 172).

They suggest that this situation is symptomatic of conservation research generally, but is also indicative of the attention placed by amphibian researchers on investigations into chytridiomycosis rather than habitat. Since their review there has also been considerable further research into frog habitat both for individual species and frog
assemblages (e.g. Blomquist & Hunter Jr, 2010), however, further work that links directly with practice is required.

Gardner et al.’s (2007) review did not consider habitat studies of individual species. Targeted habitat studies, particularly for threatened species where conservation concerns direct enquiry, have been undertaken for many species, for instance in Australia, *Litoria raniformis* (Heard, Robertson, & Scroggie, 2008), *Litoria boorooolongensis* and *Pseudophryne corroboree* (Hunter, 2007) and *Philoria frosti* (Hollis, 2004). These studies focus on distribution, habitat and microhabitat, and may also include studies of predation by introduced species, monitoring and evaluation programs and infection with chytridiomycosis.

Frogs have complex life histories and are often reliant on particular components of the habitat at different stages: particular resources are required for eggs and tadpoles (e.g. Altig, Whiles, & Taylor, 2007; Martin & Cooper, 1972), areas with high cover and plentiful resources at the time of metamorphosis and, terrestrial habitats at adult life stages (Dodd Jr & Cade, 1998). Amphibian habitat is not only related to life stages, but needs to be considered at different scales including landscape (e.g. Ficetola, Marziali, Rossaro, De Bernardi, & Padoa-Schioppa, 2011; Guerry & Hunter Jr, 2002; Houlahan & Findlay, 2003; Mazerolle, Desrochers, & Rochefort, 2005), site or wetland (e.g. Hunter, Osborne, Smith, & McDougall, 2009) and within wetland (microhabitat) (e.g. Gorman & Haas, 2011). The interaction between scales may also influence habitat use (Denoël & Lehmann, 2006) and several studies acknowledge this when they combine research into macro and micro landscape features (e.g. Blomquist & Hunter Jr, 2010; Popescu et al., 2013). Consideration of habitat requirements in urbanised landscapes has also become a major feature of frog research (Hamer & McDonnell, 2008), with several researchers making the link between constructed wetlands such as stormwater retention ponds (e.g. Hamer & Organ, 2008; Hamer, Smith, & McDonnell, 2012) and those on golf courses (e.g. Hodgkinson, Hero, & Warnken, 2007a; Hodgkinson, Hero, & Warnken, 2007b; Jackson, Kelly, & Brown, 2011; Saarikivi, Knopp, Granroth, & Merilä, 2013) with frog conservation efforts.

While only 67% of amphibian species worldwide are reliant on freshwater for the completion of their lifecycle (Hilton-Taylor et al., 2009, p.23), for the majority of Australian frogs the presence of water is a vital component of habitat (Anstis, 2013).
Recent research has focussed on the availability of water for frogs. In some cases availability of water habitats has been linked to concerns regarding climate change. Wassens, Walcott, Wilson, and Freire (2013) discuss the availability of rain-fed wetlands for frogs in inland Australia after a period of extreme drought. Other studies have been focussed on the availability of water in landscapes where the water supply is largely regulated both for individual species (e.g. Kupferberg et al., 2012) as well as frog assemblages (e.g. Babbitt & Tanner, 2000; Paton & Crouch III, 2002; Tockner, Klaus, Baumgartner, & Ward, 2006). In Australia’s Murray-Darling Basin there has also been a focus on individual species (e.g. Wassens et al., 2010) as well as frog assemblages (e.g. McGinness, Arthur, Ward, & Ward, 2014; Wassens, Healy, & Watts, 2011; Wassens & Maher, 2011) in regulated landscapes.

Connectivity of amphibian habitat is a major area of research (e.g. Cushman, 2006; Cushman, Landguth, & Flather, 2013; Westgate, Driscoll, & Lindenmayer, 2012) not only for pond-breeding frogs (Semlitsch, 2008) but for other amphibians such as salamanders (Searcy, Gabbai-Saldate, & Bradley Shaffer, 2013). Connectivity is often studied in the context of metapopulation theory of frogs (e.g. Hale et al., 2013) but has also been acknowledged as important in other contexts (Marsh, Fegraus, & Harrison, 1999; Marsh & Trenham, 2001; M. A. Smith & Green, 2005). Amphibian conservation biologists have called for more focus on connectivity concerns in both research and environmental practice (Pittman, Osbourn, & Semlitsch, 2014; Semlitsch, 2000, 2002).

In this section, the importance of research into amphibian habitat has been demonstrated, including the need for knowledge of vegetation structure for breeding, shelter and foraging, hydroperiods and water regimes, and landscape scale studies which address connectivity and mobility issues. In particular, the lack of information into the particular needs of target species (such as those listed as threatened and data deficient) has been well recognised in the literature. In the following section I outline what was known of the target species for this study, Sloane’s Froglet, including its habitat prior to the commencement of the research presented in this thesis.
1.4 SLOANE’S FROGLET

Sloane’s Froglet (*Crinia sloanei*, Littlejohn 1958) is a member of the Myobatrachidae family which contains approximately 82 species distributed only within the Australian region (Anstis, 2013). Myobatrachids are small to medium size ground-dwelling frogs. They have no discs or small discs on their fingers and toes and most species have no webbing on their toes (Anstis, 2013). The *Crinia* genus contains 16 species and occurs over most of Australia except for very dry areas. They breed in water and lay a small number of eggs which are attached to vegetation or to the substrate (Anstis, 2013).

Sloane’s Froglet is a small ground-dwelling froglet, generally around 15 – 20 mm long. It has a brown or browny-grey back often with darker brown or olive markings and males may also have orange or ochre coloured spots (Plate 1.1) (Anstis, 2013; pers. obs.; Littlejohn, 1958).

![Plate 1.1. Female and male Sloane’s Froglets in amplexus. Photograph taken at Thургоona, NSW in July 2010. (David Hunter)](image)

Many species of the *Crinia* genus are relatively well known; for instance there is considerable research into the sympatric *Crinia signifera* (Lauck, 2005; Lemckert, 2001; Lemckert & Shine, 1993; Littlejohn, 1964, 2008; Mac Nally, 1979; Odendaal & Bull, 1983; Odendaal, Bull, & Nias, 1982; Williamson & Bull, 1995; Wong, Cowling, Cunningham, Donnelly, & Cooper, 2004) and into the similarly threatened *Crinia tinnula* (Goldingay & Taylor, 2006; Letnic & Fox, 1997; Lowe, Castley, & Hero, 2013; Meyer, Hines, Clarke, Hodgon, & Gynther, 2004; Renwick, 2006; Simpkins, 2013;
Simpkins, Shuker, Lollback, Castley, & Hero, 2014). There is, however, very little known about Sloane’s Froglet. Hero et al. (2006) in their overview of the conservation status of Australian frogs list it as DD – “data deficient” (p. 318).

1.4.1 The discovery and life history of Sloane’s Froglet

In 1957 Murray Littlejohn, then of the Zoology Department of the University of Western Australia, and now Honorary Associate Professor at the University of Melbourne, was travelling through the Riverina district of New South Wales and Victoria in Australia when he noticed a different frog call from those of the two species of *Crinia* (*signifer* and *parinsignifera*) that he was studying. He ascertained that the call he heard came from a new species of froglet which he named Sloane’s Froglet, *Crinia sloanei*, and described in 1958 (Littlejohn, 1958).

![Plate 1.2. Patsy Littlejohn recording frog calls. Murray was outside of the vehicle with the microphone. (Murray Littlejohn)](image)

Calls were recorded in the field (Plate 1.2) and compared with that of the two sympatric species using oscillograms. The difference in call between the species is distinctive, with Sloane’s Froglet producing a short, high pitched chirp. Subsequent to his discovery of the species Littlejohn undertook some analyses of its calls when attempting to quantify the differences in the mating calls of the genus *Crinia* (Littlejohn, 1959). Littlejohn (1958) also described morphological differences with an
emphasis on the difference in throat and belly colour and markings among the three species.

The species was formally described on the basis of specimens collected along the south bank of the Murray River opposite Tocumwal, NSW; and this site became the type locality for *Crinia sloanei*. The species was named after Patsy Littlejohn’s uncle, Ian Sloane, of Savernake, NSW, in appreciation of his support of the Littlejohn’s field studies (M. Littlejohn, pers. comm.).

A description of the tadpole of the species was undertaken by Anstis, from preserved material lodged with the Australian Museum taken at Mulwala (Anstis, 2002), however characteristics which distinguished the tadpole from those of *C. parinsignifera* were unable to be determined. The description has been updated in Anstis’ (2013) recent comprehensive description of Australian frogs and tadpoles, however significant features that distinguish the tadpole from other *Crinia* species are lacking.

No other research into the detection or life history of Sloane’s Froglet has been undertaken.

### 1.4.2 Distribution of Sloane’s Froglet

There is no comprehensive overview of the distribution of Sloane’s Froglet. Cogger (1983) gives a broad description of its occurrence in northern Victoria and central NSW. Information of the early records of Sloane’s Froglet are available in a very valuable but uncited thesis which provides details on the biogeography of Victorian anurans (Brook, 1989). Sloane’s Froglets’ presence or absence has been recorded in a small number of survey reports (Gosper, 2002; Mac Nally et al., 2009; Ward, 2004; Wassens, Sass, Swan, & Thompson, 2004).

No targeted research has been undertaken into the distribution of Sloane’s Froglet since the work informing the original description, however incidental records exist in the wildlife databases of NSW and Victoria.

### 1.4.3 Speciation of *Crinias*

When studying the calls of Sloane’s Froglet, Littlejohn (1959) postulated that it belongs to the superspecies group of *Crinias* known then as the *Crinia insignifera* group. The ongoing argument regarding the origin and speciation of the genus *Crinia* (Barendse,
1984; Heyer, Daugherty, & Maxson, 1982; Roberts & Maxson, 1988; Symula, Keogh, & Cannatella, 2008) has paid little attention to Sloane’s Froglet, however in 2001 Read, Keogh, Scott, Roberts, and Doughty (2001) determined that *C. sloanei* is most closely related to the west Australian *Crinia* clade than either the *parinsignifera* or *signifera* clades whose species predominantly occur in the eastern states of Australia.

### 1.4.4 Sloane’s Froglet and *Crinia* biology and ecology

There is very little knowledge of Sloane’s Froglet biology or ecology. Littlejohn’s (1958) description provided some information regarding habitat. He wrote that in the Wangaratta - Whitfield area “the habitat consisted of shallow temporary ponds in clay soil, but in the other localities the species was generally restricted to temporary ponds in the river valleys and up to five miles on either side of the larger rivers” (Littlejohn, 1958, p. 223). Anstis (2002) adds that males call from “temporary ponds, flooded grassland, ditches and swamp areas” (p. 176). Anstis (2002) reports that the very small eggs of Sloane’s Froglet are laid “on substrate or attached to submerged vegetation” (p. 176).

A substantial amount of research into the biology and habitat ecology of the two sympatric species *C. signifera* and *parinsignifera* has been undertaken, and this provides useful context for Sloane’s Froglet studies. Research into the biology of these two *Crinia* species has focused on calling and breeding behaviour. Littlejohn analysed the calls of *C. signifera* and determined significant structural differences between the calls of disjunct populations (Littlejohn, 1964). Investigation into the detectability of *C. signifera* showed that it calls more strongly at night and has slightly increased calling close to rainfall events (Lemckert, 2001). The relationship between reproduction, loss of body mass and mortality for *C. signifera* (Lemckert & Shine, 1993) showed high levels of reproductive effort and increased mortality in breeding season. *C. parinsignifera* and *C. signifera* breed at the same time of the year, in winter, although *C. signifera* commences breeding 6 – 8 weeks earlier in the season. In both species the males have discrete calling stations (Mac Nally, 1979, 1985).

Ecological studies of *C. signifera* and *parinsignifera* have been focused on habitat associations. In their study of species richness and abundance in floodplain areas Healey et al. (1997) confirm a relationship between *C. parinsignifera* and creeping
grass, *Paspalum distichum*. The ability of *C. signifera* to colonise ponds was affected not only by habitat characteristics but also by landscape features (Lauck, 2005).

No similar biology or habitat studies have been undertaken for Sloane’s Froglet.

### 1.4.5 Threatened *Crinia*

Of the 14 species found in the genus *Crinia* two are officially designated as Vulnerable in Australian state or federal legislation, *Crinia tinnula*, Wallum Froglet and *Crinia sloanei*, Sloanes Froglet (Clayton, Wombey, Mason, Chesser, & Wells, 2006). *C. tinnula* is an ecological specialist limited to paperbark and sedge swamps in north-eastern NSW and south-eastern Queensland. It is listed as Vulnerable under both the NSW *Threatened Species Conservation Act 1995* and the Queensland *Nature Conservation Act 1992*.

A report advocating the nomination of Sloanes Froglet as a Vulnerable species (Anonymous, nd) resulted in the species being declared as Vulnerable on the NSW *Threatened Species Conservation Act* (1995) in May 2008 (Office of Environment and Heritage, 2011). The declaration suggests that contributing factors in this froglet’s decline include habitat destruction and fragmentation, land clearing, altered water regimes, and presence of introduced fish predators including Plague Minnow, Carp, Trout, and Redfin Perch. In addition, the determination notes that decline in records of Sloanes Froglet is consistent with the introduction and spread of chytridiomycosis into Australia (Office of Environment and Heritage, 2011).

No research has been undertaken into the perceived decline of Sloane’s Froglet. For instance, information about Sloane’s Froglet has not been included in recent studies of anurans within the Murray-Darling Basin (Mac Nally *et al.*, 2009; Mac Nally *et al.*, 2014; Trotter, 2012; Wassens *et al.*, 2011) who report that data regarding the species was inadequate for modelling purposes or the species was unable to be detected during the survey period.

### 1.4.6 Sloane’s Froglet and chytridiomycosis

No research had been undertaken into the possible infection of Sloane’s Froglet with chytridiomycosis. This disease has been a major threat to frogs worldwide, particularly in cooler, high elevation parts of the world. Research into Australian instances suggests that while chytridiomycosis may be present across the continent, it does not
cause significant mortalities in regions of lower elevations and higher temperatures such as that within which Sloane’s Froglet is distributed (Berger et al., 2004).

To summarise, very little is known about Sloane’s Froglet: knowledge of its habitat is found only briefly in the paper originally describing the species (Littlejohn, 1958) and one sentence from the personal observations of Anstis (2002). As the species is now listed as threatened, there is an urgent need to develop knowledge of its current distribution and habitat that can be used to conserve the species.

While development of new knowledge of this species could be useful, conservation biologists frequently discuss the gap between ecological research and environmental practice (e.g. Roux, Rogers, Biggs, Ashton, & Sergeant, 2006). Transdisciplinary research is fundamentally directed towards the link between research and practice (Zscheischler and Togga, 2014). In order for new knowledge to be useful it needs to be mobilised. In the next section I review knowledge exchange literature that may point to factors enabling or constraining the use of the new knowledge about Sloane’s Froglet that I have developed during research for this thesis.
1.5 NEW KNOWLEDGE AND ENVIRONMENTAL PRACTICE

There is considerable discussion about the relationship between scientific research and environmental practice (Roux, Rogers, Biggs, Ashton, & Sergeant, 2006), and knowledge exchange practices (Fazey et al., 2013). While acknowledging that “environmental practice” often has a much broader meaning, here, and throughout this thesis I use the terminology “environmental practice” to include and be limited to natural resource management; nature conservation, biodiversity and threatened species management; and, environmental water management, undertaken particularly by agencies and non-government organisations. There is widespread desire that knowledge generated from research should be incorporated into practice and used in management situations. Discussion on the best way to undertake this is ongoing (e.g. Reed, Stringer, Fazey, Evely, & Kruijsen, 2014). In this context, the need for ecological research to move away from objective positions, where the researcher is detached from the research outcomes, towards an approach within which the researcher is responding to and involving her/himself with immediate problems has been argued and sometimes accepted (e.g. Begon et al., 2009, p. vii).

The discussion regarding the exchange and application of knowledge to environmental practice has been seated not just within knowledge exchange inquiries such as Fazey et al. (2013), Fazey, Fazey, Salisbury, Lindenmayer, and Dovers (2006), Raymond et al. (2010) and Reed et al. (2014) but within a variety of contexts including scientist-practitioner communication; policy and management interfaces; best available science and adaptive management; and, advocacy, all of which are briefly reviewed below. Following that review I provide examples of case study research illuminating knowledge exchange processes in environmental research and practice.

1.5.1 Practitioner-researcher communication

There has been considerable research into the relationship between practitioners and scientists, with a lack of good communication between them frequently cited as a reason for poor or ineffective policy, implementation of environmental measures or adoption of new information (e.g. Scott, Rachlow, & Lackey, 2008). Poor communication is sometimes reported to be a result of differences in organisational cultures and philosophies (Roux et al., 2006; Scott et al., 2008). Roux et al. (2006) acknowledge Rogers (1995) when they state that the “diffusion of new knowledge
would be simple if there were no social and cultural divides between the suppliers and prospective adopters of knowledge” (Roux et al., 2006).

Improved communication between practitioners and scientists has been seen as a prerequisite for effective conservation and there has been a call for all parties to take measures to do so whether they be ecologists and landholders discussing frogs (Carr & Hazell, 2006); pond scientists seeking the application of their knowledge (Oertli, Céréghino, Hull, & Miracle, 2009); wetland ecologists and managers (Ryder, Tomlinson, Gawne, & Likens, 2010); forest scientists and policy makers (Joyce, 2003); conservation biologists seeking better application of their work (Salafsky, Margoluis, Redford, & Robinson, 2002); or, river basin managers exploring the barriers to implementation and relationships between scientists and policy makers (Slob, Rijnveld, Chapman, & Strosser, 2007).

The use of collaborative efforts as an approach which will allow the better implementation of scientific environmental knowledge has been strongly recommended (e.g. Gawne, Crase, & Watson, 2010). Collaborative work approaches allow knowledge to be built and shared between experts and practitioners (Raymond et al., 2010; Roux et al., 2006; Thomas, 2003). Recently, Australian wetland ecologists have entered the natural resource policy discussion, following the legacy of Peter Cullen, advancing the case for collaboration between and across disciplines in order to produce shared knowledge which meets the needs of users (Ryder et al., 2010, p.826). They support Roux et al. (2006) who suggest that “scientists cannot afford to remain detached experts who deliver knowledge to managers, but must assume the roles of collaborative learners and knowledge generators in a science–management partnership” (Roux et al., 2006).

1.5.2  Policy development, research and environmental practice

Researchers, policy makers and environmental practitioners are well aware that there is a gap between scientific research, policy development and implementation and this gulf is currently under review and discussion internationally (e.g. Lake, Likens, & Ryder, 2010). The reasons for the gulf together with suggestions for overcoming it have been addressed especially in literature regarding water reform (Tomlinson & Davis, 2010).
Wellock (2010) in his powerful analysis of the adoption of ecosystem management by the US Forest Service uncompromisingly states that in most cases scientists have little influence on policy development. He states that

\[\text{policy experts explain that in a pluralistic political culture government agencies respond to their own interests and political pressure. Scientists, whose studies are often riddled with inconclusive results, have only limited influence in shaping the debate.... Scientists, who are often disinclined to compromise, are largely shut out of final decisions and are relegated to being providers of information, information that is often ignored (p. 382).}\]

The complex nature of environmental problems with the need for cross-disciplinary and integrated responses adds an extra level of difficulty to developing policy (Ross & Dovers, 2008). Researchers, policy makers and practitioners are also expected to respond quickly to new levels of complexity in environmental decision making, for instance the need to understand and develop responses to climate change has increased the level of difficulty (Mercer, Christesen, & Buxton, 2007).

Hart and Calhoun (2010) and Lindenmayer and Likens (2009) are among those who suggest that there are very few examples where integrated policy responses across environmental issues have been developed and implemented at appropriate scales and timeframes. Increasingly there is discussion on how to frame and undertake integrated policy responses (e.g. Saravanan, McDonald, & Mollinga, 2009; Shockley, 2009; Steyaert & Jiggins, 2007).

1.5.3 **Best available science and adaptive management**

In a special issue of Marine and Freshwater Research, Lake et al. (2010) state that “one of the challenges facing freshwater ecologists is to contribute the ‘best available scientific knowledge’ to the sound management of water resources” (Lake et al., 2010, p.734).

While new knowledge may or may not play a role in environmental practice when it is revealed, best available science (BAS) not only plays a role but may determine outcomes in legislative cases (Green & Garmestani, 2012). The United States Endangered Species Act (ESA) requires the use of BAS to support cases where an action may put a species in danger of extinction. Green and Garmestani (2012) assert that while in theory this is significant, in practice the emphasis in enacting the law is on
“available” rather than “best” and as such agencies are not required to generate new knowledge, may ignore data and are able to use their discretion to accept or reject scientific evidence. They recommend the use of an adaptive management approach to ensure decisions are re-evaluated especially when uncertainty is high, however many researchers have indicated that undertaking adaptive management within the ESA is not possible (e.g. Camacho, 2007).

Gerlach, Williams, and Forcina (2013) also question the uncertainty and ambiguity surrounding the concept and use of BAS. They show that choices of BAS are heavily influenced by institutional factors and so the standard of BAS is ambiguous.

For those who support evidence-based decision-making the prospect of using BAS is alluring. For BAS to be effective a clear definition is necessary that includes:

(i) a clear definition of what constitutes ‘science’; (ii) an objective means to rate the quality of the scientific information (ie. To distinguish the best science); and (iii) a determination of the availability of information (Bogert, 1994).

However, as ecologists as well as knowledge exchange experts are well aware, knowledge changes over time as it is constructed and shared (Fazey et al., 2013). And so, BAS is not a static, but a dynamic process which means that decision-making and practice needs to be reviewed and iterative (Ryder et al., 2010).

The discipline and practice of adaptive management with its emphasis on learning, describing, predicting and doing (Argent, 2009) within an explicit structure offers a promising framework for the incorporation of new knowledge in environmental practice. Adaptive management involves “learning from implementation” and includes planning, implementing, monitoring and learning (Allan & Curtis, 2003). It involves a mix of:

- management activities designed to enable learning;
- reflection on the outcomes of those management activities;
- provision of mechanisms for multi-disciplinary and multi-stakeholder involvement; and

Adaptive management encourages learning and practice to be closely linked and enables practice even within complex and uncertain situations.
Both Green and Garmestani (2012) and Ryder et al. (2010) recommend the complex and iterative approach of adaptive management when discussing the application of BAS to environmental problems. Argent (2009) explains that “[D]ata and knowledge are essential in the descriptive component of adaptive management” and that if they are lacking there is an impetus to gather them (p. 20). However, he also suggests that for a problem to be tackled in “an inclusive and integrated manner” within an adaptive management framework a “responsible authority” must be prompted to do so (p. 12). This suggests that new knowledge not only needs to be made available, but also mobilised (Phipps & Shapson, 2009) before an adaptive management process can be undertaken. For knowledge to be mobilised, sometimes advocacy needs to be undertaken.

1.5.4 Advocacy

Advocacy involves acting on beliefs, and advocative claims concern questions about the right actions to be taken (van Herten & Runhaar, 2013). Advocacy then involves “both ‘facts’ and ‘values’” (van Herten & Runhaar, 2013, p.1006). In the field of amphibian research and its context of accelerated biodiversity loss the involvement of the researcher with the environmental issues and challenges is widely accepted and encouraged. Collins et al. (2009) in their exploration of global amphibian decline promote an advocacy role for scientists at the outset when in the foreword Thomas Lovejoy discusses the relationship between his ethical position and his role as a scientist:

*When does a researcher stop being a scientist and begin being an advocate? When doing science, I work and think like a scientist. But I am also a citizen, and it is not only correct but, in my view, also is incumbent upon us as scientist-citizens to state what we think the implications of science are. If we don’t, then, who will?* (Collins et al., 2009, p.xiii)

In Australia, especially within the field of freshwater ecology, there is a strong legacy of building a relationship between scientists and practitioners or managers. This has been left to us by one of our revered scientists and founding member of the Wentworth Group of Concerned Scientists (Cullen, 2004), Peter Cullen, who saw that “beneficial outcomes are unlikely unless science can be actively engaged in the development and assessment of appropriate policies” (Cullen, 2006, p.1) and also recognised that
“scientists commonly hold strong values about desirable outcomes” (Cullen, 2006, p.10).

Within the disciplines of conservation biology and environmental science, discussion about the role of scientists in policy, education and advocacy abounds (e.g. Gerlach et al., 2013; Noss, 2007). The range of peri-research activities that may be considered ‘education’ or ‘advocacy’ includes publishing essays in well regarded journals such as Conservation Biology (e.g. Nelson & Vucetich, 2009), contributing to government boards, developing educational materials, and proliferating value-driven messages on social media. The drivers for advocacy are less commonly discussed, but may relate to pragmatic needs to fund research or may reflect a driving environmental ethic (e.g. Soulé, 1985).

Traditionally, many scientists have not been involved in decision-making for policy or management practises, as advocates for particular management actions or about particular conservation issues or even in explaining the results of their research to the public (Lach, List, Steel, & Shindler, 2003). Lach et al. (2003) explain that this position derives from the philosophy of positivism and perceived nature of science where the role of scientists is to provide objective information rather than involve themselves in management. The prevailing positivist paradigm developed in the Enlightenment has a long and strong tradition (Nowotny, Scott, & Gibbons, 2001). In this context, science is perceived as both certain and “cold, straight and detached” (Latour, 1998). Some scientists fear that their credibility suffers when they participate in advocacy roles (Lach et al., 2003).

Scott et al. (2008) assert that the role of scientists is to conduct rigorous research and develop unbiased scientific information that can then be conveyed to decision-makers via professional societies in order to shape environmental policy. In fact, Scott et al. (2008) argue that scientists should undertake

high-quality, policy relevant science followed by aggressive efforts to bring the results of their work, and the policy and management implications of those results, to decisionmakers and to those who lobby decisionmakers on the issues (p. 869.) (My emphasis).
Gerlach et al. (2013, p.213) report that others including (Meine & Meffe, 1996; Noss, 2007; Shrader-Frechette, 1996) see merit in scientists advocating policy positions through the results of their research.

1.5.5 **Case Studies of knowledge exchange between environmental researchers and practitioners**

Examples of case study research into knowledge exchange and environmental practice shed light on the current topics under discussion.

Calhoun, Jansujwicz, Bell, and Hunter Jr (2014) provide a case study of research and practice concerning vernal pools in Maine, USA over a period of 15 years. They discuss “the development and testing of new conservation approaches that link scientific knowledge, stakeholder decision-making, and conservation outcomes” (p. 11002) which they consider important to conservation of the small ponds which occur on private land. Vernal ponds are important for invertebrate and amphibian species to breed in and the ecosystem services that they provide, but their management is constrained by their small, ephemeral nature, lack of public awareness of them, uncertainties over quality and location and “fragmented regulatory authority at all governmental scales” (p. 11003). They discuss the importance of repeated negotiations by scientists and managers over the science-policy boundary and suggest that “flexible, solutions-oriented research and conservation approaches, trust and collaboration among scientists and decision-makers, and interdisciplinary, engaged research can create opportunities for...novel mechanisms for conservation” (p. 11007).

Slob et al. (2007) discuss the case study of the EU Project AquaTerra which “delivers scientific information of value for river basin management” (p. 867). They suggest that the challenge in this project is not just linking the communities of scientists, policy makers and stakeholders, but bringing scientists from very different disciplines together to use a language that they can all understand. They emphasize the importance of multidisciplinary teams and the importance of transdisciplinary research methods as well as the involvement of stakeholders in the research process and an emphasis on learning processes (p. 873).

Carr and Hazell (2006) in their case study of research into frog diversity in south-eastern Australia argue that “improving the communication between landholders and
ecologists will result in better conservation outcomes” (p. 3177). In this case where “complex, diverse ecological processes influence and are influenced by socio-cultural and political conflict, diversity, ignorance and uncertainty” (p. 3187) in order for better communication to be achieved, researchers need a deeper appreciation of the social context for their research.

Raymond et al. (2010) use case studies from the United Kingdom, Solomon Islands and Australia to discuss the complexities of linking different types of knowledge. While acknowledging the complexity of categorising knowledge types they focus on scientific and experiential or local knowledge. The case studies presented do not have the focus on “environmental practice” as it has been delineated for the purpose of this thesis, but the discussion presented is relevant in that they provide insight into knowledge exchange processes. The cases are: the Sustainable Uplands project in the UK which involves adapting to environmental changes at three sites; sustainable development in Kahua, Solomon Islands and mapping landscape values for conservation and tourism planning in Victoria, Australia. They conclude that integrating different knowledge types presents a variety of challenges including the attention needed by researchers to identifying different beliefs which underpin knowledge claims and engaging different knowledges; validating different knowledge claims; evaluating knowledge integration mechanisms; and, monitoring the level of application of outputs. They also noted that in the Solomon Islands case where the research was “effectively embedded in application” that “communities are beginning to implement their own programmes which are partly based on the results of the ongoing research” (p. 1774).

van Herten and Runhaar (2013) provide in-depth discussion of the case of the European Eel, which is in a state of severe decline. In this case, “drastic protection measures were only taken 70 years after the first warning signs and 11 years after explicit advice” (p. 1002). They discuss advocacy and knowledge utilisation surrounding “the controversial and deadlocked policy process aimed at eel stock protection” and identify discourses of the stakeholders in the decision-making processes influencing policy development and actions. They reveal that there are “fundamentally different value priorities and basic perceptions” (p. 1016) between the stakeholders and show that scientists could not contribute as they disagreed themselves.
In another example of an environmental stalemate, Weber, Memon, and Painter (2011) offer an enlightening discussion of knowledge exchange, management impasses and scientist and community values in their case study of water resource management in the Selwyn watershed, Canterbury in New Zealand. In this case study, different computer modelling approaches to understanding water resource allocation have been adopted and preferred by different stakeholders and “both sides are convinced that their respective approach should guide water management decisions and policies” (p. 50). Weber et al. (2011) argue that in this case of impasse within an adversarial setting “the adoption of a civic science approach increases the prospect that the scientific information being produced will impact key policy and management decision” (p. 67). Civic science is understood as a collaborative approach in which scientists make an effort to “articulate and illuminate science content in the context of social issues” (p. 57) and is described as being first called upon by Lee (1993). However, the paradox here is that such an approach is unlikely to be adopted given that “the kinds of information-sharing, trust, and cooperation central to the civic science concept do not exist in sufficient quantity” (p. 67).

In these cases, the difficulties of knowledge exchange in complex social-ecological systems; the nature of communication between scientists and practitioners; the perceptions, understanding and use of different types of knowledge; the importance of multidisciplinary teams and transdisciplinary methods and the influence of values in knowledge exchange are developed as explicit topics of research relevant to the field of environmental knowledge exchange. All of these may prove relevant to the case for Sloane’s Froglet. Fazey et al. (2013) in their recent review of knowledge exchange and development of a research agenda for environmental management identify these topics and many more in the 80 questions that they propose require attention.

In the next section I describe my study aims.
1.6 STUDY AIMS

Amphibians are in decline world-wide and habitat loss and modification has been identified as a major threat to them. In order to combat the threats, knowledge of habitat is essential. For the rare and little known species, Sloane’s Froglet, no such knowledge yet exists. Knowledge generation itself is not enough to ensure that new knowledge is incorporated into environmental practice. Knowledge utilisation is dependent on contextual factors including how it is communicated, understood and valued. In this thesis I aim to explore both the distribution and habitat of Sloane’s Froglet and knowledge exchange factors which enable the utilisation of new knowledge for Sloane’s Froglets’ benefit.

This research is presented as a transdisciplinary case study with two main complementary parts. I aim to provide fundamental information on the autoecology of the unknown, small (in a variety of contexts effectively, invisible) species of frog, Sloane’s Froglet. This includes previously unknown information about its distribution and habitat at two scales.

This case study sits within a much broader research objective, which is to provide an exploratory analysis of the relationship between new knowledge of water-dependent threatened species and environmental practice. This broader objective is explored with the assistance of the autoecological case study; through examining the responses of environmental professionals and stakeholders to questions regarding the way new knowledge about Sloane’s Froglet was or could be incorporated in decision-making; and, finally by developing a framework which supports the transdisciplinary approach which I have undertaken.

I am confident that the research I have undertaken regarding Sloane’s Froglet for this thesis provides vital knowledge for management of the species as well as a sound basis for further research. During the study period I have also been an educator and advocate for the species. The transdisciplinary research approach undertaken has allowed me to understand and discover the broader ramifications of these actions for environmental practice. Combining this with a rigorous social research approach has allowed me to develop a model or framework for an informed and collaborative approach to conservation research and practice which I term “Intentional Ecology”.
accordance with my objective, the specific study aims and questions are listed below and in Figure 1.1.

**Aim 1: To investigate the distribution and habitat of Sloane’s Froglet.**

**Question 1** Where is Sloane’s Froglet? (Chapter 2)

**Question 2** What are the habitat characteristics of the waterbodies occupied by calling Sloane’s Froglets? (Chapter 3)

Subquestions  
What is the best time of year to detect Sloane’s Froglet?

What is the detection probability for the surveys undertaken during the peak calling period?

**Question 3** Which parts of the waterbody does Sloane’s Froglet use in peak calling periods? (Chapter 4)

**Aim 2: To investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia using a case study of Sloane’s Froglet**

**Question 1** How is the case for Sloane’s Froglet (as I experienced it) relevant to knowledge exchange processes and applied transdisciplinary enquiry? (Chapter 5) This question also responds to Aim 3 below.

**Question 2** What constrains or enables the use of new knowledge in environmental practice? (Chapter 6)

**Aim 3: To explore the value of combining ecological enquiry and social research in one study**

**Question 1** What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research approaches? (Chapter 7)

**Question 2** What are the outcomes of applying this framework to the Sloane’s Froglet case? (Chapter 7)
**Thesis aim:** Provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach.

### Chapter 1
**General Introduction, thesis overview and literature review**

#### Aim 1: Investigate the distribution and habitat of Sloane’s Froglet

- **Chapter 2:** Where is Sloane’s Froglet?
- **Chapter 3:** What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?
- **Chapter 4:** Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?

#### Aim 2: Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focussing on the Sloane’s Froglet case study

- **Chapter 5:** How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?
- **Chapter 6:** What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)

#### Aim 3: Explore the foundations for and value of combining applied ecological and social research in one case study

- **Chapter 7:** What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches? What are the outcomes of applying this framework to the Sloane’s Froglet case study?

#### Thesis aim and aims 1, 2 and 3

- **Chapter 8:** Conclusion. Summary of results and recommendations for future research

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**Figure 1.1** Thesis aims, questions and chapters
1.7 THESIS STRUCTURE

This thesis comprises the current introductory chapter and seven additional chapters.

In Chapter 2, I review the historical distribution records for Sloane’s Froglet. This provides an overview and framework for where the species is or may be found in Australia. I then present the results of my own distribution studies undertaken from 2010 to 2013 in southern Australia in which I discovered important populations of Sloane’s Froglet.

In Chapter 3, I reveal the results of research into the habitat used by Sloane’s Froglet and discuss the nature of the habitat and the implications of this for conservation management. This chapter focuses on the habitat used by Sloane’s Froglet at the wetland scale, comparing the characteristics of waterbodies that Sloane’s Froglet uses during the peak calling period, with characteristics of waterbodies that Sloane’s Froglet is absent from. In order to inform the habitat study, research into the detection of Sloane’s Froglet is also presented and discussed.

In Chapter 4, I continue to focus on the habitat of Sloane’s Froglet during peak calling periods. However, this chapter is devoted to microhabitat use by Sloane’s Froglet, that is, the within-waterbody characteristics of habitat. This chapter provides information on research conducted at selected waterbodies that Sloane’s Froglets was present at and is congruent with that provided in Chapter 3 although at a finer scale. This chapter presents the final ecological findings of the thesis and chapters 2, 3, and 4 together provide fundamental information regarding Sloane’s Froglet that has been previously unavailable.

In Chapter 5, I investigate knowledge exchange, advocacy and the nature of knowledge with an autoethnographical account of my journey of research of and advocate for Sloane’s Froglet. In this chapter I point to themes which will be further explored in chapters 6 and 7.

In Chapter 6, I investigate how the new knowledge about Sloane’s Froglet has been, or could be, incorporated into environmental practice, and more broadly how new knowledge influences practice. This chapter provides the methods, results and analysis of a qualitative social study centred on interviews with environmental practitioners.
In Chapter 7, I explore the relationships between the processes of the applied ecological research with that of the social research undertaken in the previous chapters. Chapter 7 presents “Intentional Ecology”, the framework for environmental research and practise which I have used in this research and which relies on concepts from environmental ethics, systems thinking, and conservation biology.

In Chapter 8, I summarise the main findings of the research and provide recommendations for future research.

Figure 1.1 is reproduced between each chapter of the thesis with the question investigated in the following chapter highlighted.

At the time of submission of this thesis, an earlier version of Chapter 2 (Knight, 2013a) has been published as a report. The report has been updated and slightly modified before inclusion in the thesis. Early and limited results from Chapters 3 and 4 (Knight, 2013b, 2014) have been published in popular formats at the request of the Albury Conservation Company and the insistence of the NSW Office of Environment and Heritage.
**Thesis aim:** Provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach

### Chapter 1
General Introduction, thesis overview and literature review

### Aim 1: Investigate the distribution and habitat of Sloane’s Froglet

#### Chapter 2
**Where is Sloane’s Froglet?**

#### Chapter 3
What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?

#### Chapter 4
Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?

### Aim 2: Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focusing on the Sloane’s Froglet case study

#### Chapter 5
How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?

#### Chapter 6
What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)

### Aim 3: Explore the foundations for and value of combining applied ecological and social research in one case study

#### Chapter 7
What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches? What are the outcomes of applying this framework to the Sloane’s Froglet case study?

### Thesis aim and aims 1, 2 and 3

#### Chapter 8
Conclusion. Summary of results and recommendations for future research
Chapter 2  The distribution of Sloane’s Froglet, *Crinia sloanei*: a review of historical distribution records and results from surveys undertaken from 2010 to 2013
2.1 INTRODUCTION

In this chapter I address the first aim of my thesis which is to determine the
distribution and habitat of Sloane’s Froglet. In this chapter I focus on distribution and
ask “Where is Sloane’s Froglet?” To answer the question I have reviewed database
records and survey reports, sought expert knowledge from herpetologists as well as
undertaking field surveys to develop as comprehensive picture as possible of the past
and present distribution of Sloane’s Froglet.

Distribution is the study of spatial arrangement of species or taxa. Knowledge of
species’ distribution also leads to knowledge of its range, the area within which a
species occurs (J. H. Brown, 1984). Species distribution changes over time in response
to seasonal events and the availability of resources and also to longer term influences
such as habitat modification. Distribution is dependent upon both biotic and abiotic
factors including environmental conditions, for example temperature and humidity,
including both averages and extreme conditions. This interaction is a complex one as
weather conditions also influence biotic factors such as predation and disease (Begon,
Townsend, & Harper, 2009). Species-abundance distributions, the relative abundance
of species within communities, is also a well-established area of ecological research
(MacArthur, 1972).

Knowledge of distribution is fundamental to management, especially for threatened
species. Distribution is considered a criterion for listing species as threatened in
Australian legislation (e.g. "Threatened Species Conservation Act (NSW)," 1995) where
their geographic distribution can be shown to have undergone a reduction.

2.1.1 Existing information on the distribution of Sloane’s Froglet

Sloane’s Froglet, (Crinia sloanei Littlejohn 1958) (Plate 2.1) has a known historic
distribution within eastern Australia in north central Victoria (Vic) and central western
New South Wales (NSW) as far north as the Queensland (QLD) border (Cogger, 1983).
It has been rarely recorded across its range, especially in the last 20 years (Anonymous,
nd). Sloane’s Froglet was listed as Vulnerable on the NSW Threatened Species
Conservation Act (1995) in 2008 (Hughes, 2008) and is considered ‘Data Deficient’ by
the International Union for the Conservation of Nature (IUCN, 2013). No systematic or
targeted surveys have been undertaken for it and no review of its distribution
undertaken prior to that presented here.
2.1.2 The research question

In this chapter I investigate the question “where is Sloane’s Froglet?” Despite the lack of recent records for the species, it seems likely that Sloane’s Froglet may still be found in the areas in which it previously occurred, and so, the chapter contains two approaches to the question. Firstly, I examine the distribution of Sloane’s Froglet from its time of discovery in 1957 (Littlejohn, 1958) to the present time as made available in wildlife databases and in other records provided by herpetologists. Secondly, I present the recent distribution information developed from surveys that I undertook in 2010, 2011, 2012 and 2013. The comprehensive overview of the past and present distribution gained through this process is then discussed in relation to key threats to biodiversity within the area, that is, the high rate of species decline, habitat loss and fragmentation in the Grassy-Box woodland region in eastern Australia; the changes to wetland and floodplain habitat and water regimes within the Murray-Darling Basin, and; the rapid development of peri-urban areas.

Plate 2.1. A male Sloane’s Froglet calling at Albury in winter. (David Hunter)
2.2 A REVIEW OF EXISTING RECORDS

In order to gain an understanding of the known historic distribution of Sloane’s Froglet, a review of all the available existing records for Sloane’s Froglet was undertaken.

2.2.1 Methods

Two main approaches were undertaken to establishing the previous distribution of Sloane’s Froglet. Firstly, state wildlife databases for Victoria, New South Wales and Queensland were accessed. Data were provided in excel sheet format with latitude and longitude. These were imported into ArcGIS (ESRI, 2011) for mapping. Records in these databases have already been through a validation process, however, they were checked and in one case a record for a tadpole was removed, as Sloane’s Froglet tadpoles are almost indistinguishable from those of *C. parinisignifera* (Anstis, 2013).

Secondly, direct approaches to herpetologists with an interest in frogs working within the inland areas of NSW, Victoria and Queensland were made. The records from these requests were also imported into ArcGIS. The source of all records was recorded in the metadata associated with each file.

2.2.2 Results

2.2.2.1 Queensland records

Queensland fauna records are held by the Queensland Museum and the Queensland Department of Environment and Heritage Protection. Neither of these databases include any records for Sloane’s Froglet. Harry Hines, a frog expert based in south-eastern Queensland confirmed that there are no records for Sloane’s Froglet in Queensland (H. Hines, pers. comm.).

2.2.2.2 New South Wales records

The NSW Wildlife Atlas is the central repository for fauna records for the entire State of NSW. The Atlas shows 50 records for Sloane’s Froglet (NSW Wildlife Atlas, accessed 10 December 2012). Six of these records are from the 1950s and 1960s; seven records are from the 1970s and 1980s; 24 records from the 1990s; and, 13 records from 2000 onwards. The earliest records for New South Wales are from Tocumwal, close to the known Victorian locations for the species. The two records from the 1960s are much further away at Round Hill and Nyngan in central NSW. More records from southern
and central NSW were added in the 1970s, 80s and 90s including records from Griffith and Lake Cowal. The first record for the species in the far north of New South Wales is on the Culgoa River near Goodooga in 1992 and Sloane’s Froglet was found at Mungindi in 1998. Other records from the 1990s and into the 2000s are mostly from southern NSW, in particular Albury, Corowa and Wagga Wagga. Figure 2.1 shows a map all of the NSW Wildlife Atlas records.
Figure 2.1. Map of all the records for Sloane’s Froglet contained in the NSW Wildlife Atlas (accessed 10 December 2012).
Three of the herpetologists who were directly contacted were able to provide further information on the distribution of Sloane’s Froglet. Phil Spark (pers. comm.) stated that in 2012 he found small populations of Sloane’s Froglet at Walgett in northern NSW and had also previously found them at Walgett and at Toorale Station near Bourke. Further investigation into photographs and voice recordings in 2014 revealed that the Walgett population were not Sloane’s Froglet, but *Crinia deserticola*, a similar species (Phil Spark, pers. Com.).

In addition to the one site in the Murrumbidgee irrigation area recorded by Dr Skye Wassens on the Wildlife Atlas, Wassens also heard Sloane’s Froglet near Corowa in 2006 (S. Wassens, pers. comm.) in areas near the Murray River. No latitude or longitude was available for this sighting and so it has not been presented in the following maps.

Dr Damian Michael undertook a survey on the Albury Environmental Lands in Albury residential and rural residential areas in winter 2012 after the presence of Sloane’s Froglet in the area had already been well established by me. He found Sloane’s Froglet at 22 of the 38 sites surveyed (D. Michael, pers. comm.) (Figure 2.2).
Figure 2.2. Map of records collected by Damian Michael in Albury NSW in 2012 (D. Michael, pers. comm.)
2.2.2.3. Victorian records

In the original description of Sloane’s Froglet, Littlejohn (1958) described its distribution as in the Murray River Valley from Mulwala to Echuca up to five miles on either side of the larger rivers, but not north of Deniliquin and Finley, and in the plains country between Wangaratta and Whitfield in Victoria. The type specimen came from a temporary pond on the south bank of the Murray River near Tocumwal (Littlejohn, 1958).

Records for Sloane’s Froglet in Victoria were obtained from the Victorian Museum and the Victorian Biodiversity Atlas. The Victorian Museum has 130 preserved specimens of Sloane’s Froglet, 92 of which are from NSW. These 92 records are all from the Murray River region of NSW, in particular, Tocumwal, Lake Mulwala and 8 km west of Howlong and were collected in the late 1950s, 1960s and early 1970s. Of the remaining records, 16 Victorian specimens collected in the 50s, 60s and 70s are also from the Murray River Region. The remaining 22 specimens were collected from Lake Hume, north-west of Nagambie and Doctor’s Swamp near Murchison. The Victorian Biodiversity Atlas contains 70 records for Sloane’s Froglet, 18 of which are Museum preserved specimens already mentioned. 25 of these records are from surveys undertaken in 1992 and 1993 in the Benalla, Murchison and Nagambie regions by Professor Andrew Bennett. The remaining records which are from the 1990s are from the same or nearby places in north central Victoria. There is an isolated record in Chiltern. The most recent records in the Atlas are from 2003 and 2004 and are from Wangaratta. Figure 2.3 shows a map of the combined records from the Victorian Biodiversity Atlas and the Victorian Museum.
Figure 2.3. Map of the records for Sloane’s Froglet contained in the Victorian Museum and the Victorian Biodiversity Atlas (accessed August 2012).
In addition to the records in the above sources, Professor Murray Littlejohn advised me that survey results from his own work and that of the two frog researchers working with him, Angus Martin and Graeme Watson (M. Littlejohn pers. comm.) were available in a Master’s thesis by Arthur Brook entitled *The Zoogeography of Victorian Anura* (1989b). The thesis also contains records gathered by Arthur Brook himself. Field data for each species was spatially represented in 5 degree grid squares. The distribution data for Sloane’s Froglet available in Brook’s (1989) thesis has been reproduced below (Figure 2.4).

![Map of sites where Sloane’s Froglet was recorded by Littlejohn, Martin, Watson and Brook. Field data for each species was spatially represented in 5 degree grid squares. (After Brook, 1989)](image)

**Figure 2.4.** Map of sites where Sloane’s Froglet was recorded by Littlejohn, Martin, Watson and Brook. Field data for each species was spatially represented in 5 degree grid squares. (After Brook, 1989)

Matt Looby from VIC Department of Sustainability and Environment commented that he had heard Sloane’s Froglet recently at the Wangaratta Common (M. Looby, pers. comm.). Keith Ward, Environmental Water Resources Officer with the Goulburn Broken Catchment Management Authority advised that Sloane’s Froglet had been recorded at Moodies’s Swamp in NE Victoria. In addition, Keith Ward advised me that there are records of four Sloane’s Froglet occurring at two sites in the Barmah-Millewa Forest in 2003/04 (reported in Ward, 2004) (Figure 2.5).
Survey work undertaken in 2006 and 2007 in north central Victoria (within its previous range) by the Australian Centre for Biodiversity at Monash University failed to detect Sloane’s Froglet (Mac Nally et al., 2009).

![Map of Sloane’s Froglet records from the Barmah-Millewa Forest (after Ward, 2004)](image)

**Figure 2.5.** Map of Sloane’s Froglet records from the Barmah-Millewa Forest (after Ward, 2004)

### 2.2.3 Summary of the knowledge from the existing historical records

Sloane’s Froglet has been recorded very rarely. When this project commenced in 2010 within NSW it had been recorded only 45 times, 18 of which have been in the last 10 years (Atlas of NSW Wildlife, May 2009). In NSW it is among the most infrequently recorded of all frogs (Anonymous, nd). During recent survey work in NSW it was not found in the northern part of the Murray-Darling Basin and at the start of the survey the only known extant population in NSW was at Thurgoona, a suburb of Albury (Anonymous, nd).

Records from Victoria show that Sloane’s Froglet has been rarely recorded there. The Victorian number of records has declined since the 1980’s. There have been no records for Sloane’s Froglet entered into the Victorian Biodiversity Atlas since 2004. There are no records for Sloane’s Froglet in Queensland.
2.3 SURVEYS 2010 - 2013

I undertook survey work targeting Sloane’s Froglet in winter and spring of 2010, 2011 and 2012. Survey work undertaken in 2010 was focused on southern NSW and northern Vic and provided knowledge of distribution that informed the habitat investigations presented in chapters 3 and 4. In 2011 I briefly visited northern NSW and continued surveys in southern NSW. In 2012 I again focused surveys on southern NSW and in 2013 a brief follow-up survey was undertaken by me and PhD supervisor Dr David Hunter in southern NSW.

2.3.1 The study region

Distribution surveys were undertaken in southern NSW and northern VIC (Figure 2.6) in the lower slopes of the South West Slopes and the Riverina bioregions of Australia (NSW National Parks and Wildlife Service, 2003) (Figure 2.10). Surveys were undertaken within a region that is also identified by its proximity to the River Murray and its floodplains, in particular the Hume to Echuca region, including the Hume to Yarrawonga and Yarrawonga to Wakool reaches (Thoms et al., 2000). In these reaches the river has a broad floodplain “up to 25 km wide, and has many anabranches, billabongs and wetlands” (Thoms et al., 2000, p. 67). Surveys were not restricted to floodplain areas and included surrounding parts of the bioregions. These areas are characterized as having flat to gently undulating topography with generally low elevations of between 150 and 300 m above sea level (NSW National Parks and Wildlife Service, 2003).

The regional towns of Albury-Wodonga and Corowa with human populations of 82,000 (Australian Bureau of Statistics, 2011a) and 5,600 (Australian Bureau of Statistics, 2011b) respectively were central to the study region. Aboriginal people have been present in the Murray-Darling Basin for at least 40,000 years (NSW National Parks and Wildlife Service, 2003). The region was first explored by Europeans in 1817 and settlements were established in the 1830s (NSW National Parks and Wildlife Service, 2003).

The region experiences hot summers and mild winters. The mean maximum temperature ranges from 13.0 °C in July to 31.2 °C in January and mean minimum temperatures 2.7 °C in July and 15.5 °C in January at Albury. Mean annual rainfall is 715 mm at Albury-Wodonga and 541 mm at Corowa (90 years of records). In both
cases the highest rainfall typically occurs in June, July and August, the winter months (Bureau of Meteorology, 2015) (Table 3.1).

The survey period followed a major drought and occurred through a La Niña event and associated flooding in south-eastern Australia. From 1997 to 2009 south eastern Australia experienced a major drought, referred to as the “Millenium Drought” (South eastern Australian Climate Initiative, 2011). During the drought annual rainfall “was 73 mm below average (or 12.4% below the 20th century mean) for the years 1997 – 2009 inclusive” (South eastern Australian Climate Initiative, 2011). Predominantly, throughout the drought the rainfall decline occurred during the autumn and winter months which are usually months where higher rainfall occurs. In March 2010 the study region experienced a high-rainfall event and flooding occurred throughout the study region (pers. obs.). During the La Niña event of 2010 – 2011 south eastern Australia recorded it fourth highest annual rainfall on record (South eastern Australian Climate Initiative, 2011).
### Table 2.1. Temperature and rainfall within the study region. Mean maximum and mean minimum temperatures and rainfall by month for Albury-Wodonga and Corowa.

(1) Albury Airport 36.07, 146.95, elevation 165 m, 24 years of records, (2) Wodonga 36.12 146.91, elevation 156 m, 90 years of records, (3) Corowa airport 35.99 146.36, elevation 143 m, 90 years of records, (4) Corowa airport 35.99 146.36, elevation 143 m, 125 years of records. Shading indicates highest rainfall months. Highlight shows greatest maximum temperatures and lowest minimum temperatures. Source: Commonwealth of Australia, Bureau of Meteorology, “Climate Data Online”, http://www.bom.gov.au/climate/data/stations/

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2.3.2 Methods

Sloane’s Froglet is considered a winter-breeding species (Littlejohn 1958, Anstis 2002), becoming active in autumn and breeding throughout the winter months. I undertook survey work each year between 2010-2012 commencing in April and continuing until October.

Surveys focused along the Murray River region from Albury to Echuca (Figure 2.6) as past and present distribution records indicated that there had been an extensive population in the area (as discussed in Section 2.2.3). The species was originally described (Littlejohn, 1958) from a specimen at Tocumwal which lies within this region (Figure 2.6). In addition, the most recent records for the species were from anecdotaly reported sightings at Albury and Corowa.

As so few recent records for the species existed, the aim of this survey work was to establish the presence of an extant population of Sloane’s Froglet, rather than to randomly survey for presence and absence across the landscape, and so surveys were targeted. Surveys were initially undertaken at known historic locations, particularly where the species had been recently recorded. After establishing the presence of Sloane’s Froglet at a site, further surveys were undertaken at wetlands adjacent to that site with ever-increasing distance from the occupied sites. The field work aimed to survey all wetlands within the region, including small, ephemeral wetlands and so the daily survey period was preceded by an intensive ground-truthing establishing the presence of wetlands already identified by an interrogation of satellite imagery. Not all waterbodies in the regions were surveyed due to difficulty or restrictions on access. Surveys were predominantly undertaken at easily accessible wetlands located on the edge of roadsides on public and private land, on public land such as Travelling Stock Reserves and in the newly established NSW River Redgum National Park. Surveys were undertaken in a vehicle and on-foot by travelling to the nearest waterbodies from confirmed sites to hear if the species was present there.

Sloane’s Froglet was detected by its distinctive call, a short chirp (Littlejohn, 1958). At a few sites in NSW a few individuals were captured to confirm identification.

At some sites once the presence of Sloane’s Froglet was ascertained the site was not revisited. Several sites were visited on multiple occasions as a detectability study
occurred concurrently to this distribution survey (Knight, data not shown). Where the sites were only visited once or twice, it was considered possible to record the presence of Sloane’s Froglet but not possible to establish its absence, and so the species was recorded as being “detected” or “not detected”. An attempt at estimating abundance was undertaken at sites which were visited repeatedly by estimating the total number of frogs calling on each visit. Abundance was categorized into five categories based on an estimate of the number of individuals calling; <six, six – 19, ≥20 - 99, and ≥100. All waterbodies were approached quietly on foot and the perimeter of larger waterbodies was circumambulated on foot. Location of the site was recorded using a global positioning system (GPS).

The Victorian sites were recorded as a result of call detection only (no Sloane’s Froglets were identified in the hand) in a car survey undertaken once with the assistance of a Department of Sustainability and Environment employee. Location was recorded with a GPS at the vehicle rather than at the waterbody, so there is possibly an error of up to 100 metres from the exact location.

In addition, Australian Geographic funded me to undertake short survey in northern NSW which was undertaken in April 2011. Sites around Yetman were surveyed following advice from field naturalist, David Egan. Sites around Mungindi were also surveyed as there are records of the species occurring in this area from 1998. Each waterbody was visited three times and circumambulated during the survey period.

A brief survey was undertaken in winter 2013 at Albury, Corowa and along the Murray River in NSW by myself and PhD supervisor Dr David Hunter. Sites were visited once only and, as with the Victorian sites, location was recorded with a GPS at the car rather than at the waterbody, so there may be a distance to the exact location.

In the hope of finding additional records to those in databases and supplied by herpetologists, several radio interviews were undertaken and informal conversations led to anecdotal information that Sloane’s Froglet had been heard in other places than those that I had already surveyed. These sites were then visited to confirm if it was indeed Sloane’s Froglet present.
2.3.3 Results

In 2010 I surveyed 174 sites for Sloane’s Froglet and the majority were visited three times. I established the presence of Sloane’s Froglet at 83 of the sites surveyed and did not detect them at 91 sites. I located Sloane’s Froglet around the regional towns of Albury and Corowa/Wahgunyah and at a few sites along the Murray River between Albury and Corowa. Over the three years of distribution research I surveyed over 400 sites for Sloane’s Froglet, many of them multiple times. Sloane’s Froglet was not detected in, and appeared to be absent from, much of the landscape as indicated in the map in Figure 2.6.
Figure 2.6. Map of all sites surveyed in 2010, 2011, 2012 and 2013 in southern NSW and northern Victoria. Important populations of Sloane’s Froglet were located in the Corowa/Rutherglen and Albury regions.
Important populations were found to occur in the Albury region (Figure 2.7) and the Corowa/ Wahgunyah/ Rutherglen regions (Figure 2.8). Sites were clustered in the peri-urban areas of these two locations. Initially, two sites were also located at Howlong and the 2013 survey confirmed the presence of Sloane’s Froglet at three further sites at Howlong and two sites just downstream in wetlands along the Murray River that had previously been dry.

What appear to be disjunct populations were located at Chiltern and Moodies Swamp near Cobram in Victoria (Figure 2.6). No Sloane’s Froglets were located in the Tocumwal region.

During the Australian Geographic funded survey in northern NSW, a small population of Sloane’s Froglet (up to 20 individual males calling) was confirmed to occur at Mungindi, but the species was not detected at any other sites surveyed (Figure 2.9).
Figure 2.7. Map of sites surveyed for Sloane’s Froglet in the Albury Region from 2010 - 2013.
Figure 2.8. Map of the Corowa region showing sites surveyed for Sloane’s Froglet from 2010 - 2013.
Figure 2.9. Map of Sloane’s Froglet sites surveyed in northern NSW in 2011. Sloane’s Froglet was only detected at one site near Mungindi.
2.4 DISCUSSION

The combined results from the historical distribution records and recent surveys show that Sloane’s Froglet is distributed widely in south eastern Australia and occurs in the Darling Riverine Plains, NSW South Western Slopes, Riverina and Victorian Midlands bioregions (Figure 2.10). It is distributed within the Murray-Darling Basin (Figure 2.10), predominantly in a region in which the highly cleared ecosystem of Grassy-Box woodland occurs (Figure 2.11) and often in peri-urban areas (e.g. Figure 2.12).

Figure 2.10. Map of all the known distribution for Sloane’s Froglet (historic records and recent surveys), the Murray-Darling Basin and the IBRA regions (IBRA Regions source: Australian Government Department of Environment IBRA7)
2.4.1 Historical distribution

The early records for Sloane’s Froglet (1950s to 1960s) are from northern central Victoria and along the Murray River near Tocumwal and Mulwala. These records were collected as a result of the intensive survey work undertaken by Littlejohn and his colleagues Martin and Watson on the distribution and calls of frogs in south-eastern Australia (Brook, 1989a; Littlejohn, 1958). This work resulted in a greater understanding of the distribution, taxonomy and evolution of frogs in south-eastern Australia which was made known through a number of publications (e.g. Littlejohn, 1957, 1959, 1963, 1964, 1965, 1966, 1981; Littlejohn & Martin, 1964, 1965a, 1965b; Littlejohn & Watson, 1973; Martin & Littlejohn, 1969) as well as The Atlas of Frogs of Victoria (Brook, 1979). Since that time surveys undertaken by Bennett in 1993 (Bennett, 1998; G. W. Brown, Bennett and Potts, 2008) show that the species is also found in the Benalla and Nagambie regions a little to the south of the initial distribution.

Early knowledge about Sloane’s Froglet distribution in NSW along the Murray River comes from the same source as the Victorian information (that is, the work of Littlejohn and colleagues). The extension of its range throughout the western slopes and eastern plains of Murray Darling Basin of NSW has come from a variety of smaller surveys and incidental records rather than large or targeted distribution surveys. It seems that at least in the past Sloane’s Froglet may have been present throughout this region (although perhaps in small and isolated populations) to the Queensland border. Although the record at Mungindi in northern NSW has been authenticated, there is some doubt about the northern NSW records for the species since the confusion with Crinia deserticola was revealed.

It seems quite likely that Sloane’s Froglet could have occurred in the past, or still may occur, in southern central Queensland given that the most northern record in NSW occurs at Mungindi and is within 200 metres of the Queensland border. The complete lack of records in Queensland may be because the species occurs there rarely or may result from a lack of familiarity with the species or lack of surveying at the appropriate time of year and time of day.

Recent broad-scale surveys in NSW and Victoria have detected few or no Sloane’s Froglets (Gosper, 2002; Mac Nally et al., 2009; Wassens, Sass, Swan, & Thompson,
2004). It seems quite likely that the concerns that led to it being listed as threatened in NSW in 2008 are real.

### 2.4.2 Current surveys

The recent targeted surveys I undertook as part of this Doctoral research show that Sloane’s Froglet does persist in the landscape in two main regions: Corowa/Wahgunyah and Albury. It has not yet been confirmed if this is a continuous population, however it seems likely given the presence of Sloane’s Froglet in wetlands between these two regions. Sloane’s Froglet occurs in Victoria throughout the Wahgunyah and Rutherglen areas. Surveys on the NSW side of the border between Corowa and Albury located Sloane’s Froglets at only seven locations near and downstream of Howlong.

Despite intensive survey effort in wetlands downstream of Corowa I was unable to locate Sloane’s Froglet in this area. Murray Littlejohn was also unable to relocate Sloane’s Froglet at Tocumwal when revisiting the area in 2007 (M. Littlejohn, pers. comm.) (Plate 2.2).

The 2003/04 records from Barmah-Millewa (which is downstream of Tocumwal) are of interest as there is the possibility of locating a larger population there. The surveys I undertook coincided with flooding of the area and while an initial attempt was made to enter the area, conditions made further survey impossible. This area of the River Murray requires follow up surveys.
Plate 2.2. Photograph of Murray and Patsy Littlejohn at the Tocumwal site that is the type locality for Sloane’s Froglet in 2007, 50 years after its initial discovery. The site was dry. No Sloane’s Froglets were located at Tocumwal in recent surveys. (Murray Littlejohn)

Distribution surveys were limited by the availability of resources. At times very wet weather limited access to sites. It is highly likely that future surveys will find Sloane’s Froglet in other parts of Victoria, NSW and Queensland. It is also likely that, following the pattern of known populations, other populations may well be small and disjunct.

As Brook (1989b) noted twenty five years ago “[T]he large area and relatively small human population of Australia have retarded the collection of basic distributional data for most animal groups” (p. 1). Since that time a great deal of research has been undertaken about Australian frogs, their conservation and habitat requirements. It remains the case that baseline data on the distribution of many species is still unavailable. With species such as Sloane’s Froglet, targeted surveys are more likely to detect the species than broader diversity surveys.
2.4.3 Landscape and habitat features of the areas within which Sloane’s Froglet is distributed

The coincidence of Sloane’s Froglet distribution within the Murray-Darling Basin and the distribution of Grassy-Box woodland, as well as its location within peri-urban areas of Albury and Corowa is of interest and may help to explain its perceived decline.

Within Australia’s Murray-Darling Basin wetland habitats have been modified and lost through widespread and large-scale changes in the water regime, loss of floodplain connectivity, and broad-scale changes in land use particularly due to cropping and horticultural activities (Finlayson, Davis, Gell, Kingsford, & Parton, 2013). The threat to biodiversity in the Murray-Darling Basin was brought to the public’s attention when awareness of the loss of colonially-nesting birds (e.g. Kingsford & Thomas, 1995) and
river red gum communities was raised and as it continued to be championed by Richard Kingsford and colleagues (e.g. Kingsford & Thomas, 1995).

As well as species and ecosystems (like the river red gums) that are in the public eye, a range of lesser known and perhaps less publicly appealing species (Stankey & Shindler, 2006 describe them as rare and little known species) have suffered declines in their abundance in the Murray-Darling system and a range of measures have been put in place in a bid for recovery (Saintilan & Overton, 2010). This recovery process has focused on the provision of water and providing water flows into internationally acclaimed wetland sites. Some smaller wetland areas as well as lesser known species have benefitted from this process (K. Ward, pers. comm.). Issues of floodplain recovery and connectivity, however, remain largely unaddressed due to complex socioeconomic factors (Kingsford, 2000) and so species and ecosystems that lie outside of the river body or specific wetlands where action has been focused are largely outside of the sphere of conservation action.

The Grassy-Box woodland region of eastern Australia has a high rate of species decline, high rates of land clearing and fragmentation (Beeton, 2006) (Figure 2.11) and altered water regimes (NSW Scientific Committee, 2002). It has been listed nationally as endangered under the Environment Protection and Biodiversity Conservation Act 1999 (Australia) as less than 5% remains and much of it occurs in isolated patches within a predominantly agricultural landscape (Australian Government Department of the Environment and Heritage, 2006).

Given the broader landscape context of significant habitat loss, habitat modification and change in water regimes, it seems highly likely that the decline of Sloane’s Froglet is related to habitat changes.

Much of Sloane’s Froglet current known distribution occurs in peri-urban areas. Important populations occur in peri-urban areas at Albury, particularly the Thurgoona suburban area, and Corowa, as well as in north-east Victoria. Figure 2.12 shows an example of the landscape that Sloane’s Froglet occurs within in the Thurgoona area. There are no established reasons for Sloane’s Froglets’ occurrences in peri-urban areas at this time.
2.4.4 Recommendations for future research

Further distribution studies need to be undertaken in Victoria, northern NSW and southern Queensland to locate any extant populations of Sloane’s Froglets. Given the current context of mistaken identification, the studies should be undertaken by experienced researchers who are familiar with and trained in identification of Sloane’s Froglet and able to differentiate it from other species.

2.4.5 What are the implications of this new knowledge for Sloane’s Froglet management?

Peri-urban areas that occur within a context of highly modified landscapes contain populations of Sloane’s Froglet important for its recovery and long-term viability. In the example above (Figure 2.12) Sloane’s Froglet occurs on the Charles Sturt University campus which is now surrounded by higher-density suburban subdivisions. Both at Albury (the Thurgoona area is planned to house an additional 50,000 people over the next 50 years (Albury City Council, 2012)) and at Corowa these populations occur in peri-urban areas which are rapidly becoming developed. Hamer and McDonnell (2008, p.2444) point out that there are not enough habitat studies for amphibians in urban areas and this is of concern given that urbanization is “the main driver of habitat loss in many parts of the world”.

Figure 2.12. Aerial photograph of the Charles Sturt University campus and surrounding suburban development showing locations where Sloane’s Froglet was detected in 2010.
It is extremely likely that, in this context, habitat used by Sloane’s Froglet will be destroyed and its known distribution curtailed. As stated by Smallbone, Luck and Wassens (2011) in their study of anurans in regional towns in south-eastern Australia “careful planning of low-lying neighbourhoods near town centres and peri-urban neighbourhoods on town fringes is required to ensure anuran conservation in urban settlements” (p. 43). This is especially the case for Sloane’s Froglet as at this time no larger populations have been located in agricultural or conservation areas.

Sloane’s Froglet is listed under the NSW Threatened Species Act, which has as its first and second objects:

- to conserve biological diversity and promote ecologically sustainable development, and
- To prevent the extinction and promote the recovery of threatened species, populations and ecological communities. ("Threatened Species Conservation Act (NSW)," 1995)

It would seem reasonable to recommend actions that protect the current known distribution, particularly, the protection of sites within which the populations occur.
2.5 CONCLUSION

The review of the historical records for Sloane’s Froglet shows that this species was distributed widely in south-eastern Australia in the Darling Riverine Plains, NSW South Western Slopes, Riverina and Victorian Midlands bioregions within the Murray-Darling Basin predominantly in a region in which the highly cleared ecosystem of Grassy-Box woodland occurs. Distribution surveys I undertook at over 400 sites from 2010 to 2013 located Sloane’s Froglet predominantly in peri-urban regions of southern NSW and northern Victoria. These areas are important for its conservation. Further work into the distribution of Sloane’s Froglet in northern Victoria and central and northern NSW by experienced herpetologists is recommended.

In the next chapter, I examine the habitat features of waterbodies in southern Australia that Sloane’s Froglet uses by comparing the characteristics of occupied sites with unoccupied sites.
**Thesis aim:** Provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach

**Chapter 1**
General Introduction, thesis overview and literature review

**Aim 1:** Investigate the distribution and habitat of Sloane’s Froglet

**Chapter 2**
Where is Sloane’s Froglet?

**Chapter 3**
What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?

**Chapter 4**
Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?

**Aim 2:** Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focusing on the Sloane’s Froglet case study

**Chapter 5**
How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?

**Chapter 6**
What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)

**Aim 3:** Explore the foundations for and value of combining applied ecological and social research in one case study

**Chapter 7**
What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches? What are the outcomes of applying this framework to the Sloane’s Froglet case study?

**Thesis aim and aims 1, 2 and 3**

**Chapter 8**
Conclusion. Summary of results and recommendations for future research
Chapter 3  Physical and vegetation characteristics of waterbodies used by Sloane’s Frogllets in winter
3.1 INTRODUCTION

In this chapter I investigate habitat use by Sloane’s Froglet and continue to address the first aim of my thesis which is to determine the distribution and habitat of Sloane’s Froglet. I ask “what are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets”? To answer this question I compared physical and vegetation characteristics of waterbodies that Sloane’s Froglet occupies in southern Australia during winter with those of waterbodies it did not occur in. In doing this I offer insight into the habitat essential for Sloane’s Froglets’ breeding success. The knowledge presented here may be considered to be part of a larger picture of habitat requirements at different scales (for instance, the landscape scale discussed in Chapter 2 and the microhabitat scale examined in Chapter 4) and of habitat used for different functions at different seasons and lifestages. As knowledge of detection parameters and probabilities is essential for such studies, I also addressed questions surrounding detection of this species.

3.1.1 Australian frog habitat research and conservation applications

Just over 10 years ago, in her review of Australian frog research and investigation of frog ecology in modified landscapes, Hazell (2003, 2004) reported that there were no studies in Australia regarding the effectiveness of habitat management for frogs. There has been some recent investigation into the habitat needs and watering requirements of some Australian frogs (for instance, Hale et al., 2013; Heard, Robertson, & Scroggie, 2004; Hunter, Osborne, Smith, & McDougall, 2009; Wassens & Maher, 2011; Wassens, Roshier, Watts, & Robertson, 2007). Investigations into the use by anurans of constructed wetland habitats, particularly in urban landscapes, have also been undertaken (e.g. Hamer & McDonnell, 2008; Hamer & Organ, 2008; Hodgkison, Hero, & Warnken, 2007). Reports of management activities in non-urban landscapes, however, appear mostly in non peer-reviewed government reports (e.g. Hunter, 2007; Knight, 2010) and little has been added to the peer-reviewed literature within the Australian context.

Despite the lack of peer-reviewed evidence regarding the potential benefits and success of habitat intervention as a management tool in many areas, reviews of the status of and threats to Australian frogs report that habitat loss and modification are
still major threats to frogs (Gillespie et al., 2011) and that habitat intervention is essential (Shoo et al., 2011).

### 3.1.2 Habitat characteristics influencing frog occupancy

Knowledge of breeding habitat is considered particularly important for conservation efforts. Studies of breeding habitat occupancy have found presence, diversity and structure of both aquatic and littoral vegetation to be suitable predictors for frog diversity (e.g. Hazell, Cunningham, Lindenmayer, Mackey, & Osborne, 2001; Wassens, Healy, & Watts, 2011; Welch & MacMahon, 2005) as well as for individual species (e.g. Heard et al., 2004; Popescu et al., 2013). Hydroperiod and water availability have also been found to influence frog occupancy (Otto, Forester, & Snodgrass, 2007; Wassens & Maher, 2011; Wassens, Walcott, Wilson, & Freire, 2013). Waterbody size and water depth have also been considered important factors (Hunter et al., 2009; Welch & MacMahon, 2005). When water quality attributes have been investigated, they have generally not been found to be significant predictors for frog occupancy (e.g. Hamer, Lane, & Mahony, 2002; Healey, Thompson, & Robertson, 1997; Wassens et al., 2011) except in research that has indicated that future increasing wetland salinity may impact upon tadpoles (Smith et al., 2007) or in specific cases where the tolerance ranges of a species are related to acidic water environments, for instance *Crinia tinnula* (Simpkins, Shuker, Lollback, Castley, & Hero, 2014).

### 3.1.3 Detection

A key issue for nature conservation whether focused on long-term monitoring or on identifying high conservation value habitats is the ability to detect the presence of a threatened species (Kery, 2002; MacKenzie et al., 2006). Many frogs are cryptic and difficult to detect. They may be small, hidden and nocturnal. For threatened frogs further complications and issues arise when aiming to detect cryptic species that may occur only in low numbers or with a limited distribution. Survey by distinguishing the frog call is a technique commonly employed (Lemckert & Mahony, 2008), however the activity and calling of many species is often only triggered by particular weather conditions or by environmental considerations (Mazerolle, 2005; Odendaal, Bull, & Telford, 1986; Wong, Cowling, Cunningham, Donnelly, & Cooper, 2004). Detection parameters for frogs usually relate to weather conditions, but may also include phenology, abundance, observer experience and survey duration (Tanadini & Schmidt,
Chapter 3

2011). In Australia, research has been undertaken into how the social environment affects frog calling behaviour (Odendaal \textit{et al.}, 1986; Wong \textit{et al.}, 2004).

The detectability of an organism has a temporal as well as a spatial component and is directly related to the ability of the surveyor to find the species. Any imperfection in detection will bias subsequent investigation into habitat associations and species recovery or decline (Gu & Swihart, 2004; MacKenzie \textit{et al.}, 2006). Challenges associated with designing and ensuring the success of detection studies have been explored within a variety of contexts and for many different groups and species (e.g. Albanese, Peterson, Freeman, & Weiler, 2007; Edwards, Cutler, Geiser, Alegria, & McKenzie, 2004; Kéry & Plattner, 2007; Kéry & Schmid, 2006), and particular attention has been paid to detection of amphibians and to accounting for detection imperfections (e.g. Canessa, Heard, Parris, & McCarthy, 2011; de Solla \textit{et al.}, 2005; Dostine, Reynolds, Griffiths, & Gillespie, 2013; Jackson, Weckerly, Swannack, & Forstner, 2006; Mazerolle \textit{et al.}, 2007).

There has been a recent, active debate arising around the importance or not of incorporating detection probabilities in occupancy modelling. Welsh, Lindenmayer, and Donnelly (2013) have argued that adjusting “occupancy models for non-detection can be as misleading as ignoring non-detection completely” and that “[I]g ignoring non-detection can actually be better than trying to adjust for it” (p. 1). Guillera-Arroita, Lahoz-Monfort, MacKenzie, Wintle, and McCarthy (2014) have responded asserting that ignoring non-detection is dangerous and could impact negatively on the quality of “statistical inference in ecology and related management decisions” (p. 1). Kellner and Swihart (2014) when reviewing 537 articles found that only 23 % accounted for imperfect detection and suggest that ecologists should consider detection more carefully when designing studies and analysing results. The discussion is not yet resolved.

It seems reasonable that where knowledge of detection parameters is limited, managing for detection probabilities in the analyses may be more important.

3.1.4 Existing information regarding Sloane’s Froglet habitat and detection

We know very little about the habitat requirements of Sloane’s Froglet, with the description by Littlejohn (1958) providing the major source of information. He
described the habitat as “shallow temporary ponds in clay soil” and “temporary ponds in the river valleys” (Littlejohn, 1958, p. 223). Anstis (2002) confirms the use of temporary ponds and adds that they occur in "flooding grassland, ditches and swamp areas” (p. 176).

No other information is available.

Littlejohn first located the new species, *C. sloanei*, by its call, stating that the call was quite distinct from that of the other two *Crinia* species found in the area (Littlejohn, 1958, p. 222). Littlejohn provides detailed description of the call characteristics including the duration, number of pulses, pulse repetition frequency, call repetition rate and approximate carrier frequency (Littlejohn, 1958, p. 224) which allow Sloane’s Froglet to be differentiated from other species. Littlejohn (1958) also provides a morphological description providing characteristics for differentiating observed specimens of Sloane’s Froglet from the similar *C. parinisignifera* and *C. signifera*.

### 3.1.5 The research question

Knowledge of the habitat used by a species is essential for management and in the case of threatened species, such as Sloane’s Froglet, may be critical for its conservation. In this chapter I ask “what are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?” I hypothesised that Sloane’s Froglet would be a habitat obligate and select a specific range of waterbody conditions and so I would be able to observe differences between occupied and unoccupied waterbodies. Further, I predicted that factors influencing waterbody selection would include (1) variables describing vegetation cover and structure within the waterbody and on the bank; (2) variables associated with the hydroperiod of the waterbody; (3) variables associated with the physical characteristics of the waterbody such as slope of the bank and depth, and; (4) variables relating to the context of the waterbody with nearby waterbodies.

To investigate the habitat I explore and quantify the physical and vegetation characteristics of 94 waterbodies. The waterbodies were selected within the region that Sloane’s Froglet is distributed within as established in the previous chapter (Chapter 2). I compare the physical and vegetation characteristics of waterbodies that Sloane’s Froglet occupies or uses with waterbodies that are not occupied by this species.
While there is some debate surrounding the issues (as discussed above), this research takes the approach that habitat studies rely on detection methods where the possibility of the data representing false absences is reduced or managed for in the analyses. To adequately approach the habitat question the following detectability questions were addressed: “What is the best time of year to detect Sloane’s Froglet?” and “What is the detection probability for the surveys undertaken during the peak calling period?” The answers to the detection questions informed the habitat study.
3.2 METHODS

3.2.1 Study area and site selection

As described in Chapter 2, surveys for Sloane’s Froglet were undertaken in southern NSW in 2010 and 83 of the 174 waterbodies surveyed were identified as containing Sloane’s Froglet (Knight, 2013a). Ninety-four waterbodies were randomly selected in the same study region in 2012, and surveyed for this habitat study (Figure 3.1). Physical and climate characteristics of the study region are provided in Chapter 2, Section 2.3.1.

To avoid prejudicing the study by selecting waterbodies from areas where the species may not have been distributed, study sites were selected only in the region in which the presence of Sloane’s Froglet had already been established. In order to randomly sample the wetlands a 100 m x 100 m grid was placed on a map of the study region (Figure 3.1) and a number allocated to each grid square. A random number table was then used to generate the grid squares where occupied sites would be sampled. An occupied site was established in that grid square through the field survey methods described in Section 3.2.2 below. The same approach was undertaken again to identify survey locations for unoccupied sites. Site selection was limited by the proximity of the site to a road, inaccessibility due to wet weather and inability to access landholders to seek permission (no landholders denied permission to undertake the survey work once approached). As the method of site choice allowed sites very close together to be chosen an “100 metre” rule was also applied to limit the possibility of spatial autocorrelation. Limiting the possibility of spatial autocorrelation between nearby sites when modelling occupancy patterns is important as local movements between waterbodies can change occupancy (Wassens et al. 2010). Hamer et al. (2002) found that waterbodies were more likely to be occupied if they were within 50m of the next occupied waterbody for Litoria aurea. As there is as yet no knowledge of the mobility of Sloane’s Froglet a conservative approach was undertaken and any site within 100 m of another site was not used.
Figure 3.1. Map showing the location of waterbodies sampled in the Corowa and Albury regions of NSW in 2012 to compare the habitat characteristics of waterbodies occupied and not occupied by calling Sloane’s Froglets
3.2.2 Detection and occupancy

In Chapter 2 issues regarding detection were addressed in a limited way and absence of Sloane’s Froglet from a site was not statistically established. Despite visiting many sites multiple times, I took the cautious position that Sloane’s Froglet was “undetected” at a site rather than necessarily absent. To provide a stronger foundation for this habitat study, I established a more rigorous approach as described in the paragraphs below. Information on key calling periods was developed from five sources: my own experience; the experience of A/Prof Littlejohn; NSW Office of Environment and Heritage guidelines (NSW Department of Environment and Climate Change, 2009); a review of existing records; and, information supplied in Lemckert and Mahony (2008). A standard survey protocol was established and analysis of detection probabilities undertaken.

I used my experience regarding the detection of Sloane’s Froglet gained in the distribution study to inform the survey design for the study of habitat presented in this chapter. Repeated surveys undertaken in 2010 indicated that Sloane’s Froglets actively and consistently called in winter during afternoons and evenings. Littlejohn’s original discovery (Littlejohn, 1958) of the species occurred in August of 1957 when he observed three mating pairs of Sloane’s Froglet. Mating pairs were collected at air temperature of “9.0°C and water temperature of 9.5°C” (Littlejohn, 1958. p. 224). Sloane’s Froglet was calling strongly in the August of 1957 and Littlejohn (1958) also provides the information that choruses were heard “over the temperature ranges: air, 5.0-10.5. °C.; water, 7.0-10.75°C” (Littlejohn, 1958, p. 224). Littlejohn confirmed winter as the best time to survey and as the time when Sloane’s Froglet was actively breeding (M. Littlejohn, pers. comm.).

Very little other information regarding the detection parameters for Sloane’s Froglet exists. In New South Wales (NSW), Australia, the government agency responsible for the Threatened Species Act 1995 provides consultants with guidelines for surveying amphibians (NSW Department of Environment and Climate Change, 2009). For Sloane’s Froglet the guidelines recommend a combination of call surveys and nocturnal searches “repeated on a minimum of two separate nights” (NSW Department of Environment and Climate Change, 2009, p. 13). They recommend surveys be undertaken in autumn, winter and spring, after rain. The information relies
on the personal comments of Daly, Anstis and Lemckert, all respected NSW frog experts and refers via Anstis (2002) to the previously described work of Littlejohn (1958). The NSW guidelines also provide the information that surveying for tadpoles of Sloane’s Froglet is not suitable as “they are unable to be distinguished from Crinia parinisignifera or C. signifera where these species are sympatric (Anstis pers. Comm) (NSW Department of Environment and Climate Change, 2009, p. 13). In their analysis of the core calling periods of frogs in the temperate areas of NSW, Lemckert and Mahony (2008) are able to access only eight records for Sloane’s Froglet and deem that this is inadequate to define core calling periods (pp. 72 - 73).

I reviewed existing Sloane’s records in the Victorian and NSW databases (which contain information on the date that frogs were located) to further confirm the best time of year for detection (following the method described in Lemckert & Mahony, 2008). The review considered only adult male Sloane’s Froglets that had been observed, but not records for individuals that had been trapped through methods such as pitfall trapping (e.g. as in the surveys undertaken by Bennett, 1998).

The most appropriate time to survey for Sloane’s Froglet was also supported by using information from surveys in 2010, 2011 and 2012, where I had recorded the presence or absence of calling Sloane’s Froglet almost every day between February and June at one pond in Thurgoona, Albury.

Presence/absence and an index of relative abundance was determined for each of the 94 sites using a standard survey approach of visiting each site a minimum of three times during winter and early spring. The presence and abundance of calling males was recorded at each visit. If just one calling male was detected at the site on any of the three visits the site was considered to be “occupied” by Sloane’s Froglet. If no Sloane’s Froglets were heard calling at any of the three visits the site was considered as an “unoccupied” site. The abundance was determined by recording an overall estimate of the number of male frogs calling at each site at each visit. The number was recorded in categories of < six individual Sloane’s Froglets, ≥ six to 19, ≥ 20 to 99 and ≥ 100. The highest abundance recorded over the three visits was used as the abundance estimate.
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The presence/absence data for the three site visits were analysed using Program PRESENCE (Hines, 2006) to establish a detection probability for the survey season after (MacKenzie et al., 2006). Single season and survey–specific detection probabilities were fitted and the most parsimonious model selected using AIC (Burnham and Anderson 1998; equation 1).

3.2.3 Sampling strategy

While there is some common ground on drivers for occupancy, for instance submerged, emergent and fringing vegetation are commonly measured (although using different sampling strategies) (e.g. Hazell, et al. 2001, Scheffers & Paszkowski, 2013, Wassens et al. 2010), there is little agreement on the drivers of frog occupancy and different studies focus on different aspects of habitat. The variables selected for this study were based on the review of the literature (refer to Section 3.1.2) as well as ones that were likely to be biologically meaningful and which could be applied across the different wetland types found in the region (after Wassens et al., 2010).

Field observations were undertaken at each waterbody during the period from late July to early September. The characteristics of the waterbody that were measured fell into two classes; physical features of the waterbody and vegetation within and adjacent to the waterbody. The type of waterbody and surrounding land use were recorded. Waterbody physical features included an estimate of the size of the waterbody by taking measurements of length and width using a TruPulse 360B Laser series rangefinder (after Hunter, Osborne, Smith McDougall, 2009); the hydroperiods (after Wassens, Hall, Osborne, & Watts, 2010; Otto, Forester, Snodgrass, 2007) gained from discussion with local landholders; an estimate of the bank slope (resulting from observations of the site during the preceding distribution studies); waterbody depth measured at the deepest part (after Hunter, Osborne, Smith McDougall, 2009; Welch & MacMahon, 2005); the relationship with waterbodies within 100m (after Houlahan & Findlay, 2003; Hamer et al. 2002); and an assessment of the nature of the overflow and any flooded or potentially flooding area adjacent to the waterbody (resulting from observations of the site during the preceding distribution studies). (Table 3.1).
Table 3.1. Physical characteristics of the waterbodies sampled in the Corowa and Albury regions of NSW in 2012 and their definitions

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total size</td>
<td></td>
<td>Size of the waterbody (m²) estimated from measurements of length and width</td>
</tr>
<tr>
<td>Hydroperriod</td>
<td>Ephemeral</td>
<td>Flooded only during large overbank flows or heavy rainfall. May not contain water every year.</td>
</tr>
<tr>
<td></td>
<td>Seasonal</td>
<td>Inundated for a period every year but may be dry for short periods</td>
</tr>
<tr>
<td></td>
<td>Permanent</td>
<td>Contain water continuously for a period of 5 years</td>
</tr>
<tr>
<td>Slope of the bank</td>
<td>Gentle</td>
<td>≥ 50 % of the bank with a slope &lt;5 %</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Estimated slope &lt;25%</td>
</tr>
<tr>
<td></td>
<td>Steep</td>
<td>Estimated slope &gt;25 %</td>
</tr>
<tr>
<td>Depth of the waterbody</td>
<td>Shallow</td>
<td>Less than 30 cm</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Greater than 30 cm and less than 100 cm</td>
</tr>
<tr>
<td></td>
<td>Deep</td>
<td>Greater than 100 cm</td>
</tr>
<tr>
<td>Relationship with nearby waterbodies</td>
<td>Isolated</td>
<td>No waterbodies within 100m of the site</td>
</tr>
<tr>
<td></td>
<td>Complex</td>
<td>Part of a complex lentic system with adjacent waterbodies</td>
</tr>
<tr>
<td></td>
<td>On a watercourse</td>
<td>A dam or low flow area on a creek or drain</td>
</tr>
<tr>
<td>Overflow</td>
<td>Yes</td>
<td>An ephemerally inundated shallow overflow is adjacent to the waterbody</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>The water runs outs from the waterbody and discharges into a creek, drain or channel</td>
</tr>
</tbody>
</table>

Vegetation characteristics included a measure of the area of the waterbody that contained aquatic vegetation, once again using a TruPulse 360B Laser series rangefinder. Vegetation was categorised into structural categories of submerged (e.g. *Potamogeton* sp.), floating (e.g. *Azolla* sp.) and emergent small stem-diameter (e.g. *Eleocharis acuta, Juncus usitatus*) and large stem-diameter emergent vegetation (e.g. *Juncus ingens, Phragmites australis*) (after Sainty, 2003). Very little floating vegetation was found at any site (< 1% cover) and so when it did occur it was pooled with the submerged vegetation category (as per Hazell *et al.*, 2001). Each vegetation structure category was then further subdivided into the component of that vegetation type with less than 30 % cover (sparse), 30 to 70 percent cover (sparse to medium) and greater
than 70 % cover (medium) (Table 3.2). Each of the vegetation subcategories that occurred at each site were visually estimated in percent cover for the entire waterbody. A Braun-Blanquet key table (Braun-Blanquet, 1928) was used to ensure consistency of cover estimates across sites. In this way I was able to describe the aquatic vegetation in such terms as, for example, “55 % of the waterbody contained sparse cover of submerged vegetation” or “25 % of the waterbody contained medium cover of small stem-diameter emergent reeds”.

Characteristics of the bank were measured within two metres of the water’s edge (after Hazell, 2004; Wassens et al. 2010). The bank was divided into five metre areas and percent cover of vegetation, leaf litter and canopy cover estimated in each two x five metre quadrat using a Braun-Blanquet key table (Braun-Blanquet, 1928) and averaged. The number of layers of vegetation was counted within two metres of the water’s edge (Table 3.2).

Table 3.2. Vegetation characteristics and % cover parameters recorded at each waterbody sampled in the Corowa and Albury regions of NSW in 2012

<table>
<thead>
<tr>
<th>Vegetation Category</th>
<th>Cover category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aquatic</strong></td>
<td>&lt; 30 % (sparse)</td>
</tr>
<tr>
<td>Submerged and floating (pooled)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 – 70 % (sparse - medium)</td>
</tr>
<tr>
<td></td>
<td>&gt; 70 % (medium)</td>
</tr>
<tr>
<td>Small stem-diameter emergent</td>
<td>&lt; 30 % (sparse)</td>
</tr>
<tr>
<td></td>
<td>30 – 70 % (sparse - medium)</td>
</tr>
<tr>
<td></td>
<td>&gt; 70 % (medium)</td>
</tr>
<tr>
<td>Large stem-diameter emergent</td>
<td>&lt; 30 % (sparse)</td>
</tr>
<tr>
<td></td>
<td>30 – 70 % (sparse - medium)</td>
</tr>
<tr>
<td></td>
<td>&gt; 70 % (medium)</td>
</tr>
<tr>
<td>Bank</td>
<td>Total % cover</td>
</tr>
<tr>
<td>Bank bare of vegetation</td>
<td></td>
</tr>
<tr>
<td>Leaf litter</td>
<td>Total % cover</td>
</tr>
<tr>
<td>Canopy cover</td>
<td>Total % cover</td>
</tr>
<tr>
<td>Number of layers of vegetation on the bank</td>
<td>Count</td>
</tr>
</tbody>
</table>
3.2.4 **Statistical analyses**

As the detection probability analysis showed that the probability of detecting a false absence was extremely low (see results Section 3.3.1, Table 3.4) it was not necessary to consider detectability in subsequent analyses exploring habitat associations.

Throughout the analyses, I intentionally used the data as gathered rather than transforming it wherever possible.

3.2.4.1. **Descriptive analyses**

In order to investigate significant differences between occupied and unoccupied sites, and ascertain parameters correlated with occupied sites, initially an univariate analysis of each habitat variable was undertaken. General descriptive statistics of median, and range were calculated and are presented for each variable. The significance of the differences between the occupied and unoccupied sites for each variable was calculated using the Mann-Whitney Rank Sum Test (U). The Mann-Whitney Rank Sum Test (U) is suitable for data (such as that presented here) which are not normally distributed and where sample sizes may be unequal (Fowler, Cohen, & Jarvis, 1998; Zar, 2010). Zar (2010, p. 146) asserts that non-parametric tests, such as the Mann-Whitney Rank Sum Test (U) is 95.4 % as powerful as an equivalent parametric test. In this case, where it was important to provide data that could be understood by practitioners (in keeping with the transdisciplinary nature of the thesis), the associated decision to not transform the data resulted in the use of appropriate non-parametric tests for significance. To determine significance, the Mann-Whitney Rank Sum Test (U) compares the medians of samples (Fowler, Cohen, & Jarvis, 1998; Zar, 2010).

As the total percent cover of some vegetation structure categories were found to be significantly different between occupied and unoccupied sites, and none of the individual cover categories (sparse, sparse –medium and medium) were, only total percent cover for each category was used in further analyses and is presented in the results. Vegetation characteristics of the waterbodies were also investigated in relation to abundance categories.

Box plots were prepared for vegetation structure categories in order to visualise the central tendencies and distribution of the data. Box plots presented show median, 25th and 75th quartile, range, outliers and extreme outliers. Outliers are those cases
with values between one and a half and three box lengths from the upper or lower edge of the box. Extreme outliers are those cases with values more than three lengths from the upper or lower edge of the box (IBM Corp., 2011). This initial assessment of the data was undertaken using IBM SPSS Statistics 20 (IBM Corp., 2011).

3.2.4.2. Preparation of data for modelling: multicollinearity and variable selection

Before commencing more complex statistical analyses of the wetland habitat the data were assessed for potential multicollinearity by generating a correlation matrix using Spearman’s Rank Correlation Coefficients ($r_s$). Variables with strong correlations ($r_s > 0.7$) were excluded from further analysis (Tabachnick & Fidell, 2013).

To reduce the likelihood of over-fitting variables to the model a further culling process was undertaken. Variables that were shown to be significant ($p<0.05$) in the univariate analysis were retained for modelling. In order to reduce the remaining variables the correlation matrix determined through Spearman’s Rank Correlation Coefficients ($r_s$) was employed. Variables that had the strongest correlation with occupied and unoccupied sites (PA) were retained for the analysis and those with a weak correlation with PA were discarded. This was the case unless there was a three way decision to be made, in which the variable kept had fewer correlations than the other variable choices.

3.2.4.3. Wetland habitat explanatory modelling

Models of the waterbody characteristics were developed to discriminate between occupied and unoccupied sites using generalised linear modelling (GLM) and the information-theoretic approach (Burnham & Anderson, 1998). The “all possible” or “best-subsets” routine was used as it is considered a powerful tool that conserves the principles of parsimony and is now widely available in most computer packages (King 2003). Modelling was undertaken using S-PLUS Version 8.2 (Tibco Software Inc., 2010).

In acknowledgment that several models may make good predictions (e.g. Van Sickle et al. 2006, Claeskens and Hjort 2008), Akaike Information Criterion (AIC) was used to identify the most parsimonious models. AIC is calculated as:
\[
AIC = k + n \left[ \ln \left( \frac{2\pi \text{RSS}}{n-k} \right) + 1 \right],
\]

where \( k \) is the number of model parameters and RSS is the Residual Sum of Squares and is used to select between multivariate models where \((k<1)\).

The second order derivative \( \text{AIC}_c \) was used to select between models for discussion as it contains a bias correction term for small sample size, and is recommended by Burnham & Anderson (2004) for use in practice because it converges to AIC as \( n \) gets large. Models with an \( \text{AIC}_c \) score that is within 2 of the \( \text{AIC}_c \) score for the first model were selected for discussion in the first instance.

Akaike weights (\( \omega_i \)) were also calculated as these can be interpreted as “the probability that any given model is the best model for the observed data in the suite of candidate models” (Johnson & Omland, 2004), and as such \( \omega_i \) provides a measure of the strength of evidence for each model. Akaike weights can also be used to indicate the relative importance of predictor variables (Johnson & Omland, 2004) and so the sum of the Akaike weights over all of the models in which the parameter appears was calculated.

In the spirit of Occam’s razor, “Shave away all but what is necessary” (Burnham & Anderson, 2004. p. 265) and because a single model with an \( \text{AIC}_c \) within 2 of the \( \text{AIC}_c \) score for the first model was consistent with the support for variables selected through the Akaike weights approach, a single model is further presented in more detail. The beta values and odds ratio for the model, and charts of the probability of occurrence for each variable in the model are presented. The relationships between occupancy and the environmental variables identified as significant through the modelling process were calculated and plotted by combining the posterior probability of occurrence across the range of values observed, to generate a posterior distribution for expected occupancy. This procedure involved holding the other variables in the model at their mean or where binomial factors were used plotting two distributions.
3.3 RESULTS

3.3.1 Detection

Individual museum and atlas records of 407 adult male Sloane’s Froglets (records of the species prior to my surveys as described in Chapter 2) were used in investigating the core calling period for Sloane’s Froglet in southern Australia (southern NSW south of a line of latitude 33 degrees 30 mins and Victoria). The review revealed that while Sloane’s Froglet has been recorded in all months of the year except February, most specimens had been observed in the winter months of June, July and August (Table 3.3). While such a review may be influenced by observer effort as much as actual calling period, it did confirm the detection and life history information provided by Littlejohn (M. Littlejohn, pers. comm.).

Table 3.3. Calling records and calling months for Sloane’s Froglet based on records of males made prior to 2010. Shaded cells indicate greater than 10 records for that month. (Source: Victorian Biodiversity Atlas, Victorian Museum, NSW Wildlife Atlas)

<table>
<thead>
<tr>
<th></th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vic</td>
<td>103*</td>
<td>5</td>
<td>29</td>
<td>81</td>
<td>5</td>
<td>20</td>
<td>11</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td>260</td>
</tr>
<tr>
<td>NSW</td>
<td></td>
<td></td>
<td>10</td>
<td>47</td>
<td>40</td>
<td>7</td>
<td>21</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td>147</td>
</tr>
<tr>
<td>Totals</td>
<td>103*</td>
<td>5</td>
<td>39</td>
<td>128</td>
<td>45</td>
<td>27</td>
<td>20</td>
<td>22</td>
<td>10</td>
<td></td>
<td>4</td>
<td>4</td>
<td>407</td>
</tr>
</tbody>
</table>

*100 of the 103 observations were from one record and date in which 100 individuals were identified.

My observations at a single pond in Albury visited daily from February to June over 3 years were that Sloane’s Froglet commenced to call on April 14 in 2010, April 16 in 2011, and April 17 in 2012.

Detection probabilities for the presence/absence data collected show there is a very high confidence that absent sites were not falsely identified. The AIC (Burnham & Anderson, 1998, equation 1) suggested that survey-specific detection probability for Sloane’s Froglet was a better fit for the data than using a constant detection probability across surveys (Table 3.4). The survey-specific detection probability revealed there was a 0.17% chance of a site being classified falsely as unoccupied.
Table 3.4. Detection probabilities (survey-specific and single survey) for Sloane’s Froglet waterbody occupancy surveys (3 surveys per waterbody) in Albury and Corowa undertaken during winter and early spring, 2012 (values in parentheses are percentages).

<table>
<thead>
<tr>
<th></th>
<th>AIC</th>
<th>Naive occupancy estimate</th>
<th>Detection probability</th>
<th>Cumulative likelihood of reporting a false absence ((1-p_1) \times (1-p_2) \times (1-p_3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey – specific</td>
<td>262.99</td>
<td>0.5745</td>
<td>(p_1=0.6101)</td>
<td>0.0016 (0.17%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(p_2=0.8874)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(p_3=0.9613)</td>
<td></td>
</tr>
<tr>
<td>Single survey</td>
<td>283.82</td>
<td>0.5745</td>
<td>0.8158</td>
<td>0.0062 (0.62%)</td>
</tr>
</tbody>
</table>

3.3.2 Waterbody characteristics

3.3.2.1. Waterbody types, surrounding landuse and physical characteristics

The surrounding landuse of the waterbodies surveyed included conservation, cropping, grazing, industrial, recreation, suburban and vacant land. Thirty seven percent of all waterbodies surveyed were situated within grazing land. Both unoccupied and occupied sites occurred within all of the surrounding landuse types recorded (Figure 3.2).

Figure 3.2. Percentage of waterbody sites in the Albury and Corowa study region that were occupied and unoccupied by Sloane’s Froglets, classified by different adjacent landuse types. The value shown above each bar indicates the number of wetlands surveyed for that landuse type (total \(n = 94\)).
The waterbodies surveyed were variable in the slopes of their banks; water depth; whether they were constructed or natural; and, in the types of vegetation occurring within them as shown in the photographs (Plates 3.1 – 3.6) on the following pages. In addition they were variable in their hydroperiods; relationships with other waterbodies; and, the way they overflowed when full (whether running out in a stream or having an adjacent shallow area that they flooded into) (Table 3.5).” Sloane’s Froglets were present in waterbodies with varying characteristics as described on the following pages (Table 3.5).
Plate 3.1. A constructed stormwater pond in the Albury area with predominantly large stem-diameter vegetation. This waterbody was not occupied by Sloane’s Froglet in 2012.

Plate 3.2. A constructed stormwater retention pond with steep banks by the side of the Hume Highway in Albury. This waterbody was not occupied by Sloane’s Froglet in 2012.
Plate 3.3. A farm dam at Thurgoona, Albury. This waterbody was not occupied by Sloane’s Froglet in 2012

Plate 3.4 A roadside drain at Corowa occupied by fewer than six Sloane’s Froglets in 2012
Plate 3.5 A large open wetland at Corowa that was occupied by Sloane’s Froglets in high abundance (n >100)

Plate 3.6. A farm dam on the outskirts of Albury that was occupied by fewer than twenty calling Sloane’s Froglets in 2012
Table 3.5. Percentage of waterbodies occupied and waterbodies not occupied by Sloane’s Froglet in the Albury and Corowa study region in 2012, classified by different physical categories

<table>
<thead>
<tr>
<th>Waterbody characteristic</th>
<th>Occupied sites (%) n=54</th>
<th>Unoccupied sites (%) n=40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank slope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gentle</td>
<td>72</td>
<td>25</td>
</tr>
<tr>
<td>Moderate</td>
<td>20</td>
<td>55</td>
</tr>
<tr>
<td>Steep</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Waterbodies within 50 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolated</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>On a watercourse</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Part of a complex</td>
<td>44</td>
<td>38</td>
</tr>
<tr>
<td>Hydroperiod</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ephemeral</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Seasonal</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td>Permanent</td>
<td>39</td>
<td>45</td>
</tr>
<tr>
<td>Waterdepth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shallow</td>
<td>39</td>
<td>15</td>
</tr>
<tr>
<td>Moderate</td>
<td>48</td>
<td>67</td>
</tr>
<tr>
<td>Deep</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Presence of an ephemeral adjacent shallow overflow</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>Present</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>Absent</td>
<td>33</td>
<td>27</td>
</tr>
<tr>
<td>Waterbody type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constructed</td>
<td>59</td>
<td>75</td>
</tr>
<tr>
<td>Natural</td>
<td>41</td>
<td>25</td>
</tr>
</tbody>
</table>

Sloane’s Froglets occurred in waterbodies with gentle, moderate and steeply sloping banks (as defined in Table 3.1) but showed a preference for waterbodies with gently sloping banks (Figure 3.3, p=0.000). Sloane’s Froglets occurred in waterbodies with ephemeral, seasonal and permanent hydroperiods. Waterbodies that were isolated and those that were on a watercourse (for instance a dam on a creek) as well as waterbodies that were part of larger complex lentic systems were occupied by Sloane’s Froglets. Sloane’s Froglets occupied waterbodies that were shallow, of medium depth and deep (as defined in Table 3.1). They also occupied waterbodies where the water spilled over and ran directly away, but showed a preference for waterbodies with adjacent shallow ephemeral overflows (Figure 3.4, p=0.000).
Sloane’s Froglets occurred in both constructed and “natural” waterbodies (Table 3.4 & 3.5, Figure 3.5). Of the 54 occupied sites surveyed 41% were classified as “natural” sites, that is they were natural open wetlands, natural depressions or gilgais. Constructed waterbodies (dams, constructed wetlands including stormwater and grey water ponds and drains) were actively used for breeding. In the only two instances where Sloane’s Froglets were located in amplexus (See Plate 1.1, Chapter 1) they were
in constructed waterbodies – once in a constructed grey water treatment wetland and the second time in a dam on a watercourse.

In addition to using a variety of natural wetland types, Sloane’s Froglets were found using farm dams, roadside drains and irrigation drains, stormwater retention ponds and other constructed wetlands where appropriate habitat was present.

![Figure 3.5. Percentage of waterbody sites in the Albury and Corowa study region that were occupied and unoccupied by Sloane’s Froglets in 2012, classified by different waterbody types. The value shown above each bar indicates the number of wetlands surveyed for that waterbody type (total n= 94).]

### 3.3.2.2. Vegetation characteristics

The median percent cover of submerged water plants, small-stem diameter emergent vegetation, and total aquatic vegetation cover was significantly (p<0.05) greater at occupied waterbodies than unoccupied waterbodies. Median percent cover of large stem-diameter rushes was not significantly different between occupied and unoccupied sites (Table 3.6 and 3.7, Figure 3.6).
Table 3.6. Median percent cover (%) and range (%) of submerged, small stem-diameter emergent, large stem-diameter emergent vegetation and total vegetation cover at waterbodies occupied by Sloane’s Froglet in the Albury and Corowa regions in 2012.

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Median cover (%)</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submerged vegetation</td>
<td>2</td>
<td>0 - 84</td>
</tr>
<tr>
<td>Small stem-diameter emergent vegetation</td>
<td>23</td>
<td>0 - 100</td>
</tr>
<tr>
<td>Large stem-diameter emergent vegetation</td>
<td>0</td>
<td>0 - 35</td>
</tr>
<tr>
<td>Total vegetation cover</td>
<td>44</td>
<td>0 - 100</td>
</tr>
</tbody>
</table>

Table 3.7. Results of the Mann-Whitney (U) Rank Sum Test for submerged, small stem-diameter emergent, large stem-diameter emergent and total vegetation cover at Sloane’s Froglet occupied (n=54) and unoccupied (n=40) waterbodies in the Corowa and Albury regions in 2012. Highlighted values indicate the variables where p < 0.05.

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Mann-Whitney U</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submerged vegetation</td>
<td>1389</td>
<td>0.012</td>
</tr>
<tr>
<td>Small stem-diameter emergent vegetation</td>
<td>1750</td>
<td>0.000</td>
</tr>
<tr>
<td>Large stem-diameter emergent vegetation</td>
<td>1099</td>
<td>0.839</td>
</tr>
<tr>
<td>Total vegetation cover</td>
<td>1674</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Figure 3.6. Boxplots (median, 25th and 75th quartile, range, outliers (o), extreme outliers (★)) showing percent cover of aquatic vegetation structure for waterbodies unoccupied and occupied by Sloane’s Froglet in the Albury and Corowa region in 2012. a) submerged cover (white), b) small stem-diameter emergent vegetation (dots), c) large stem diameter emergent vegetation (black), d) total vegetation (diagonal hatch)

The median percent cover of bare ground on the bank was significantly lower (p<0.05) at waterbodies occupied by Sloane’s Froglet than at unoccupied waterbodies. The median percent leaf litter cover on the bank and canopy cover over the edge of the waterbody were not significantly different between occupied and unoccupied waterbodies (Table 3.8, Figure 3.7). The number of layers of vegetation (1, 2 or 3) on the bank was also significantly different between waterbodies (p=0.047, Figure 3.8) with a greater proportion of occupied sites having only one layer of riparian vegetation and a lesser proportion of occupied sites having three layers of vegetation when compared to unoccupied waterbodies.
Table 3.8. Results of the Mann-Whitney (U) Rank Sum Test for bank characteristics of bare bank cover, leaf litter and canopy cover at Sloane’s Froglet occupied and unoccupied waterbodies in the Corowa and Albury regions in 2012. Highlighted values indicate the variables where p < 0.05

<table>
<thead>
<tr>
<th>Bank cover characteristic (% cover)</th>
<th>Mann-Whitney U</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank bare of vegetation</td>
<td>707</td>
<td>0.003</td>
</tr>
<tr>
<td>Leaf litter</td>
<td>1,140.5</td>
<td>0.567</td>
</tr>
<tr>
<td>Canopy cover on the bank</td>
<td>1,121</td>
<td>0.701</td>
</tr>
</tbody>
</table>

Figure 3.7 Boxplots (median, 25th and 75th quartile, range, outliers (o), extreme outliers (✱)) showing percent cover of vegetation cover of banks for waterbodies unoccupied and occupied by Sloane’s Froglet in the Albury and Corowa regions in 2012. a) bareground (white), b) leaflitter (diagonal hatching), and c) canopy cover (dots).
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Figure 3.8. Percentage of waterbodies surveyed in the Albury and Corowa regions in 2012 with 1, 2 or 3 layers of vegetation on the bank comparing sites unoccupied (n=40) and occupied (n=54) by Sloane’s Froglets

3.3.3 Abundance of Sloane’s Froglets at waterbodies and correlations with waterbody characteristics

Of the 54 occupied Sloane’s Froglet waterbodies, 12 were estimated to contain fewer than six calling Sloane’s Froglets, 21 contained between 6 and 19 calling Sloane’s Froglets, 16 contained between 20 and 99 Sloane’s Froglets and five contained over 100 Sloane’s Froglets (Table 3.9). The last category is conservative regarding abundance and consists of waterbodies that contained high densities of Sloane’s Froglets with estimates of over 500 calling males at some visits.

Table 3.9. Number of waterbodies sampled (n=54) that were occupied by the different abundance categories (very low, low, medium and high) of Sloane’s Froglets in the Albury and Corowa regions in 2012.

<table>
<thead>
<tr>
<th>Abundance descriptor</th>
<th>Estimated abundance</th>
<th>Count (n = 54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>&lt;6</td>
<td>12</td>
</tr>
<tr>
<td>Low</td>
<td>6 - 19</td>
<td>21</td>
</tr>
<tr>
<td>Medium</td>
<td>20 - 99</td>
<td>16</td>
</tr>
<tr>
<td>High</td>
<td>&gt;100</td>
<td>5</td>
</tr>
</tbody>
</table>

Both median percent cover of emergent small stem-diameter vegetation and total vegetation cover were correlated with Sloane’s Froglet abundance categories (Figure 3.9). Small stem-diameter and total vegetation cover were lowest at unoccupied...
waterbodies and slightly greater at both very low and medium abundance waterbodies. Low abundance waterbodies contained highly variable vegetation cover. Small stem-diameter emergent vegetation cover and total vegetation cover of high abundance waterbodies was much greater than that at all other sites (Figure 3.9)
Figure 3.9. Boxplots (median, 25th and 75th quartile, range, outliers (○) and extreme outliers (●)) characteristics of the vegetation cover of waterbodies surveyed in the Albury and Corowa regions in 2012 with unoccupied, very low, low, medium and high abundance categories for Sloane’s Froglet. a) submerged cover (white), b) small stem-diameter emergent vegetation (horizontal lines), c) total vegetation cover (dots).
3.3.4 Modelling characteristics of waterbodies occupied by Sloane’s Froglets

Preparation of the data for modelling (as described in Section 3.2.4.2) resulted in seven variables being included in the modelling process (Table 3.10).

Table 3.10. Description of the variables used in developing the explanatory model for waterbody characteristics of those unoccupied and occupied by Sloane’s Froglets in the Albury and Corowa regions in 2012.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>emVEG</td>
<td>The total percent cover of the waterbody with small stem-diameter emergent vegetation</td>
</tr>
<tr>
<td>percSUBTA</td>
<td>The total percent cover of the waterbody with any completely submerged vegetation</td>
</tr>
<tr>
<td>BKSLOPE</td>
<td>The slope of the waterbody bank, gentle, moderate, steep (as defined in Table 3.1)</td>
</tr>
<tr>
<td>WATDEPTH</td>
<td>The depth of the water in the waterbody, shallow, moderate or deep (as defined in Table 3.1)</td>
</tr>
<tr>
<td>OVERFLOW</td>
<td>The presence or absence of an adjacent ephemeral shallow overflow</td>
</tr>
<tr>
<td>EVNooflayers</td>
<td>The number of layers of vegetation on the bank</td>
</tr>
<tr>
<td>EVBareground</td>
<td>The percent of the bank that was bare of vegetation</td>
</tr>
</tbody>
</table>

By using GLM and the information-theoretic approach (Burnham & Anderson, 1998) I identified four models with an $\text{AIC}_c$ difference of $<2$ which are explanatory of waterbody selection by Sloane’s Froglet (Table 3.11).

The percent of the waterbody with small stem-diameter emergent vegetation was present in all four models as was the presence or absence of an adjacent ephemeral shallow overflow. The percent of the bank that was bare of vegetation was present in three of the four models, and the slope of the bank and the number of layers of vegetation on the bank in two of the models.

I assessed the relative importance of individual variables in the four models by summing the Akaike weights ($\omega_i$) for all models containing the variable of interest (Table 3.11). This technique provides an indication of the importance of each variable in the context of the set of models considered (Buckland, Burnham, & Anderson, 1997; Burnham & Anderson, 2002; Johnson & Omland, 2004) and has been widely used elsewhere (e.g. Svenning, Normand, & Skov, 2008; Yamanaka et al., 2009). This
approach established that the presence/absence of an adjacent ephemeral shallow overflow (OVERFLOW) had the highest summed Akaike weight ($\sum \omega_i = 0.8642$), followed by the percent cover of emergent small stem-diameter vegetation (emVeg) ($\sum \omega_i = 0.8088$), and the percent cover of the bank bare of vegetation (EVBareground) ($\sum \omega_i = 0.8007$), while the slope of the bank (BKSLOPE), the No of layers of vegetation on the bank (EVNooflayers), the percent cover of submerged vegetation (percSUBTA) and the waterdepth (WATDEPTH) had lower Akaike weights (Table 3.11).
Table 3.11. Generalised linear modelling selection summary for habitat features of waterbodies unoccupied and occupied Sloane’s Froglet. Table includes, Akaike Information Criteria (AIC), number of parameters (K), Akaike’s Information criteria adjusted for small sample sizes (AICc), difference in AIC ($\Delta_i$), Akaike weightings ($\omega_i$), percent of unoccupied (0) and occupied (1) sites correctly predicted by the model, significance (p) and pseudo R squared. Summed Akaike weights ($\Sigma \omega_i$) for each parameter from all models are also provided. Model in bold is that model for which further detail is provided in Table 3.12 and Figure 3.10.

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC</th>
<th>K</th>
<th>AICc</th>
<th>$\Delta_i$</th>
<th>$\omega_i$</th>
<th>Percent correctly predicted</th>
<th>P value</th>
<th>Ps R sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>emVeg+factor(BKSLOPE)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>100.7393</td>
<td>7</td>
<td>102.0416</td>
<td>0</td>
<td>0.1151</td>
<td>0=77.5% 1=75.9%</td>
<td>&lt;0.0001</td>
<td>0.3235</td>
</tr>
<tr>
<td>emVeg+factor(BKSLOPE)+factor(OVERFLOW)+EVBareground</td>
<td>101.5918</td>
<td>6</td>
<td>102.5573</td>
<td>0.8525</td>
<td>0.0889</td>
<td>0=70% 1=75.9%</td>
<td>&lt;0.0001</td>
<td>0.3012</td>
</tr>
<tr>
<td>emVeg+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>101.9204</td>
<td>5</td>
<td>102.6022</td>
<td>1.1810</td>
<td>0.0869</td>
<td>0=70% 1=83.3%</td>
<td>&lt;0.0001</td>
<td>0.2830</td>
</tr>
<tr>
<td>emVeg+factor(OVERFLOW)+EVBareground</td>
<td>102.4152</td>
<td>4</td>
<td>102.8647</td>
<td>1.6759</td>
<td>0.0762</td>
<td>0=77.5% 1=77.8%</td>
<td>&lt;0.0001</td>
<td>0.2636</td>
</tr>
</tbody>
</table>

Summed Akaike weights ($\Sigma \omega_i$)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERFLOW</td>
<td>0.8642</td>
</tr>
<tr>
<td>BKSLOPE</td>
<td>0.8088</td>
</tr>
<tr>
<td>WATDEPTH</td>
<td>0.6549</td>
</tr>
<tr>
<td>EVNooflayers</td>
<td>0.5385</td>
</tr>
<tr>
<td>EVBareground</td>
<td>0.8007</td>
</tr>
<tr>
<td>percSUBTA</td>
<td>0.2377</td>
</tr>
</tbody>
</table>
The model selected for further detailed investigation contained only the three variables with the highest summed Akaike weights of percent cover of small stem-diameter emergent vegetation, the presence or absence of an overflow and the percent cover of bareground. While not having the highest overall AICc, the model contained the lowest number of variables and exhibited the highest percent correctly predicted classification table of the top four models. The beta values and odds ratio for these three variables (Table 3.12) show that Sloane’s Froglets are 450 times more likely to occupy the waterbody when an adjacent ephemeral shallow overflow is present; and that Sloane’s Froglets are more likely to be present with greater cover of small stem-diameter emergent vegetation, and less bare ground on the bank.

Table 3.12. Beta values, standard error, significance and odds ratio for the three variables and constant in the model of characteristics influencing the occurrence of Sloane’s Froglets in waterbodies in the Albury and Corowa regions in 2012.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta value</th>
<th>Standard Error</th>
<th>Significance</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERFLOW</td>
<td>1.503</td>
<td>0.515</td>
<td>0.004</td>
<td>4.494</td>
</tr>
<tr>
<td>emVeg</td>
<td>0.032</td>
<td>0.012</td>
<td>0.008</td>
<td>1.032</td>
</tr>
<tr>
<td>EVBareground</td>
<td>-0.021</td>
<td>0.011</td>
<td>0.054</td>
<td>0.980</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.596</td>
<td>0.436</td>
<td>0.171</td>
<td>0.551</td>
</tr>
</tbody>
</table>

Based on the probability plots (Figure 3.10), a combination of the presence of an overflow, increasing waterbody cover of emergent small stem-diameter vegetation, and decreasing bare ground on the bank are explanatory factors for the selection of waterbodies by calling male Sloane’s Froglet during the breeding period.
Figure 3.10  Fitted curves for the relationship between expected occupancy and the two significant habitat variables ((a)EmVeg and (b) EVBareground) identified in the GLM (OVERFLOW held at 1 and 0). Dotted lines demark upper and lower confidence intervals. Bar chart for the expected occupancy with upper and lower confidence intervals for the binomial factor ((c) OVERFLOW) identified in the GLM (other variables held at their means)
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3.4 DISCUSSION

3.4.1 Detection of Sloane’s Froglet

The experience gathered over the four years of data collection indicated that within the study area, Sloane’s Froglet commenced calling in early to mid-April and continued to call into August, September and early October. Sloane’s Froglets were only found in amplexus in July. Sloane’s Froglet consistently called during the day as well as into the evening in winter and early spring and my detection advice is now available in Anstis (2013).

The choice of mid-winter surveys was vindicated by the detection probability analysis undertaken for this study. The survey-specific detection probability (0.17%) indicated that there was a very low chance of falsely identifying an absent site when three site visits are undertaken. This would suggest that a standard survey method which is founded upon a minimum of three site visits during the afternoon and evening of the peak calling season is adequate to detect Sloane’s Froglet by call for an experienced observer. This finding is consistent with the findings of MacKenzie and Royle (2005) who state that “sampling units should be surveyed a minimum of three times when detection probability is high (> 0.5 survey⁻¹)” (p. 1105). The indication is that the current standard guidelines for survey of Sloane’s Froglet in NSW (NSW Department of Environment and Climate Change, 2009), which state that a minimum of two surveys are sufficient, should be revised.

3.4.2 Characteristics of the waterbodies occupied by Sloane’s Froglets

Sloane’s Froglets occupied a range of waterbody types. Waterbodies in which they occurred were constructed or “natural”; either situated within complex lentic systems, isolated or on watercourses; having ephemeral, seasonal or permanent hydroperiods; and, shallow or deep. Significant features of waterbodies which differentiated between occupied and unoccupied sites included the slope of the bank, with Sloane’s Froglet preferring gently sloping banks, and the presence of an ephemerally inundated shallow overflow area adjacent to the waterbody. Vegetation structure and percent cover were also different between waterbodies occupied and unoccupied by Sloane’s Froglet. In particular, the presence of small-stem diameter emergent vegetation was significantly higher in occupied than in unoccupied sites. Sloane’s Froglets were also more likely to occupy waterbodies with less bare ground on the bank.
3.4.2.1. Sloane’s Froglets occupy a variety of waterbody types

In this study it was found that Sloane’s Froglet occupies ephemeral, seasonal and permanent wetlands with a range of water depths. The context of the waterbody was also variable as some were isolated and others were part of complex wetland systems.

In his description of Sloane’s Froglet, Littlejohn (1958) describes the waterbodies that Sloane’s Froglet was found in as shallow temporary ponds and Anstis (2013) reiterates this and adds that they may be found in “flooded grassland, ditches and swamp areas” (p. 176). My research confirms their use of such waterbodies but shows that they also use other types of waterbodies that are moderately to relatively deep and with seasonal and permanent hydroperiods. These findings may suggest that Sloane’s Froglet is more of a generalist than previously hypothesised. Like the sympatric C. signifera that breeds in “temporary to semi-permanent flooded ditches, streams, grassland, or permanent ponds and dams” (Anstis, 2013, p.576) and C. parinisignifera which is associated with “ponds or swamps or flooded grassland” (Anstis, 2013, p. 563), Sloane’s Froglet appears to occupy a range of sites.

Two physical characteristics were significantly different between waterbodies occupied and unoccupied by Sloane’s Froglet: the slope of the bank, and the presence or absence of an adjacent ephemerally inundated shallow overflow. There was a correlation between gently sloping banks and the presence of Sloane’s Froglet. Gently sloping banks may provide larger areas of shallow water in a waterbody and also provide an area where small stem-diameter vegetation that responds to both inundation and drying periods is able to establish (Roberts & Marston, 2011; Webb, Wallis, & Stewardson, 2012).

The presence of ephemerally inundated shallow overflows adjacent to the waterbody within which Sloane’s Froglet was located is of interest. It appears that Sloane’s Froglet uses these areas at some stage of its life cycle. It was observed that in periods of heavy rain, when these areas were flooded, Sloane’s Froglets actively called from them, however the period of time that these areas retained water has not been ascertained; and the duration of Sloane’s Froglet stay in them and their use of these areas have not been studied. These areas may be analogous with the rain-fed wetlands examined by Wassens et al. (2013) in their recent study of tadpole response to rainfall events. Shallow ephemeral overflows may also exhibit similarities with the
well-studied vernal ponds of the northern hemisphere (Calhoun, Arrigoni, Brooks, Hunter, & Richter, 2014; Calhoun, Jansujwicz, Bell, & Hunter Jr, 2014; Gamble & Mitsch, 2008; Green, Hooten, Grant, & Bailey, 2013; Paton & Crouch III, 2002) that provide seasonal opportunities for amphibian breeding. Further research into the relevance of ephemeral shallow overflows for Sloane’s Froglet lifecycle is required.

The use of constructed and “natural” waterbodies by Sloane’s Froglet is of interest given the context of its distribution in highly modified landscapes. During the peak calling period in July and August Sloane’s Froglets occurred in constructed as well as natural waterbodies. Of all sites occupied by Sloane’s Froglet 59% were constructed waterbodies. Sloane’s Froglets were observed not only calling in constructed waterbodies, but also in amplexus and laying eggs. In addition to using a variety of natural wetland types, Sloane’s Froglets use farm dams, roadside drains, irrigation drains, stormwater retention ponds and constructed wetlands where appropriate habitat is present.

Many international studies have investigated the use of constructed waterbodies by anurans (e.g. Denton & Richter, 2013; Shulse, Semlitsch, Trauth, & Williams, 2010; Simon, Snodgrass, Casey, & Sparling, 2009). The benefits of constructed wetland habitats for frogs as well as other biodiversity have been previously studied within the Australian landscape (e.g. Brainwood & Burgin, 2009; Hamer & Organ, 2008; Markwell & Fellows, 2008). Hazell et al. (2001) investigated the abundance and diversity of frog species using natural wetlands and farm dams in south eastern Australia and concluded that many but not all species use farm dams. Thirteen species were detected in the surveys. *Crinia signifera* and *C. parinisignifera*, sympatric species with *C. sloanei* for much of its range, were shown to use natural and constructed ponds. Hazell et al.’s (2001) study showed that the abundance of species varied between natural and constructed waterbodies with sites “with high levels of emergent vegetation cover that do not contain fish [are] likely to support a high number of frog species, regardless of their origin (i.e. natural or constructed)” (Hazell et al., 2001, p. 69). They noted that two frog species were completely absent from farm dams and were only found in natural ponds connected to flowing water. The constructed waterbodies that Sloane’s Froglets use are not limited to farm dams. Sloane’s Froglet
was present in some of the stormwater retention ponds, wetlands constructed for grey water treatment, roadside drains, and irrigation drains surveyed.

Sloane’s Froglet occupied some, but not all of the stormwater ponds surveyed. Only low to medium abundances of Sloane’s Froglets were recorded in stormwater ponds, but never high abundances. It seems likely that the use of stormwater ponds by Sloane’s Froglet would be dependent on suitable habitat characteristics (such as the presence of emergent vegetation as described in the following sections) which may also be correlated with untested variables of stormwater ponds such as age and substrate. The use of stormwater retention ponds by amphibians has also been investigated both internationally (e.g. Scheffers & Paszkowski, 2013) and in the Australian context (e.g. Hamer, Smith, & McDonnell, 2012). In these cases, and contrary to Hazell’s (2001) remarks concerning the origin of the pond, the habitat quality of stormwater ponds remains in question, with concerns that constructed ponds may be providing limited or poor quality habitat compared with natural ponds (Scheffers & Paszkowski, 2013).

In the case of Sloane’s Froglets, it is highly likely that frogs use roadside and irrigation ditches and drains with appropriate vegetation for breeding as well as refuge, foraging and dispersal. Male froglets actively called from drains during peak breeding times. Few studies focus on the use of drains as anuran breeding sites. Mazerolle (2005) investigated the use of constructed ditches by pond breeding amphibians. He found that many individuals occurred in ditches and survival in these structures was high. He found that no breeding occurred in the structures as “no calling males, egg masses, or tadpoles were detected” (2005, p. 584). Rather, Mazzerolle concludes that ditches provide temporary habitat for individuals and function as corridors as they move around the landscape.

The use of constructed waterbodies by Sloane’s Froglet for breeding (and potentially for dispersal) is important for the conservation of the species and the implications are discussed below in Section 3.6.

3.4.2.2. **Features of the vegetation important for Sloane’s Froglet**

This study showed that Sloane’s Froglets are more likely to occur in waterbodies that contain aquatic vegetation, especially small stem-diameter emergent vegetation.
Sloane’s Froglets occupied waterbodies with significantly greater percent covers of in-waterbody vegetation including submerged, small stem-diameter emergent vegetation and total vegetation cover than that in unoccupied waterbodies. Sites with a high abundance of Sloane’s Froglet had a significantly higher percent cover of small stem-diameter emergent vegetation than any other sites, occupied or unoccupied. Occupied waterbodies also had significantly lower levels of bare ground on the bank and a simpler bank vegetation structure with fewer sites with trees and shrubs, and more sites with just one ground storey layer than unoccupied waterbodies.

Small stem-diameter emergent vegetation typically grows in shallow water and its presence may reflect a range of hydrological conditions, such as water depth and stability of water levels as well as productivity (Barrett, Nielsen, & Croome, 2010; Casanova & Brock, 2000). The presence of ground-storey vegetation on the bank at sites with greater covers of emergent vegetation is likely to represent a continuity of habitat across the land-water interface.

Aquatic and fringing vegetation characteristics have been shown to be important both for individual species and in relation to frog diversity (e.g. Lane, Hamer, & Mahony, 2007; Popescu et al., 2013; Scheffers & Paszkowski, 2013). Several Australian studies have discussed the importance of vegetation structure, particularly at the land-water interface for pond-dwelling species (Hazell, 2004; Healey et al., 1997). The extent of bare ground on the bank has also been previously shown to be an indicator of species presence and richness (Hazell et al., 2001).

In their study of frog diversity in the Murray Floodplain, a region which substantially overlaps with this study area, Wassens et al. (2011) found that aquatic vegetation diversity, rather than vegetation cover, acted as a discriminator for occupied and vacant sites for five of the seven frog species investigated, but that occupancy by C. signifera and C. parinisignifera increased with increasing cover of fringing vegetation. Trotter (2012) found that occupancy for C. parinisignifera responded to an increase in short emergent vegetation cover and increased aquatic vegetation complexity. Emergent vegetation cover in the water margin has been found to be significant for other Australian ground-dwelling frogs including Limnodynastes tasmaniensis, Uperoleia laevigata and C. parinisignifera (Hazell et al., 2001).
This study focussed on the habitat characteristics of waterbodies occupied by Sloane’s Froglet during peak calling periods, however aquatic vegetation structure can influence multiple life-history stages of frogs (e.g. Egan & Paton, 2004; Purrenhage & Boone, 2009; Scheffers & Paszkowski, 2013). The presence of small-stem diameter emergent vegetation may be useful for Sloane’s Froglet activities throughout its complex life cycle including for ovipositioning, foraging, metamorph growth, and predator avoidance by tadpoles, metamorphs and adults. For instance, Anstis (2013) observation that Sloane’s Froglet eggs are “laid singly, mostly attached to submerged vegetation” (p. 580) accord with my observation that eggs are laid on submerged stems of \textit{E. acuta} or other small-stem diameter grass and reed species. While Sloane’s Froglet tadpoles are unable to be distinguished from those of the sympatric \textit{C. parinsignifera} (Anstis, 2002), it is likely that they feed on “fine particles and algae in sediments and on vegetation” (Anstis, 2013, p. 582) once again reinforcing the need for aquatic vegetation at different life stages.

This study identified wetland habitat characteristics suitable for Sloane’s Froglet and that which appears unsuitable, but it has been circumscribed by the range of available habitat. Wetlands within the study region have been affected by the landscape scale changes in wetland health and hydrology and floodplain connectivity prevalent across the Murray-Darling Basin (Finlayson, Davis, Gell, Kingsford, & Parton, 2013); loss, fragmentation and modification of habitat widespread throughout the Grassy-Box Woodlands in eastern Australia (Lindenmayer, Crane, Michael, & Beaton, 2005) and through the development of peri-urban, industrial and suburban areas currently being undertaken throughout the study region. This study is therefore limited in its ability to indicate the habitat quality of these waterbodies and there is the potential for this research to be describing sub-optimal habitat (after Hazell, 2004). Data on the abundance of Sloane’s Froglets in particular waterbodies can help in examining this issue. Those waterbodies with the highest covers of small stem-diameter emergent vegetation and total vegetation contained much higher abundances of Sloane’s Froglets than other sites. Further information on habitat quality could be obtained by investigating and assessing recruitment success across a number of sites.

At the commencement of this discussion I stated that Sloane’s Froglet may be more of a habitat generalist than previously suspected, however it is clear that gently sloping
banks, together with emergent vegetation, a bank area vegetated with understorey species and the presence of an adjacent ephemerally inundated overflow, all influence the use of waterbodies by Sloane’s Froglet. In the research presented in the next chapter (Chapter 4) I explore the characteristics of waterbodies that Sloane’s Froglet occupy in more detail by focussing on the microhabitat that Sloane’s Froglet uses within the waterbody. While it may appear at this point that Sloane’s Froglet is a generalist, in the next chapter this picture is refined and I propose that while Sloane’s Froglets use a variety of waterbodies, calling males in peak breeding season are only using specific parts of them.

3.4.3 Recommendations for future research

3.4.3.1. Study season

I chose to focus on the habitat used during the breeding period, as management of breeding habitat is a core requirement for the ongoing survival of a threatened species (e.g. Ferreira & Beja, 2013; Lind, Welsh Jr, & Wilson, 1996; Thomas, Owen-Smith, Drake, & Alexander, 2014). Habitat variables for the waterbodies surveyed in this study were collected in one season only, in the peak calling period, winter and early spring, which is the wettest time of the year in the study region. Habitat characteristics of the waterbodies were not collected during summer, the hottest and driest season in south-eastern Australia.

This limitation leads me to ask two questions. Firstly, is there some feature of the wetland habitat that occurs in and is observable in summer that contributes to the selection of winter habitat by Sloane’s Froglet? There may well be some characteristic of the wetlands during the dry season when they contain less water, different vegetation assemblages and different productivity levels that contributes to their usefulness for Sloane’s Froglets in winter. Secondly, what habitat does Sloane’s Froglet use in summer? Sloane’s Froglets were observed calling from clay cracks and from the surface of the waterbody prior to rain and wetland filling. However, there is no information on the refuges they use during dry periods. While the use of clay cracks may be common for some species (Wassens, Watts, Jansen, & Roshier, 2008), others use leaf litter and coarse woody debris (e.g. Heard, Robertson, & Scroggie, 2008).
Many of the areas where Sloane’s Froglet occurred were part of complex wetland systems that include multiple ponds of varying depths as well as drains and creek overflows. Survey work undertaken in 2009 (at the end of south eastern Australia’s great Millennium drought, but before the very wet period commending in March 2010 as indicated in Chapter 2, Section 2.3.1) located Sloane’s Froglets mostly in waterbodies adjacent to regulated water supplies, in particular sewerage treatment works or near regulated stormwater retention ponds. This suggests that ponds with more permanent hydroperiods may play an important role as refuge sites. Both of these questions deserve more research attention.

3.4.3.2. Predation by introduced fish

Sloane’s Froglets occupied waterbodies exhibiting ephemeral, seasonal and permanent hydroperiods. The presence and breeding success of frogs in ephemeral and seasonal waterbodies (Pechmann et al. 1991) and reduced numbers in waterbodies with permanent hydroperiods has been previously linked with the absence or reduced number of fish (Hamer & Parris, 2013), which may act as predators upon frog eggs and tadpoles (Kats & Ferrer, 2003). The use of waterbodies with significantly greater percent covers of in-waterbody vegetation including submerged, small stem-diameter emergent vegetation and total vegetation cover than unoccupied waterbodies may provide Sloane’s Froglet tadpoles with increased protection from aquatic predators through the provision of refuge habitat, however, habitat complexity has been found not to influence fish predation on tadpoles in some situations (Baber & Babbitt, 2004).

In this study the presence of fish and their potential impact upon Sloane’s Froglet were not investigated, however, *Gambusia holbrooki* and *Cyprinus carpio*, both significant pest species within the study area (Morgan & Buttemer, 1996; Pyke & White, 2000; Reynolds, 2009), were observed in waterbodies that Sloane’s Froglet was present and absent in. Further research into controlling pest fish species in waterbodies occupied by Sloane’s Froglet may be warranted.

3.4.3.3. Connectivity and mobility

This study focussed on the habitat characteristics of specific waterbodies that Sloane’s Froglets used during breeding season and did not consider the nature of potential connections between waterbodies or the mobility of Sloane’s Froglet. However, it is
well established that frogs with their complex life cycles depend on the linking of complementary habitats at multiple spatial scales and that populations are structured as patchy networks or metapopulations (e.g. Hale et al., 2013; Marsh & Trenham, 2001; Pope, Fahrig, & Merriam, 2000). As such, connections across the landscape and between waterbodies are just as important for frog survival as the characteristics of the waterbodies used for breeding (Cushman, 2006; Cushman et al., 2013). Even when the classical interpretation of metapopulation theory (local extinction and recolonisation) is not applied to frog populations, frogs have been shown to depend on the spatial arrangement of ponds as a best recruitment model (Marsh, Fegraus, & Harrison, 1999). Dodd Jr and Cade (1998) state that “[C]onservation efforts for wetland-breeding amphibians that concentrate solely on the wetland likely will fail without consideration of the adjacent terrestrial habitat” (p. 331).

Sloane’s Froglets were also mobile and clearly moved into ephemeral waterbodies to breed. My observations over four years suggest that Sloane’s Froglet is highly mobile and moves between waterbodies both within years and across years, but no research has been undertaken into its mobility, connectivity requirements or metapopulation dynamics. Determining these aspects of its ecology and behaviour requires carefully designed research. Where this has been done for other species, for instance, Litoria raniformis (Hale et al., 2013), or the pond-breeding newt Notophthalmus perstriatus and toad Gastrophryne carolinensis (Dodd Jr & Cade, 1998) considerable research has been undertaken at a number of sites over a number of years. Given the context of rapid urbanisation and fragmentation of Sloane’s Froglet habitat these questions deserve immediate attention.

3.4.4 What does this new knowledge mean for the management of Sloane’s Froglet?

Some preliminary findings from this study have been published in popular format as Sloane’s Froglet, Crinia sloanei (a 2 page brochure) (Knight, 2013b) and Sloane’s Froglet interim habitat guide and management recommendations (a booklet) (Knight, 2014).

3.4.4.1 Management of existing habitat

The presence of small stem-diameter emergent vegetation and littoral vegetation appears to be a key to the use of waterbodies by Sloane’s Froglet. Where higher
percent covers of vegetation were present, higher densities of Sloane’s Froglet were found. Several management actions can impact on the presence of vegetation within waterbodies including slashing, grazing, the application of herbicide, dam desilting, revegetation activities and changes to hydroperiod.

Sloane’s Froglets occur in wetlands and dams grazed by sheep, cattle and horses. However, sites where Sloane’s are most abundant have very low numbers of stock. The effect of grazing on anuran abundance and diversity has previously been tested (e.g. Healey et al., 1997; Verga, Leynaud, Lescano, & Bellis, 2012). Approaches which maintain ground cover and reduce pugging, such as fencing of dams and provision of alternative water sources, especially during peak breeding times, may benefit Sloane’s Froglet (Plates 3.7 and 3.8).
Plate 3.7. A wetland site on the outskirts of Albury where Sloane’s Froglet was observed in high abundance in 2012. This site is in a conservation area.

Plate 3.8. A wetland site on the outskirts of Albury (the same site as in plate 3.7) occupied by Sloane’s Froglet in 2010, 2011, and 2012. Photo taken in winter 2013 (the following year after the photo in plate 3.7) after heavy grazing during winter. This site is in a conservation area.
No research has been undertaken into the effect of herbicides and other toxins on Sloane’s Froglets. It is reasonable to suppose that herbicides may directly and indirectly impact Sloane’s tadpoles and frogs as they do with other amphibians (Mann, Hyne, Choung, & Wilson, 2009). Limits on herbicide use, especially on roadside drains may benefit Sloane’s Froglets.

Revegetation with trees and shrubs of shallow grassy depressions used by Sloane’s Froglets for breeding is a significant threat (Plate 3.9). Revegetation of dam edges and riparian edges of slow moving shallow waters should be patchy, allowing for the entry of sunlight and provision of basking areas. Experimenting in introducing aquatic vegetative diversity in constructed wetlands may benefit Sloane’s Froglet.

Plate 3.9. A shallow ephemeral waterbody near Corowa occupied by Sloane’s Froglet that was sprayed out and revegetated with tree species in 2012.

3.4.4.2. Habitat loss and habitat construction

As previously described (Chapter 2) many Sloane’s Froglet sites occur in areas where development is rapidly intensifying and the loss of both wetland and adjacent connecting habitat is a major threat to the species. There are many studies worldwide that look at the affects of urbanisation on amphibians (e.g. Ficetola & De Bernardi,
2004; Parris, 2006; Scheffers & Paszkowski, 2012) and suggest amelioration activities which would also be of benefit to Sloane’s Froglet (e.g. Hamer et al., 2012; Hodgkison et al., 2007; Scher, Chavaren, Despreaux, & Thiéry, 2004).

Hamer and McDonnell (2008) state the case succinctly when they write:

_In order to maintain amphibian diversity in urban and suburban landscapes we need to:_

1. **prevent further habitat loss and degradation of habitat quality, including aquatic and terrestrial habitat;**
2. **ensure the availability of targeted species of amphibians to maintain viable metapopulations and regional communities, and/or individuals for reintroduction into restored or newly-created habitats;** and
3. **develop strategies to reconnect the landscape and allow amphibians to disperse between suitable habitats** (Hamer & McDonnell, 2008, p.2444).

For Sloane’s Froglets’ continued survival it is imperative that ecological connectedness is maintained. As Semlitsch (2002) states, alteration and loss of wetlands, especially small, temporary wetlands reduces the number and density of waterbodies available for reproduction and recruitment as well as the total number of amphibians able to establish new populations. Strategies that may assist in reconnecting or maintaining connectivity across the landscape for Sloane’s Froglet include incorporating the knowledge presented here regarding vegetation type and waterbody characteristics into the design of constructed wetlands, including stormwater retention ponds and maintaining grassy roadside drains rather than building kerb and gutters.
3.5 CONCLUSION

This study, comparing the characteristics of 54 waterbodies occupied by Sloane’s Froglet with 40 waterbodies in the same region unoccupied by Sloane’s Froglet, has provided previously unknown information on the preferred habitat attributes of this species. In winter, Sloane’s Froglet occupy waterbodies with more gently sloping banks, greater small stem-diameter emergent vegetation cover and the presence of an adjacent ephemerally inundated overflow when compared with unoccupied sites. This information has implications for the management of waterbodies that Sloane’s Froglet occupies. While the study provides foundational information on wetland breeding habitat, it does not provide information on habitat during the hot dry period of the year or factors that may affect connectivity of habitat.

In the next chapter (Chapter 4) I continue to investigate the habitat used by Sloane’s Froglet. I investigate the habitat that Sloane’s Froglet is using within individual waterbodies at a microhabitat scale. I also examine the spatial separation between individual Sloane’s Froglets and frogs of other species within waterbodies.
The thesis aims to provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach.

Chapter 1
General Introduction, thesis overview and literature review

**Aim 1:** Investigate the distribution and habitat of Sloane’s Froglet

Chapter 2
Where is Sloane’s Froglet?

Chapter 3
What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?

Chapter 4
Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?

**Aim 2:** Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focussing on the Sloane’s Froglet case study

Chapter 5
How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?

Chapter 6
What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)

**Aim 3:** Explore the foundations for and value of combining applied ecological and social research in one case study

Chapter 7
What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches? What are the outcomes of applying this framework to the Sloane’s Froglet case study?

**Thesis aim and aims 1, 2 and 3**

Chapter 8
Conclusion. Summary of results and recommendations for future research
Chapter 4  Within the wetland: microhabitat and spatial factors influencing the use of parts of waterbodies by Sloane’s Froglets
4.1 INTRODUCTION

In this chapter I continue to investigate habitat use by Sloane’s Froglet and further address the first aim of my thesis which is to determine the distribution and habitat of Sloane’s Froglet. Habitat can be investigated at many scales, and the research presented here may be considered to be at the microhabitat scale. While the previous chapter responded to questions about the differences between waterbodies that Sloane’s Froglet uses, in this chapter I ask “Which parts of the waterbody does Sloane’s Froglet use during peak calling periods?” In answering this question I intend to take the first step in understanding the within-waterbody use of the wetlands that Sloane’s Froglet inhabits. I investigate both the microhabitat features of the waterbodies as well as the relative spatial separation between Sloane’s Froglet and other frog species present. I continue to focus on the habitat used during peak calling periods and, as such, my approach is congruent with that discussed in Chapter 3 although at a finer scale. This chapter presents the final ecological findings of the thesis and chapters 2, 3, and 4 together provide fundamental knowledge of Sloane’s Froglet distribution and habitat that was previously unknown.

4.1.1 Microhabitat definitions

The concept of microhabitat use and the importance of small-scale studies has been recognised for many decades (e.g. Mohr, 1943; Price, 1978). Microhabitat investigations have strong foundations in many fields of ecology. For instance, recent studies investigate the nesting habitat of birds (e.g. Latif, Heath, & Rotenberry, 2011), the use of tree hollows and artificial hollows (e.g. Goldingay & Stevens, 2009), the microhabitat of flora (e.g. Sommers, Elswick, Herrick, & Fox, 2011) and microhabitat of non-Anuran herpetofauna (e.g. Searcy, Gabbai-Saldate, & Bradley Shaffer, 2013; Urbina-Cardona, Olivares-Pérez, & Reynoso, 2006).

Despite the proliferation of microhabitat investigations, the concept of microhabitat is rarely defined. It has been considered as a suitable term for describing the habitat of smaller organisms (Chapman & Reiss, 1999 p. 106) and is generally considered as a fundamental component of a species’ niche (while not reflecting the entire complexity of the niche concept) (Chase & Leibold, 2003) or a “very specific local condition” (Braude & Low, 2010, p.150) that is both scale or precision dependent of broader habitat and temporally variable. Delineating the microhabitat for a species may
depend on the species size, mobility, dispersal activities, breeding needs, foraging activities, trophic interactions and be influenced by dynamic changes to the habitat. Discussion regarding microhabitat may therefore be seated within a framework of resource partitioning, interspecific and intraspecific competition, community structure, and predator-prey relationships. In addition to the variability around the appropriate scale of study for microhabitat, recent research has identified that microhabitat studies may be in fact describing suboptimal microhabitat as a result of lack of optimal conditions due to habitat loss and fragmentation (Latif et al., 2011).

4.1.2 Microhabitat studies and conservation practices

Microhabitat studies make a significant contribution to conservation efforts and practices. For instance, in all of the studies previously cited in this chapter, authors have made links with management activities. Latif et al. (2011) state that the vegetation restoration efforts may affect predator behaviour or change predator communities and so impact upon bird recruitment in the Mono Lake tributaries. Sommers et al. (2011) in a study of microhabitat preferences of Lilium catesbaei discuss how dispersion factors for plants are important for management. They focus on the importance of leaf litter and light availability for their case study and relate these factors to the management of fire. Goldingay and Stevens (2009) discuss the importance of artificial tree hollow such as nest boxes to the management of Australian hollow-using birds and microbats. Searcy et al. (2013) assert the microhabitat differences between the terrestrial amphibian, Ambystoma californiense, and other terrestrial amphibians and make the explicit statement that for endangered taxa “effective management hinges on understanding the variability in habitat use across time and space” (p. 80). It seems likely that frog microhabitat studies as with studies for other groups contribute to conservation efforts and improve management practices. This has been shown to be the case, as discussed in the following sections.

4.1.3 Anuran microhabitat

Frog diversity is often correlated with diversity of wetland habitat features (for instance, Hazell, Cunninghing, Lindenmayer, Mackey, & Osborne, 2001; Wassens, Sass, Swan, & Thompson, 2004), and diverse “microtopography and aquatic habitats” (Semlitsch, 2002, p. 622) are necessary for different activities. Frogs are not only are
selective about which waterbodies (and terrestrial areas) they inhabit (as discussed in the previous chapter), most selectively use particular portions of wetlands that they occupy (e.g. Gillespie, Lockie, Scroggie, & Iskandar, 2004). Use varies for each species according to seasonal changes and breeding, refuge and foraging needs (e.g. Rowley & Alford, 2007). For aquatic-breeding frogs, breeding activities are dependent on microhabitat features. Wells (2007) points out that

probably the most common mating system for aquatic-breeding frogs is for males to gather in choruses around suitable breeding sites. Males call from the shores of ponds and streams, from elevated perches on vegetation, rocks, or other prominent sites, from the surface of the water, or, in a few species, from underwater... Usually, males maintain some minimum distance between themselves and their neighbours (p. 350).

While male gatherings are not the only mating system for frogs, Wells (2007) points us in the direction of considering the use of different aspects of habitat by different species, as well as the influence of behavioural characteristics on positioning during breeding activities.

4.1.4 **Spatial patterning and breeding behaviour of pond-dwelling anurans**

Habitat features are not the only determinant of within-waterbody spatial patterning. Studies have established that spatial patterns can occur even in relatively homogenous habitats (e.g. Mac Nally, 1985). Amphibians exhibit spatial patterning related to factors such as inter and intra competition (Wells, 2007). Spatial organisation for a limited number of species has been investigated in the Australian context (e.g. Wassens, Roshier, Watts, & Robertson, 2007), including for species that are sympatric with Sloane’s Froglet, C. signifera and C. parinisignifera (Mac Nally, 1979).

Spatial organisation of frogs within waterbodies has been related specifically to breeding behaviours. Aggregations of calling males through extended breeding seasons have been well documented for many species (Wells, 2007) and for the Myobatrachids, in which family Sloane’s Froglets belong, lek-like behaviour has been previously researched (e.g. Harrison & Littlejohn, 1985; Mac Nally, 1979; Robertson, 1984). Male frogs aggregate in groups termed ‘leks’ during the breeding season similar to lek breeding arrangements of birds and mammals, where males gather and compete for females, but unlike for the latter, in anurans the locations of leks are
“determined at least in part by the distribution of suitable aquatic breeding sites” (Wells, 2007, p. 352). The locations of male frogs and their aggregations then also may be related to suitable oviposition sites (Wells, 2007).

4.1.5 The relationship between amphibian microhabitat studies and conservation practice

Knowledge of within wetland habitat use, or microhabitat use, as well as knowledge of habitat at other scales is considered fundamental to conservation and management efforts for amphibians (Semlitsch, 2002). Amphibian microhabitat studies may be considered small-scale studies and the purport of such studies is that “knowledge of species-specific habitat relationships can also be considered an important component of conservation and management” (Gorman and Haas, 2011, p. 313). Where active management for a focal species is undertaken, the microhabitat characteristics of the waterbody that are suitable for the particular species are of great import. In recent research into the conservation of the Oregon Spotted Frog, Popescu et al. (2013) argue that critical habitat for frogs is ill defined due to a lack of “species-specific data on habitat use and movement both within individual sites (microhabitat selection) as well as at the landscape-scale (macrohabitat selection)” (p. 689). In fact, all recent studies describing microhabitat purport to do so with the aim of informing better conservation practices. Heard, Robertson, and Scroggie (2008) point out that microhabitat studies benefit conservation practices as “such studies may identify specific microhabitats, or microhabitats with particular attributes, which individuals rely upon for day-to-day survival or reproductive activities” (Heard et al., 2008, p. 414).

4.1.6 Key microhabitat features for frogs

Investigations into specific niche characteristics and microhabitat have been undertaken for several anuran species as indicated in the examples presented below. Comparisons of habitat selection between related or sympatric species often focus on describing and comparing habitats which are used for specific activities such as feeding or breeding (e.g. Gorman & Haas, 2011; Mac Nally, 1985).

Several studies have focussed on microhabitat use of stream-breeding anurans. Examples include the use of refuges behind waterfalls and between rocks and basking spots in waterfall splash zones, as well as streamside vegetation within 15 m of the
bank for the endangered *Litoria nannotis* (Hodgkison & Hero, 2001); leaf litter and vegetation within 20 m of the stream for *Mixophyes iteratus* (Lemckert & Brassil, 2000); burrows in soil and shelters under logs in areas >500 m from water sources for *Helioporus australiacus* (Lemckert & Brassil, 2003); and distance to a riffle or pool, height above the water and distance from litter and rocks for a group of stream-dwelling frogs in Sulawesi, Indonesia (Gillespie *et al*., 2004).

For pond-breeding amphibians the structure of vegetation based on growth form (submerged, emergent and floating), vegetation height and depth and stem-density (categorised as dense, semi-open or open) (Popescu *et al*., 2013, p. 692) were found to be important by Popescu *et al*. (2013) in their microhabitat study of *Rana pretiosa*; water-depth, the slope of the bank and density of vegetation cover by Semeniuk, Lemckert, and Shine (2007) in their study of *Bufo marinus* and native frogs in north-eastern NSW; deep leaf litter and low vegetation for *Litoria brevipalmata* (Lemckert & Slatyer, 2002); increasing pool area, water depth, midday temperature and extent of bare substrate for when the microhabitat features of ponds used by *Pseudophryne corroboree corroboree* (Hunter, Osborne, Smith, & McDougall, 2009); and, vegetation structure (submerged and emergent), woody debris, water depth and movement and frog level canopy cover for *Lithobates okaloosae and L. clamitans clamitans* in Gorman and Haas (2011). For pond-breeding frogs the important microhabitat features have differed from stream-dwelling frogs, with less focus on distance to water source and the physical characteristics of rocks and splash zones and more on vegetation structure both within the waterbody and directly adjacent to it. Some similarities with stream-dwelling amphibian microhabitat features exist that link frog locations with leaf litter and distance to cover. In the case of pond-breeding frogs, elements of microhabitat that are reported as significant across studies include vegetation structure and cover both within and directly adjacent to the waterbody, leaf litter, depth of water and slope of bank.

### 4.1.7 Existing information regarding Sloane’s Froglet microhabitat

Littlejohn (1958) comments that Sloane’s Froglets were found in shallow, temporary ponds, but there is no other information available regarding Sloane’s Froglet microhabitat or spatial patterning.
4.1.8 The research question

In this chapter I ask “Which parts of the waterbody does Sloane’s Froglet use during peak calling periods?” Based on existing studies for other frog species which found that vegetation structure (including submerged and emergent aquatic vegetation) and water depth, in particular, influence microhabitat selection, I hypothesised that Sloane’s Froglet would exhibit strong selection at the microhabitat level. I also hypothesised that Sloane’s Froglet would exhibit selection based on spatial separation with other frogs using the waterbody, as the literature indicates that breeding behaviour influences spatial patterning.

To investigate the microhabitat I explore and quantify the vegetation and physical characteristics in the immediate vicinity of individual Sloane’s Froglets and compare these with randomly chosen sites that Sloane’s Froglet was not using. While this study does not include a spatial analysis of distribution patterns within the waterbody, distance relationships (referred to in this chapter as “relative spatial separation”) between calling Sloane’s Froglet males and calling males of other frog species are investigated and their importance as a component of within waterbody use is proposed. The microhabitat and relative spatial separation features are discussed in relation to both habitat requirements and behavioural characteristics of Sloane’s Froglet.
4.2 METHODS

4.2.1 Study region and site selection

As described in Chapter 2, a population of Sloane’s Froglet was identified in southern NSW in 2010 and a number of waterbodies in Albury and Corowa were identified as containing Sloane’s Froglet (Knight, 2013). Sloane’s Froglets, their microhabitat and relative spatial separation characteristics were sampled at sites within twelve of these waterbodies in 2011 (see Figure 4.1). Characteristics of the study region are provided in Chapter 2, Section 2.3.1.
Figure 4.1 Map showing the location of 12 waterbodies in the Albury and Corowa regions in which sites used and unused by Sloane’s Froglet were sampled in 2011
The pool of available waterbodies for sampling was taken from the distribution data collected in 2010 and included only waterbodies that Sloane’s Froglet was detected within in 2010. Waterbodies were chosen from two broad locations, Albury and Corowa. Potential waterbodies were limited to those accessible in wet weather and for which permission from the landholder was available. These accessible waterbodies were stratified by estimated abundance of Sloane’s Froglet (once again, determined in 2010). Waterbodies that had an estimated abundance of fewer than six Sloane’s Froglets were excluded. The remaining waterbodies were then numbered, a random number table was generated and six waterbodies in each region were randomly selected for the study.

The waterbodies sampled included farm dams, dams in conservation areas, dams with associated shallow ephemeral wetlands (e.g. Plate 4.1), constructed wetlands used for stormwater retention and grey water treatment (e.g. Plates 4.2 and 4.3), shallow natural depressions in paddocks (e.g. Plate 4.4 and 4.5), and large natural wetlands. Size of the waterbodies was highly variable with the smallest being a paddock depression of approximately 330 m² and the largest natural wetland approximately 30 ha. The estimated abundance of Sloane’s Froglet at these waterbodies ranged from below 10 individuals at the smaller, less vegetated farm dams to over 500 individuals at the large natural wetlands at Corowa (Table 4.1).
Table 4.1. Characteristics of the waterbodies in which individual Sloane’s Froglets and unused sites were sampled in 2011 for the microhabitat survey. Site identifier key A=Albury, C=Corowa

<table>
<thead>
<tr>
<th>Region</th>
<th>Site Identifier</th>
<th>Waterbody type</th>
<th>Estimated Area (m²)</th>
<th>Estimated abundance category (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albury</td>
<td>A1</td>
<td>Constructed wetland</td>
<td>12 205</td>
<td>20 - 99</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>Dam</td>
<td>9 168</td>
<td>&gt;100</td>
</tr>
<tr>
<td></td>
<td>A3</td>
<td>Stormwater retention pond</td>
<td>532</td>
<td>6 - 19</td>
</tr>
<tr>
<td></td>
<td>A4</td>
<td>Dam and adjacent natural depression</td>
<td>2207</td>
<td>6 - 19</td>
</tr>
<tr>
<td></td>
<td>A5</td>
<td>Dam</td>
<td>732</td>
<td>6 - 19</td>
</tr>
<tr>
<td></td>
<td>A6</td>
<td>Constructed wetland</td>
<td>2 539</td>
<td>20 - 99</td>
</tr>
<tr>
<td>Corowa</td>
<td>C1</td>
<td>Shallow paddock depression</td>
<td>330</td>
<td>6 - 19</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td>Natural depression</td>
<td>6 972</td>
<td>20 - 99</td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>Large natural wetland</td>
<td>20 000</td>
<td>&gt;100</td>
</tr>
<tr>
<td></td>
<td>C4</td>
<td>Shallow paddock depression</td>
<td>1 166</td>
<td>20 - 99</td>
</tr>
<tr>
<td></td>
<td>C5</td>
<td>Large natural wetland</td>
<td>339 056</td>
<td>&gt;100</td>
</tr>
<tr>
<td></td>
<td>C6</td>
<td>Dam</td>
<td>796</td>
<td>6 -19</td>
</tr>
</tbody>
</table>
Plate 4.1. Waterbody A4 at Thurgoona sampled for the Sloane’s Froglet microhabitat study. Dam and ephemeral depression

Plate 4.2. Waterbody A3 sampled for the Sloane’s Froglet microhabitat study. Stormwater retention dam at Albury
Plate 4.3. Waterbody A6 sampled for the Sloane’s Froglet microhabitat study. A constructed wetland which fills seasonally at Wonga Wetlands, Albury

Plate 4.4. Waterbody C1 sampled for the microhabitat study of Sloane’s Froglet undertaken in 2011. A small ephemeral paddock depression at Corowa
Plate 4.5. Waterbody C2 sampled for the microhabitat study of Sloane’s Froglet undertaken in 2011. Large paddock depression at Corowa which fills seasonally
4.2.2 Sampling strategy

Field observations were undertaken in 2011 at each waterbody during the period from late July to early September that coincides with the key calling period for Sloane’s Froglet as described in Chapter 3. Calling males were identified via triangulation by two observers. Triangulation is generally recommended when trying to trace a call for positive identification of a species (Department of Environment and Climate Change, 2009). Two people are positioned around the calling frog and are then able to ascertain the exact location of an individual. In this situation, as Sloane’s Froglet is highly cryptic, small (thus making it very difficult to see) and dives quickly when disturbed, the presence of a frog at a site was determined by identifying the spot it was heard calling from, using triangulation, rather than by necessarily visually observing it. Determining its position by seeing it may have biased the data towards those sites with habitat assemblages where individual frogs were more easily visible.

A one m$^2$ quadrat was placed around each individual frog, with the estimated position of the frog at the centre of the quadrat. This one m$^2$ area is referred to as a “site”. Assessing microhabitat in one m$^2$ quadrat is consistent with other studies (e.g. Gorman & Haas, 2011; Hollis, 2004). The quadrat placed around an individual Sloane’s Froglet will be referred to as a “used site”.

The aim was to measure the variables for five individual Sloane’s Froglets at each waterbody, but in response to varying conditions, the number varied. The variables for five used sites (sites in which male Sloane’s Froglets were sitting, calling) were measured at nine waterbodies, however, three waterbodies contained only three calling males. At these sites measurements of the variables could only be taken for the three used sites. In total 54 used sites were sampled across the 12 surveyed waterbodies. Microhabitat variables were measured within each quadrat.

On the same night that the Sloane’s Froglet microhabitat was recorded, variables were also measured for randomly chosen unused sites within each waterbody. In order to generate random unused sites a random number table was used to determine a location at a degree around the circumference of the waterbody and a distance from the bank into the waterbody. If a calling Sloane’s Froglet was found within the one m$^2$ quadrat at the site, it was discarded and another one randomly selected. These sites
will be referred to as “unused sites”. In total 57 unused sites were sampled across the twelve waterbodies. Randomly chosen unused sites were selected in that part of the wetland where the water depth was less than 60 cm (pilot work indicated that calling male Sloane’s Froglet only used shallow waters).

4.2.3 Variables measured

Three types of variables were measured in each quadrat: physical characteristics including water depth and distance to bank; structural vegetation characteristics; and distances to the nearest other Sloane’s Froglet calling and to the nearest frog of another species calling (relative spatial separation). Measurements of the distance between the middle of the quadrats and other calling frogs were recorded as it was noticed during the distribution study (Knight, 2013 and Chapter 2) Sloane’s Froglet appeared to be aggregating or clustering in parts of waterbodies that superficially, at least, appeared to be relatively homogenous, and with awareness that pond-breeding behaviours may be influencing spatial positioning (after Mac Nally, 1985; Wells, 2007). As well as site characteristics, a description of the whole wetland was recorded following the methodology described in Chapter 3. The species and abundance of other frogs present in each wetland was also recorded.

4.2.3.1 Physical characteristics

Water depth was measured in cm using a metric ruler in the centre and at each of the corners of each quadrat and was averaged. The centre of the quadrat equated to the place an individual frog was perching. The distance from the centre of the quadrat to the bank was measured with a metric tape in metres. The percentage of the quadrat that was above the water level (on the bank or in the littoral zone) was estimated where the quadrat placement covered both bank and aquatic areas of the waterbody.

4.2.3.2 Vegetation structure

Vegetation was categorised into functional categories of submerged and emergent vegetation. Submerged vegetation included that with a predominantly submerged form such as *Potamogeton* spp. (pondweeds) as well as any vegetation that was completely submerged at the time of sampling including species that may normally be considered emergent, but were completely inundated (such as clumps of old *Eleocharis acuta*, Common spikerush). As very little floating vegetation such as *Azolla*
sp. (pond fern) was found at any site (as indicated in Chapter 3), when it did occur it was included within the submerged vegetation category (after Hazell et al., 2001). The emergent vegetation category included any vegetation that emerged above the surface of the water and predominantly included reeds (e.g. *Juncus usititus* and *E. acuta*) and grasses (e.g. *Cynodon dactylon*, Common couch).

Each of the vegetation categories that occurred in the quadrat were estimated in percent cover. A Braun-Blanquet key table (Braun-Blanquet, 1928) was used to ensure consistency of cover estimates across sites. The percent cover was also estimated for the area where there was bare substrate (not obscured by vegetation or leaf litter) and the percentage of the quadrat where there was leaf litter visible on the bottom. In addition, the percent cover was recorded for any area within the quadrat and above the water level that was bare of vegetation. Finally, the percent cover of the canopy directly above the quadrat was estimated and recorded.

For emergent vegetation the minimum and maximum height above the surface of the water was measured with a metric ruler in centimetres. As well as the structural characteristics of the vegetation, the dominant vegetation species present within each quadrat were recorded.

4.2.3.3. Relative spatial separation

Three variables were measured at each quadrat to assess relative spatial separation in the waterbody. These variables were distance to another Sloane’s Froglet calling at that waterbody and distance to a frog of another species calling at that waterbody (measured in metres using a tape) as well as the species of the nearest other frog calling (identified by call).

4.2.4  Data analyses

In order to investigate significant differences between used and unused sites, and ascertain parameters correlated with used sites, the data were first descriptively analysed. Following the descriptive analysis, and after a variable selection process (explained below), an explanatory model was developed through generalised linear modelling (GLM). The data from all sites were pooled as environmental conditions, including rainfall, elevation and topography were similar across the study region.
Chapter 4

(Chapter 2, Section 2.3.1) and it is likely that the Sloane's Froglets occurring there are one continuous population.

4.2.4.1. Description analyses

In order to investigate significant differences between used and unused sites, and ascertain parameters correlated with used sites, initially an univariate analysis of each variable was undertaken. General descriptive statistics of mean, median, and range were calculated for each variable. The significance (p) of the differences between the used and unused sites for each variable was calculated using the Mann-Whitney Rank Sum Test (U). A significant difference between the used and unused sites for that variable was established where p < 0.05 (Fowler, Cohen, & Jarvis, 1998, p. 104). The Mann-Whitney Rank Sum Test (U) is suitable for data (such as that presented here) which are not normally distributed and where sample sizes may be unequal (Fowler, Cohen, & Jarvis, 1998; Zar, 2010). To determine significance, the Mann-Whitney Rank Sum Test (U) compares the medians of samples (Fowler, Cohen, & Jarvis, 1998; Zar, 2010).

Box plots were prepared for vegetation and relative spatial separation parameters in order to visualise the central tendencies and distribution of the data. Box plots presented show median, 25th and 75th quartile, range, outliers and extreme outliers. Outliers are those cases with values between one and a half and three box lengths from the upper or lower edge of the box. Extreme outliers are those cases with values more than three lengths from the upper or lower edge of the box (IBM Corp., 2011). This initial assessment of the data was undertaken using IBM SPSS Statistics 20 (IBM Corp., 2011).

4.2.4.2. Preparation of data for modelling: multicollinearity and variable selection

Before commencing more complex statistical analyses of the microhabitat and relative spatial separation variables, the data were assessed for potential multicollinearity by generating a correlation matrix using Spearman’s Rank Correlation Coefficients ($r_s$). Variables with strong correlations ($r_s > 0.7$) were excluded from further analysis (Tabachnick & Fidell, 2013).

Because the total number of sample sites (n=111) was relatively small compared to the number of measured habitat variables the initial sets of variables were culled in a two
step process prior to modelling. Variables which showed significant differences (p<0.05) between used and unused sites were retained. The Spearman’s Rank Correlation (rho) was then used to guide decisions for culling the variables with p>0.05. This additional culling step was undertaken to reduce the likelihood of over-fitting variables to the model. Those variables that had the strongest correlation with used and unused sites (FRSP) were retained for the analysis and those with a weak correlation with FRSP were discarded. Where there was a correlation between two variables, the variable with the strongest correlation with FRSP was kept and the other discarded. This was the case unless there was a three way decision to be made, in which the variable kept had fewer correlations than the other variable choices.

4.2.4.3. Microhabitat and relative spatial separation modelling

Models were developed to discriminate between used and unused sites within the waterbodies. Generalised linear modelling and the information-theoretic approach was used to develop an explanatory model for the used and unused sites (Burnham & Anderson, 1998). The “all possible” or “best-subsets” routine was used as it is considered a powerful tool that conserves the principles of parsimony and is now widely available in most computer packages (King 2003). Modelling was undertaken using S-PLUS Version 8.2 (Tibco Software Inc., 2010).

As in Chapter 3, in acknowledgment that several models may make good predictions (e.g. Van Sickle et al. 2006, Claeskens and Hjort 2008), Akaike Information Criterion (AIC) (equation 1, Chapter 3, Section 3.2.4.3) was used to identify the most parsimonious models. The second order derivative AICc was used to select between models for discussion as it contains a bias correction term for small sample size, and is recommended by (Burnham & Anderson, 2004) for use in practice because it converges to AIC as n gets large. Models with an AICc score that is within 2 of the AICc score for the first model were selected for discussion in the first instance.

Akaike weights (\(\omega_i\)) were also calculated as these can be interpreted as “the probability that any given model is the best model for the observed data in the suite of candidate models” (Johnson & Omland, 2004), and as such \(\omega_i\) provides a measure of the strength of evidence for each model. Akaike weights can also be used to indicate the relative importance of predictor variables (Johnson & Omland, 2004) and so the sum of the
Akaike weights over all of the models in which the parameter appears was calculated and is presented.

A single model is further presented in more detail. The beta values and odds ratio for the model, and charts of the probability of occurrence for each variable in the model are presented. The relationships between occupancy and the variables identified as significant through the modelling process were calculated and plotted by combining the posterior probability of occurrence across the range of values observed, to generate a posterior distribution for expected occupancy. This procedure involved holding the other variables in the model at their mean.
4.3 RESULTS

4.3.1 Physical characteristics of used and unused sites

All Sloane’s Froglets occurred within the waterbody and not on the surrounding bank or riparian area. Sloane’s Froglets were located in those parts of the waterbody with very shallow water having a median water depth of 8 cm (range 0 - 32 cm). The median water depth was significantly shallower at used sites than the randomly selected unused sites (p=0.013) (Table 4.3, Figure 4.1).

![Boxplot showing water depth of sites within waterbodies](image)

**Figure 4.1.** Boxplot (median, 25th and 75th quartile, range, outliers (o)) showing water depth of sites within waterbodies that were used or unused by Sloane’s Froglet in 2011.

Two measurements relating Sloane’s Froglets’ position in relation to the bank were taken. The highest values for the percentage of the bank that was within the one m² quadrat for Sloane’s Froglet was 30%. The median bank area was significantly lower at used sites (p = 0.025) (Table 4.2). Distance to the bank from used sites was found to be highly variable, and related to the size of the wetland. The median distance to the bank was 4 m, but in the larger wetlands sampled Sloane’s Froglet occurred at 190 m from the bank edge.
**Table 4.2.** Results of the Mann-Whitney (U) Rank Sum test for average water depth, % quadrat on bank and distance to bank comparing Sloane’s Froglet used sites and unused sites within waterbodies in the Albury and Corowa region in 2011. Highlighted values indicate the variables where \( p < 0.05 \). \( n = 111 \)

<table>
<thead>
<tr>
<th>Physical characteristics of the site</th>
<th>Mann-Whitney (U)</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average water depth (cm)</td>
<td>1 118.5</td>
<td>0.013</td>
</tr>
<tr>
<td>% quadrat on bank</td>
<td>1 301.5</td>
<td>0.025</td>
</tr>
<tr>
<td>Distance to bank (m)</td>
<td>1 744.5</td>
<td>0.162</td>
</tr>
</tbody>
</table>

**4.3.2 Vegetation**

Vegetation at the wetlands consisted predominantly of low reeds such as *Eleocharis acuta* and inundated grasses including *Paspalum cynodon* and *P. distichum*. Submerged water plants such as *Potamegeton* spp. (Pondweeds) as well floating vegetation such as *Azolla* sp. occurred less frequently.

**4.3.2.1. Vegetation cover**

There was considerable range in the % cover of each vegetation type within the Sloane’s Froglet used sites (Table 4.3). None of the 54 sites that were used by calling males were empty of emergent vegetation with a median cover of 37.5 % (range 4 – 100 %), and while some sites contained little completely submerged vegetation, those that did generally had greater emergent vegetation. While large parts of some of the waterbodies in which sampling took place did contain areas of open unvegetated water, only eight of the 57 randomly selected unused sites had less than 5 % vegetation cover. In comparison, all used sites contained some vegetation and the median for all vegetative cover within a used site was 70 % (range 4 – 100 %).
Table 4.3. Median and ranges for vegetation structure categories at 54 Sloane’s Froglet used sites in 12 waterbodies in the Albury and Corowa area in 2011

<table>
<thead>
<tr>
<th>Vegetation structure</th>
<th>Median ( % cover)</th>
<th>Range (% cover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility to substrate</td>
<td>7.5</td>
<td>0 - 96</td>
</tr>
<tr>
<td>Leaf litter on substrate</td>
<td>0.0</td>
<td>0 - 55</td>
</tr>
<tr>
<td>Submerged plant cover</td>
<td>10.0</td>
<td>0 - 95</td>
</tr>
<tr>
<td>Emergent reed cover</td>
<td>12.5</td>
<td>0 - 90</td>
</tr>
<tr>
<td>Emergent grass cover</td>
<td>5.0</td>
<td>0 - 99</td>
</tr>
<tr>
<td>Total emergent cover</td>
<td>37.5</td>
<td>4 - 100</td>
</tr>
<tr>
<td>All vegetative cover</td>
<td>70.0</td>
<td>4 – 100</td>
</tr>
<tr>
<td>Canopy cover</td>
<td>0.0</td>
<td>0 - 50</td>
</tr>
</tbody>
</table>

Canopy cover directly above the site was generally low with only 5 of the 54 used sites having any canopy cover. The canopy cover over those sites ranged between 5 and 50 %. There was no significant differences (p < 0.05) for used and unused sites for any vegetation percent covers (Figure 4.2, Table 4.4).
Figure 4.2. Boxplots (median, 25\textsuperscript{th} and 75\textsuperscript{th} quartile, range, outliers (o), extreme outliers (•)) for % cover of vegetation structure characteristics of all Sloane’s Froglet used and unused sites within waterbodies in the Albury and Corowa region in 2011. (n= 111) a) Visibility to the substrate (white), b) Leaf litter (black), c) Submerged vegetation (dotted), d) emergent reed cover (horizontal stripes), e) emergent grass cover (vertical stripes), f) all vegetation cover (diagonal stripes), g) canopy cover (line).

Table 4.4. Results of the Mann-Whitney (U ) Rank Sum Test for vegetation structure (% cover) comparing 54 Sloane’s Froglet used sites and 57 randomly selected unused sites within waterbodies in the Albury and Corowa region in 2011. n = 111

<table>
<thead>
<tr>
<th>Vegetation structure % cover</th>
<th>Mann-Whitney (U)</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility to substrate</td>
<td>1 326.5</td>
<td>0.194</td>
</tr>
<tr>
<td>Leaf litter on substrate</td>
<td>1 541</td>
<td>0.515</td>
</tr>
<tr>
<td>Submerged plant cover</td>
<td>1 705.5</td>
<td>0.310</td>
</tr>
<tr>
<td>Emergent reed cover</td>
<td>1 687.5</td>
<td>0.373</td>
</tr>
<tr>
<td>Emergent grass cover*</td>
<td>1 576</td>
<td>0.690</td>
</tr>
<tr>
<td>Total emergent cover</td>
<td>1 757</td>
<td>0.198</td>
</tr>
<tr>
<td>Total vegetation cover*</td>
<td>1 704</td>
<td>0.249</td>
</tr>
<tr>
<td>Canopy cover</td>
<td>1 604.5</td>
<td>0.343</td>
</tr>
</tbody>
</table>

* n = 110
4.3.2.2. **Vegetation height**

The median height of all emergent vegetation at used sites was 13 cm and the median maximum height 41 cm (Table 4.5). There was no significant differences for vegetation height between Sloane’s Froglet used sites and unused sites (Figure 4.3, Table 4.6).

<table>
<thead>
<tr>
<th>Vegetation Height (cm)</th>
<th>Median (cm)</th>
<th>Range (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average height of emergent reeds</td>
<td>24</td>
<td>0 – 84</td>
</tr>
<tr>
<td>Maximum height of emergent reeds</td>
<td>40</td>
<td>0 - 150</td>
</tr>
<tr>
<td>Average height of emergent grasses</td>
<td>7</td>
<td>0 – 47</td>
</tr>
<tr>
<td>Maximum height of emergent grasses</td>
<td>12</td>
<td>0 - 97</td>
</tr>
<tr>
<td>Average height of all emergent vegetation</td>
<td>13</td>
<td>3 - 96</td>
</tr>
<tr>
<td>Maximum height of all emergent vegetation</td>
<td>41</td>
<td>9 - 150</td>
</tr>
</tbody>
</table>

**Table 4.5. Vegetation height for Sloane’s Froglet used sites (n=54) within waterbodies in the Albury and Corowa regions**

**Figure 4.3** Boxplots (median, 25th and 75th quartile, range, outlier (o), extreme outlier(•)). showing vegetation heights of sites unused (n=57) and sites used (n=54) by Sloane’s Froglet within waterbodies in the Albury and Corowa region in 2011. a) Average height of emergent reeds (white), b) Maximum height of emergent reeds (diagonal hatching), c) average height of emergent grass(dots), d) maximum height of emergent grass(dark squares), e) average height of all emergent vegetation (vertical stripes), f) maximum height of all emergent vegetation (crosshatching)
Table 4.6. Results of the Mann-Whitney (U) Rank Sum Test for vegetation height comparing 54 Sloane’s Froglet used sites and 57 randomly selected unused sites within waterbodies in the Albury and Corowa region in 2011. $n = 111$

<table>
<thead>
<tr>
<th>Vegetation Height</th>
<th>Mann-Whitney (U)</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average height of emergent reeds</td>
<td>1533.5</td>
<td>0.974</td>
</tr>
<tr>
<td>Maximum height of emergent reeds*</td>
<td>1 449</td>
<td>0.754</td>
</tr>
<tr>
<td>Average height of emergent grasses</td>
<td>1 587</td>
<td>0.768</td>
</tr>
<tr>
<td>Maximum height of emergent grasses#</td>
<td>1 594.5</td>
<td>0.607</td>
</tr>
<tr>
<td>Average height of all emergent vegetation</td>
<td>1 520</td>
<td>0.911</td>
</tr>
<tr>
<td>Maximum height of all emergent vegetation</td>
<td>1 624.5</td>
<td>0.614</td>
</tr>
</tbody>
</table>

* $n = 107$, # $n = 110$
### 4.3.3 Relative spatial separation

#### 4.3.3.1. Distance to other individual calling frogs

The distance to another calling male Sloane’s Froglet from the frog located at used sites ranged from 0.1 m to 10 m with a median distance of 2.5 m. The distance from a used Sloane’s Froglet site to a calling male frog of a different species ranged between 0.5 and 15 metres with a median of 3 m (Table 4.7).

**Table 4.7.** Distance from each individual Sloane’s Froglet to the nearest other calling frog at Sloane’s Froglet occupied sites in the Albury and Corowa regions in 2011

<table>
<thead>
<tr>
<th>Distance to another calling frog</th>
<th>Median (m)</th>
<th>Range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to another Sloane's Froglet</td>
<td>2.5</td>
<td>0.1 - 10</td>
</tr>
<tr>
<td>Distance to a frog of another species</td>
<td>3</td>
<td>0.5 - 15</td>
</tr>
</tbody>
</table>

The distance between a Sloane’s Froglet and another Sloane’s Froglet was significantly (p < 0.05) shorter than the distance measured between an unused randomly selected microhabitat site and the nearest calling Sloane’s Froglet. This was also the case for the distance between Sloane’s Froglet and calling male frogs of other species within the waterbody. The distance from a used microhabitat site (one where a Sloane’s Froglet was sitting, calling) to another calling frog of any species was short, when compared with the distance between an unused randomly selected microhabitat site and the nearest calling male frog (Table 4.8, Figure 4.4).

**Table 4.8.** Results of the Mann-Whitney (U) Rank Sum comparing distance to another calling frog at Sloane’s Froglet used sites with unused sites within water bodies in the Albury and Corowa region in 2011. Highlighted values indicate the variables where p < 0.05.

<table>
<thead>
<tr>
<th>Distance to another calling frog (m)</th>
<th>Mann-Whitney (U)</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to another Sloane's Froglet (n=105)</td>
<td>571.5</td>
<td><strong>0.000</strong></td>
</tr>
<tr>
<td>Distance to a frog of another species (n=97)</td>
<td>757</td>
<td><strong>0.003</strong></td>
</tr>
</tbody>
</table>
Figure 4.4. Boxplots (median, 25th and 75th quartile, range, outlier (o), extreme outlier (★)) for distances to another Sloane’s Froglet calling (white) and distance to another calling frog of any species (hatched) comparing unused sites with used sites within waterbodies in the Albury and Corowa region in 2011.

4.3.3.2. Species of other frogs calling

Sloane’s Froglet occurs at waterbodies that are also used by other winter-breeding species of frogs. In particular, *C. parinisignifera*, *C. signifera* (at Albury and Corowa) and *L. paraewingi* (at Albury only) were observed to be actively calling in winter at many of the waterbodies occupied by Sloane’s Froglet. In early spring *Limnodynastes tasmaniensis* became the dominant species calling from, and breeding in, waterbodies occupied by Sloane’s Froglet.

For nine of the sites that Sloane’s Froglet occupied there was no frog of another species calling (ie. Sloane’s Froglet was the only species of frog calling at that waterbody at the time of sampling). At 30 of the remaining 45 sites the closest other frog calling was a *C. parinisignifera*. At the remaining 15 sites the nearest neighbour was *Litoria paraewingi* at one site, *C. signifera* at nine sites and *Limnodynastes tasmaniensis* at five sites.
4.3.4 Modelling Sloane’s Froglet within-waterbody use

Preparation of the data for modelling (as described in Section 4.2.5.2) resulted in six variables being included in the modelling process (Table 4.9).

Table 4.9. Variables used in developing the explanatory model for sites within the waterbody occupied and unoccupied by Sloane’s Froglet in the Albury and Corowa regions in 2011.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>wataver</td>
<td>The average depth of the water within the one m² quadrat</td>
</tr>
<tr>
<td>BANKAREA</td>
<td>The percent of the quadrat that was on the bank above the water level</td>
</tr>
<tr>
<td>SUBPLCOV</td>
<td>The total percent cover of any completely submerged vegetation</td>
</tr>
<tr>
<td>EMRDHTMAX</td>
<td>The maximum height of any emergent reeds in the quadrat</td>
</tr>
<tr>
<td>DISTSAME</td>
<td>The distance to another Sloane’s Froglet calling at the time of sampling</td>
</tr>
<tr>
<td>DISTOTHER</td>
<td>The distance to a frog of any other species calling at the time of sampling</td>
</tr>
</tbody>
</table>

GLM and the information-theoretic approach (Burnham & Anderson, 1998) identified two models with an AICc difference of <2 which are explanatory of site selection by Sloane’s Froglet (Table 4.10). The average depth of the water, the percent of the quadrat that was on the bank above the water level, the distance to another calling Sloane’s Froglet and the distance to another calling frog of another species were present in each of the two top ranked models, while the percent cover of submerged vegetation occurred only in the second model.

Initially, rather than assuming the best fit of a single model, I assessed the relative importance of individual variables by summing the Akaike weights ($\omega_i$) (Table 4.10) for all models containing the variable of interest. This technique provides a better indication of the importance of each variable in the context of the set of models considered (Buckland, Burnham, & Anderson, 1997; Johnson & Omland, 2004) and has been widely used elsewhere (Claeskens & Hjort, 2008). This approach established that the distance to another calling Sloane’s Froglet and another calling frog of another species had the highest summed Akaike weights ($\Sigma \omega_i=0.9999$), followed by the area of the quadrat above the bank (BANKAREA) ($\Sigma \omega_i=0.8118$), and the average water depth
(wataver) \( \Sigma \omega_i=0.7742 \), while the two vegetation categories, the cover of submerged vegetation (SUBPLCOV) and the maximum height of emergent vegetation (EMRDHTMAX) were of less importance (Table 4.10).
Table 4.10. Generalised linear modelling selection summary for Sloane’s Froglet used sites and randomly selected unused sites within waterbodies in the Albury and Corowa regions in 2011. Table includes, AIC, number of parameters (K), Akaike’s Information criteria adjusted for small sample sizes (AICc), difference in AIC (Δi), Akaike weightings (ωi). Summed Akaike weights (Σ ωi) for each parameter from all models are also provided.

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC</th>
<th>K</th>
<th>AICc</th>
<th>Δi</th>
<th>ωi</th>
<th>Percent correctly predicted</th>
<th>P value</th>
<th>Ps Rsq</th>
</tr>
</thead>
<tbody>
<tr>
<td>wataver+BANKAREA+DISTSAME+DISTOTHER</td>
<td>91.2420</td>
<td>5</td>
<td>91.8134</td>
<td>0</td>
<td>0.2913</td>
<td>0=76.6% 1=84.1%</td>
<td>&lt;0.0001</td>
<td>0.3554</td>
</tr>
<tr>
<td>wataver+BANKAREA+SUBPLCOV+DISTSAME+DISTOTHER</td>
<td>91.7592</td>
<td>6</td>
<td>92.5669</td>
<td>0.7535</td>
<td>0.1999</td>
<td>0=76.6% 1=79.5%</td>
<td>&lt;0.0001</td>
<td>0.3672</td>
</tr>
<tr>
<td>wataver+BANKAREA+EMRDHTMAX+DISTSAME+DISTOTHER</td>
<td>93.0618</td>
<td>6</td>
<td>93.8695</td>
<td>2.0561</td>
<td>0.1042</td>
<td>0=76.6% 1=79.5%</td>
<td>&lt;0.0001</td>
<td>0.3569</td>
</tr>
<tr>
<td>BANKAREA+DISTSAME+DISTOTHER</td>
<td>94.3220</td>
<td>4</td>
<td>94.6993</td>
<td>2.8858</td>
<td>0.0688</td>
<td>0=70.2% 1=81.8%</td>
<td>&lt;0.0001</td>
<td>0.3151</td>
</tr>
</tbody>
</table>

Summed Akaike weights (Σ ωi)

- DISTSAME: 0.9999
- BANKAREA: 0.8118
- SUBPLCOV: 0.3978
- DISTOTHER: 0.9999
- wataver: 0.7742
- EMRDHTMAX: 0.2620
The model selected for further detailed investigation contained only the four variables with the highest summed Akaike weights of average water depth, the percent of the quadrat that was on the bank above the water level, the distance to another Sloane’s Froglet calling at the time of sampling and the distance to a frog of another species calling at the time of sampling. This model had the highest overall AICc, as well as containing lowest number of variables and exhibited the highest percent correctly predicted classification table of the top two models (Table 4.10).

The beta values and odds ratio for these four variables (Table 4.11) and the probability plots (Figure 4.5) show that that Sloane’s Froglets are more likely to occupy sites within a waterbody with decreasing distances to another calling Sloane’s Froglet and decreasing distances to another species of calling frog as well as having less area of the site occurring above the water level and with shallower water depths.

Table 4.11. Beta values, standard error, significance and odds ratio for the four variables and constant in the model of characteristics influencing the occurrence of Sloane’s Froglets in sites within waterbodies in the Albury and Corowa regions in 2011

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta value</th>
<th>Standard Error</th>
<th>Significance</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>wataver</td>
<td>-0.064</td>
<td>0.030</td>
<td>0.035</td>
<td>0.938</td>
</tr>
<tr>
<td>BANKAREA</td>
<td>-0.102</td>
<td>0.056</td>
<td>0.069</td>
<td>0.903</td>
</tr>
<tr>
<td>DISTSAME</td>
<td>-0.235</td>
<td>0.078</td>
<td>0.003</td>
<td>0.791</td>
</tr>
<tr>
<td>DISTOTHER</td>
<td>-0.142</td>
<td>0.064</td>
<td>0.027</td>
<td>0.867</td>
</tr>
<tr>
<td>Constant</td>
<td>2.985</td>
<td>0.698</td>
<td>0.000</td>
<td>19.796</td>
</tr>
</tbody>
</table>
Figure 4.5. Fitted curves for the relationship between expected occupancy and the four significant variables (a) wataver, (b) BANKAREA, (c) DISTSAME, and (d) DISTOTHER, identified in the GLM for Sloane's Froglet microhabitat study undertaken in the Albury and Corowa regions in 2011. Dotted lines demark upper and lower confidence intervals. Values for the three other variables were held at their means.
4.4 DISCUSSION

The results of this study show that selection of calling sites by male Sloane’s Froglets was not random, and was related to specific microhabitat and relative spatial separation attributes. For Sloane’s Froglets it seems likely that within-waterbody use involves complex interactions between habitat features and behavioural attributes.

4.4.1 The importance of the littoral zone and aquatic vegetation

The wetland scale study reported in the previous chapter (Chapter 3) showed that the presence of both riparian and aquatic vegetation contributed to the selection of waterbodies by Sloane’s Froglets. Microhabitat studies for many other frog species also indicate the importance of structural features of the vegetation for site selection (e.g. Gorman & Haas, 2011; Heard et al., 2008; Popescu et al., 2013). It was expected this would be reflected in the microhabitat results for this study as well.

The importance of differing vegetation structure and height for site selection was not demonstrated in this study. There were no significant differences between the submerged and total vegetation cover, and the emergent vegetation cover or height at used and unused sites.

This may reflect the choice of variables measured and there may be an unmeasured variable that is influencing site selection. It seems likely that the lack of correlation with vegetation is in part at least a result of the sampling strategy. In order to answer the question asked “which parts of the waterbody does Sloane’s Froglet use during peak calling periods?” unused sites were only selected within waterbodies that Sloane’s Froglet occupies. It would be expected that these waterbodies would contain suitable habitat. In addition, sampling for randomly selected unused sites was limited to a maximum water depth of 60cm, as pilot work had indicated that Sloane’s Froglets were not found in depths greater than 60 cm (and indeed none of the individuals sampled in this survey were in water deeper than 32 cm).

Within this relatively shallow wetland area or littoral zone, the water level rises and falls and vegetation associated with shallow and ephemerally inundated areas such as reeds and grasses is prevalent (Barrett, Nielsen, & Croome, 2010; Roberts & Marston, 2011; Webb, Wallis, & Stewardson, 2012). This limitation of the sampling design to shallow areas limited the amount of variability measured at each waterbody as areas
that contained open water, or wetland plants associated with deeper waters were excluded.

Despite the lack of significant difference between vegetation cover and height at used and unused sites, all of the sites used by calling males contained submerged and/or emergent vegetation with small stem-diameters. Often this vegetation was *Eleocharis acuta* or *Cynodon dactylon* (see Plates 4.6 and 4.7). *E. acuta* is a short-medium sedge species, common in the wetlands of the study region where it occurs in shallow water and wet-dry habitats in waterbodies and drains alongside roads. It can form dense mono-specific stands (Roberts & Marston, 2011). *C. dactylon* is a mat-forming grass which grows through the warmer months and is common on the margins of wetlands in the region. It grows in “shallow water or on infrequently flooded sites” (Roberts & Marston, 2011, p. 70).

A floristic analysis of the vegetation at sites may have revealed differences that were hidden in the structural analysis.

**Plate 4.6.** Microhabitat site with predominantly emergent *Eleocharis acuta* used by a calling male Sloane’s Froglet at Corowa in 2011
The question of the potential for this research to be describing suboptimal habitat selection (following Latif et al., 2011 in the introduction to this chapter) by Sloane’s Froglet was not directly addressed in the research design, however it is a question which deserves some attention, especially considering the fragmented and modified nature of the waterbodies in the study region.

4.4.2 Sloane’s Froglets occupy very shallow water within the waterbody

All calling male Sloane’s Froglets were located within the waterbody and not on the edge or bank of the waterbody. Those that were located visually were found to be floating on the water surface or gripping small pieces of vegetation (see Plates 4.8 and 4.9). During the four year study period Sloane’s Froglets were only observed out of water infrequently, when moving from one place to another and when calling from the floor of an empty pond prior to rain.
Plate 4.8. Male calling Sloane’s Froglet on the surface of the waterbody at site A2 (David Hunter)

Plate 4.9. Male Sloane’s Froglet gripping vegetation on the surface of the waterbody at site A2. (David Hunter)
Mac Nally (1979, 1985) in his studies of the sympatric and related *C. parinisignifera* and *signifera* found that their preferred calling stations were from the “land/water interface zone” (1979, p. 301) and that “70% of all calling males were located on land within 10 cm of the water” (1985, p.335). Calling from land adjacent to a waterbody is not an uncommon strategy for pond-breeding Myobatrachids and other species sympatric to Sloane’s Froglet such as *Uperoleia laevigata* exhibit such behaviour (pers. obs.). Sloane’s Froglets did not call from the bank of the waterbody.

The depth of the water in which Sloane’s Froglets were floating or sitting was a significant variable for site selection. All males in the microhabitat study were calling from very shallow water (median 8 cm, range 0 – 32 cm). At times, and as noted in the previous chapter (Chapter 3) on waterbody scale habitat characteristics, the shallowness of the water is a reflection of the nature of the entire waterbody. However, several of the waterbodies in the microhabitat study had deeper areas of water that were not used by Sloane’s Froglet which suggests that Sloane’s Froglets prefer to call from shallow water.

Shallow water warms quickly and stays warmer than surrounding air temperatures after dark. For a small frog such as Sloane’s Froglet which is using energy for breeding at the coldest time of the year, shallow water provides important opportunities for thermoregulation. Warmer body temperatures may enhance the ability to breed. For instance, there have been many studies into the relationship between body temperature and calling energetics (Lemckert & Shine, 1993; Wells, Taigen, & O’Brien, 1996).

Shallow water also often contains littoral wetland vegetation such as inundated grasses and reeds suitable for ovipositioning, foraging and tadpole shelter (Casanova & Brock, 2000).

### 4.4.3 Relative spatial separation and Sloane’s Froglet breeding behaviours

The distance measurements taken between calling Sloane’s Froglets and other Sloane’s Froglets as well as other calling male frog species indicated that frogs were clustering or aggregating in particular parts of the waterbodies sampled. More recent microhabitat studies of pond-breeding frogs tend to focus on vegetation or other habitat characteristics rather than relationships with positions of other individual frogs.
(e.g. Gillespie et al., 2004; Gorman & Haas, 2011; Popescu et al., 2013). In this context it was a surprise to find that for Sloane’s Froglet, relative spatial separation was a significant component influencing site occupation. When the context is reframed to include anuran breeding behaviours it is a reasonable expectation. As Wells points out:

\[I\]n fact, most anuran choruses exhibit some degree of spatial structuring. Individual males typically maintain some minimum distance between themselves and their neighbours... The distance at which males tolerate other calling males is relatively plastic, and tends to decrease as the number of males in a chorus increases. (2007, p.294).

Mac Nally (1979, 1985) in his research on the two *Crinia* spp. sympatric with the Sloane’s Froglet population studied here Discusses how territories are maintained between both conspecific and heterospecific individuals when the sites are largely homogenous environments. He asserts that “*behaviour primarily determines spacing, rather than topography or vegetation patterns*” (Mac Nally, 1979, p.301). Mac Nally (1985) further points out that habitat preferences or selectivities are not the only driver allowing different species to coexist. Other factors include predation, physiological tolerances and interspecific interaction. He considers that:

*habitat differentiation per se does not account for all the possible ways in which spatial segregation can occur. Some workers have shown that behaviour can lead to spatial segregation without concomitant habitat segregation* (1985, p. 329).

While habitat features also influence site selection for Sloane’s Froglets, the breeding behaviours which may be explanatory of relative spatial separation are in themselves complex. The literature points to two key components: male lek-like behaviour and female ovipositioning.

Male Sloane’s Froglets congregated during peak calling periods. This behaviour can be considered similar to lek breeding arrangements where males gather to compete for females. Wells (2007) points out that there is debate in the literature between those that think lek systems are less common than resource-based territories and he argues that for Myobatrachids like other primitive anurans with inguinal amplexus (such as Sloane’s Froglet) lek mating systems are common as
oviposition sites...cannot be easily monopolised by individual males. Where this is the case the egg laying behaviour is commonly to attach eggs individually to plants or other substrates, or to scatter them individually (Wells, 2007, p. 352).

Several studies have discussed the general relationship between male perching sites and female oviposition sites (Gillespie et al., 2004; Hollis, 2004). Gillespie et al. (2004) report that “general observations indicated that oviposition sites of most species were associated with the microhabitats in which the adult frogs were found” (p. 439) and surmised that male frogs may choose to call from sites with suitable habitat for females to deposit eggs.

As yet, little is known about Sloane’s Froglet egg-laying behaviour. Anstis (2013) states that “[V]ery small eggs[are] laid singly, mostly attached to submerged vegetation such as grass stems or leaves, or on the substrate in shallow water” (p. 581). She observed eggs at Corowa in 2010 attached to the stems of Eleocharis acuta (M. Anstis, pers. comm.). The eggs themselves are only 1.1 to 1.2 mm and so are difficult to observe in their natural setting. I have observed only one female laying eggs. She deposited her eggs singly attached to blades of grass (Plate 4.10).

Plate 4.10. Sloane’s Froglet eggs attached to submerged grass. Photo taken at Thurlgoona, NSW in 2010 in a wetland in close proximity to site A6.

In this context it seems likely that Sloane’s Froglets are congregating within an area of the pond where there is suitable habitat for egg-laying, establishing territories there, and then calling vigorously to attract the best mate who can lay eggs nearby, even though the males are unable to defend individual grass stems. This is similar to
behaviour for *C. signifera* and *parinisignifera* previously observed (Mac Nally, 1979, 1984).

### 4.4.4 Recommendations for future research

The research presented in this chapter has provided some insight into the complex and potentially interacting factors that influence Sloane’s Froglet positioning within waterbodies during winter, the peak breeding season. The climate in the study region consists of cool, wet winters and hot, dry summers and many of the waterbodies that Sloane’s Froglet occupies exhibit ephemeral or seasonal hydroperiods. Investigation into microhabitat use during summer would potentially provide important information for Sloane’s Froglet management, for instance, it may be dependent on deep clay cracks during dry periods.

### 4.4.5 What does this new knowledge mean for the management of Sloane’s Froglet?

Some preliminary findings from this study have been published in popular format as *Sloane’s Froglet interim habitat guide and management recommendations* (Knight, 2014).

#### 4.4.5.1. Microhabitat and water management

For breeding Sloane’s Froglets in the middle of winter water depth is of particular importance. Within existing ponds, activities such as drain clearing or filling of shallow areas are likely to impact upon Sloane’s Froglet. If considering Sloane’s Froglets needs when constructing wetlands, then designing shallow areas suitable for aquatic vegetation is essential. This recommendation is consistent with recommendations generally made for encouraging frog occupancy of constructed ponds. As mentioned in Chapter 3, Semlitsch (2002) points out the importance of diverse microtopography and aquatic habitat. When constructing wetlands he recommends including

*warm and shallow areas for primary production and thermoregulation and a littoral zone of vegetation, will help ensure diverse microhabitats for calling, ovipositing, foraging, growth and refuge* (p. 622).

Shallow margins of ponds as well as shallow wetlands are particularly vulnerable to overgrazing and pugging (Plate 4.11) by cattle and sheep. While Sloane’s Froglet persists where grazing occurs, it may be beneficial to reduce numbers or remove stock.
in peak breeding periods. It may also be beneficial to fence the waterbody and provide an alternative watering point.

Plate 4.11 Pugging by horses on the edge of a farm dam in Thurgoona, Albury occupied by a small number of calling male Sloane’s Froglets

4.4.5.2. Breeding behaviours

Behaviour and interactions with frogs of other species influences site occupancy by Sloane’s Froglets. Any unexpected activities or issues which change frog community structures then have the potential to affect Sloane’s Froglet breeding activities and success. Providing a broader space (temporally, spatially and with relation to issues) that allows behavioural characteristics of their life to continue is potentially just as important as managing within waterbodies.
4.5 CONCLUSION

This is the first and only study into within-waterbody use by Sloane’s Froglet. By comparing habitat and relative spatial separation variables at used sites with those at unused sites during peak calling periods I have established that complex interactions between spatial and habitat factors influence site selection. Sloane’s Froglets use shallow areas within the waterbody and do not call from the bank during the peak calling period. The data suggests that Sloane’s Froglets also exhibit both conspecific and heterospecific territorial spatial patterning. The study did not show significant differences between vegetation cover at used and unused sites and the lack of vegetation differences between sites suggests that that the relative spatial separation differences are highly significant for site selection.

This study has been limited to studying the variables associated with calling males during peak calling periods. It can hint at, but explicitly tells us nothing of, the microhabitat needs of female Sloane’s Froglets undertaking ovipositioning activities, and Sloane’s Froglet foraging requirements, and the requirements of tadpoles. The study was limited to one season and as such we still have no knowledge of microhabitat selection during non-calling periods, or which microhabitats Sloane’s Froglet uses when the waterbodies they actively breed in dry up.

The management implication of this work is that individual site management with particular care for the shallow margins of wetlands is critically important for the continued breeding success of Sloane’s Froglet. The importance of behaviour in influencing site selection suggests that broader measures that conserve community dynamics across regions are also essential.

This is the last chapter of this thesis investigating the ecology of Sloane’s Froglet. A summary of the research results and recommendations for further research are provided in Chapter 8. In the next chapters of this thesis I proceed to investigate how new knowledge, such as that presented here, can influence environmental practice and how the transdisciplinary approach of including ecological research and social research in one body of work can be of benefit to both research and practice.
Chapter 4
**Thesis aim**: Provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach.

**Chapter 1**
General Introduction, thesis overview and literature review

**Aim 1**: Investigate the distribution and habitat of Sloane’s Froglet

**Chapter 2**
Where is Sloane’s Froglet?

**Chapter 3**
What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?

**Chapter 4**
Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?

**Aim 2**: Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focussing on the Sloane’s Froglet case study

**Chapter 5**
How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?

**Chapter 6**
What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)

**Aim 3**: Explore the foundations for and value of combining applied ecological and social research in one case study

**Chapter 7**
What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches?
What are the outcomes of applying this framework to the Sloane’s Froglet case study?

**Thesis aim and aims 1, 2 and 3**

**Chapter 8**
Conclusion. Summary of results and recommendations for future research
Chapter 5  My case for Sloane’s Froglet. A researcher’s account of knowledge exchange and advocacy for a rare and little-known threatened species.
5.1 INTRODUCTION

Very shortly after commencing my Doctoral research I became an advocate for Sloane’s Froglet as I was concerned for its well-being and I wished to see my research findings applied. I persisted in my role as researcher, and the two roles became strongly entwined as I tried to mobilise my research findings; continue my ecological research; and, reflect and learn from the knowledge exchange experience I was participating in. This chapter explores that journey of advocacy. In entitling the chapter “My case for Sloane’s Froglet” my intention is to emphasise the ecological research already presented while demonstrating and critiquing how I act as a knowledge broker and an advocate for Sloane’s Froglet.

I choose the word ‘advocacy’ rather than words such as “providing information” or “education” as my actions were directly influenced by my values and ethics. While discussion about the appropriateness of advocacy by environmental scientists abounds (e.g. Lach, List, Steel & Schindler, 2003; Lacky, 2007; Scott et al. 2008), very few accounts of the advocacy journey appear in the literature. As Nelson & Vucetich, 2009 state “[M]uch has been written about advocacy by scientists” (p. 1090, my emphasis). Some of our greatest scientists, such as Paul Erlich and the Australians, Tim Flannery and Peter Cullen, are or have been some of the environment’s greatest advocates, but write very little about what constitutes advocacy for them. In environmental crises such as that described by Martin et al., 2012, advocacy actions for the Christmas Island pipistrelle are indirectly indicated, but not described or discussed. Descriptions and discussions about advocacy seem to largely rest within the more popular rather than peer-reviewed literature and discussions of individual’s actions such as Kaiser’s (2000) article in Science which describes the particular advocacy actions of individual scientists are rare.

In this chapter I move from the ecological studies that have informed chapters two, three and four and commence to address the second and third aims of my thesis. As noted in Chapter 1, the processes of knowledge exchange are fundamental to the application of research findings in environmental practice (Fazey et al., 2013; Reed, Stringer, Fazey, Evely, & Kruijsen, 2014; Roux, Rogers, Biggs, Ashton, & Sergeant, 2006). The second aim of my thesis is to explore and investigate the factors that allow and constrain the use of new knowledge by environmental practitioners in regional
Australia using Sloane’s Froglet as a case study. In this chapter, I ask “How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary research?”

In order to explore my knowledge exchange and practice-related questions I use an approach that is fundamentally different from the hypothetico-deductive, positivist approach used in the previous three chapters. Knowledge creation and exchange are human activities, and for the more socially focused side of my research I create qualitative data and explore them using use inductive reasoning. In this chapter, I use autoethnography to describe my attempts to inform the wide community about, and advocate for, Sloane’s Froglet and reflect on my motivations in so doing.

As well as pointing to some of the intricacies of knowledge creation and exchange throughout this chapter, I also begin to address my third aim of exploring the value of combining applied ecological enquiry and social research in one study by suggesting key themes related to the benefits and difficulties of developing a transdisciplinary case study.

5.1.1 The autoethnographic approach

Autoethnography is “an autobiographical genre of writing and research that displays multiple layers of consciousness” (Ellis, 1999, p. 673). Its origin lies in the field of anthropology, particularly in those ethnographies that were written by anthropologists about their own people (Muncey, 2010). Autoethnography places the individual in the context of their culture, in my case a culture of university student researcher, advocate and environmental practitioner. Autoethnography “can help us to examine, more self-consciously and analytically, what we are thinking about and doing in our professional practice” (White, 2001, p. 100).

Autoethnography appears to be rarely used within an ecological research context. A search of the SAGE online journal database revealed no relevant articles for “autoethnography” and “frogs” or “amphibians” or “feminist science” or “ecology” or “biodiversity” or “nature” although there was one recollection of frogs being collected and squashed in childhood from Doane (2001). There is a strong history, however, of both describing nature and reflexively exploring a person’s relationship with it in the
natural sciences. Consider, for example, Thoreau’s *Walden* (Thoreau, 1854) and the beautiful work of Annie Dillard (Dillard, 1974).

I found it challenging to move from the more formulaic presentation I used to describe Sloane’s Froglet habitat into the much more open space of autoethnography. I present this chapter as a data chapter. I also ask you to consider it not only as data but as a story and in so doing recognise and honour the values of stories in understanding our world (as described in Cameron, 2012).
5.2  METHOD

In constructing this chapter I have followed a social science and humanities tradition which allows the writer to both express their story in the hope of evoking a response in the reader (Crawley, 2012) and also to reflect upon it in a similar way to that used to reflect on interviews or other socially derived (Humphreys, 2005). Personal stories may be seen as being as “trustworthy and cherished as the stories of the researched” (Kirpitchenko & Voloder, 2014, p. 7). The power of this approach is that it allows diversity and individuality and so provides both author and reader the opportunity to become involved in the complexity of the subject matter (Crawley, 2012).

The story provided in this chapter is constructed in two ways. The first and final sections were constructed in the final stages of my thesis production, reflecting back upon the journey as a whole. These two sections frame the story and were developed once I had become deeply familiar with the outcomes of my research. These first and final sections look backwards on the process as a whole and are presented in “Bookman Old Style” font as it appears here.

The middle sections of “Journeying with Sloane’s Froglet” were constructed as a narrative based on the diary (journal) entries that I made at the time of the events taking place. Throughout the research process I kept diaries containing details of the ecological work that I was undertaking; who I had met or talked with recently; what I had thought about in relation to my research; the application of it; developments affecting Sloane’s Froglet; and, my ethical constructs associated with all of these. I documented events and thoughts in my diary regularly and I have chosen to construct a story from the diary entries that are particularly relevant to advocacy. At times there are gaps in my diary and I have also referred to emails sent and received, as well as flyers used to promote events, to reconstruct the story more fully. The story that has been developed from the diary and emails is presented in Calibri font with shading applied as it appears here.

During the story, I point to important themes that arise and that are congruent with themes presented in the following two chapters. The discussion and analysis of the themes that arise is constrained intentionally within this chapter as I wish to let the story engage the reader as well as raise conceptual material important to my thesis. My approach is to point to themes and concepts that arise from the story rather than
dwell on them. In Chapters 6 and 7 I discuss the themes and concepts in more detail as they are also raised by the participants I interviewed in undertaking research into knowledge exchange. The discussion of themes in this chapter is presented in the Calibri font used throughout the thesis.
5.3 JOURNEYING WITH SLOANE’S FROGLET

My journey with Sloane’s Froglet involved focussed ecological research, developing experiential knowledge, knowledge exchange and advocacy. I was not expecting this to happen, in fact, part of my reasoning for undertaking a PhD was to change my life direction which has been focussed on working full-time in employment that aimed to protect natural places or threatened species. When I developed my research proposal, I did not expect the section on knowledge exchange to be partly founded on my personal story, but rather a topic area to explore in the expectation that I would be generating new knowledge of a little researched entity. But events, values, ethics, intent.... took over. And I see that there may be value for another researcher or practitioner to read my story and consider some of my threads that inform research processes, knowledge exchange, values and environmental ethics.

Autoethnography is often used as a tool not only to analyse and reveal complex stories but also “to include the heart” (Ellis, 1999, p. 669) and capture the imagination of the reader (Muncey, 2010). Why I chose an advocacy role will reveal itself to you as the story progresses, but in the short initial section I would like to introduce Sloane’s Froglet to you in another way than the one already presented. The way that speaks to my heart.
I heard my first Sloane’s Froglet in Albury, he was sitting in a dam in a
friend’s backyard. He had a little chirp and then together with another
one they set up a whole rhythm, chirp, chirp...chirp, chirp...chirp,
chirp. He was intriguing, I couldn’t see him, he was so little, so well
camouflaged and yet he was sitting there, sitting up, saying here I am,
here I am, little frog in the suburbs that no one knows anything about.
Here I am, a little frog clothed in nothing but mystery. Here I am
chirping in the middle of winter, ready to breed on a cold wet night.
The first Sloane’s Froglet I caught and held in my gloved hand was a
female. She was swimming in the reeds of one of my favourite places,
Tasha’s pond (Plate 6.1), in Corowa, it was dark and late and cold and I
picked her out with my head torch and reached down and scooped her
up. I was so excited; she had a nice fat tummy and was so beautiful.
Now, five years later, I know how rarely females are seen. The old
saying “Children should be seen and not heard” does not apply to
Sloane’s Froglet. Sloane’s Froglet can be heard if you know what to
listen for, when to listen, and you submerge yourself into the landscape
and search carefully, but rarely seen unless you are a keen and
experienced frogger willing to take your time and stay out while your
gumbooted feet freeze. Later, there was the first moment I found a lot of
Sloane’s Froglets in one spot. The first time I heard a chorus of Sloane’s
Froglets I didn’t know what it was. I froze, listening, is that them? Is
that what they sound like when there are lots of them instead of half a
dozen? They sound so excited all chorusing together. They sounded
excited. And I feel excited when the nights get cold, when the frosts
start. I feel “something is about to happen”. Gleaming days, cold
nights. Something will happen, my frogs will start calling and I will
start doing fieldwork, out there with them, discovering them.
Understanding them. Being in wet cold places in the dark sloshing
around in the mud, listening to frogs, watching tadpoles, seeing the
night sky, looking at the characteristics of ponds, being with my frogs,
discovering their froggy ways.
Plate 5.1. Tasha’s pond, a beautiful remnant of a once much larger wetland, in a peri-urban setting on the edges of Corowa township, that contains a high abundance of Sloane’s Froglets

Sloane’s Froglets intrigued me, a reasonable reaction for a scientist as science is based on curiosity (Marder, 2011). A willingness to ask the next question, to observe and wonder, is fundamental to the scientific process.

Can values and emotion assist in scientific enquiry? I am delighted by my frogs (mine in my feeling of responsibility for them and that they possess me) and I care for my frogs. I also hold an ethic that includes honouring the intrinsic values of the non-human world (as described in Hay, 2002) and caring for it in its variety (as described in Donovan, 2006).

Latour (1998) states:

Science is certainty; research is uncertainty. Science is supposed to be cold, straight, and detached; research is warm, involving, and risky. Science puts an end to the vagaries of human disputes; research creates controversies. Science produces objectivity by escaping as much as possible from the shackles of ideology, passions, and emotions; research feeds on all of those to render objects of inquiry familiar (p. 208).

I think in the case presented in this thesis, both the emotions and the ethic assisted in the research. They did not detract from my ability to study Sloane’s Froglet in the most rigorous way possible. In fact, they pushed me to be careful with my survey design, to think closely about the methods I was using, to actually stand there late into the cold nights, carefully calculating the random selection of microhabitat sites; to act with intention and purpose. Both the feelings and the ethics were explicit, in that I recorded them; and considered, in that I explored them within the theoretical
framework provided to me by environmental philosophy, and so they provided a foundation that pushed me to do my work better.

In the following story I describe my advocacy journey.

When I first started finding out about Sloane’s Froglet in 2009 and 2010 a few people really inspired me. One of them was a great herpetologist who helped set up this PhD, in particular, the framework for the ecological questions in this PhD. But also my good friends, two knowledgeable women with environmental interests and training, helped me a lot, and they were so enthusiastic about this little frog. I contacted Murray Littlejohn, the original human discoverer of Sloane’s Froglet, at the commencement of my research, to gain some knowledge about Sloane’s Froglet. He was pleased that someone was doing research on Sloane’s Froglet. Quite a few people helped me, one lovely person heard me speak on the Australian Broadcasting Commission’s (ABC) radio one Sunday morning and came and helped me, then she made me some postcards from a Sloane’s Froglet photo I had and I sent them out and gave them away, and as a result an employee of the Victorian Department of Environment helped with some survey work. So I felt I had some allies. These allies were not only helpful in doing field work and developing approaches, they also supported me at some times and to differing levels in my Sloane’s Froglet information and advocacy journey. As well as studying Sloane’s Froglet, I started talking about Sloane’s Froglet to whoever would listen (and whoever wouldn’t).

My initial desire to talk developed because I wanted to know more about Sloane’s Froglet. Like many environmental practitioners, I was used to building my knowledge through conversations with my friends and colleagues. And so I spoke to herpetologists and froggers that I knew and to the friends and colleagues that they suggested might know something of Sloane’s Froglet. But no-one seemed to know much about Sloane’s Froglet. Some had never even heard of it, and of those that had no-one had actually seen one, although one of my colleagues mentioned that they had “heard one a few years ago”. There was not much information on the web. I could not even find a good recording of a Sloane’s Froglet (and so we made one) and there was no recording available for a chorus of Sloane’s Froglets. There were only a very few photos of Sloane’s Froglets and none of a female. In fact, I believe that the photo presented in this thesis (Chapter 1, Plate 1.1) of the pair in amplexus which Dr David
Hunter took for me one wet and stormy July night in a swamp in Thurgoona, and which is presented in Anstis (2013), is still the only photo publicly available of a female.

One of the people that I contacted was an ex-colleague of mine who had put together the initial report for the nomination of Sloane’s Froglet as a threatened species (Anonymous, nd). He told me that he knew about “Sloanes” because he was into frogs as a kid and grew up in Albury. He wondered if it might be endangered as he had been part of a large process that included undertaking frog surveys on the Darling floodplain and although it had been wet and there were lots of different species of frogs about, he had not come across any “Sloanes”. It got him “wondering” and so he checked the wildlife atlas database and there “appeared to be a problem, even though most people hadn’t seemed to have noticed”. He added that he thought it was a weakness of the process of threatened species legislation in NSW, that someone had to notice and prepare a nomination before any threatened species considerations could come into play and he kindly forwarded me the nomination report for Sloane’s Froglet (pers. comm.), the identity of a person preparing a nomination for listing of a threatened species is protected and so his report is presented as Anonymous, nd. and he is not named in this thesis). I, too, wondered.

Talking about Sloane’s Froglet became part of my raison d’etre. Once I established that there was an extant population of the species and that it occurred in areas that were quickly being developed I talked even more. I found that an extraordinary process in several ways. It was both inspiring and disheartening, because I felt for the first four years, while a few people heard me talking, very few were really listening or thinking about Sloane’s Froglet. So... I spoke to quite a lot of people about Sloane’s Froglet (Table 5.1 provides information on the organisations mentioned here), I spoke to the Corowa Landcare Group, I spoke to the Tabletop community forum, I spoke to the Chiltern Landcare Group, I spoke to the Woolshed Thurgoona Landcare group (Plate 6.3), I spoke to the Bethanga Landcare Group and the Holbrook Landcare Group. I spoke on the ABC’s national radio as well as their regional radio. I spoke to the local newspaper. I spoke to the Office of Environment and Heritage (OEH), that didn’t seem to have an immediate effect, so I wrote to them. I spoke to the Murray Catchment Management Authority. I talked with managers at the Goulburn Broken Catchment Management Authority. I spoke to people who managed areas of land with multiple
wetlands that contained Sloane’s Froglet about possible approaches to managing for Sloane’s Froglet. I rang consultants who worked in the regions and had power in making environmental recommendations and told them about Sloane’s Froglet. Consultants rang me and asked for information about Sloane’s Froglet. I developed two unsuccessful funding applications for capacity building and monitoring grants for Sloane’s Froglet. I spoke to the Albury City Council, to the Corowa Shire Council and I spoke to the Albury Conservation Company.

The outcome of the presentation that I made to the Albury Conservation Company was really wonderful because they decided to actively support my work. They didn’t just support my work financially, although they did contribute to my stipend, they also supported me in trying to raise awareness of a little forgotten species of frog that few people really cared about. I felt supported that there were six thoughtful and informed Board members\(^1\) all aware and actively engaged in Sloane’s Froglet conservation. That was actually a wonderful thing, because I felt very disheartened that hardly anyone was interested in Sloane’s Froglet, that there was little interest in caring for it. The Albury Conservation Company has continued to be strongly supportive of my work and continue to be involved in Sloane’s Froglet conservation. What great people and a forward-thinking organisation.

\(^1\) One of the directors of the Albury Conservation Company (ACC) was also one of my PhD supervisors. She abstained from the discussion and voting concerning my funding application to the ACC as is required by the ACC conflict of interest rules.
**Table 5.1.** Organisations that I spoke to and the roles that they have relevant to Sloane’s Froglet management.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Role (relevant to the case)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statutory Authorities</strong></td>
<td></td>
</tr>
<tr>
<td>Albury City Council</td>
<td>The organisation responsible for providing services and regional planning for a local government area in NSW covering 313 km$^2$ and with a population of 50 000 people based around the regional city of Albury. The first local government in NSW to have Biocertification (see NSW OEH section below) awarded following the development of a threatened species and development plan. (Albury City Council, 2010). Contains an important population of Sloane’s Froglet (refer to Figure 2.7, Chapter 2).</td>
</tr>
<tr>
<td>Corowa Shire Council</td>
<td>The organisation responsible for providing services and regional planning for a local government area in NSW covering 2,400 km$^2$ and with a population of 11 000 people based around the regional town of Corowa (Corowa Shire Council, nd). Contains an important population of Sloane’s Froglet (refer to Figure 2.8, Chapter 2).</td>
</tr>
<tr>
<td>Murray Catchment Management Authority (GBCMA)</td>
<td>Now known as Murray Local Land Services, this is the NSW government department responsible for natural resource management (as well as agriculture, biosecurity, and emergency management) of 40 000 km$^2$ in southern NSW (NSW Trade and Investment, 2015).</td>
</tr>
<tr>
<td>Goulburn Broken Catchment Management Authority</td>
<td>The GBCMA is the peak natural resource body for an administrative catchment in northern Victoria. They are responsible for the delivery of water to Moodies Swamp, which contains a large seemingly disjunct population of Sloane’s Froglets.</td>
</tr>
<tr>
<td>NSW Trade and Investment Crown Lands</td>
<td>Manage Albury Environmental Lands, lands put aside as a result of the biocertification process to be managed for the environment. Some of these areas are inhabited by Sloane’s Froglet.</td>
</tr>
<tr>
<td>NSW Office of Environment (OEH)</td>
<td>NSW State department responsible for protecting and conserving the NSW environment. Has carriage of the NSW <strong>Threatened Species Conservation Act 1995</strong> which aims to conserve threatened species and provides for biodiversity certification of land which is a streamlined biodiversity assessment process for areas marked for development. Headed by an elected representative on the NSW parliament, The NSW Minister for the Environment.</td>
</tr>
<tr>
<td>Australian Government Department of the Environment</td>
<td>Australian or ‘Federal’ department responsible for protecting and conserving the environment. Has carriage of the <strong>Environment Protection and Biodiversity Act</strong> which protects nationally and internationally important biodiversity. Headed by an elected representative on the Australian parliament, The Minister for the Environment.</td>
</tr>
<tr>
<td>Organisation</td>
<td>Role (relevant to the case)</td>
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<tr>
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<tr>
<td><strong>Private companies</strong></td>
<td></td>
</tr>
<tr>
<td>Albury Conservation Company</td>
<td>The Albury Conservation Company (ACC), established in 2006, aims to protect and enhance the natural environment in Thurgoona, a suburb of Albury. The ACC is a registered environmental organisation governed by a board of six people (Albury Conservation Company, 2015).</td>
</tr>
<tr>
<td><strong>Institutional landholders with Sloane’s Froglets present</strong></td>
<td></td>
</tr>
<tr>
<td>Charles Sturt University, Albury</td>
<td>Charles Sturt University (CSU) is an Australian regional University. The Albury campus is based in Thurgoona and contains several constructed wetlands in which Sloane’s Froglets occur.</td>
</tr>
<tr>
<td>Riverina TAFE National Environment Centre (NEC)</td>
<td>The Riverina TAFE (Technical and Further Education) NEC provides training in natural resource management and is located adjacent to CSU in Thurgoona, a suburb of Albury. The TAFE grounds contain several dams and ephemeral ponds containing Sloane’s Froglets.</td>
</tr>
<tr>
<td><strong>Landcare and Community Groups</strong></td>
<td>Established for over 30 years in Australia, Landcare is a community-based approach to managing and restoring the environment and improving sustainability (NSW, 2015).</td>
</tr>
<tr>
<td>Woolshed Thurgoona Landcare Group</td>
<td>The Landcare group active in the Thurgoona and Tabletop suburbs of Albury, areas which have many waterbodies inhabited by Sloane’s Froglets.</td>
</tr>
<tr>
<td>Table Top community forum</td>
<td>Community group with infrequent forums focussed on issues of interest to residents of the suburb of Tabletop in Albury which contains an important population of Sloane’s Froglet.</td>
</tr>
<tr>
<td>Corowa and District Landcare Group</td>
<td>The Landcare group covering the Corowa Shire area, which contains important populations of Sloane’s Froglets</td>
</tr>
<tr>
<td>Chiltern Landcare Group</td>
<td>The Landcare group located in northern Victoria around the village of Chiltern. Two large wetlands in the landcare area are inhabited by Sloane’s Froglets.</td>
</tr>
<tr>
<td>Holbrook Landcare Group</td>
<td>Landcare group to the north of Albury in region in which Sloane’s Froglet has been recorded in the past, and where I undertook surveys, but did not detect it.</td>
</tr>
<tr>
<td>Bethanga Landcare Group</td>
<td>The Landcare group in the region in which I live. Sloane’s Froglet has not been recorded as occurring here, but has been recorded in neighbouring locations.</td>
</tr>
</tbody>
</table>
The importance of networks in building and sharing knowledge is well documented. Networks of people that you went to university with, important people in your field that you can call on, people that might fund your work all contribute to the work being mobilised. Knowledge mobilisation seems to be on the edge of knowledge sharing and knowledge utilisation and can be considered as “eliciting or spreading knowledge to a wider range of recipients, possibly with the intent of increased application of knowledge” (Fazey et al., 2013, p.20). Collaboration in building knowledge in ecology is seen as essential by many scientists and practitioners (e.g. Roux et al., 2006; Ryder, Tomlinson, Gawne, & Likens, 2010) both because of the complexity of the systems in which we live and work and in order for it to be effectively applied in practice.

Working together to build knowledge and collaborative efforts is difficult to undertake as a solitary PhD student. While many research groups work together with established researchers and higher degree students, in this case I think the fact that Sloane’s Froglet and its context was so unknown (for instance, very few people had very little and not current information on its distribution) limited the opportunities to collaborate. Who would be the appropriate people to collaborate with? Working within established networks, such as friends or previous work colleagues, as I did where possible, may go some way towards building a shared and collaborative approach.

While collaboration is recommended by many researchers in environmental fields of inquiry for instance, Ryder et al. (2010) and Cullen et al. (1999) in wetland ecology, Beeton, Bosch, and Ross (2003) and Kohlhagen, Fryirs, and Semple (2013) in adaptive management, and Pooley, Mendelsohn, and Milner-Gulland (2014) in conservation biology, it may also be perceived as an indirect inhibitor of the use of new knowledge. Some organisations repeatedly turn to the same data providers (Gerlach, Williams, & Forcina, 2013a), so potentially missing the opportunity to incorporate new knowledge and approaches.

Planning for knowledge exchange is also considered an essential task leading to knowledge utilisation. I did not plan, I talked. As a research student I did not feel that I had the resources to develop a comprehensive knowledge exchange plan at the outset of my work to disseminate knowledge about Sloane’s Froglet as would be generally recommended (Reed et al., 2014). It was not my job; my task was to “do” a
PhD. I did not even know if there was going to be any interesting knowledge to disseminate, or who it might be shared with. And so, my approach to knowledge dissemination was *ad hoc* and naive, if enthusiastic. As Stankey and Shindler (2006) point out “*Confusing the provision of facts and detail with building public understanding and support is a mistake, however. Sound information is necessary to building and supporting sound decisions but is insufficient by itself to ensure such a result*” (Stankey & Shindler, 2006, p. 32). My approach may also be considered to be an example of a scientist trying to transfer an inert body of knowledge, an approach considered less effective than a knowledge sharing and construction approach (Fazey *et al.*, 2013; Roux *et al.*, 2006).

Having an individual or group as a champion for new knowledge (such as the Albury Conservation Company) is also a theme that is discussed in the literature. Gerlach, Williams, and Forcina (2013b) discuss collaboration and the importance of advocacy groups in data selection for natural resource management and indicate that “*data selection for use in making biodiversity management decisions is reliant on the social construction of which data sources are deemed acceptable by others*” (Gerlach *et al.*, 2013b, p. 343). The field of stakeholder analysis in natural resource management also provides a forum for discussing the importance of influential people in assisting with knowledge sharing and utilisation (e.g. Prell, Hubacek, & Reed, 2009; Reed *et al.*, 2009). The champion is conceived as being important for the knowledge to be both disseminated and utilised. In particular, having someone or a group of people more powerful or accepted within the community to help disseminate new knowledge is often seen as making the difference between knowledge being utilised and not utilised. In this case for Sloane’s Froglet, without the support of the ACC, I believe very little would have happened. The theme of networks and knowledge sharing is explored in more detail in the next chapter.
Back to my story...

It seemed to me in 2010, 2011 and 2012 that nobody with the power to influence development approvals was particularly worried that I’d found Sloane’s Froglet in places that were being rapidly developed, certainly there was very little action to this end. Important populations of Sloane’s Froglet were found on the outskirts of Albury and Corowa, where the land use is changing quickly from agricultural or rural lifestyle, to more dense suburban development and where the drainage is changing and the vegetation is changing as a result. I was particularly concerned about the issues in Albury and those in Thurgoona (a suburb of Albury). In the Albury City Council area a development plan has been approved to house an additional 50,000 people in new houses that will be built on farming and peri-urban lands that are the home to Sloane’s Froglet. The development plan had actually been put together with reference to a threatened species conservation strategy (Davidson, Datson, & McLennan, 2004) and areas had been put aside for conservation as well as development. The resulting development plan had been ‘biodiversity certified’ (terminology commonly shortened to “biocertified”), by the NSW Minister for the Environment (Department of Environment and Climate Change and Water NSW, 2010) (Figure 5.1).
Chapter 5

Albury Local Environmental Plan 2010

The Minister for Climate Change and the Environment made an order conferring biodiversity certification on the Albury Local Environmental Plan 2010 effective from the gazettal date of 25 February 2011 until 24 February 2021.

The certification covers almost the entire Albury local government area (LGA). A number of areas within the Albury LGA have, however, not been biodiversity certified, and these are shown in the order.

Details are available in the Proposed Biodiversity Certification for the Albury Local Environmental Plan 2009 (09539alburybiocert.pdf, 2.3MB).

Figure 5.1. Notification of biodiversity certification in Albury. (Office of Environment and Heritage, 2014)

This plan was lauded as the first of its type in Australia and a great way of protecting biodiversity as well as providing certainty for development (Local Government and Shires Association, 2011). Neither the plan nor the biocertification documents acknowledge the presence of or take protective measures for Sloane’s Froglet. I found it paradoxical that we had this wonderful forward-planning biodiversity certification in Albury that allowed for development and also put aside areas for nature conservation, but no one with influence seemed to me to be interested in incorporating this new knowledge I’d found into the plan or if they were they were unable to act. I was told the timing was wrong – no one had realised that Sloane’s Froglet was there and that it hadn’t been listed as a threatened species until after the planning was complete (Sloane’s Froglet was listed as a threatened species in 2008 and the knowledge of the presence of Sloane’s Froglet in the Albury area and the finalisation of the biocertification occurred around the same time). I felt that some may have considered my advocacy as inappropriate, especially because it may have been seen as contrary to the desire to ensure the establishment of biodiversity certification. I had been advised that there was a mechanism within that certification for incorporating new knowledge. I wanted to see that happen, but as a PhD student, I didn't have much influence.

In order that Councils and others would know that they had a little threatened frog in their area that they needed to care for I put together a distribution report based on the data which I have presented in Chapter 2, which was published by the Institute for Land, Water and Society (Knight, 2013a) and so available on the web. It took me some time to prepare and publish and I distributed a draft before official publication.
I couldn’t get any co-ordinated, regional scale action for Sloane’s Froglet, so I kept talking. There were some individual issues where I felt like I made a difference. Somebody mentioned to me that down in Corowa they were going to dig through one of the major wetlands (Tasha’s Pond) for Sloane’s Froglet, and I went down and talked to the council about this. I talked to one of the engineers on the council and they made changes in the planning so as not to disturb the wetlands there. Members of Corowa and District Landcare Group were also very supportive and invited me to address several meetings and endorsed a proposal to seek funding for Sloane’s Froglet activities. There was an exception too with the Riverina TAFE, they straight away took on managing for Sloane’s Froglet, and starting working actively for its wellbeing on their lands. Also the Albury Environmental Lands became interested in Sloane’s Froglet after a period of time. The Goulburn Broken CMA decided to make a water allocation to Moodies Swamp (not just for Sloane’s Froglet, but it would benefit them).

But if management is only site by site, and it’s only by chance that you hear about possible impacts then we all know that ad hoc management of threatened species leads to death by a million cuts, and this is actually the paradox of this whole situation. In this case, where the government had made a movement forward to have biocertification of an area for development, so that site by site threatened species assessment did not have to occur and so that there wouldn't be death by a thousand cuts for a lot of species, it actually seemed to curtail action for this particular threatened species.

I became very frustrated. I kept researching and then I realised in mid-2012 that one of the newer sites I had identified which was a series of natural temporary wetlands (gilgais) full of Sloane’s Froglets was special and contained diverse native vegetation. I asked some more friends to help me – we did a soil core of the bottom of the wetland and worked up a vegetation species list and I did some information searches on the web and realised that these wetlands were listed as a critically endangered type of wetland under the Federal *Environment Protection Biodiversity Conservation Act 1999* (Australia) (*EPBC*). I thought surely there will be some action now. I contacted the people responsible for the enforcement of the *EPBC* in the Australian Government because this Act not only protects threatened species on Australian government-owned land, but also protects species and communities that are considered endangered nationally as well as internationally. They responded to me in an email
that “the Albury Wodonga Corporation was in 2004 granted an exemption by the then Environment minister-Ian Campbell-from the application of s28 of the EPBC act (actions of Commonwealth agencies) in relation to its sale, management or development activities” (pers. comm.). So this beautiful little series of wetlands, even though they were listed as a critically endangered wetland nationally and occurred on land owned by the Australian government weren’t protected, were exempt from the Act. After the authorities discussed the situation with their legal section they advised that the department’s position was that once the land was sold, the provisions of the Act would again apply (pers. comm.). I felt like I was hitting my head against a brick wall over and over again. Although individual people, schools, school kids, and Landcare groups were interested and excited by Sloane’s Froglet, there seemed to be no mechanisms or no interest at a different level in protecting it.

This started to change I think in July 2013, when I organised a meeting together with the Albury Conservation Company and the NSW OEH, which was held at Thurgoona, where we got together the major stakeholders and talked about Sloane’s Froglet. At this time I also prepared a two-page brochure about Sloane’s Froglet (Knight, 2013b). This meeting (4 years into my research) really brought Sloane’s Froglet to people’s attention, and it seemed like there was a lot of interest.

After that meeting which was held in October 2013 a Sloane’s Froglet working group was established and met once. I don’t know if there have been any more meetings of the Sloane’s Froglet working group; I hope it is still functioning. I haven’t heard, perhaps because I indicated that I wasn’t in a position where I was able to keep travelling and doing things for free. This was a problem for me throughout the research and advocacy period, where I felt divided, I wanted to advocate and share my knowledge, and I also wanted to protect my intellectual property and hoped for some recompense for my time and expertise.

Early in 2014 NSW OEH commissioned me to provide some interim habitat guidelines for the Sloane’s Froglets at Thurgoona which I prepared and they published as a little booklet. I was unwilling to prepare the booklet. Firstly, I hadn’t analysed all my results

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2 S28 is that section which requires approvals for activities that significantly affect the environment.
and it seemed inappropriate to put out a booklet when you know that within a year there will be a much better scientific basis to the information in it. Secondly, I wanted to include some case study information about how people have succeeded in encouraging Sloane’s Froglet in their backyards or paddocks, but that wasn’t incorporated. It was never clear to me who the audience for the booklet was intended to be. Thirdly, I was concerned about the static nature of a booklet, the knowledge we have about Sloane’s Froglet is very basic, and there is so much we still don’t know about it – questions about its mobility and the importance of the landscape in between wetlands and also about how its life story relates to its use of habitat particularly worry me. A booklet makes it appear that we are knowledgeable and can act in an informed way – I wanted a process of adaptive management rather than an inert booklet. But at least the draft booklet was circulated and it seemed like there was some interest in the species and I know that as a result of that, for instance, the council became better informed, which might be useful.
Plate 5.3. One of my favourite seasonal wetlands in Thurgoona. This photo is taken in summer 2013. In winter the wetland fills and is home to a medium abundance of breeding Sloane’s Froglets as well as five other species of frogs.

Plate 5.4. Destruction of the seasonal wetland in Plate 5.3 in December 2014.
Yesterday (December 2014) I drove past another Sloane’s Froglet wetland with bulldozers in it, preparing the wetland to build a shopping centre on it. It was a beautiful wetland (Plate 5.3) with not only Sloane’s Froglets living happily there but a diverse range of other species. Then I looked more closely and realised that they had only cleared the wetland area of the block and not the rest of the vegetation (Plate 5.4). Why? I worried that they considered the presence of Sloane’s Froglet a threat and decide to put the bulldozer through before someone brought the problem to the attention of someone who cared. Although I don’t know if this was the situation here, this kind of behaviour is such a well-established phenomenon that it is addressed in policy. In NSW some species are considered “sensitive” and if it is the situation that they “are considered to be at serious risk from threats such as disturbance or exploitation” (Office of Environment and Heritage, 2013) then in public databases the geographic coordinates of their sightings are only supplied in a “denatured” format which generalises the locality (Department of Environment, 2009). I wonder at people’s motivations, but mostly I wonder if there is enough momentum for conservation of Sloane’s Froglet to persist?

Today (January 2015) a young woman from the Australian Government’s department that enforces the Environment Protection and Biodiversity Act 1999 (Australia) rang me (on my mobile phone – how did she get my number? and what a surprise!). She said it had come to the department’s attention that Albury City Council intended to put a road through an area that looks to her like a collection of gilgais that might well meet the determination for critically endangered wetlands; said she had heard my name somewhere and asked me to advise her on it. While this is far from the first time that someone has rung me to ask for free information about frogs and wetlands, this was the first time that someone in a position of power (an enforcement officer of a federal Act) has approached me with the idea that they might stop or change a development action which seems like a foregone conclusion. I wonder who told her about it in the first place, someone apart from me is now motivated to act! I wonder if my activities and advocacy have at last reached some critical threshold or gained some ongoing self-maintaining momentum?
Throughout the journey I published information in popular format (Knight, 2013a, 2013b, 2014), even though I felt some ambivalence in so doing. Reed et al. (2014) state as their fourth principle that it is important to deliver “tangible results as soon as possible that will be valued by as many of your stakeholders as possible” (Reed et al., 2014, p.341). While I did not consider that I had any actual stakeholders, perhaps Sloane’s Froglets do, and I was clear that the people making the decisions about development on Sloane’s Froglet sites needed to know where those sites were as soon as possible and potentially disseminating knowledge about Sloane’s Froglet habitat could benefit the species.

During this process and journey of advocacy I “transgressed” the science to society boundaries, an act that transdisciplinary theorists (Pooley et al., 2012; Schroll & Staerdahl, 2001) consider is fundamental to transdisciplinary studies. My actions integrated myself as an academic researcher with non-academic participants “in pursuing a new goal” (Pooley et al. 2012, p. 24) that was, to apply the knowledge gained, and conserve Sloane’s Froglet. The “action imperative” (van Kerkhoff, 2014, p. 145) that some consider integral to transdisciplinary research was also in evidence as I took my new knowledge from its research context into the broader realm of society.

The meeting of key Sloane’s Froglet stakeholders held in July 2013 demonstrates the power in people coming together to share knowledge and provided some momentum for new knowledge to become mobilised. This is a theme that is evident in the next chapter (Chapter 6) where I report on the importance of forums for knowledge exchange as indicated by several interviewees. The strength of bringing stakeholders together to learn new information is well established in the literature (e.g. Schusler et al., 2003). A validation as well as a “championing” process was also in evidence at this meeting as the NSW OEH and the ACC joined forces to host and present information at the meeting.

Political will and institutional processes which enable or constrain the use of new knowledge in environmental practice is a theme which occurs in the literature (Martin et al., 2012; van Herten & Runhaar, 2013). In the case for Sloane’s Froglet, although it was not surprising that political will to reconsider the parameters for development in the Albury region was lacking, I was shocked that the legislation developed to protect species and communities that are travelling towards extinction seemed to completely
fail in this situation (at least within the timeframe of this study). Perhaps this is less surprising when we consider that Australia has recently hosted its first extinction of a mammal for 60 years and the most recent mammal extinction in the world, the Christmas Island pipistrelle (*Pipistrellus murrayi*) (Martin *et al.* 2012). The extinction of the pipistelle is not linked with lack of knowledge both of its plight and how to remedy it, but with lack of “informed, empowered and responsive governance and leadership”, “institutional accountability”, and the need for “quick decisions” (Martin *et al.* 2012, p. 280).

The “moment of mobilisation” is another knowledge exchange theme which I will return to in the next chapter. There seems to be a moment in time when momentum is gained by new knowledge and a point when the knowledge itself moves from a sphere of being little-known to being understood or commonly acknowledged by a broader number of people, or even becoming “mainstream”.

And so to conclude...

When I started this PhD, I expected to provide facts, to provide some certainty about Sloane’s Froglet. Instead I’ve created models (pretenders to reality) of places that I, a human being, perceive little male Froglets might live based on my gestalt brought to life with hours, days, weeks spent in swamps recording detailed data and the help of a competent ecological research designer and a kind and communicative statistician. I thought I might then translate those clear, unchanging facts into information or knowledge that a department or a landholder
might enact quite easily and I would easily report on the straightforward factors that allowed that to happen (with the help of an excellent social researcher), but.... Quite often as I’ve moved across disciplines (ecologist to social researcher to philosopher) or roles (researcher to advocate) and ploughed my way through murky swamps (metaphorical ones, I felt quite at home in the real ones) I’ve felt like a fish pulled from the water and flapping helplessly on the bank haphazardly trying to return to its element or even more like one of those tissues that ends up in the washing machine, fragmented, disarrayed, in pieces. The complexity of it all, the soup of understanding, processes, formulas, expectations has astonished me. But my purpose, my hope, my intent has remained clear, to complete a PhD and to carry my mysterious Froglet from a place of obscurity to a place where it may be seen, even perhaps known, in a way that may be understood by scientists, practitioners, people that share their/its [wet]land and, honoured and cared for as another part of the complex “forces of evolution, natural and human history, political inequities, cultural contestation, biological and chemical processes” (Alaimo, 2008) in which we all live. For now I’m very tired of talking and I just want to complete my PhD and I hope and pray that my tiny, unknown, nondescript, quiet-calling Froglet can generate some interest and be allowed its place in the world.
**Thesis aim**: Provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach.

**Chapter 1**
General Introduction, thesis overview and literature review

**Aim 1**: Investigate the distribution and habitat of Sloane’s Froglet

**Chapter 2**
Where is Sloane’s Froglet?

**Chapter 3**
What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?

**Chapter 4**
Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?

**Aim 2**: Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focussing on the Sloane’s Froglet case study

**Chapter 5**
How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?

**Chapter 6**
What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)

**Aim 3**: Explore the foundations for and value of combining applied ecological and social research in one case study

**Chapter 7**
What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches? What are the outcomes of applying this framework to the Sloane’s Froglet case study?

**Thesis aim and aims 1, 2 and 3**

**Chapter 8**
Conclusion. Summary of results and recommendations for future research
Chapter 6  Knowledge exchange processes and constraints: insights from the case for Sloane’s Froglet
6.1 INTRODUCTION

In this chapter I respond further to the second aim of my thesis, to investigate the factors that enable and constrain the use of new knowledge in regional Australia focussing on the Sloane’s Froglet case study. I use the case study of Sloane’s Froglet to ask “what constrains and enables the use of new knowledge in environmental practice?” The question is focussed on the knowledge exchange processes between researchers and environmental practitioners, the latter limited to those undertaking natural resource management; nature conservation, biodiversity and threatened species management; and, environmental water management, undertaken within agencies and non-government organisations as discussed in Chapter 1 (Section 1.5).

Knowledge exchange is defined as “processes that generate, share and use knowledge through methods appropriate to the context, purpose and participants involved” (Fazey et al., 2013, p.19). I focus on knowledge sharing (and transfer) and knowledge utilisation, although factors influencing knowledge generation are also explored. I ask “What factors enable practitioners to find new knowledge or constrain them from finding it?” and “What factors enable practitioners to use new knowledge or constrain them from applying it?”

The questions explored in this chapter relate directly to chapters two, three and four in which I presented newly determined knowledge regarding the distribution and habitat requirements for Sloane’s Froglet. In keeping with the practice of many ecologists (particularly conservation biologists) an underlying assumption of my work was that by directing my research to answering distribution and habitat questions, some action could then be taken to reduce the threats to Sloane’s Froglet and ameliorate its condition in the “wild”. Habitat manipulation, whether it be reconstruction, recreation of fundamental processes such as water regimes, and creation, protection or connection of specific places is one of the forefront activities of agencies, organisations and individuals with an environmental agenda, so it could be presumed that knowledge of distribution and habitat would influence their decisions and actions. As Stankey and Shindler (2006) point out “[T]ypically, scientific knowledge of species, processes, and functions is regarded as the foundation of sound management policy” (p. 32).
The application of new ecological knowledge to environmental practice is dependent upon the knowledge becoming known as well as factors (for instance, political and funding constraints), that enable or constrain its utilisation. The relationship between scientists generating new knowledge and environmental practitioners (whether agents or landholders) sharing and utilising it is also an important factor in knowledge exchange. That relationship between scientists and environmental practitioners, and the factors enabling and inhibiting knowledge exchange and utilisation between them, have come under previous scrutiny in disciplines including conservation biology (e.g. Braunisch, Home, Pellet, & Arlettaz, 2012) and environmental policy (e.g. Brunner et al., 2005; Steyaert & Jiggins, 2007). In the case study I present in this thesis I bring the language and concepts of knowledge exchange developed by social scientists and educators (Fazey et al., 2013; Phipps & Shapson, 2009; Raymond et al., 2010) into the conservation biology and environmental practice field.

The chapter explores the Sloane’s Froglet case study and moves beyond to the broader context of knowledge exchange in environmental matters in regional Australia. The chapter does not review or analyse the plethora of decision-making and prioritisation processes or decision support tools used in environmental and natural resource decision-making. Rather, it considers processes and contexts around knowledge exchange and utilisation. The focus is the factors which contribute to environmental professionals finding new knowledge and how this new knowledge contributes to or influences decision-making (or not) and subsequent practice. The chapter is founded on the reflections and insights of the professionals. The methods for gaining and analysing these reflections are presented below, after a brief definition of key terms. The results are then discussed with reference to supporting literature.
6.1.1  **Implied meanings of knowledge and new knowledge**

Considerations of what knowledge is and how it may be defined or understood abound (e.g. Evely, Fazey, Stringer, & Reed, 2012; Nowotny, Scott, & Gibbons, 2001; Raymond *et al.*, 2010). Knowledge may be considered as “facts”, specific pieces of knowledge developed through a positivist approach, conclusively “supported” and based upon substantial scientific theory (e.g. Goldenberg, 2006); “information”, knowledge which carries intrinsically within it the notion of transfer or sharing with another human (after Evely *et al.*, 2012); “tacit knowledge” based on experience (Polanyi, 1997); “learnings” which suggest that the knowledge is built from a complex interactive process of expertise and experience (e.g. Brewer, 2013), “research results” which may come as the result of substantive hypothetico-deductive or inductive analysis of data; or a complex “knowledge production” enterprise such as that detailed by Gibbons *et al.* (1994) and Nowotny *et al.* (2001) which is inclusive of societal and scientific inputs and the exchange between them.

In this chapter, knowledge is considered to be evidence-based and expert knowledge, as well as experiential knowledge. Often the knowledge discussed refers to that developed and provided in Chapters 2, 3 and 4, that was based on “agreed principles or process of study, including reliability and validity” (Raymond *et al.*, 2010, p. 1769) and an evidence-based approach. My expertise developed during my research into Sloane’s Froglet would be considered knowledge, that is, expert knowledge. Raymond *et al.* (2010) consider that expert knowledge is qualitatively different from “scientific” knowledge and acknowledge that it

> [R]eflects a depth of experience, which may or may not have been derived through structured and formalised processes (e.g. Research or explicit use of reflection in practice). Typically experts have many years of experience and practice...Experts can often recognise patterns and issues that are not easily recognised by novices”  (p. 1768).

Experiential knowledge is also acknowledged and includes personal individual or local knowledge held by a specific group of people derived from experience (Raymond *et al.*, 2010). The importance of experiential knowledge has long been acknowledged and relates to the concept of “tacit knowledge”. Tacit knowledge was first been explored and defined by Polanyi (1967 in Polanyi, 1997). Polanyi begins with “we know more than we can tell”. (Polanyi, 1997, p. 136). Tacit knowing is based on experience;
conceptual and sensory information as well as images that together bring meaning. Polanyi considers that tacit knowing is at the basis of science as it provides for knowledge of a problem, gives the scientist the capacity to pursue the problem as well as the sense of anticipation for the “implication of the discovery arrived at in the end”. (Polanyi, 1997, p. 145).

The concept of “new” knowledge has the implied meaning of knowledge recently discovered or generated but also refers to knowledge that had been previously established, but was new to the participants in this study.

6.1.2 Knowledge exchange

The knowledge exchange terminology that I use to discuss my data relies heavily on Fazey et al. (2013) Knowledge exchange: a review and research agenda for environmental management. As well as dividing knowledge exchange into the three stages of knowledge generation, knowledge sharing and knowledge utilisation, Fazey et al. provide “implied meanings” of some of the terms used when discussing knowledge exchange processes (2013, p. 20). The following table (Table 6.1) is derived from their work and reproduces their “implied meanings”. The terms with their meanings are used throughout the remainder of this chapter. The term “knowledge utilisation” although used in Fazey et al.'s (2013) work is not defined; based on my understanding of the Fazey et al.'s (2013) work I offer the following: knowledge utilisation implies the application or trial of knowledge to a practical situation by practitioners.
### Table 6.1. Knowledge exchange terms and their implied meanings (after Fazey et al. 2013, p.20)

<table>
<thead>
<tr>
<th>Term</th>
<th>Implied meaning</th>
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<tbody>
<tr>
<td>Knowledge generation</td>
<td>Implies ‘new’ knowledge produced as an outcome of some form of process, but does not indicate the nature of the process. It does not explain whether the ‘new’ knowledge is discrete from, or a product of, past knowledge and experience</td>
</tr>
<tr>
<td>Coproduction of knowledge</td>
<td>Implies a process where knowledge is or can be produced through interaction with others, possibly with people with different perspectives and backgrounds, through cooperative endeavours and mutual learning</td>
</tr>
<tr>
<td>Knowledge transfer</td>
<td>Implies knowledge is portable, a linear direction, delivery and reception in a one-way process</td>
</tr>
<tr>
<td>Knowledge sharing</td>
<td>Implies a similar process to exchange (a multiple path process) but possibly with greater recognition by those involved of the value of the knowledge of those with whom they are sharing</td>
</tr>
<tr>
<td>Knowledge translation</td>
<td>Implies communication using a mediated language modified for recipients</td>
</tr>
<tr>
<td>Brokerage of knowledge</td>
<td>Implies disputed knowledge, deliberation between different parties, and possibly mediation through a third party to resolve dispute</td>
</tr>
<tr>
<td>Knowledge mobilisation</td>
<td>Implies eliciting or spreading knowledge to a wider range of recipients, possibly with the intent of increased application of knowledge</td>
</tr>
<tr>
<td>Transformation of knowledge</td>
<td>Implies changing the knowing or knower’s towards a different state or condition in the process</td>
</tr>
</tbody>
</table>
Aspects of knowledge exchange, including collaboration and advocacy, that are less explicitly discussed in Fazey et al.’s (2013) work also come under discussion in this chapter. Fazey et al. (2013) follow Gerrish et al. (2011) in proposing that effective knowledge exchange is about “the interaction of different types of experts and through this, the exchange of socially distributed, embodied, contextualized and skilful expertise” (Fazey et al., 2013, p.27). The concept of collaboration, as expressed here, is interwoven with knowledge exchange stages. Collaboration may occur at any of the stages of knowledge exchange and may be understood in environmental research and practice as scientists (social and natural), policy makers, managers and practitioners working together to generate, share and use knowledge (after Ryder, Tomlinson, Gawne, & Likens, 2010).

While Fazey et al. (2013) acknowledge that different values and beliefs “influence the flow and transformation of knowledge” (p. 24) they do not discuss the role of advocacy in knowledge exchange. The latter is essential to my discussion. van Herten and Runhaar’s (2013) analysis of the lack of action surrounding the conservation of the European Eel as presented in Chapter 1 (Section 1.5.5) is helpful in this context as it addresses some of the concepts and processes of knowledge exchange and advocacy. In their case study they view scientists and research institutes, as well as other stakeholders, as advocative. Advocative claims rest on both “facts” and “values” (van Herten & Runhaar, 2013, p. 1006) and so knowledge itself is used strategically according to the values of different interest groups. Advocacy is a process which may be interwoven with all stages of knowledge exchange.

Knowledge exchange may also be understood in the context of “wisdom”. For some, knowledge sits as one component within a framework of “data, information, knowledge and wisdom” (Bierly, 2000, p. 598) and the capability to “create, integrate and apply knowledge is critical” (Bierly, 2000, p. 596). Wisdom, then, enables the effective choice and application of appropriate knowledge. Effective knowledge exchange may be dependent upon organisational wisdom (Bierly, 2000). Wisdom has also been discussed in terms of “phronesis” or practical intelligence and judgment. This kind of practical wisdom arises from “intuitive insight, in people who are directly engaged with the world” (Shotter, 2014, p. 235). Rowley argues that within our “knowledge based economy” (Rowley, 2006, p. 251) with its focus on organisational
learning, knowledge and knowledge exchange have been explored and conceptualised while “discussion of wisdom is relatively absent” perhaps because it is “seen as being too elusive a concept” (Rowley, 2006, p. 252). Wisdom and phronesis take us beyond knowledge because they involve judgement.
6.2 RESEARCH METHODS

To explore the question “what constrains and enables the use of new knowledge in environmental practice?” I undertook semi-structured interviews with 11 environmental practitioners. These interviews provided insight and a depth of understanding about knowledge exchange processes around the new knowledge created regarding Sloane’s Froglet detection, distribution and habitat as well as regional perspectives on knowledge exchange between researchers and environmental practitioners more broadly.

6.2.1 Semi-structured interviews

Interviewing “provides a way of generating empirical data about the social world by asking people to talk about their lives” (Holstein & Gubrium, 2003, p.4) and is a widely used technique for conducting systematic social enquiry. Interviewing can be understood as an encounter in which knowledge is constructed and so “the interview is more than a simple information-gathering operation; it’s a site of, and occasion for, producing knowledge itself” (Holstein & Gubrium, 2003, p. 6). In the interviews undertaken for this research, participants (predominantly interviewees, but also the interviewer) reflected upon their experience during the interview process and the process itself provided context and opportunity for developing knowledge.

Interviews can be highly structured or more freely flowing (Holstein & Gubrium, 2003). I used semi-structured interviews to provide the data for this chapter because I was interested in the participants’ interpretations of knowledge exchange developed through their own experience and from their own perspective. Semi-structured interviews allowed room for personal experiences and different viewpoints to be explored.

I developed general topic areas and guiding questions in an interview guide (Figure 6.1). The interview guide was developed to guide and prompt me through the process of interviewing rather than being prescriptive. There were no formal questions that interviewees were expected to answer and the interviews were constructed as we talked about the research question.
The case for Sloane’s Froglet interview guide

I’ve generated new information about Sloane’s Froglet and I’m interested in what might influence that being applied. I’m more generally interested in how new knowledge influences decision-making in natural resources, or threatened species or water management, all of those things; how people hear about new information, how they source it and then whether it actually influences decision-making or not, what drives them to do that, so that’s the general area.

I thought maybe the best way to start would just be if you could tell me a bit about your role and what you do.

So then when you’re doing your threatened species management or water management and implementation, how do you source new information?

Can you give me an example?

Do you get surprises about what is happening?

What sort of knowledge do you use? E.g. Lots of work goes into modelling now – how do you perceive that?

Peer-review?

Do you pursue relationships with researchers?

Some research seems to get acted on and some doesn’t?

Can you give me an example?

Whether it actually influences decision-making or not, what drives that process?

What are the constraints to implementing actions based on new information?

Is it dependent on an individual pursuing action?

Adaptive management processes?

With Sloane’s Froglet it was a surprise to find these large extant populations in the wetlands on the Hume to Yarrawonga part of the river and around Albury and Corowa. How would you go about getting a change in actions to respond to that?

Figure 6.1. Interview guide for the semi-structured interviews undertaken with 11 participants discussing knowledge exchange for Sloane’s Froglet and regional environmental practice

Participants were chosen through purposive sampling as described by Flick (2007, pp. 29 - 30). The purposive criteria were: environmental practitioners experienced in the management of biodiversity (including threatened species), and environmental water delivery, and; environmental practitioners currently working within the region within which Sloane’s Froglet is distributed. The first criterion was limited to biodiversity and water management as these two fields are likely to have the most impact upon amphibian species which require both terrestrial and aquatic habitats to complete their life history.
The 11 people interviewed had varying levels of experience with and knowledge of Sloane’s Froglet (Table 6.2). Three of them had spent time with me in the field when I was undertaking research for the ecological characteristics of Sloane’s Froglet, and through that process had become knowledgeable about Sloane’s Froglet. Another four of those interviewed had exchanged information with me through conversation about Sloane’s Froglet and possible approaches to its conservation. Three of those had received early access to results in the form of written advice to assist the management of places and watering events or assist in prioritising management for Sloane’s Froglets. The remaining four interviewees had not been involved in the Sloane’s Froglet ecological case study but had received the published distribution report (Knight, 2013a) prior to the interview. These four interviewees were in positions that may be involved in Sloane’s Froglet management in the future, because they manage environmental or biodiversity programs for places where Sloane’s Froglet did or was likely to occur. Despite the familiarity of the participants with the Sloane’s Froglet case, the interview content tended to be broad ranging rather than focussed solely on Sloane’s Froglet.

3 In fact, one of these managers contacted me in January 2015 to disclose that Sloane’s Froglet has just been found in the area that they undertake water management on. I confirmed their call recording as a Sloane’s Froglet at the request of their consultant.
Table 6.2. Interview participant characteristics including experience with, and knowledge of, Sloane’s Froglet, whether working in an area in which Sloane’s Froglet is currently established as occurring, and whether they may be considered as a “practitioner-researcher”

<table>
<thead>
<tr>
<th>Participant group</th>
<th>Environmental water practitioner</th>
<th>Biodiversity practitioner</th>
<th>Both environmental water and biodiversity practitioner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experienced with Sloane’s Froglet in the field during the thesis research</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Discussed Sloane’s Froglet in the past as well as receiving written information</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Been provided with Sloane’s Froglet written information only</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Has a PhD or peer-reviewed publications as well as experience in environmental practice (practitioner-researcher)</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Works in an area in which Sloane’s Froglet has been established as currently occurring</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Total number of participants</td>
<td>4</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

This study aimed to gain insight from program managers and implementers rather than researchers. None of the interviewees considered their primary role to be research although some of them undertook research or had been involved in research activities in the past (for instance, four of the interviewees had PhDs and another had just co-authored a paper in a well-respected journal). These five individuals may be considered as “practitioner-researchers”. All of the interviewees were involved in environmental practice at some level, mostly in a position that they described as “manager” or “project officer”. None of them indicated their primary purpose to be policy development, but rather were involved in implementation or delivery of water for both government agencies and non-government organisations or in biodiversity or threatened species management within Landcare organisations, regional catchment management organisations or state government agencies.
6.2.2 Research ethics

I considered two facets of research ethics. Firstly, institutional ethical approval, related to research governance, was required prior to commencement of the research. To this end, I sought and received approval from the University’s Human Research Ethics Committee. I provided detailed information about the proposed research and methods and copies of information and consent forms, and I described how I would ensure that my participants remained anonymous. The protocol approval number is 2014/029.

Research ethics goes beyond research governance (McAreavey, 2014). One-off approval for a project does not constitute an ongoing ethical approach to the research. For the research presented in this chapter, interviews took place in the context of a small region in which many environmental practitioners knew one another. Interview participants expressed different attitudes towards anonymity. Some expressed their desire, both verbally and by email, that their identities and organisational affiliations be kept secret. They indicated their concern at potentially being personally identified if their employing organisation or the state that they worked in were mentioned. Other participants were not concerned about anonymity, and ensured their name and organisation were recorded during the interview. For them, it was important to have their contribution acknowledged. All of the interview participants provided written consent for their interviews to be used as data in this thesis and in any subsequent articles. In order to meet the requirements of the ethical research approval and the wishes of those that were concerned about their anonymity, no individual identities and only broad details of their organisational affiliation are provided.

6.2.3 Creating the data

For ten of the participants, interviews were undertaken in person. I either visited the participant in their workplace, or they met me at Charles Sturt University. One interview was undertaken on the telephone. Interviews took between 45 and 150 minutes. All interviews were recorded using a digital voice recorder.

The recorded interview was transcribed into a written document by a transcription company. Transcripts were provided as “verbatim” transcripts, neither “clean”, nor “strict verbatim”, the document included, for example <sighs> and <laughter>,

Alexandra Knight
interviewer interjections and broken sentences, but did not include the capture of hesitancy markers such as “uhms” and “ahs” (SmartDocs, 2014).

I used the computer-based, qualitative research package NVivo (NVivo qualitative data analysis software. Version 10, 2012) to manage the large quantity of data created through the interview processes.

6.2.4 Thematic analysis

I undertook thematic content analysis of the interview transcripts following the method of Guest, MacQueen, and Namey (2012). Thematic analysis involved close reading to identify and categorise phrases, sentences and paragraphs with similar thematic content. The labels (codes) assigned to the categories were developed inductively, that is the analysis was begun with “as few preconceptions as possible, allowing theory to emerge from the data” (O’Reilly, 2009, p. 104). In the first instance I allowed the words of the participants to reveal themselves as themes, without applying any external construct, apart from my own understanding and experience to the material. I then undertook a secondary analysis of the thematically arranged data using the knowledge exchange terminology from Fazey et al. (2013) (presented in Section 6.1.2, Table 6.1 above) to further define and differentiate aspects of the knowledge exchange process. Finally, as the data presented the opportunity to explore how different ontologies affect knowledge exchange, I reviewed my labels and the interview data to explore how participants’ values and beliefs were integral to their understanding of knowledge exchange and associated actions.

The depth of understanding, reflective quality, diversity of stories and applications and the willingness for participants to reveal their inner thoughts both delighted and astounded me, and I have a responsibility to adequately present their views while building a relevant and useful case study. Wengraf (2001) reports that such data richness inevitably incurs, and “data-reduction” is essential to development of a case or argument. In these circumstances it is important that “your ‘condensation’ remains as true as possible to its complexities, that you ‘represent’ your data as well as possible” (Wengraf, 2001, p. 338). It is also possible that the researcher in undertaking data reduction may miss details which are significant or provide deeper or contrary insight. Following Wengraf’s advice, I have not only aimed to present tendencies developed from the data, but also the exceptions to those tendencies.
6.3 ENABLERS OF AND CONSTRAINTS ON KNOWLEDGE EXCHANGE: INSIGHTS FROM THE SLOANE’S FROGLET CASE AND ENVIRONMENTAL PRACTICE IN REGIONAL AUSTRALIA.

Thematic analysis revealed five key themes related to the case for Sloane’s Froglet:

1. the way environmental practitioners understand or perceive what knowledge is, and how it is constructed, affects knowledge sharing and utilisation;

2. different vehicles and media for communication between scientists and practitioners are used and accepted in different ways, and influence the effectiveness of knowledge exchange;

3. environmental practitioners perceive knowledge generation and exchange as part of a process of continual learning and that process is considered as essential in underpinning monitoring and evaluation and adaptive management;

4. environmental practitioners hold values, and believe that scientists hold values, both of which affect knowledge exchange, advocacy and the development and use of influence in environmental practice; and,

5. contextual factors and processes such as political will, institutional processes and community interests and beliefs enable or constrain knowledge sharing and utilisation.

I present the data and discussion of each of the five themes outlined above in separate sections which are summarily entitled as: the way environmental practitioners understand “knowledge”; communication between scientists and practitioners: the vehicles for knowledge transfer or sharing; continual learning and adaptive management; values, advocacy and influence; and, contextual factors influencing knowledge exchange. In each section where possible I present specific Sloane’s Froglet related interview data as well as data from the regional context. Data from the interviews is presented as selected verbatim quotes which exemplify aspects of the theme. The participant providing the data is acknowledged by a code, for instance “R1” (simply understood as the first respondent who participated in an interview) which links the quotation to the participant without identifying them. I discuss the
themes in relation to the literature presented in Chapter 1, section 1.5. To conclude each section I provide a summary linking the theme to the case for Sloane’s Froglet.
6.3.1 The way environmental practitioners understand “knowledge”

People consider and understand what knowledge is differently from one another and they have different beliefs about what they consider knowledge is (Evely et al., 2012). While some may consider that knowledge provided from a scientific expert is simply ‘factual’, others may see that knowledge is constructed through a variety of mechanisms including the development of experiential knowledge and pattern recognition, anecdotal knowledge and culturally held knowledge (e.g. Raymond et al., 2010). My analysis indicates that participants had different understandings of knowledge, knowledge generation and sharing processes.

6.3.1.1 Evidence-based knowledge and other knowledges

Participants indicated that the provision of evidence-based knowledge was important in ensuring that knowledge could be utilised. A lack of evidence or perception that the knowledge was not substantially tested could lead to the knowledge not being utilised.

But willingness to take on new information, [name of organisation]--I guess it is conservative, but take a very analytical view of it, like what is the evidence there? What is that coming from? Is there any basis to this? Before you would actually go forward and do anything. R8

Expertise that was not encapsulated in a written form could be utilised by practitioners, but even when it was developed from a substantial base of evidence might not be considered “knowledge” at all until it was written down.

I ring up them and I say, “Well, just exactly what do they need and what do you think they want?” And they'll actually tell you stuff that they’re not prepared to write down. Because it’s not knowledge that, it’s still untested knowledge. R5

Evidence-based, written knowledge was felt to be important for knowledge utilisation by some participants, but others included other types of knowledges and considered those knowledges when making management decisions.

people are extending knowledge, extending beyond what’s proven, and extending beyond science and we just have to make a management assessment of that risk I suppose. R9

In the conversation following the excerpt above, the participant explicitly referred to knowledge other than that built by researchers following a hypothetico-deductive approach and the expertise associated with that, to knowledge that is built through
experience, anecdotal information, cultural knowledge and information that may have been deduced from one-off experiences. These sorts of knowledge rather than that based on empirical data or “expert opinion” are now being formally acknowledged as important in the decision-making processes that inform environmental practice.

*that sort of opens another kind of area that I think is developing in terms of information and knowledge at the moment, Alex, and that’s participative knowledge if you like, so there are more engagement processes and working groups and technical reference groups and things where people come together to bring their knowledge. Now they’ve always got to be there as part of the process but there is much more emphasis on public participation in groups of people working out both their needs from a human perspective, but you know, fitting in their knowledge around things. And so information then can be, you know, your scientific information but it might also be experiential information, anecdotal stuff that people bring to the table. Or cultural knowledge that people bring to the table.*

These kinds of knowledge were seen as needing validation.

*they all rest on different kind of sets of assumptions and validation processes* 

Fazey, Fazey, Salisbury, Lindenmayer, and Dovers (2006) assert the necessity of using these kinds of knowledge in conjunction with other approaches as “*experiential knowledge has limitations and there is much potential for people to generate erroneous thinking*” (p. 8).

6.3.1.2. Experiential knowledge

Experiential knowledge can be very powerful in sharing, constructing and mobilising knowledge and this is well established in the discipline of education (Beard & Wilson, 2006). There is also a well-established link between experiential learning and engagement with nature in the science education field (e.g. Drissner, Haase, Nikolajek, & Hille, 2011). Experiential knowledge was considered important by practitioners for knowledge construction, sharing and utilisation. Experiential knowledge is used by environmental practitioners both in their own decision-making (Pullin, Knight, Stone, & Charman, 2004) and in formal processes (Fazey et al., 2006) which enable knowledge utilisation.

Frog surveys undertaken with practitioners developed into understanding that was then used in their practice.
Interviewees discussed their practices of constructing knowledge “in the field” in relation to many situations and how building knowledge in that way is strongly connected with knowledge utilisation.

The [type of group] group just does this all the time, we’ll stand, 10 or 15 of us will stand at a wetland and look out over it and each of us will have quite a different bit of knowledge to bring into that wetland. ... as a result we all build up an amazing corporate knowledge together over that site. R5

The participant quoted above went on to speak about the power of making decisions “in the field” and how that practice leads directly to knowledge utilisation and implementing particular practices. This kind of process was considered not only powerful, but also essential to knowledge utilisation in some situations.

a very, very powerful way. And we’re dealing with Indigenous people and landholders, that’s the only way really. There’s no point sitting around a table. You have to go out there. R5

“In the field” discussions were not only useful for knowledge sharing and influencing knowledge utilisation, they also led to recognition of the possibility that current practice was ill-informed and were powerful in leading to changes in project or policy direction.

Because we’re doing the weeding and you’re pulling out pyracantha and it’s got little Thornbill nests in it, things like that, and you think, “Ah, geez. What the hell are we doing?” R10

In this case, the question that developed about the damage to native bird populations by reducing the vegetative weed cover was discussed by the group “in the field”. The outcome of the discussion was that the group learnt that small woodland birds are declining in Australia and so they developed a collaborative project with a Masters student to investigate the effects of the weeding they were doing on the little woodland birds. The new knowledge generated through collaboration with the student led to a subsequent change for the group in weeding practice. Raymond et al.
(2010) suggest that this type of local community knowledge as well as personal knowledge can be derived from experience of local ecosystems.

Others suggested that while making decisions “in the field” might be useful, it was impractical. Budget and time constraints would prohibit the approach.

*that would be extremely effective, absolutely, put them on the spot so they understand what’s behind it, it’s a good strategy if you had endless amounts of time and board members who were doing nothing else except being a board member.* R8

For environmental practitioners, the body of knowledge that they build up through time as well as through experience “in the field” can lead them to become experts at their work. Raymond *et al.* (2010) suggest that this type of knowledge “reflects a depth of experience, which may or may not have been derived through structured and formalised processes” (p. 1768). Participants expressed the importance of the experience that they had built over time through personal observation in enabling knowledge generation and utilisation.

*I know because I’ve got my eye in and I’ve seen it before, not because I’ve necessarily read about it. I’ve just seen it. And I’ve been out there when it’s gotten wet.* R5

*So I put forward a range of scenarios, that we might do under very wet, wet, and average, and dry scenarios with different wetlands and different in-river watering actions potentially... So basically, I suppose I’ve been working in the [name of river] catchment for 18 years, and so that knowledge enables me to throw up all the possible scenarios.* R4

It was also acknowledged that intuition and/or pattern recognition was a type of knowledge used in making practical decisions. This could be categorised as tacit knowledge, which Evely *et al.* (2012) define as “*that which cannot be articulated, but is acquired and exchanged by experience-based learning*” (p. 6) or Raymond *et al.*’s (2010) implicit knowledge which is defined as “[*K*n]o*w*l*edge that an individual is aware of but which they may not have yet articulated in a form accessible to others (orally or in written form)” (p. 1768).

*When I started in 1990 that supporting evidence was very small, we had to use the best available knowledge and research and gut feeling. I mean we’ve all got an intuitiveness about what needs doing by virtue of our life experience of*
Implicit knowledge was also considered important in driving institutional responses to issues.

*those people with that history and knowledge of that real perspective on what might make a difference and what can be a solid way forward, they’re the ones that get to be in the position of influence and decision-making.* R1

6.3.1.3. Uncertainty about the nature of knowledge

Uncertainty about the nature and state of knowledge and the apparent disagreement of ecologists about key concepts has been seen as a major concern for the utilisation of knowledge in environmental practice. This concern was reflected in the interviews, for example,

*in terms of having a targeted systematic ongoing approach to this game, we as a community, whether it be threatened species managers and people who are in the academic game, that consider themselves threatened species conservation biologists, we do ourselves no end of disservice. Managers are constantly faced with differences of opinion, lack of unity, it is just a, you know, one of the things I keep wanting to promote and see happen in our agency is that we have more leadership, we have more people at a high level of management that have *real knowledge* and feel empowerment to make good solid decisions.* R1 (my emphasis)

It is unclear from this statement whether R1, when speaking of differences of opinion, is speaking of the state of ecological knowledge or the values associated with different scientists’ positions or a combination of both. Nor is it clear what “real knowledge” is. The implication is that good environmental practice can only come from “real knowledge” understood by those in power. The participant appears to feel frustrated at working within a context in which the person highly values threatened species and conservation and cannot find clarity about the nature of knowledge, how colleagues value it, and its construction and application.

Similarly, in the context of water management in New Zealand, Weber, Memon, and Painter (2011) discuss the impasse that inhibits decision-making and remark that:

*[I]mplicit to this line of reasoning is the belief that allowing scientific experts to sort through the science without interference from the bias inherent in political battles will lead to objective, empirically verified, and authoritative conclusions grounded in facts* (p. 50).
This is not necessarily the case where different approaches to knowledge building (for instance, the use of different models exemplified in Weber et al.’s case) and different values associated with differing knowledges are held by the scientists involved. Where agreement is not made, decision processes are driven by “adversarialism and ultimately gridlock” (Weber et al., 2011, p.50), which prevent knowledge utilisation.

6.3.1.4. Perceptions of knowledge transfer and sharing

"Are there threatened species, like any listed threatened species on the site?" So someone has said to him contact me and I’ll be able to tell him that. And so I told him that he was looking at the biggest population of Sloane’s probably in the world....They were a little bit intimidated. R11

The practice of knowledge transfer with an implied meaning in which knowledge is portable, perhaps even inert or a “thing” (Evely et al., 2012) and that the process of exchange is unidirectional or one way (Fazey et al., 2013) continues to occur, and occurred frequently in the Sloane’s Froglet case. In the story related above a landholder rang to find out about threatened species on their land before developing it and was presented with an “intimidating” “fact”.

Some practitioners demanded knowledge transfer and saw knowledge and the process of knowledge exchange as straightforward.

there’s a lot of guff, I just want the key points, and I want to know how those key points apply to what I’m doing. I don’t know that it’s that complicated. R2

Viewing knowledge exchange as a unidirectional process where the owner or creator of the knowledge provides it to those who need it is, however, viewed by many as passé in environmental research and practice. The term “knowledge transfer” has been severely critiqued by some as it infers that knowledge can be neatly packaged and sent to “grateful recipients” (Davies et al. 2008, p. 189). The term knowledge exchange is now preferred (Pardoe, 2014, p. 3).

it certainly isn’t the case now but back then the idea was that a manager was somehow an empty vessel and the scientists would just come along and pour a whole lot of knowledge into us and we’d go off and do everything that they said. There was no kind of reciprocal, there was no real sort of reciprocal understanding and respect at the time R5

The concept of knowledge exchange as a multi-directional sharing process is well established in the environmental fields discussed by these practitioners.
We share that information because it’s based on hopefully a mutual regard for each other and also a mutual desire to see something good happen. But I’m an idealist like that so – but yes, there certainly are plenty of scientists who find it difficult to do that I guess. And yeah, I’m very much in the camp of well, if you don’t share your science well, what’s the point. R5

6.3.1.5. Collaboration and coproduction of knowledge

Participants placed great emphasis on collaboration and coproduction of knowledge: an emphasis which is also evident in the literature (e.g. Cullen et al., 1999; Roux, Rogers, Biggs, Ashton, & Sergeant, 2006). Coproduction of knowledge and collaboration throughout projects are seen as a key to effective multi-directional knowledge sharing (Ryder et al., 2010). Calhoun, Jansujwicz, Bell, and Hunter Jr (2014) link the greater utilisation of knowledge about vernal pools (and their amphibian populations) with “the flexible, solutions-oriented collaborations and trust between scientists and decision-makers (fostered over 15y) and interdisciplinary engaged research” (p. 11002).

While collaboration is thus generally acknowledged as useful, opportunities for collaboration within Doctoral research projects were limited as discussed in Chapter 5. However, in this PhD program, some fieldwork was undertaken with environmental practitioners working within the region. On this particular night,

[W]e went out and found nothing, like nothing and then came across that population there on [Name of street] Street, that was the “Woohoo” moment I reckon. Because then once we found that population, then they seemed to pop up all over the place, but that was like the first big discovery. R11

This experience of finding a large group of Sloane’s Froglet was memorable, both for me and this participant. This seemed to be a moment of generating new knowledge together about the distribution of Sloane’s Froglet and also about sites with high abundance. It provided us with some experiential knowledge that informed future decisions about where to search for Sloane’s Froglet sites. This site is one of those few that has received subsequent management attention for the benefit of Sloane’s Froglet (perhaps partially as a result of the experience in finding it together, as the participant has some influence on management).

Generally, collaboration and coproduction were discussed in relationship to positive relationships developed between researchers and practitioners, but there were
exceptions. Despite the predominant feeling that scientists and practitioners were working well together, some strong feelings about the academic-practitioner divide were expressed.

_The other barrier that keeps coming up again and again, and this is my personal opinion, is that — well two things. Scientists or academics particularly, because there are scientists and then there are academics and they’re quite different things. Academics, who produce papers and think they’re producing papers with a management outcome, often aren’t really because they’re not — how do I put it? Often this research has been done, and it’s not necessarily been done in consultation with an NRM agency or organisation. If you want them to accept the work you’re doing, and incorporate it into their planning, you need to have consulted with them at least part of the time anyway. Do you know what I mean? There’s no point coming to, in my opinion, coming to an NRM agency for example, and saying, I’ve done all this research and you need to do this, this and this for this species. <BANG> Here you go. R2_

6.3.1.6. _Moving towards mobilisation_

Participants indicated a view that there was a “moment of mobilisation” when new knowledge enters another space.

_I think I have always found with information that there’s a momentum so you build your momentum up and after a while it just sort of seems to, it just takes on a life of its own and you can watch it grow. And that’s when I think you know you’ve mainstreamed it is when that sort of starts to happen R5._

They spoke of this particularly in regard to the Sloane’s Froglet case in how it changed their individual endeavours.

_I think that this has had — the work on Sloane’s Froglet has probably had the most profound influence of anything in the thinking of how I manage all the [name of a place]. People ... jokingly refer to me as “the frog man” because I’m passionate about them R7_

They also spoke of mobilisation with regard to community values and actions.

_Well I think it’s created that interest. I know I can only really speak of my own local community with it and they love the stuff, ...and there’s now other people that are happy to continue on with it, continue with the theme and keep things moving, because it’s interesting to them._ R9

Participants also gave me advice on mobilising my new knowledge.

_don’t underestimate getting that little bit of information into the, in front of the managers and they’ll start — that information will start to become kind of_
mainstream and that’s essentially what you’re trying to do is take your little bit of information that you think is fabulous and great to you and you need to mainstream it. You need to get it into the mainstream of the debate and so it’s not unusual to be talking about it.

While there is considerable discussion around knowledge exchange terminology (Phipps, 2012), Fazey et al. (2013) provide an implied meaning of “elicit[ing] or spreading knowledge to a wider range of recipients, possibly with the intent of increased application of knowledge” for the concept of knowledge mobilisation.

Knowledge mobilisation may also be directly related to the concept of research impact, in particular, impact beyond academic debate, an outcome increasingly seen as a core activity for universities (Pardoe, 2014, p. 1). Tangible impact resulting from research is dependent upon conditions and contextual factors (Morton, 2015, p. 35). Research uptake, use and impact implies “engagement, activity and change” (Morton, 2015, p. 37). Morton considers that research impact may be better achieved by working closely with research users, but all the potential uses or research cannot be anticipated and so a process of emergence coincides with knowledge mobilisation. (p. 53).

While I have generally co-opted Fazey et al. (2013) terminology, my concept of mobilisation may be applied to the process of new knowledge entering a larger realm than it previously occupied, not just a wider range of recipients and may be related to diffusion theory where “innovation is communicated through certain channels over time among members of a social system” (Rogers, 1962, p.12 in Gerlach, Williams, & Forcina, 2013b). While the knowledge may not become “mainstream”, it enters a place where it may become applied or understood in a wider context. In the case of Sloane’s Froglet this happened with the intent of the knowledge generator pushing it forward, but it may not always be the case that knowledge is spread and reaches a point of mobilisation with that intent driving it.

6.3.1.7. Summary – understanding knowledge

Participants revealed that they had differing views of the nature of knowledge and knowledge transfer and sharing processes. Evidence-based knowledge, or knowledge built from scientific research, was considered important for utilisation and was highly valued. Expert knowledge, or knowledge built “through years of experience” important in recognising “patterns and issues that are not easily recognised by
novices” (Raymond et al., 2010, p. 1768) was highly valued and sought after by practitioners. Knowledge developed in the field and from years of management practice, defined as experiential knowledge, was considered important in decision-making and in knowledge becoming utilised. Other types of knowledge than empirically based scientific knowledge, for instance, anecdotal and cultural knowledge, were used in participative practices and these sorts of knowledge were expected to be validated. Finally, there was uncertainty about the nature of knowledge, particularly the relationship between scientific knowledge and values, and how knowledge constructed from both could be applied in practice.

Knowledge transfer was viewed as an “uncomplicated” one way flow, and also as a multi-directional knowledge sharing process. Knowledge coproduction and collaboration was considered important for knowledge utilisation.

In the Sloane’s Froglet case, the experiences I shared with practitioners in the field were reflected upon by participants and may have shaped their subsequent actions for Sloane’s Froglet. Mobilising and sharing the knowledge gathered was considered important by environmental practitioners, and in some cases the knowledge developed about Sloane’s Froglet had entered a larger realm and become utilised. In addition, “facts” about Sloane’s Froglet were transferred by environmental practitioners to the wider public.
6.3.2  Communication between scientists and practitioners: the vehicles for knowledge transfer or sharing

6.3.2.1  Electronic and social media

While newsletters and radio broadcasts were both considered useful media for revealing new knowledge, the internet, twitter, and the use of the search engine Google were considered fundamental to the processes of knowledge exchange. Participants recommended the use of social media.

*So with you, if you had a Twitter you would have, “Sloane Froglets found in 20 wetlands between Hume and Yarrawonga,” and then a link. And I’d go oh, I’d look at that and I’d go oh, I wonder where they are? So yeah, it’s really interesting, Twitter, for getting little bits of information out there.*  
R5

Acknowledgement has been made of the importance of web sites devoted to particular environmental research-practice issues (e.g. Sutherland, Pullin, Dolman, & Knight, 2004), and the need to develop them to share amphibian expertise within Australia has been raised (Shoo et al., 2011). While the use of social media (such as Twitter) for knowledge exchange is considered controversial (e.g. de Araugo & Bechervaise, 2014), some studies have used it as an investigative tool into the public’s understanding of environmental topics (e.g. Kirilenko & Stepchenkova, 2014).

The availability of information via the world wide web was acknowledged.

*really I just use Google. Like I’ve recently entered, it’s about dogs and the impact of dogs on wildlife and whether there should be new no dog areas or dog off leads there. You just Google the impacts of dogs on wildlife and twoosh.*  
R10

The implications of the change to using electronic media and particularly the dominance of search engines such as Google as compared, with for instance, searching for information in articles or books in libraries, were considered far reaching by the interviewees, impacting on the way people understood knowledge, the validity of knowledge and the influence that different types of knowledge have on practitioners thinking and subsequent actions.

*the passage of knowledge is changing so rapidly, or has changed so substantially from maybe a classic model of, you know, research and development and application and government agencies having a role in that ... I’m sitting in a library from knowledge moving out of the library and on to the*
internet and people just go straight there for their information. So it’s all very sudden and instant and accessible and that changes, you know, the validation process that was part of that sort of training, so people can access information that’s, you know, well substantiated or they can access information that was a thought bubble in someone’s head equally easily. And it can be equally influential in their thinking. R9

The use of the internet was seen as providing the opportunity for expertise to become widespread and was recommended as a valid platform for environmental knowledge exchange.

And I think now with technology and the internet I think it’s just so easy to get the information. When I started you really did need to be an expert in that field to know what information was out there. Like Sloane’s Froglet. I can put in that and I can probably get 90% of the literature that you know of from three years study. From five minutes of Google. It’s just bloody fantastic. R10

6.3.2.2. Peer-reviewed literature

Peer-reviewed literature was not viewed as a significant medium for knowledge transfer or sharing. It’s apparent irrelevance related to lack of availability to practitioners,

Papers are the forefront of course, for the latest in research because it’s gone through that peer review process and it’s papers which are “gold bullion” in carriage for supporting environmental water allocations, in theory. So in reality what happens is, we don’t have access to papers. R3

It’s a real problem, like practitioners, if you aren’t attached to an institution and you’re like us, where the projects chop and change, so we don’t tend to put value on subscribing to some of those more scientific journals, getting access to them is really hard. R8

Lack of time to read a journal article was also given as a reason for not reading articles.

I don’t have time in my workload these days, to really put time aside to do – to source articles, read them, note them, you know, sort of synthesise them in my head and get a handle on them. R2

Both lack of availability to practitioners and the lack of time to read journal articles have been established in the literature when discussing the use of peer-reviewed literature in practice (Arlettaz et al., 2010; Pullin et al., 2004).
Accessibility and time availability were not the only, or perhaps major constraint, on use. The time lag between knowledge generation and publication was also given as a reason for not using articles, as suggested by the following.

*Typically, we learn about new information prior to it being published. In terms of the valuable information that we use for our programs, typically we’ve found out about the work and know about the relevant information before it's actually gone to press.* R1

6.3.2.3. Networks and conversations

The importance of networks in knowledge sharing has long been established and advocated for in environmental practice (e.g. Cullen, 1990). Despite the importance placed by interviewees on electronic mechanisms for knowledge exchange, the use of their own networks and the conversations that took place within those networks were considered by all interviewees as the most important way that they found new knowledge. When discussing how they found new knowledge, all interviewees discussed the importance of conversations whether in person or over the phone and word-of-mouth transfer of information. Many interviewees expressed great confidence that these mechanisms would provide them with a sound and comprehensive knowledge source.

*I source new information through word-of-mouth. A lot, probably the most information I source, is through word-of-mouth.* R1

*What I’m more likely to do is go talk to someone who I know – already know is on top of the latest literature, to save me doing that. It’s not ideally how I’d like to operate, but that’s probably more likely what would happen.* R2

In some cases, even though a formal project was in place to manage a particular species, no formal knowledge transfer occurred between researchers and managers; word-of-mouth and networks played a crucial role in knowledge transfer.

*there was no formal approach I’m pretty sure, it was just word got around that "They found one" and I guess that we rely on some of our local people that we know, our networks, to tell us what's going on out there.* R8

Conversations were the key to knowledge exchange.

*It’s the individual conversations that I find really significant.* R5
In this context the ability of managers to approach researchers was considered vital to knowledge transfer.

And I think that’s really crucial, I mean because I will do is I’ll just talk to [name of head of research organisation], I’ll ring him up and because he’s so across all of the research and, ... I can just ring him up and download his brain about something, and that’s really crucial. R5

Surprisingly, with the emphasis placed on informal networks and casual conversations, there was very little mention of a perceived inability to contact the appropriate person. It was noted, however, that some people may feel awkward directly contacting a researcher.

Especially for people who don’t know [name of a frog researcher], people who don’t know won’t ring her up because they don’t know her. R5

In discussing their networks and the exchange of knowledge through them, environmental practitioners focussed on established networks and on contacting people that they already knew, even using networks that they had established many years before at university. They also suggested that these networks were in some cases quite small as there were few people with expertise within the field or regional area. The process of individuals sharing knowledge with individuals that they already know and accept may be akin to institutional practices where data used in biodiversity management is selected partly because it comes from sources that are already known and accepted by the organisation intending to use it (Gerlach, Williams, & Forcina, 2013a; Gerlach et al., 2013b). When considering the use of networks and conversations in knowledge exchange, the nature of the network, if it is closed or established, may be a constraint on the sharing and utilisation of new knowledge as well as an enabler of it.

6.3.2.4. Forums and knowledge exchange networks

Forums and other formal knowledge exchange networks were considered by participants to facilitate knowledge sharing.

Actually, I hosted a [name of place] research conference this time last year... we had about 20 different presentations – prior to that I had one a couple of years earlier – but it was basically to pull all the researchers ... it’s actually quite critical to what we’re talking about here – to pull together all the researchers, gave them 15 minutes talk time, five minutes question time, and I wanted them
to present to the audience, which was largely natural resource managers who we focused for the audience. R3

Forums such as this are now widely used and are often formed with both scientists and practitioners presenting (e.g. Oertli, Céréghino, Hull, & Miracle, 2009) or with them presenting together where there is an acknowledgement of coproduction of knowledge (e.g. Lefroy, Bailey, Unwin, & Norton, 2008). Forums were seen as opportunities to “touch base” and were also conceptualised as knowledge sharing between practitioners, for example:

this particular one is going to be a bigger one with a lot more people involved ... so lots of learnings, lots of advice to share. R6

When discussing the opportunities for knowledge sharing around Sloane’s Froglet a forum was suggested.

What if we do a frog summit? So I’ll tell them, do a frog summit. R11

All participants also discussed the importance of collaboration with researchers, including working with established researchers and research organisations and as well as using research students to not only construct new knowledge, but to communicate it. Participants also spoke of the generation of knowledge by the organisation itself, by using its own researchers to gain knowledge or by contracting researchers or consultants to answer specific questions.

But in a lot of cases, with the work that I’ve done, the new information has come about through we’ve sought it out, we’ve wanted this information so we’ve set up a situation where we’re gaining that new information, whether it be getting researchers in, contractors, doing the work ourself. R1

6.3.2.5. Summary – vehicles for knowledge exchange

Interviewees expressed that using established networks and having conversations were the most important methods for them to find new knowledge. They also indicated that forums and formal knowledge exchange networks were particularly important in enabling them to locate and understand new knowledge. Social media and the use of the internet were also understood as important media for knowledge exchange and considerations of the nature and value of the knowledge available in them were evident in the participants’ words. Peer-reviewed literature, although
understood as being a validating process for knowledge, was considered irrelevant to the knowledge exchange process.

In the case of Sloane’s Froglet, knowledge exchange has occurred largely though word of mouth, by using established networks, and through presentations at Landcare or other group meetings (as indicated in Chapter 5). Participants confirmed that theses were important mechanisms enabling knowledge to be communicated. Moving towards mobilisation as discussed in Section 6.3.1.6, when new knowledge enters a greater realm, may be dependent upon communicating beyond established networks. Practitioners did not indicate the importance of written information for the sharing of new knowledge. For Sloane’s Froglet an A 2-page brochure (Knight, 2013b) as well as the distribution report (Knight, 2013a) and most recently a booklet about habitat (Knight, 2014) are available, although no new peer-reviewed literature has yet been published. Two of the three are available in electronic form, which was indicated as important for knowledge exchange. The meeting held in July 2013 (and discussed in Chapter 5) may be categorised as a forum with knowledge exchange occurring between scientists, practitioners and other stakeholders as well as a validating process where an external and authoritative agency publicly supported the use of new knowledge about Sloane’s Froglet. This kind of sanctioning may be important for the new knowledge to be more widely adopted as suggested by the work of Gerlach et al. (2013a, 2013b). Participants suggested that use of electronic and social media as well as another forum would enhance knowledge sharing for Sloane’s Froglet.
6.3.3 Continual learning and adaptive management

6.3.3.1 Continual learning

Knowledge and expertise were not considered as something that could be complete by the participants, especially in relation to little-known species.

You do need to think that you don’t know it all but you do need to think that you’re an expert because if you’re not giving advice in an authoritative way it just doesn’t get listened to. So in terms of your Sloane’s Froglet advocacy you know that you don’t know anything. You know that you don’t know enough about it....But you know that you know more than anybody else and so the advice that you give is you’re the expert. You’re going to give us the best advice. But you may be wrong over certain things and you may change or adapt your advice as you go. You can speak fairly confidently that Thurgoona is a real stronghold and you have done a pretty extensive survey but it maybe that, once people start looking out for it, it may be somewhere else. R10

In this excerpt, R10 is suggesting that my expertise is essential to advocating for Sloane’s Froglet. The participant sees that society values the expert and that value allows me to have authority in the way that the knowledge is utilised. At the same time the participant is acknowledging that knowledge is constructed over time and that better knowledge may become available. The construction of knowledge over time is not an unusual concept. Knowledge grows.

because there’s always things being found or recognised or talked about, that haven’t been there before. It’s like we had the [name of place] orchid was another one that I’ve worked there for years and only in the last few years they found it and it became a big thing, and the Sloane’s Froglet was another one. R11

This process of continual learning was viewed as an essential part of knowledge exchange by other interviewees.

If you pretend you know everything and pretend that there’s nothing left to learn and pretend that everything’s going to go according to plan then you’re left with failing every time it doesn’t go according to plan and with no basis for which to come back and say, well actually I’ve changed my mind I want some more water or less water or we want to extend this. R6

For Sloane’s Froglet decisions that affected environmental practice at individual sites (as outlined in Chapter 5) were made before very much was known. As R10 points out
after the first year of my PhD we knew something of its distribution, but we didn’t know

*the habitat that it likes, the seasons, whether it was likely to move or just stay in the one pond, all that type of thing to make a sensible decision. But you can make good decisions that just get better is the way I look at it. If you’re open to that. R10*

For Sloane’s Froglet, understanding that knowledge may be “expert”, but is still being constructed and that we are in a process of continual learning may be essential to Sloane’s Froglets’ survival. The publication of the interim habitat guidelines (Knight, 2014) offers a paradox seated within this understanding of knowledge. The “best available” (Green & Garmestani, 2012) knowledge has been published in a limited and popular form, but very important factors to do with connectivity and mobility have not been explored. While the knowledge may be added to in the future, at this stage there is no proposal to research these factors. Within a framework of aggressive land development it seems likely that new knowledge is needed and an approach that incorporates ongoing monitoring and intervention essential.

### 6.3.3.2. Adaptive management and/or trial and error

Interviewees explicitly spoke of the importance of “adaptive management” to incorporating knowledge in practice. They also alluded to descriptions of learning both from management actions and monitoring and evaluation as “adaptive management”. Adaptive management is discussed in Chapter 1 (Section 1.5.3). It offers a framework in which new knowledge may be incorporated into ongoing environmental practice. Adaptive management involves “learning from implementation” and includes planning, implementing, monitoring and learning (Allan & Curtis, 2003).

All participants spoke of adaptive management, not surprisingly given that “[R]egional scale adaptive management has become part of the rhetorical landscape of natural resource/environmental management” (Allan, 2009). They expressed an explicit understanding of the components of adaptive management.

*I was in this lucky job whereby initially I was doing research, I then was responsible for extracting from that research what it meant for water management, and then I could actually pick up those recommendations and implement those into water management plans, and I also occupied the role where I was responsible for implementing those water management plans and*
identifying future research and monitoring. So, I was actually involved in the four quadrants of adaptive management, and I loved it because I really like research that has management outcomes R3

However, they also acknowledged confusion, subtleties and complexities about the way that adaptive management may be understood and applied.

Albeit very limited and lacking a solid research element, there's very much an approach of "Hey, we just need to start doing actions, so what can we do?" Which is fine, although I think – and there is, this is built into it, there does need to be a really solid adaptive management element to that, whatever your definition of adaptive management is. R1

No instances of adaptive management approach that might be considered active adaptive management “designed to test hypotheses” were reported for Sloane’s Froglet. In one instance, a trial and error approach or “evolutionary adaptive management” (Walters & Holling, 1990) example of action for Sloane’s Froglet was reported. Trial and error is not considered to be “adaptive management” by some researchers and advocates of the approach (e.g. Allan, 2009).

The opportunity to create habitat for Sloane’s Froglet was discussed in the context of trial and error.

I report against those guiding principles to see how I’m doing because – and creation of wetlands is one of them….we’ve made one, and I’m not really happy with it, but it’s a trial and we’ll wait and see. I know there’s a dam about 200, 300 metres further down and a lot of grass between. If, in a couple of years’ time, when it’s vegetated and we find Sloane’s Froglet there, whoopee doo, I’ve created another area, it’s a Sloane’s Froglet habitat. R7

One instance that might be considered passive adaptive management with a focus on “implementation of an historically informed best practice of policy, followed by review” (Allan, 2009) in very specific situation was provided by a participant. The practitioner was informed about practice for controlling predation of fishes on frogs. In this case, the practitioner also demonstrated that he or she had reviewed and evaluated a previous action at the site and was intent upon improving the practice.

then I’ve got a pipe from the creek that when the creek runs I can top up the dam. So if there’s a year where the swamp’s filled but it’s drying out, and the creek’s running, I can top it up and make sure they have the duration for the tadpoles to get through. So I’m lucky to have that sort of control over it, and I can also drain the dam, which I’ve tried to do, to reduce the population of
Gambusia and Weather Loach which may have negative...yeah impacts on the recruitment of the Sloanes and other frogs, and I tried that last year. I tried it the first year unsuccessfully pumping it out and then it flooded, and flooded again. And last year dried it out and limed the residual pool that had some Weather Loach in it that were jumping around with the lime and stuff. And the amount of waterbirds that were there eating all these fish in the last month as it dried down was unbelievable for such a small little dam. It was just 30-40 Ibis and 10-15 Egrets and stuff eating all this fish. And it got down to a, you know, I won’t be able to get rid of the Weather Loach because they just burrow into the mud, but all the Gambos died but then they were back again when it filled up, but there was a lesser population, so hopefully the Sloanes did really well in that past year. But it is handy being able to top it up from the creek. If it’s a dry year it might mean the difference between a failed breeding event and a successful one, so that’s the main aim to keep it full for a duration for the Sloanes. R4

New knowledge of Sloane’s Froglet was utilised and applied in two individual and specific practical situations with the intent of learning from the results over time. The particular approach reflected the interests and expertise of the individuals undertaking the activities. In these instances the approach did not include developing hypotheses and replicating experimental design, nor did it include monitoring and evaluation techniques, incorporating specific measures which would allow reflection on possible learnings and ways of applying learnings to future situations, but there was an intent to learn from the actions undertaken.

6.3.3.3. Incorporating new knowledge in adaptive management

Beeton, Bosch, and Ross (2003) suggest that adaptive management provides an opportunity for the creation and exchange of new knowledge as it allows environmental practitioners to “detect ‘surprise’ through systematic monitoring” and points out that “Lee (1999) regards ‘surprise learning’ as essential to expand the boundaries of understanding” (Beeton et al., 2003). However adaptive management and governance processes, even when organizationally embraced, are not necessarily enacted by agencies or practitioners. In this discussion about whether monitoring and evaluation or policy enabled or directed using new information about Sloane’s Froglet, the response was

Not to my knowledge, no. There’s nothing, yeah, not to my knowledge. If there’s something there, then it hasn’t been communicated down to staff at my on ground level. R11
In a response to a suggestion that an adaptive management approach to Sloane’s Froglet in Thurgoona would be valuable it was indicated that it would be too expensive.

*what we can afford to fund is just that first question. Are they increasing, staying, stable or decreasing? ...we just don’t have the money for really full scale research like that.* R10

6.3.3.4. Summary – continual learning and adaptive management

Participants indicated that knowledge was continually being constructed and created and perceived this as a process of continual learning. Environmental practice was informed by the present state of knowledge, but could be improved as knowledge was constructed and new knowledge added to the existing body of knowledge. Practitioners also acknowledged that sometimes new knowledge required them to change existing practice directions. All participants indicated an awareness or understanding of adaptive management and particularly saw its association with the monitoring and evaluation components of their existing projects or programs.

No one explicitly suggested that an active adaptive management framework might enable the utilisation of new knowledge for Sloane’s Froglet. Some participants described their attempts at individual efforts to undertake environmental practices that would benefit Sloane’s Froglet and those descriptions were placed within a context of improving practice over time.
6.3.4 Values, advocacy and influence

Fazey et al. (2013) remark that while it is established that “environmental management involves exchange of knowledge between people with different backgrounds and cultures” there are still many questions about “the way different backgrounds, experience, values and perspective affect [KE] (knowledge exchange)” (p. 28). They also acknowledge that individual “experience and values influence the way that people engage with knowledge and ideas” and the wider contextual factors that influence knowledge exchange (p. 33). Fazey et al. (2013) specifically suggest that researchers investigate how different values and beliefs as well as motivations influence the flow of knowledge.

In this section I present and discuss the values of individuals that participants described as being important to knowledge exchange. A value is defined as

an organised set of preferential standards that are used in making selections of objections and actions, resolving conflicts, invoking social sanctions, and coping with needs or claims for social and psychological defences of choice made or proposed (Rokeach, 1979, p. 20).

Values can serve as standards to guide activities and can also drive behaviour (Rokeach, 1979). This meaning is consistent with that of “held values” used in natural resource management literature (e.g. Seymour, Curtis, Pannell, Allan, & Roberts, 2010) who report (after Lockwood, 1999) that “held values” are ideas or principles people hold as important, which are generally abstract or conceptual and that guide action.

Practitioners spoke about their own values in regard to knowledge exchange as well as the environment. They also revealed their opinions and beliefs about the values that they perceived scientists to hold. The values that both researchers and practitioners held were seen as important in mobilising knowledge. When researchers combined their knowledge with their values they could become an advocate. Advocacy is situated within a broader social context where power and privilege influence choices and actions (Hatt, 2013). Practitioners did not explicitly address this social context, but made it apparent that the influence of a particular person could lead to knowledge utilisation.
6.3.4.1. Values of practitioners influence knowledge exchange

Participants provided insight into how their own values influenced knowledge exchange. Many of them expressed the responsibility they had in their employment to know everything about their area in order to do their work properly.

> look I’m just an open funnel. I just want to know the information whether it’s good or bad. R3

> the extent to which that’s pursued and undertaken is like I guess anything, is very much driven by individuals. R1

> we try to use the best information that we can. R11

> so I’ll go and do a thorough survey myself. R10

> It’s my job, but it’s probably I was the right person chosen for the job in that respect that I have a passion for most things I do. R7

Environmental practitioners considered that knowledge itself was something to get excited about and that it is desirable to share knowledge.

> it might be ten hours a year that each person on average is putting, and their doing that because they live nearby and they want to learn about their place. So knowledge is something that we share and get excited about. R10

> it really is I guess everybody’s desire to share that knowledge and to let people know, make the effort to let people know that this is a resource if you need it. R11

Curiosity was seen as a valuable element in knowledge generation.

> she was sending me pictures and saying, “What do you think this red stuff is,” on the side of the, on the soil. And I didn’t have a clue. I’ve never seen sulphatic sediment so I didn’t know what it was. And she sort of, she’s a bit of a sleuth. R5

Others expressed personally held values as motivators for the use of knowledge. In some cases this was a value associated with threatened species or biodiversity.

> I’ll manage for slime moulds where I know water management objectives – or what it needs. R3

> I mean the beauty of it is that you’ve got this amazing garden in there that does its thing and you look at it and say, okay, it’s struggling a bit and you kind of
add the missing ingredient and then you just stand back and see what happens and learn from it rather than controlling it, engineers are engineers because they want to control every little aspect and make it just the way they want and do exactly what they want. I think foresters and natural resource managers and the like do what they do because they just want to tweak and see it do its own thing. I really like that, it’s good fun, just got to hold your nerve when it gets a little scary. R6

It wasn’t a mandatory requirement but I guess I had a soft spot for frogs and I think it gives a good picture of wetland health if you can get an idea of what the frogs are doing. R6

In other cases, participants indicated that they valued action and the utilisation of new knowledge. Action was required, even in the face of uncertainty.

It’s better to do something than nothing. But it’s the Hippocratic Oath, at first do no harm. Yeah, very conscious of not doing harm first. R7

Participants’ values were at times revealed as an ethic or code for behaviour.

personally, I don’t think extinctions acceptable, I think we should challenge the system. R1

my working life’s all about doing dirty deals and you never get ideal. It’s always a compromise and it’s how good a compromise can you get is basically your starting point. R10

6.3.4.2. Perceptions of the values of researchers influence knowledge exchange

Practitioners also explicitly identified the values of researchers as important to the knowledge sharing process. In particular, practitioners discussed the benefit in having knowledge sharing relationships with those researchers who valued their knowledge being communicated and utilised.

What really works is, where people are intrinsically keen to get the outcomes or the findings of the research, particularly if it’s got a management outcome, to come back to the managers and say, “This is what I’ve found, this is important, this is what you could have as a management recommendation.” This is why, a couple of years ago I think, when I first learned of your work on Sloane’s Froglet was to say, “Okay, we’ve found these things, have you got an idea now of what habitat requirements there are of the species and could you have a go at writing a water management recommendation for us?” R3
In discussion, practitioners identified what they perceived to be the held values of the researcher. They also revealed their own values when they discussed the importance of the approachability and helpfulness of individual researchers.

> he’s very much focused on his work being used by people to the point that even you can ring him up him and say, well we’re trying to do this because the research says we should do this and we’re having trouble and he’ll say fine I’ll come out next week and help you with it and without no payments, no invoices, no contracts, no tenders, no nothing, ... things like that are just awesome. R6

Practitioner-researchers also recognised that their values and motivation to inform others was essential for effective knowledge utilisation.

> for years I just assumed that it’s an iconic species, it’s on the brink, somehow people know about it, somehow just by virtue of its iconic status and the fact that it’s so critically threatened and found in an amazing part of the world, somehow people both within and outside the agency, must just know what’s going on. But the reality is how would they if I wasn’t actively pursuing engagement with different groups in different forums, telling them about what’s going on? So yeah, I think a big and very important part of this game. R1

Researchers who did not openly share their knowledge were viewed as constraining knowledge utilisation.

> the first thing you should be doing is telling your local Landcarer or something, about information that’s been found for the area. I mean I know there’s lots of complications with that, but yeah, I think that’s really a vital piece of information for people and practitioners ... If you haven’t got that piece of information, it stuffs everything up. R8

The competitive nature of some researchers and organisations who consistently kept their knowledge secret was also considered to constrain knowledge exchange.

> often it’s quite hard to get information. Nobody is really willing to— I mean I can sort of understand that, but ..., it’s ridiculous. Everything is secret squirrel because it’s competing organisations and all that sort of thing, that can get quite tedious. R8

As well as commenting upon researchers who actively shared their knowledge, environmental practitioners spoke of their perceptions of scientists’ values towards their own work. Interviewees spoke well of scientists who held standards that were perceived as objective.
they’re giving you knowledge no strings attached. They’re not trying to get a--
the objective is to preserve the threatened species wildlife of Thargoona. It’s
not, “We want to limit the number of houses or…” So you need to come from
that. So that’s what academics have. Someone like me, I’m wanting to save
everything and I’m wanting to limit the houses so I’ve come from a more
involved perspective. R10

In this case I had to point out that I did actually have quite an “involved perspective”.
Even so, the value of the scientist’s position was reiterated.

But they’re more trusted. Even if they don’t deserve it. R10

The consideration of scientists’ values was reflected in how interviewees felt about the
relationships between scientists and practitioners. Practitioners felt that scientists
respected them and that trust had been built. Predominantly, the relationship
between the two was felt to have improved.

I think it’s really changed now. I think there is an enormous amount of, a lot
more respect for the manager from the scientists I think now because, and I
think that’s because the personal relationships have been built up, amongst
people I know anyway. The strong personal relationships get built up between
those groups and the trust gets developed. R3

In some cases participants strongly-held values translated into a moral code that they
felt should be followed by researchers. They indicated that researchers “should”
undertake sharing processes with the knowledge that they generate in ways other
than through peer-reviewed literature.

I would say if you’re being funded by the Australian Government and you’ve
decided that that’s the end of your job, and someone else can work out how to
incorporate it into NRM, I personally think that’s a little bit irresponsible, but
okay. Not all research has a strong management focus, nor should it, but I
don’t think it’s reasonable to produce your paper, or your publication and
publish it in a high ranking journal and whatever, and then sit back and go
okay, well you guys can just... R2

scientists have an ethical responsibility to ensure that they’re doing work that
makes a difference and talking about that work. R5

6.3.4.3. Advocacy and influence

Advocacy involves combining “facts” or knowledge with values and speaking out (e.g.
van Herten & Runhaar, 2013) (as discussed in Section 6.1.3).
Scientists who held values associated with spreading knowledge about their work were considered as advocates and perceived as important in the knowledge exchange process.

*That’s also a really interesting part of that story is the importance of scientists who are prepared to speak out and the importance of that, an independent academic who can speak out, because the public servant can’t do it.* R5

When considering the situation of potential damage to a large wetland with a high abundance of Sloane’s Froglets my advocacy was perceived as important to the outcome. I asked the participant how the local government would have found out that they were about to damage habitat of a threatened species “if I’d just like written my PhD and not talked to them?” The response was that

*They wouldn’t have I don’t think. Unless someone actually took that information to them, it’s not something that they seek.* R11

The development of an advocacy role was considered important in utilising knowledge where the outcomes of not using it were considered highly risky.

*One of the things that really worries me with this game is that we can lose a hell of a lot just through virtue of the fact that no one’s even aware of it going on and I think whether it be people at your own agency making more informed decisions, or the public being empowered to be part of the decision-making process, and just being aware and appreciating biodiversity issues, we have to be somehow engaging in various ways. I guess that falls into the realm of advocacy.* R1

Influential and established scientists were considered extremely important in advocating not only for biodiversity, but for the utilisation of new knowledge. In the following situation, newly discovered knowledge about sulphatic sediments in wetlands along the River Murray was considered a major threat to wetland health, as well as an issue needing consideration when planning environmental flows. Influential scientists assisted in the knowledge exchange process, the knowledge was brought to the attention of the media and politicians took an interest, resulting in major funding being made available to study and respond to the issue.

*this is where sometimes science needs help from other people to push the case. So we were trying to push it and nobody was really paying a great deal of attention. We were going to the Murray Darling Basin Commission I think it*
was at the time and saying, “This is a serious issue,” and blah, blah, blah and nobody was really paying a great deal of attention. R5

Through the use of personal networks a prominent scientist who was a member of the Wentworth Group of Concerned Scientists (Cullen, 2004) was contacted and taken to view and experience the issue in-situ.

and because he’s a media person and when he speaks the media listen to him......a bit like Richard Kingsford for instance or Max [Finlayson], the media will listen to them, Flannery and all the rest, he rang up the paper, or got in contact with The Australian or something and on that weekend we were on page 3 of The Australian about this issue. R5

In some situations where practitioners felt the need for an advocate, it was not always a scientist that was called upon.

There’s another woman there in the [name of government department] environmental delivery section called [name of person] and she’s a very, very clever lady and she knows how to work the decision making processes with the states and she’s also quite influential with [name of person], she’s able to present information to him in a way that will change his mind on things, whereas, it won’t change his mind when I go to him, because she’s working within the agency she’s very influential with him, so I often end up ringing her and feeding information to her and she will then go and on my behalf covertly if you like to talk around more senior people, she’s also very helpful with managing the other states. R6

Many of the interviewees spoke of the importance of passionate and committed individuals in ensuring knowledge exchange and utilisation. They perceived that the individual did not need to be a scientist, they needed to have a driving value that motivated them to undertake the role over years and at different organisational levels.

but my experience is that when things work well there’s a passionate individual involved and, you know, it might be the scientist, it might be a government agency person, then they might be the same and those examples or it might just be a landcare co-ordinator or community person or landholder. R9

Unlike the role of the influential scientist-advocate above, the importance of that person being situated within an organisation to drive knowledge utilisation was commented upon.

And other thing that I think is probably important for getting these sorts of projects happening, is having a champion within the organisation. R2
In terms of community groups, any community group I see has always got at least one passionate person in the group and generally it’s more than one. I think if you’ve got more than one in a group it’s going to live long like ours. R10

This kind of personal passion was admired and was seen as galvanising the community or agency around it and so allowing room for new knowledge utilisation.

I really admire people with the capacity to do that because the only thing they’re getting from it, you know, they’re just driven by passion and the only reward really is the outcome. R9

Personalities and networks, that drives a lot of business in the world I think, it does. And like personality of people, I reckon it does determine sometimes what goes forward and what doesn’t, unfortunately sometimes. I would concur with that, people are passionate about things, it makes everyone else excited about it so it’s good. R8

Practitioners also spoke of their own values and commitment in ensuring knowledge utilisation.

So there’s that sort of attitude I guess that I have, keep pushing, keep pushing people by showing them the positives of it. And I guess to turn around and say oh well, it’s just, you’re never going to make it perfect, or you’re never going to have a proper flood so why do it, it’s sort of like well, I don’t know. That feels like giving up to me. R5

6.3.4.4. Summary – values and advocacy

Participants spoke in strong terms of their own values around knowledge exchange, including their desire and responsibility to know everything about the area that they worked in. These values were supported by the values that they held about nature and the natural world, expressed as wonder and as an opinion that we should endeavour to protect it. Participants also expressed that they valued action even in the face of uncertainty.

Participants revealed their perceptions and expectations of the values held by scientists. They hoped that scientists would hold values that would enable knowledge exchange. They also expected a scientist to be objective, but at the same time to act and be involved with the application of their work. Advocacy was considered essential both to knowledge sharing and knowledge utilisation. Participants reported upon both scientists and non-scientists as advocates. It is well established that values can drive behaviours and be motivators for action (Rokeach, 1979). For knowledge to become
more widely known and ultimately utilised, values expressed by environmental practitioners such as curiosity and enthusiasm for knowledge or a responsibility to know everything about their work need to be linked with the values of a scientist that allow or enable knowledge sharing and drive a belief by both parties that knowledge should be utilised.

Participants indicated a curiosity about Sloane’s Froglet and an enthusiasm for frogs generally. In Chapter 5 I indicated my willingness to advocate for Sloane’s Froglet. Combined these have led to limited actions for the benefit of Sloane’s Froglet as indicated in Section 6.3.4.2 where the practitioner asked me to provide watering and habitat guidelines and then applied the information to a management situation. Constraints other than those of personally held values appear to have limited application of the new knowledge for Sloane’s Froglet.

The lack of research into Sloane’s Froglet between 1958 and 2010 as well as the current limits to action based on the new knowledge provided by me may well reflect the social discourse of power (e.g. Hatt, 2013) and privilege which limits who can speak, in what form, and who is allowed to be heard. The role of power is often used to explain how gender, race and class inequities for humans are enacted (Weber & Messias, 2011) but may also explain how something like a small frog can be ignored. Sloane’s Froglet appeared largely forgotten until its listing as a threatened species in 2008, a process which allowed focus on it to become legitimised.

The social discourse of power may also partially explain the limited use of the new knowledge learned and disseminated through this PhD process. As Augsburg (2015) points out the transdisciplinary approach “challenges the university modus operandi of disciplinarity” and junior transdisciplinary researchers are intellectual risk takers who “transgress academic convention and, in so doing, can put their careers at risk if they are not sufficiently grounded or established in their own research programs” (p. 241). As a junior and transdisciplinary researcher, my findings sit less easily in the dominant threatened species discourse.

As well as the social discourse of power, political will, community and public interest and values, funding and resourcing availability, institutional processes and policy and legislation influence the use of new knowledge. These are discussed in the next section on external enablers and constraints on knowledge exchange.
6.3.5 **Contextual factors influencing knowledge exchange**

Nowotny *et al.* (2001) assert that science can “no longer be regarded as an autonomous space clearly demarcated from the ‘others’ of society, culture and (more arguably) economy” (p.1). Longino (1987) also reminds us that “scientific enquiry takes place in a social, political and economic context” (p. 62). Knowledge is “not produced at some remote ideal site and then transferred to ‘society’ to be adapted or shaped to some practical purpose” and as such it is contextualised (Nowotny *et al.*, 2001, p. 121). Knowledge exchange practices are also inevitably influenced by contextual factors. Nowotny *et al.* (2001) also suggest that these factors are so interdependent and transgressive that “they have ceased to be distinctive and distinguishable” (p. 1). Despite this perceived difficulty, in this section I describe some of the “external” or “contextual” factors that participants perceived affected knowledge exchange processes.

Participants spoke of external factors both enabling and constraining knowledge sharing and knowledge utilisation. External factors included political will, community and public interest and values, funding and resourcing availability, institutional processes and policy and legislation. They also spoke of some greater force or synergy that may enable action.

> With the planets align and the right politician or senior bureaucrat has funding and motivation and everything lines up then yeah, amazing what can happen. 
> R6

6.3.5.1. **Societal and community influence**

In the case of water delivery, knowledge construction was seen to be closely linked to the social context.

> I’ve seen the rise of, which I’m finding really interesting because I remember talking about this many, many years ago with very early advocates of it, is the rise of the social dimension to water. So it’s kind of become increasingly about that rather than the pure science or the pure ecology....R5

Knowledge sharing and ultimately utilisation was seen to be intrinsically linked to the welfare of society and important for societal wellbeing.

> It’s not about telling everybody your frog’s important. It’s about people believing that frogs in general and that wetlands and rivers are important in general because it effects their social, it effects their mental health.  R5
New and very specific knowledge utilisation was seen to be dependent upon the acceptance of a broader social attitude towards biodiversity.

And I find that really interesting....I’m convinced that the only way that we can make a change is to change social attitudes and if we can change the social attitudes your frog will be protected, you know what I mean? R5

Environmental practitioners focussed on threatened species management also spoke convincingly of the importance of the broader social context for knowledge utilisation.

if I think about this in detail, it all comes back to some dude sitting in a concrete jungle, eating a hamburger being totally disconnected from nature and being totally unaware or totally not caring about where that hamburger came from.... We live in a society that is disconnected, doesn’t value a lot of the things that I value in terms of biodiversity and the environment around us and that then drives a lot of the political will to resource and enact this game to a level that I would be happy to see resourced and enacted. R1

The knowledge sharing process was also understood to be influenced by specific community interest. The context around the Sloane’s Froglet distribution work was seen as a vital component in ensuring that the knowledge was shared and used.

And particularly if you’ve got something that you can show is a bit unique, like in Corowa for example, to say it’s a real hotspot for Sloane’s Froglet, it makes them feel important, it makes them feel like they, you know, that it’s worth something to them because it’s a bit unique to that neck of the woods. R11

Thurgoona is known as the Squirrel Gliders-Sloane’s Froglet place and people feel proud about that and start to look after them. Which I think that’s what the board--that’s where we want to head and I think we have pushed things that way and there is a bit of that ownership. R10

In this case the community is described as wanting to protect Sloane’s Froglet because it is unique and in their “own backyard”.

As well as the community having an interest in their own area and the biodiversity unique to it, they were considered to have developed a psyche which favoured action for some species over others.

they are in the public psyche, people see water birds, they’ve got a public appeal, you can show someone a water bird and they will go, “Fantastic, isn’t that cute.” You show someone a frog in a hand – we’ve all had the experience, half go, “Oh that’s nice, interesting,” and the other half go, “Eew,” or people just view frogs as bait, although it’s been illegal for 30 years. It’s just that frogs don’t have the cute cuddly syndrome within the public. R3
In these circumstances the community was acknowledged to be a driver in developing particular projects.

I’m there to fulfil milestones, meet stakeholder needs, and make sure we get good stuff done on the ground, and we’re going to do that by meeting community needs. So we’re doing what the community wants us to do, and by incorporating the best possible science and knowledge while we can. R2

We also had community members coming to us talking about all the new fish that they were seeing after the floods and things, so it kicked off an idea to then say "Well we should do some fish surveying and find out what species are around and maybe find out a bit about where this Southern Pygmy Perch might have come from" R8

And occasionally we get some left-field enquiries from landholders to do wetland watering on their place that we mightn’t have known if they’re wetlands before. So we add that into the mix, R7

In some cases community understanding of environmental and institutional processes was seen as hampering practice.

the community expects us to manage 100% of the ecosystem to its fullest ability but we’re given 5% of the water that used to sustain that whole ecosystem. I mean that’s a great return on investment if you had a 5% capital and demanded 100% at outcome. R3

6.3.5.2. Political will, funding and resourcing

All interviewees spoke of political willingness to resource or not resource particular projects as fundamentally important in enabling or constraining the use of new knowledge. They also spoke of a broader “political issue” of the concern or lack of it for environmental issues generally as fundamental to constraining knowledge creation, sharing and utilisation. Political will to adequately address and resource environmental practice, whether it was threatened species management or environmental watering was considered important in knowledge utilisation.

I actually think that this game has a lot to be proud of and a lot to feel hopeful for, and a lot to put on the table and demonstrate that we’ve gone from very little to a lot, we can make informed decisions and I think whether or not good decisions and good management is made, is a more broader political issue. So we can learn a whole lot of great things about Booroolong frogs or some other species, and have a good idea about right, we’re pretty confident the way we need to go forward and what information we need and what resources we
need. Whether we can achieve that, it's actually a much bigger broader political issue. R1

At this broad scale, participants also spoke of the need for greater expertise within Australia to inform environmental management, and the need for billion dollar investment by politicians in new research that they felt was needed to support the research, monitoring and evaluation and practice being undertaken.

Funding availability and the institutional processes required to access funding for new projects were considered a major constraint on the use of new knowledge. At times the need for new knowledge to fit into existing programs was seen as a limitation on its use, however organisations were willing to persevere in the face of lack of support.

you’re constantly trawling for opportunities and how we might be able to bring money in. I mean it sounds like it’s all about money, but it’s to bring funds here to do things is what it’s all about and the things that you do in biodiversity anyway, haven’t changed much in 15 years I’ve been working there. But the way you badge it changes all the time, R8

like at the moment [name of place] Landcare have a project they want to fund and they were hoping that our organisation would fund it for them, though the powers that be in our organisation think it’s contradictory to what we should be doing, so they are now seeking alternative funding for it. But we’re not so much helping them do it, they’re just taking it off their own bat and saying "Okay. We can’t get money from here, let’s look at where else we can get the money from" R11

Despite their perseverance, it was felt that they were unlikely to mobilise their idea in the context of existing funding arrangements.

the reality is though, if it’s contradictory to what the funding terms are, they won’t get it, it doesn’t matter how much they scream and holler, if it doesn’t meet the funding bodies requirements, they won’t get the money. R11

In some situations, funding and political will were not seen as a constraint on practice, and monitoring and evaluation processes as well as application of the knowledge developed had successfully continued over 20 years.

So yeah, we’ve been lucky. It’s kind of been a continual thing, if something winds down something else has wound up. And then something else has wound up, and the Commonwealth have continued to throw money, so that’s probably why we’re most fortunate, because we haven’t had any big gaps. R4
The political context was understood to influence other factors in knowledge utilisation apart from funding arrangements. In specific circumstances, such as providing water for the environment in drought conditions, politicians may have opposed particular knowledge utilisation, but legislation and institutional processes ensured that activities went ahead. In the situation referred to below the new knowledge that a vulnerable fish species had been located in a particular area enabled practice.

*we had local members and politicians jumping up and down, we had community jumping up and down about it, but at the end of the day we don’t make species go extinct, R3*

In many cases political will was seen as substantially constraining the effective use of new knowledge, the generation of knowledge and specific environmental practice.

*I just feel like I’m being told to go into a boxing match with the world heavy championship title holder and, “Oh, just before you go in there we’re going to tie one of your hands behind your back and see how you go.” R3*

*All of this is through, you know, a mire of physical and political and financial and other constraints. R9*

6.3.5.3. **Institutional processes enable and constrain new knowledge utilisation**

Institutional processes were seen to influence whether knowledge would be used or not. In some situations, they were seen to have a direct effect on the application of new knowledge, whereas in others they were seen to indirectly affect the application through, for instance, the complexity of a bureaucratic process or the number of agencies involved in making a decision.

In the case of Sloane’s Froglet, and as discussed in Chapter 5, the biodiversity certification, “biocertification” undertaken in Albury (Department of Environment and Climate Change and Water NSW, 2010) was held up as an exemplar of new legislation that would protect threatened species at a regional scale (Local Government and Shires Association, 2011) and so an improvement on the previous model of site by site impacts upon threatened species (Walker & Walmsley, 2008). As mentioned in Chapter 5, new knowledge regarding Sloane’s Froglets’ presence in Albury has not been able to be incorporated in the biodiversity certification, nor has biocertification been reviewed as a result of the new knowledge, even though new knowledge was
explicitly expected to be developed and currently many areas that Sloane’s Froglet inhabits are being destroyed.

*I think the hardest thing is when the new information actually contradicts the direction that you’re heading in. So that was a bit like the--we came to an agreement on the biocertification and then there’s this new information which says, “Hey guys. You needed to consider this as well.”* R10

*So I would have been hesitant, ... to then say, “Oh, sorry. We overlooked Sloane’s Froglet and it requires this and this and this.”* R10

you make promises that say to Council, to the Corporation, “Alright. If we enter this, if you do this, then you can put your houses here without actually having to worry about threatened species because we’ve already addressed it.” So just a few years later you say, “Hold on. Bad luck. It...” In some ways, the certification, although it did have that clause, I don’t think we were revisiting. That would be a major rethink. Like it was a deal that was done. And both parties had to live with it. So when there’s new information there’s one, it got a new phase because we missed something and two, what’s this going to mean to not only this certification but to other examples because, like I say, Albury was the example of biocertification.* R10

Gerlach et al. (2013a) explain that there is a tendency for institutions to exhibit “path dependency” when deciding which data is used in biodiversity management decisions. Gerlach follows Pierson and Skocpol (2002) in explaining that

*Once actors have ventured far down a particular path, they are likely to find it very difficult to reverse course* (Pierson & Skocpol, 2002, p. 695).

This may be because it is too costly to do so or the alternatives that were possible have become lost (Gerlach et al., 2013a). While Gerlach et al. (2013a) apply the concept of path dependency to the experiences of selecting data for biodiversity management, it seems that the concept could equally explain the institutional tendency exhibited in the biodiversity certification for the agencies involved to be unwilling to incorporate new knowledge in their planning mechanisms.

Some participants felt that their use of new knowledge was dependent upon the advocacy, aims and approvals of other agencies or peak bodies.

*if OEH came to us and said, hey, this is potential work that needs to be done on Sloane’s, we need to do this, this and this. We think your role in it could be this. Would you consider – can we get this happening, or can we keep it on the back-burner, then that would be the way it would happen.* R2
Institutional processes were perceived as being substantial constraints to the application of new knowledge.

there’s political, institutional constraints which are actually enormous. I actually think institutional constraints are probably the biggest problem and so they’re things like approval processes and non-adaptive bureaucratic processes, so they tie you up in tape, red tape and you can’t get things done, happening quickly. So if you want to get a wetland watered it could take you four months just to get the approvals. R5

Other environmental practitioners, while feeling that constraints were present, did not feel that they were a major impediment to knowledge utilisation.

Some of the internal management processes of [name of state government agency] can be a little bit frustrating, but I’ve found ways around that that doesn’t affect the project. The constraints are probably necessary to stop me from going off on weird ideas. I appreciate the constraints, put it that way, I’m not against them. They’re probably necessary, it’s governance. I’m very careful with the funds. No, I don’t think there’s a lot of constraints. R7

The lack of integration of agencies and the need for multiple approvals was seen as constraining practice.

it’s incredibly wasteful in terms of I spend a huge amount of my energy trying to get all the agencies going in the same direction that I want to go. R6

I’ve got a list of regional bodies and aquatic based sort of organisations that have got an interest. I think I’m up to 350 across Australia. That’s pretty substantial, you know. And there’s also a whole lot of different legislation involved of course, and all sorts of different agendas happening. The idea of integration just still hasn’t caught on. It just hasn’t caught on yet R5

When examining the case of the extinction of the Christmas Island Pipistrelle Martin et al. (2012) discuss the institutional factors that constrained the utilisation of knowledge of impending extinction and recommend that “processes that ensure institutional accountability must be in place “ (p. 279) and that decisions must be made quickly rather than delayed in bureaucratic processes.

Lack of communication between different parts of an organisation were also considered as constraining knowledge sharing and utilisation.

within organisations, there’s silos of information as well. ... but it never surprises me that one arm of an organisation does something and the other half
don’t even know, having worked in those sort of environments, it never surprises me. R8

Risk aversion by government and agencies was also considered a constraint.

it’s been my experience that people have become much more risk averse and I don’t think that’s going to change in a hurry. R5

The constraint of risk aversion by organisations was expressed particularly in relation to impacts on landholders or other third parties resulting from environmental water delivery.

Third party impacts downstream is probably the real reason and agencies unwillingness to deal with those and government’s unwillingness to deal with those. Once they’re dealt with so either governments decide that it is okay for them to have a measure of impact given that the existence of Hume Dam is protected these people from flooding all this time and they’re only really getting a flood back that they would have had previously or something like that, if government wants to make a decision they’re happy to go with making the third party impacts and no doubt they’ll eventually see someone in court and sort out what their obligations really are, if the government’s willing to do that then so be it. R6

The lack of integration of agencies is a theme that has been established as constraining knowledge utilisation in other cases. In the vernal pools case as discussed by Calhoun et al. (2014) “the fragmented regulatory authority at all governmental scales” (p. 11003) is considered to complicate responses aiming to protect the pools.

6.3.5.4. Summary – contextual factors

The societal context, as well as community values, were understood by practitioners to both constrain and enable knowledge generation, exchange and utilisation. The use of new knowledge was understood to be particularly constrained by political will and political will also influenced resourcing availability. In some cases institutional processes were not seen as a constraint on new knowledge utilisation, however, some participants viewed complex bureaucratic processes and the plethora of organisations involved in environmental practice as a significant impediment to knowledge exchange and utilisation.

For Sloane’s Froglet, while legislation and policy protect it, institutional norms may be considered as impeding its conservation. Unwillingness to change an existing direction
may be understood as “path dependency” (after Gerlach et al., 2013a) and new knowledge about Sloane’s Froglet’s distribution and habitat has not yet been applied in the environmental planning for the Thargoona region in a way that reflects the objective of the Threatened Species Conservation Act to “prevent the extinction and promote the recovery of threatened species” (“Threatened Species Conservation Act (NSW),” 1995).
6.4 DISCUSSION

6.4.1 The complexity of knowledge exchange processes

The environmental practitioners whose reflections are presented and discussed in this chapter indicated that knowledge exchange is a complex process and that many themes influence and interact to enable and constrain knowledge transfer or sharing and knowledge use. Environmental practitioners indicated that apparently straightforward factors such as the media researchers uses to transfer knowledge and the funding opportunities available all enable and constrain knowledge exchange. More fundamentally, the context in which researchers and practitioners are working and the external processes surrounding them affect knowledge exchange and utilisation. As well, practitioners’ own values and those of people working with them and their understanding of the nature of knowledge as well as acceptance of other people’s understanding of the nature of knowledge influence all stages of knowledge exchange.

This chapter represents five themes that the participants considered important in enabling and constraining knowledge exchange: the nature of knowledge; knowledge communication media; continual learning and adaptive management; values; and, external factors. I have separated those themes in order to present them, however they are interactive. For instance, the relationship between individual values and external factors such as societal norms is well established (e.g. Seymour et al., 2010). How knowledge is understood has strong relationships with concepts of continual learning and adaptive management and both influence and are influenced by the media used to share knowledge.

The complexity of knowledge exchange for the application of environmental knowledge has been examined theoretically (e.g. Evely et al., 2012; Fazey et al., 2013); as applied in broad situations (e.g. Gerlach et al., 2013a, 2013b) and in a number of case studies (Calhoun et al., 2014; Martin et al., 2012; Raymond et al., 2010; van Herten & Runhaar, 2013; Weber et al., 2011), which support and broaden the understanding of the five themes presented here. The Sloane’s Froglet case study contributes to that broader understanding of knowledge exchange by providing detailed insight into those five themes. Importantly, it calls directly upon the insights and reflection of environmental practitioners themselves, as people experienced in
knowledge sharing and enabling the use of new knowledge, to build understanding of processes that may benefit researchers and practitioners when they wish to apply or develop impact from their research.

6.4.2 Limitations of the method

I experienced a limitation to the research approach in that my existing relationship with many of the participants affected the interview process. I knew many of the interviewees, both through my Sloane’s Froglet research and through previous work roles I had undertaken prior to becoming a research student. It is not uncommon for social researchers to conduct fieldwork with friends and community members, and this may be considered in the light of an “insider” or “outsider” relationship with participants. Relationships are complex and as Kiritchenko and Voloder (2014, p.8) discuss that the distinction between insider and outsider is dynamic and “we can all draw upon multiple forms of identification, one can find themselves an insider at one moment and an outsider at another” (after Merton, 1972).

I found a limitation in the interview process in that many interviewees were aware that I had made a strong personal investment in forwarding the Sloane’s Froglet case. Because of this I found it awkward to directly ask them what should have been done or could be done to improve knowledge of and action for Sloane’s Froglet and so I am quite sure that some have opinions that weren’t expressed. Despite this limitation, the conversations reveal important considerations for knowledge exchange and utilisation.

6.4.3 Recommendations for future research

Fazey et al. (2013) have provided an exhaustive list of future research questions (80 in total) for the area of environmental knowledge exchange which covers topic areas such as “defining and conceptualising” knowledge exchange (p. 24), exploring its “efficiency and effectiveness” (p. 24) and the “role of power in influencing” knowledge exchange (p. 25) and these types of questions have also been explored in the literature cited just above. In adding to those questions and explorations, my recommendation is to consider that different methodological approaches to the questions will assist in building stronger and more useful understanding. In the case reported upon in this thesis, my own experience as a researcher-advocate, together with the insights of
environmental professionals, provide a rich picture of the complexities of new knowledge sharing and utilisation. I feel that the evidence here suggests that there is particular benefit in further exploring the insights of environmental professionals into knowledge exchange not only because of their role in utilisation, but because of their often deep knowledge of sharing and mobilisation processes linked with those parts of their professional roles dealing with collaboration and extension.

6.4.4 What are the implications of the knowledge built and shared in this chapter for the management of Sloane’s Froglet?

The knowledge built and reported upon in this chapter indicates that the generation of new knowledge itself about Sloane’s Froglet and its habitat is not sufficient for the knowledge to become mobilised or utilised. The development of a thesis, with the potential for peer-reviewed publications to follow, while it has allowed the research to be undertaken, may actually be irrelevant to the knowledge becoming utilised as reported in Section 6.3.2.2.

The implication developed from the themes presented here is that for new knowledge of Sloane’s Froglet to be utilised, the ecological knowledge would need to be supported by a value-laden approach that generates advocacy, preferably with the assistance and support of an influential person or persons and with the validation of an established and respected organisation. In addition, the inclusion of environmental practitioners and potentially other community members or stakeholder groups in a collaborative approach to knowledge generation and the acknowledgement of their experiential knowledge would be essential for the utilisation of new knowledge about Sloane’s Froglet.
6.5 CONCLUSION

This is the last chapter exploring my second aim to investigate the factors that allow and constrain the use of new knowledge by environmental practitioners in regional Australia. The environmental practitioners who participated in this study have helped to build a complex and rich understanding of the nature of knowledge exchange, not just in relation to Sloane’s Froglet but also to environmental matters in regional Australia. Enablers and constraints of new knowledge exchange included perceptions of the nature of knowledge, media for communication, understanding of continual learning and adaptive management, values and institutional and political factors. These themes not only stood alone, but interacted with each other and the knowledge presented in complex and iterative ways.

In the next chapter (Chapter 7) I use a theoretical approach to explore a framework that supports and is inclusive of the applied and transdisciplinary nature of the work I have reported upon in the previous chapters. I call this framework “intentional ecology”.
**Thesis aim**: Provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach

**Chapter 1**
General Introduction, thesis overview and literature review

**Aim 1**: Investigate the distribution and habitat of Sloane’s Froglet

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<tr>
<th>Chapter 2</th>
<th>Chapter 3</th>
<th>Chapter 4</th>
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<td>Where is Sloane’s Froglet?</td>
<td>What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?</td>
<td>Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?</td>
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**Aim 2**: Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focusing on the Sloane’s Froglet case study

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<td>How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?</td>
<td>What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)</td>
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**Aim 3**: Explore the foundations for and value of combining applied ecological and social research in one case study

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<td>What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches? What are the outcomes of applying this framework to the Sloane’s Froglet case study?</td>
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**Chapter 8**
Conclusion. Summary of results and recommendations for future research

**Thesis aim and aims 1, 2 and 3**
Chapter 7  Little frog, big questions. A framework of intentional ecology.
7.1 INTRODUCTION

My research has been both applied and transdisciplinary, one body of work about Sloane’s Froglet and the context in which it occurs. The research approach and the thesis document acknowledge systems thinking, in particular that I am working within a complex social-ecological system (after Berkes & Folke, 1998), in which Sloane’s Froglet takes the prominent position, and in which the ecological and social aspects of the study are intertwined, rather than sequential. In this chapter I examine the research approach with its multiple foci on advocacy and knowledge exchange as well as ecology. In doing so I address the third and final aim of my thesis, to explore the foundations for, and value of, combining applied ecological and social research in one case study. I ask “What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional environmental research and practice approaches? I ask “what are the outcomes of applying this framework to the Sloane’s Froglet case study?”

The framework that I develop is a conceptual framework rather than an analytical framework and so includes “concepts, assumptions, expectations, beliefs and theories” that support and inform my research (Maxwell, 2005, p.39). As is expected with such a conceptual theory, as well as using existing theory, the construction of it has relied on my experiential knowledge and knowledge gained from previous formal studies (Maxwell, 2005). While I have termed this a conceptual framework, it also calls for action and provides specific advice and recommendations for how to act in future transdisciplinary studies. The completed framework as presented in Figure 7.4 includes theoretical and ethical foundations, actions, filters and constraints, and informing disciplines.

In Chapters 2, 3, and 4 I described and discussed the distribution and habitat of Sloane’s Froglet and linked the knowledge generated through the research with possible management actions. I used established empirical, hypothetico-deductive approaches in my descriptive analyses (Tabachnick & Fidell, 2013) and inferential multi-hypothetical approaches in modelling habitat (Burnham & Anderson, 2004; Johnson & Omland, 2004) to build an understanding of the distribution and habitat of Sloane’s Froglet in the belief that those approaches would provide an acceptable body of knowledge to researchers and practitioners alike. Management recommendations
are included in each chapter to present the research in a way that inherently promotes its application.

In Chapter 5 I described how my values and emotions motivated my research as well as drove my journey of advocacy. In particular, I hold strong beliefs based on values of the intrinsic worth of the non-human world and so Sloane’s Froglet right to continue to live *in-situ*; that we (humans, non-humans, ecological processes and interactions) are all interconnected and dependent upon one another for our well-being; and, that my research which could be applied to management actions *should* be applied. As Cullen (2006) points out “[S]cientists commonly hold strong values about desirable outcomes, and should be welcome in the political debates as society grapples with the various issues“ (p. 10). I also believed that undertaking advocacy did not and should not be perceived to affect the credibility of my science, a position much discussed and well-supported (e.g. Noss, 2007; Pooley, Mendelsohn, & Milner-Gulland, 2014; Shrader-Frechette, 1996). As Noss states:

*A conservation biologist can be an objective scientist and an advocate for the diversity of life and other normative values at the same time, with no contradiction* (Noss, 2007, p. 18).

In order to operate effectively as a researcher-advocate it is important to be aware of the dual roles and the values associated with them and to act within a reflective framework.

In Chapter 6 environmental practitioners describe how their own values as well as what they perceive to be the values of scientists influence the utilisation of knowledge. They also describe how external factors or filters such as community beliefs and opinions and political will influence knowledge exchange. For ecological research to be applied, the connections between the research process and the values and societal context are necessarily strong.

When starting my PhD, I sought a research framework that would explicitly acknowledge and support: application of research outcomes; the exploration of values and external filters; the importance of bringing different approaches and methodologies to questions or topics; and my emotional investment in the research. Personally held values as well as external filters are often codified into an ethical position. I sought a discipline that was founded upon an ethical position consistent
with my understanding. I was unable to find any one discipline that supported this approach and so have called upon facets of conservation biology, systems thinking and contemporary feminist theory to develop an approach which I term “intentional ecology”.

In this chapter I describe the foundations and framework of intentional ecology; discuss the Sloane’s Froglet case study in relation to the framework; and the ways in which the framework has benefitted the case study.

7.1.1 The nature of science and research

Bringing values and context to the work presented here reflects current discourses in contemporary philosophy of science; that science and the research process are not value-free (e.g. Latour, 1998; Longino, 1987), nor free of the societal context in which they are undertaken (Nowotny, Scott, & Gibbons, 2001).

Scientists are inevitably involved in science rather than being unparticipating observers (Midgley, 2003, p. 84). Latour (1998) frames this discussion in a comparison of “science” and “research” and distinguishes the positivist approach to science from a research that involves the participation of the researcher:

Science is certainty; research is uncertainty. Science is supposed to be cold, straight, and detached; ... Science produces objectivity by escaping as much as possible from the shackles of ideology, passions, and emotions; research feeds on all of those to render objects of inquiry familiar (p. 208).

Longino (1987) explains the import of contextualisation for our role as researchers when she states that:

[If we recognize, however, that knowledge is shaped by the assumptions, values and interests of a culture and that, within limits, one can choose one’s culture, then it’s clear that as scientists/theorists we have a choice. We can continue to do establishment science, comfortably wrapped in the myths of scientific rhetoric or we can alter our intellectual allegiances. While remaining committed to an abstract goal of understanding, we can choose to whom, socially and politically, we are accountable in our pursuit of that goal. (p. 61).

7.1.2 The meaning of “intention”

I sought terminology that would incorporate both the consideration of values and external filters (societal, institutional and cultural influences) as well as the active
application of research. I have chosen the word “intentional” to describe the research approach.

Intention is complex and goes beyond a discussion of value-free science into the realms of choice and action. Intention infers choice based on values and external filters as well as the ethical position developed from them. “Intentional” suggests that it is not random or by mistake that something is done – there is meaning to it. As von Wright (1971) in his work *Explanation and Understanding* explains

> Understanding is also connected with intentionality in a way that explanation is not. One understands the aims and purposes of an agent, the meaning of a sign or symbol, and the significance of social institution or religious rite. This intentionalistc ...dimension of understanding has come to play a prominent role in more recent methodological discussion (p. 6). (original emphasis)

Intention, then, can be linked with aims and purposes, meanings and significance. My methodologically plural approach has drawn on von Wright’s concept that intentionality does play a role in methodological choice. Intention is also inextricably linked with action. ““Action...normally presents two aspects: an ‘inner’ and an ‘outer’. The first is the intentionality of the action, the intention or will ‘behind’ its outer manifestations” (von Wright, 1971, p. 86.)

Actions undertaken in both my research and my advocacy have been situated within and defined by intentions. The methods then undertaken have been chosen with intent. Some of the intention is explicit, with many seemingly simple intentions. For example, I intend to reveal some of the nature of an effectively invisible frog. I intend to study habitat as I believe that habitat studies can reveal information that is useful for management. The Office of Environment and Heritage intends to take an interest in the research because Sloane’s Froglet is listed as threatened under the NSW *Threatened Species Conservation Act 1995* and as such it has an imperative to do so. I intend to model the frog habitat as that is an accepted approach to frog habitat studies.

There is also a range of unspoken or unclarified intentions. For instance, environmental professionals currently research and work within a framework that expects that knowing about habitat will lead to practice and change outcomes for individual species. This expectation rarely has adequate reference to the constraints on knowledge utilisation.
The Sloane’s Froglet case provides an example of those constraints. In the context of providing homes for an increasing population of humans in Thurgoona, Sloane’s Froglet habitat is being destroyed quickly and this is certainly not an isolated case of habitat destruction of a species. Is the intent to create habitat and so a space for the rare and little-known species in the face of a human population of seven billion people? The context for this viewpoint is that we can manage habitat for individual species without a consideration of the more complex social-ecological factors that are evident when considering the nature of the human population.

An alternative context to the one in which we consider habitat protection and reconstruction possible, one which considers the complex interactions between species, humans and the biosphere has been developed by Matthews (2013) who states that:

[Instead of continuing to put pressure on the biosphere, stopping short only at the point of endangerment of species, we should be seeking to optimise the populations of all species...Ecological optimisation of the human population would entail dramatic reduction, since our present population has been achieved at massive cost to other populations (Matthews, 2013).]

The intention embedded in the suggestion from Matthews (2013) (that we reduce the human population) is both controversial and threatening to current institutional practices and societal norms. The understanding exemplified in the concept of the complexity and interrelationships of the biosphere, however, is one that is required if a more systemic approach is desired. Understanding that immediate choices of action are embedded in larger context is essential to systemic understanding (e.g. Steffen et al., 2015). A systemic approach enables different research and practice, as discussed in for instance, Ison et al. (2011)

Intention is based in our ethics as well as filtered by institutional responses and dominant paradigms. Intent has to do with morals (what ought and ought not be), beliefs (what is held to be true) and actions. Intent is value-laden and so leads to ethical considerations.

It is reasonable for those who act and advocate as well as research to reflect upon, question and expose the intention they bring to their work, as it will shape approaches, methods, and outcomes. Doing so contextualises the work, and provides
opportunity for its application to be more clearly understood. It also exposes differing foundations and values that can help build understanding among collaborators, whether they be researchers or practitioners. Exposing the intention of research provides the opportunity for researchers to work within a discipline that exhibits ethical congruence with their approach.
7.2 INTENTIONAL ECOLOGY

7.2.1 Theoretical frameworks for intentional ecology

In his seminal article on the nature of Conservation Biology, a discipline which overtly addresses the application of science to environmental and conservation problems, Soulé (1985) states that “ethical norms are a genuine part of conservation biology, as they are in all mission- or crisis-oriented disciplines” (p. 727). The ethical framework of Conservation Biology is based on four postulates, that: diversity of organisms is good; ecological complexity is good; evolution is good; and, biotic diversity has intrinsic value (Soulé, 1985, p. 729) (my emphasis). Soulé points out that the last postulate is fundamental to conservation biology. Intrinsic value which situates worth in nature in and of itself is juxtaposed with instrumental value in which nature is valued according to its usefulness to humans. Soulé acknowledges that the concept of intrinsic or instrumental value is the basis for much discussion amongst environmental philosophers and indeed it is a distinguishing feature of different ecosophies (e.g. Hay, 2002; Norton, 2013).

The journal for Conservation Biology website currently states that

[T]he Society for Conservation Biology has the following organizational values. 1. The natural diversity of organisms, ecological complexity, and evolutionary processes have value and are necessary to support all species, including humans (Society for Conservation Biology, 2015).

It seems through this statement that Soulé’s original stance has been broadened to include processes as well as diversity and complexity, and to include other philosophies of value apart from intrinsic. This general statement offers a broad framework that provides some help in understanding the values environmental researchers might bring to their work, but does not assist them to deepen their understanding or learn to reflect upon their ethics, as one would hope of a discipline founded explicitly and genuinely founded on ethical norms. Conservation Biology does, however, provide an explicit motivation to undertake applied research as well as a strong foundation for the development of rigorous methods and the sound collection and use of environmental data.

Systems theorists provide environmental researchers and practitioners with some motivation and guidance for exploring values and ethics. For example, Midgley (2003)
demands that scientists consider their values and in so doing strengthen their work. He argues that

*marginalizing the exploration of values makes science more prone to ideological manipulation, not less so.*

*The crux of my argument is that the value judgments that inevitably flow into decisions on what to research are inevitably influenced by whatever macrosocial and economic forces exist in society* (Midgley, 2003, p. 92).

Midgley (2003) goes beyond argument to provide three tools within an intervention science framework with which to undertake research. He states that:

*[A]t the bare minimum, I suggest that an adequate methodology for systemic intervention should be explicit about three things: boundary critique, theoretical and methodological pluralism, and action for improvement* (p. 89).

He recommends questioning the boundaries of research and critically reflecting upon what is being included and excluded in each piece of research, because researchers are making decisions which are inclusive and exclusive and affect the direction of research. Secondly, Midgeley (2003) recommends that researchers incorporate multiple theoretical and methodological frameworks into their work. Finally, he recommends action. Midgley describes intervention as “*purposeful action by an agent to create change*” (Midgley, 2003, p. 77).

These three tools are useful for the researcher who sees her or his self as deeply seated and participant in applied research such as amphibian ecologists who are exhorted to become advocates and “*state what we think the implications of science are*” (Collins et al., 2009, p.xiii) and so are incorporated in intentional ecology. The researcher can consider these three tools: to reflect on boundaries, use multiple approaches and to act.

Feminist science (e.g. Longino, 1987; Subramaniam, 2009) which provides a critique of the objective nature of science, as well as contemporary feminist theory (e.g. Levy, 2013; Stephens, 2012) that builds on ecofeminist theory (as detailed in e.g. Buckingham, 2004; Merchant, 1980; Plumwood, 1993), also have something to offer the framework of intentional ecology. The need to reflect and to act could also be based upon an ethic that embraces

*the possibility that we are not distinct entities operating in isolation from the material world and that we are not separate from nature; rather, we are bound*
up and entangled in this complex and messy world of ours (Alaimo 240 -41) .
Our own health and the health of the natural environment are deeply interrelated and inseparable (Levy, 2013, p. 16).

The sense of interconnectedness between humans and nature has been expressed elsewhere in feminist theory, for instance Bennett’s (2004) discussion of thing-power materialism sees that it has the ability to “induce a greater sense of interconnectedness between humanity and nonhumanity” and so it might “mobilize the will to move consumption practices in a more ecologically sustainable direction” (p. 367).

This is similar to Midgley’s (2003) explanation of the stance of complexity theorists and systems thinkers that “everything in the Universe is interconnected” (Midgley, 2003, p. 84). In this case the scientist is more than a passive observer, and is an integral part of the world he or she observes.

Contemporary feminist theory adds to the recommendations supplied by Midgley (2003). Levy (2013) provides examples of scholars who bridge the gap between social and “hard” sciences and who

*inspire other feminists to consider deepening their scientific literacy. This is important because feminist theorists could mobilise scientific findings, particularly those that point to our interconnectedness, to put forward a case for an ethic of care and love towards the environment and toward other bodies (p. 19). (My emphasis)*

The quote from Levy is, in other words, another call to action based on values. Where Midgley (2003) calls for purposeful action, Levy (2014) is calling for the mobilisation of scientific findings. Levy goes beyond a call for action, to a case for an ethic of care and love, a call to our heart.

The call for care is a well established one, and is some cases is based upon an appeal to emotions which may reside alongside science, as promoted by Hay (2008) who writes

*[T]here needs to be room for the emotional response alongside the science of biodiversity, for the potentially powerful policy informant of the fellow-feeling that humans often have for the rest of life – what Wilson has called ‘biophilia’ (Wilson 1984) and what I have elsewhere described as the ‘ecological impulse’ (Hay, 2003) (Hay, 2008, p. 7).*

Jaggar (1989) states that emotion plays a useful role in not only the application of knowledge, but the construction of knowledge. Theorists such as Donovan (2006)
assert that an emotional response to a nonhuman is not enough to ensure an ethical response in humans, and describe how care theory may be applied to the treatment of nonhuman animals despite the critique applied to it. Animal care theory has been established as a “major vein of animal ethics theory” (p. 305) and Donovan (2006) proposes that humans respond to the animal world (if not to the biosphere) in a way that respects and cares for it while not imposing our voice on it. The third tool for intentional ecology is an emotion of care.

The theoretical foundations of intentional ecology include the disciplines of conservation biology, systems theory and contemporary feminist theory (Figure 7.1).  

![FOUNDATIONS: Theoretical frameworks that inform intentional ecology](image)

The intentional ecology framework has been constructed by seeking similarities and overlaps between Midgely’s (2003) work and the work of contemporary feminist theorists including Plumwood (1993), Donovan (2006),and Levy (2013) as well as the environmental philosophy of Hay (2008), and developing a combination of actions that are described more fully in Section 7.2.2 below.

### 7.2.2 The application of intentional ecology

So, how would one apply the conceptual framework of intentional ecology to applied transdisciplinary research? In this section I describe how a combination of four actions
when practiced constitute intentional ecology. In section 7.3 I provide an analysis of and reflection on how intentional ecology has been used in developing and undertaking the research and practice for the *Case for Sloane’s Froglet*, as this reflexive study may assist other researchers endeavouring to encompass such an approach.

Four actions, developed from conservation biology, intervention science and contemporary feminist theory when combined, constitute intentional ecology. Taken alone, they do not constitute an intentional approach. Intentional ecology requires *combining* the factors: reflecting upon our boundaries, taking multiple approaches, acting for improvement, and applying care to the natural world (Figure 7.2).

![Figure 7.2. Actions that when combined constitute intentional ecology](image)

1. Reflecting upon and being explicit about boundaries. Choosing and defining the “*right boundaries for a unit of analysis is a central problem in every science*” (Hutchins, 2010, p. 705). In reflecting on the boundaries placed upon research, researchers consider the limitations to the study question. For intentional ecology the boundaries include the filters of external factors such as institutional processes and societal norms (as discussed above and described in Chapter 6, Section 6.3.5). This action also requires actively reflecting, in an informed manner upon the internal values and ethics that are held and which drive intent.

2. Using multiple approaches. This action is developed in contrast with what may be considered the positivist tradition of methodological “monism” (von Wright, 1971). Multiple approaches may include using different methods based on inductive and deductive reasoning. It may also include considering different
knowledge construction approaches such as the coproduction of knowledge and the use of experiential knowledge.

3. Advocate and act based upon values. This involves intentional action based on knowledge developed through the research process as well as individually held values. It involves mobilising intention beyond the sphere of science and into the applied realm.

4. Acting with care for humans, non-humans, the biosphere and the interrelationships among them. This action involves applying care to the natural world. The action is based upon emotion as well as an ethical code discussed within environmental philosophy. It involves ensuring that researchers’ and their collaborators’ actions are based on care for the biosphere, non-humans and humans.

Environmental research and practice are generally filtered, enabled and constrained by political will, institutional and normative processes, research fashions and dominant paradigms, filters extensively explored by the environmental practitioners that I spoke with and reported upon in Chapter 6. The filtering processes might also be considered to be the ideologies or “macrosocial and economic forces” (p. 92) that Midgley (2003) describes when he asks us to make explicit the value judgements that we use to decide upon our research rather than marginal to science. Intentional ecology, too, is influenced by these external filters.

Stephens (2012, 2013) has also considered the complementarity between systems and contemporary feminist theory. She delivers five principles for project management which exhibit some similarities with the four actions for intentional ecology I present in this Chapter and which I have developed independently to her work.

Figure 7.3 presents intentional ecology, with theoretical foundations, actions, and filters.
Figure 7.3. Intentional ecology – foundations, actions, and filters
7.2.3 **Intentional ecology and transdisciplinary research**

Intentional ecology, with its emphasis on multiple methods and acting for improvement necessitates transdisciplinary or integrated research. Transdisciplinary studies or integrated research such as that presented in this thesis are usually situated within a collaborative framework, where ecologists and social scientists work together.

Clark and Stankey (2006) advise that

> [I]ntegrated research is about achieving holistic understanding of complex biophysical and social issues and problems. It is driven by the need to improve understanding about such systems and to improve resource management by using the results of integrated research processes.

> Traditional research tends to fragment complex problems, focusing more on the pieces of problems rather than the whole that comprises multiple interrelationships and interactions. The outcome is that a lot is known about the parts (e.g., recreation, fish, and wildlife) but relatively little about how they are interrelated.

> There seems to be general agreement that integrated questions must drive the search for integrated understanding, but tradition, inertia, institutional culture, budgets, training, and lack of effective leadership foster reductionism (at worst) or minimal degrees of integration (at best) rather than any substantial, sustainable effort toward integrated research (Clark & Stankey, 2006).

There have been many recent studies espousing the necessity for collaborative research as the realisation has grown that the complex social-ecological systems cannot be understood and manipulated through the efforts of one discipline alone (e.g. Lake, Likens, & Ryder, 2010; Pooley et al., 2014; Ryder, Tomlinson, Gawne, & Likens, 2010; Wilby et al., 2010).

The complex nature of many environmental issues has led them to be described as “wicked problems”. Wicked problems are those that are both difficult to define as well as complex to manage, where there is uncertainty over the consequences of actions and often contested expert views (e.g. Allan, 2009). Understanding wicked problems also necessitates the development of transdisciplinary studies. Ryder et al.(2010) suggest that many players from different disciplines and with different types of knowledge are needed to address wicked issues and the approach is invariably controversial (p. 825). Furthermore, the

> creation of interdisciplinary teams in an adaptive management framework is an essential process to identify research questions, create a ‘taxonomy’ of
available information and facilitate the incorporation of new scientific information as it becomes available” (Ryder, 2010, p. 825).

Norgaard (2008), in his discussion of the Millennium Ecosystem Assessment, notes the benefits of building understanding with collaborators.

[a source of considerable hope, emerged as well. A significant number of scientists learned how to deliberate together, combine their separate disciplinary frameworks, and form a collective analytical ability that was more than the sum of their individual contributions. Personal or experiential knowledge (i.e., the things scientists learn through being engaged, informed citizens, in their general education and participation in scholarly communities and from their field research) played an important bridging role in the deliberative learning process (Norgaard, 2008 p. 863).

In a case specifically related to amphibians, Calhoun, Jansujwicz, Bell, and Hunter Jr (2014) demonstrate the importance of “interdisciplinary and engaged” (p.11005) research and state that:

Flexible, solutions-oriented research and conservation approaches, trust and collaboration among scientists and decision-makers, and interdisciplinary, engaged research can create opportunities for the development of novel mechanisms for conservation (Calhoun et al., 2014, p.11005).

The research approach promoted by Calhoun et al. (2014) which explicitly involves decision-makers or practitioners within the research process is considered a key feature of transdisciplinarity (Zscheischler and Togga, 2014; Augsburg, 2014).

While collaboration has been considered a “core feature of transdisciplinarity” (Mobjörk, 2010, p. 869), transdisciplinarity may also be considered as an attribute of an individual (Augsburg, 2015). Little research has been undertaken into the experiences of individuals undertaking transdisciplinary studies, yet Augsburg (2015) notes that these individuals have as a foundation “a desire to improve society and to contribute to the advancement of the common good” (p. 233). Qualities of individuals undertaking transdisciplinary research such as “curiosity about and willingness to learn from other disciplines” (Bruce et al., 2004. p. 464) and the ability to look beyond one’s own disciplinary boundaries (Godemann, 2008) are consistent with the framework of intentional ecology.

Acts of collaboration alone do not ensure the success of the process. Not only are collaborative and transdisciplinary research and practice difficult to achieve, and
understanding between collaborators whether they be researchers or researchers and practitioners (as reported in Chapter 6) difficult to build, but other factors inhibit their effective application. For instance, in the case of sharing and utilising new knowledge, Gerlach, Williams & Forcina (2013a) argue that collaboration may affect data use in environmental practice due to “the desire to select data that are popular or sanctioned by fellow collaborators” and that where this is the case collaboration may not encourage a “constant and objective search for best available science” (p. 220). Within a transdisciplinary framework, whether it be collaborative or not, an understanding of intention can clarify processes and build stronger understandings.
7.3 EXPLORING THE APPLICATION OF INTENTIONAL ECOLOGY TO THE SLOANE’S FROGLET CASE

The research that I undertook for this thesis has been with the intention to generate knowledge, raise awareness, make action, and apply care. In this section I apply the four actions of intentional ecology to the Sloane’s Froglet case study to provide an example of their application; show the considerations that have arisen from the application of the framework; and, describe the benefits of the framework.

7.3.1 Reflect upon and be explicit about your boundaries

Intentional ecology requires awareness and articulation of the boundaries to the research undertaken. Exposing intentions which motivate action, whether the action is to influence management or to undertake applied research, can support a rich and complex science-society building of knowledge. As pointed out by Midgley (2003),

“A key means we have to protect ourselves from totalizing ideologies is critical reflection, understood as the subjective and intersubjective exploration of values as well as statements of fact. If we divorce the exploration of values from science, then a key weapon in our arsenal for identifying and critiquing totalizing ideologies has been marginalized” (Midgley, 2003, p. 92).

In the case of collaborative research, Pooley et al., (2014) affirm that “all researchers should consider the shaping effects of their personal and disciplinary values, motivations, and conceptual frameworks” (p. 29).

Boundaries may be imposed or promoted by external filters such as institutional frameworks and the availability of funding or internal values and interests. Boundaries may be made explicit by carefully defining the problem and area of study and looking outside of that area for new knowledge or alternate approaches. In the Sloane’s Froglet case boundaries associated with producing knowledge within the framework of PhD research were instantly established and included institutional norms regarding what constitutes a PhD as well as funding availability (e.g. Gannon, 2006). In addition several specific boundaries confine the study and these are discussed below.

7.3.1.1 Ecological boundaries

The ecological research presented in this thesis is developed from data gathered on calling adult male Sloane’s Froglets only. Froglets were surveyed in winter only within a study region of southern Australia. The research has provided foundational
knowledge of the species within a particular region and season, and knowledge of female and tadpole Sloane’s Froglets may be inferred from the knowledge developed about males, but the knowledge on females and tadpoles is not explicitly developed. There were sound scientific reasons for these limitations to or boundaries around the research, including the lack of knowledge of extant populations of Sloane’s Froglets in other parts of Australia and the difficulty in locating female Froglets and in identifying tadpoles. The knowledge developed within these boundaries may be applied to a more holistic management approach for waterbodies within the region and also inform future research and practice in other regions should Sloane’s Froglet be located elsewhere.

Other boundaries were delineated by choice. For example, I intentionally chose to research habitat rather than chytridiomycosis (which is perceived as the other major threat to frogs). The boundary that I placed around my research here was informed by Gardner et al. (2007) who strongly argue for the need for habitat studies; the influence of my supervisors; and in consideration that there have been few if any recorded frog mortalities due to chytridiomycosis in the kind of environment (hot and low elevations) the study region sits within. Finally, my choice of studying habitat was informed through my persuasion by what I believe is a dominant paradigm in conservation biology and environmental practice, that humans are in a position where they can protect, restore and reconnect habitat. I believe strongly that the knowledge I have built about habitat is both of good quality and useful for management.

If I were to undertake more research into Sloane’s Froglet I would aim to understand its mobility; its use of very ephemeral waterbodies; and, the importance of the spatial arrangement and connection between sites. These choices result from the knowledge built and shared over the course of the research. It was not a question that was evident at the start of the PhD period when so little was known. In fact, it was not until the third year of field studies, after I reviewed all my distribution records, that the importance of this became evident to me after an epiphany when reading

*If beings are bounded entities, what is the ground of their being and what lies between them? Is the space empty, insurmountable, riddled with conflict, or perhaps relational and bearing traces of God?* (Bird Rose, 2012, p. 131) (My emphasis).
as well as (Semlitsch, 2008) and (Cushman, 2006) for insights into connectivity and mobility for frogs.

7.3.1.2. Research and practice fads and favours

What some may consider both research and management “fads” have also delineated the research boundaries. For instance, as reported in Chapter 4, I was surprised that my results indicated spatial and, so potentially, behavioural factors as important, rather than vegetation within the waterbody. I had reviewed recent literature for my field work, and that literature was strongly focused on the influences of habitat, suggesting by omission that spatial and behavioural factors were not important. However, looking further back in the literature shows that behavioural investigations undertaken in the 1970s and 1980s (e.g. Mac Nally, 1979) found spatial characteristics strongly influenced by behaviour. When I discussed that research with several ecologists they suggested that “everyone was doing it back then” and while I am not suggesting that the discipline of behavioural ecology is a fad, the focus now appears to be on habitat studies. I believe this relates to the considerable set of values informing the notion that we can manage habitat and the associated funding availability for habitat research. If the paradigm is that knowledge of habitat will result in application of research results to benefit species, results focussed on behaviour are difficult. How would they be implemented? How do you change behaviour in a Froglet?

“Fads” or “fashions” are evident in environmental practice as well as in environmental research. As R1 commented in the interview undertaken when exploring knowledge exchange in Chapter 6:

*I think the threatened species game, it’s in terms of the approach that I think is applicable or the approach that I think is valuable to achieving successful threatened species management, comes in and out of favour. So there’s been – so for quite a while, there was a push to have very targeted planning and very – and funding of very specific targeted research and management to try and benefit threatened species, and then for various reasons, there was a flow away from that to a more broader landscapey type approach to biodiversity management, which meant that in terms of having a targeted approach to threatened species conservation, there was reduced funding and motivation for it in a lot of respects. I think in our agency at the moment, there’s a trend back to having a very targeted specific approach which is good. R1.*
Both of these “fads” or “things in favour” may be considered as external filters or societally developed contexts that influence the practice of intentional ecology.

7.3.1.3. Social research

As with the choices made when studying the ecology of Sloane’s Froglet, boundaries are also evident in the social research undertaken. The case study material presented reflects the state of advocacy and knowledge exchange in regional south eastern Australia. The strong links between the themes that were inductively revealed in the analysis of the material and the concepts presented in the reviewed literature suggest that the discussion has a broader application. It also suggests that those researching knowledge exchange practices could benefit from exploring their own boundaries, and spend more research effort in collaboratively building understanding of effective knowledge exchange activities with environmental practitioners.

The consideration or reflection upon boundaries presented here has revealed some of the external factors that have enabled and constrained the research, and the choices made and allowed the formation of recommendations for future research directions.

7.3.2 Use multiple approaches

As discussed in section 7.2.3, intentional ecology necessitates methodological pluralism and a transdisciplinary approach.

7.3.2.1. Ecological methods

In this thesis I have used established ecological methods to the study of distribution and habitat of Sloane’s Froglet in an attempt to construct a picture as close to a perceived objective reality as possible within specific acceptable research boundaries. In line with this approach I developed hypotheses and predictions as well as undertaking a modelling approach which allowed for multiple competing hypotheses and inference, designed a method for field research, gathered data, analysed data and presented it for discussion.

Intentionally, I left my data untransformed as much as possible, an approach which is established (e.g. O’Hara & Kotze, 2010; Keil, 2013). This allowed me to present information that may otherwise be difficult for managers to interpret. I used well-established statistical approaches that allowed for the use of untransformed data. I
also prepared models using generalised linear modelling because the approach is robust and convincing.

7.3.2.2. Social research methods

In approaching my experience of the case for Sloane’s Froglet and reporting upon environmental practitioners’ insights into knowledge exchange, I used an inductive approach as I wished to explore and understand the data, rather than explain it. This involved developing a cohesive story from very complex data and I felt the burden of reducing the knowledge built (particularly through the interviews) while still adequately representing the participants’ rich experiences.

That rich experience added significantly to an understanding of the nature of possible methodological plurality, as participants acknowledged and included knowledge built from experience and anecdotal evidence as well as cultural knowledge as important approaches to understanding. They indicated that continual learning was an important consideration. They also indicated that methods of knowledge production should be inclusive of coproduction and collaboration and that these were important considerations and frameworks for environmental research and management.

7.3.2.3. The transdisciplinary approach

I set out to use a methodologically plural approach, and to complete a transdisciplinary body of research in order to both reveal the complexity in the case for Sloane’s Froglet and to provide insight into the processes that may enable action for this species. This process has not been without heartbreak. Eigenbrode, O’Rourke, Wulforst...Bosque-Pérez (2007) point out that integrated research raises “conceptual and methodological challenges” that are disparate and difficult (p. 55). I greatly appreciated the assistance of associates with a wide range of research foundations and approaches. I believe there may be great benefit in the use of a collaborative team when crossing boundaries and gathering and mobilising processes from different disciplines. As (Norgaard, 2008) points out and Ostrom in her discussion of social-ecological systems reiterates “the ecological and social sciences have developed independently and do not combine easily” (Ostrom, 2009 , p. 419). Despite the difficulties, the transdisciplinary approach has been both exciting and illuminating and, I believe, is essential for addressing the ongoing challenges facing environmental research and practice.
7.3.3 Advocate and act based upon your knowledge and values

7.3.3.1. Advocacy

The practical application of sharing knowledge and acting for improvement that I developed for the Sloane’s Froglet case is evident in the exposé provided in Chapter 5 of the advocacy role I undertook. My values led me to an advocacy role and I would not recommend following this path to the extent that I did to every researcher, especially an early career researcher without a consistent income. The additional work impacted upon my ability to complete my PhD quickly and efficiently. Despite the effects on my PhD, I believe the role was essential, as R11 articulated “Unless someone actually took that information to them, it’s not something that they seek”.

The rich knowledge and experience of the interviewees that I report upon and discuss in Chapter 6 adds to our knowledge of how advocacy and action can be undertaken and so the research itself iteratively supports the approach of ensuring knowledge becomes utilised.

7.3.3.2. Adaptive management and knowledge exchange

The environmental practitioners that I spoke with provided great insight into how knowledge might be shared, mobilised and utilised and therefore how as a researcher I could “act for improvement”. The practitioners emphasised the field of adaptive management (Holling, 1978) which provides an opportunity for rigorous scientific approaches to be applied in an informed and considered manner (where contexts and intent are made explicit), and one where research results may not just be published in peer-reviewed literature, but directly applied.

Adaptive management provides a well-developed and tested framework for the application of new knowledge (if that knowledge becomes mobilised) as well as the opportunity to reflect upon boundaries and improve practice and research.

The field of environmental knowledge exchange (e.g. Fazey et al., 2013) also offers important insights for application of new knowledge. Knowledge exchange literature discusses the enablers and constraints of sharing, generating and building knowledge so that it may be utilised, although it has an underexplored capacity for investigating practitioners’ insights into the knowledge exchange processes.
Advocacy for Sloane’s Froglet and the, albeit limited, collaboration with environmental practitioners when undertaking the research have led to beneficial actions being undertaken for the species in particular situations. An adaptive management approach to looking after this species has not yet been fully instigated, perhaps because the knowledge around it has yet to become truly mobilised and enter a “mainstream” realm where it will be considered in institutional processes.

The important points that environmental practitioners raised and that are raised within the literature about adaptive management and knowledge exchange inform intentional ecology, and as a result of the research undertaken, I consider these as “informing disciplines” to intentional ecology (Figure 7.4).
Figure 7.4. Intentional ecology, theoretical foundations, actions, filters and informing disciplines
7.3.4 With care for the biosphere, humans, non-humans, and their interconnections

Finally, where does “care” lie? While I have exhibited some care for my colleagues and the broader environment throughout this journey, my deeper care rests with my Froglet. A clue to care is ensconced within Chapter 5 in which I express my delight in Sloane’s Froglet, in its beauty, its tiny nature, its seeming courage as it chirps and breeds in the middle of cold wet winters and in so doing provide my expression of Hay’s (2008) ecological impulse. The clue also exists when I refer to it as “my Froglet”. The possessive pronoun is not always used to indicate ownership of something. It may indicate association, and indeed I have been referred to as “that frog lady” or “oh you’re the Sloane’s Froglet woman” many times over the last five years. “My” may also be inversed and suggest that I am possessed by Sloane’s Froglet. I feel that I have become as close to Sloane’s Froglet as to any dear friend who has led me on a great adventure and broadened my knowledge and understanding, whose life I shared and wellbeing I worried about. Ultimately, I believe the “my” here refers to the heavy burden of care and responsibility that I feel for Sloane’s Froglet and its future and this has been a motivating force throughout my PhD.

7.3.5 The benefits of intentional ecology for the Sloane’s Froglet case

For me, as a student undertaking doctoral research, the benefit of having a framework that pushed me to consider the research boundaries and how my own values affected them; to reflect upon what research and advocacy actions to take; and, which drove me to consider and incorporate disparate methodologies was great. The application of the framework has encouraged and facilitated a transdisciplinary study which delivers applied research in a complex context. It has driven me to develop a thesis which is richer for its representativeness of the complex space in which Sloane’s Froglet is situated. It has also encouraged me to learn and apply very different methodologies and reflect upon the strengths of them all. For me, with my strong care for the natural world, intentional ecology has provided a theoretical framework in which my attempts to act and advocate based on my increasing knowledge are not seen as limiting my credibility, and my care for the species can be understood as a motivating force which does not harm or limit my ability to present sound evidence. Most importantly, intentional ecology has provided a platform and imperative for action.
As well as benefiting me as a researcher, the intentional ecology framework has provided benefit in the case for Sloane’s Froglet. Knowledge exchange and advocacy early in the development of the knowledge have had beneficial outcomes for Sloane’s Froglet. In particular, the early awareness of the context of its distribution contributed to an urgency for action. The feeling of care for this small species has been shared with the community and motivated them to learn about and act with care for Sloane’s Froglet. The Albury Conservation Company became aware of the situation of Sloane’s Froglet quickly and so a champion for Sloane’s Froglet that could support both it and me was established. Individual sites were protected even as new knowledge was being created. Most importantly, the new ecological knowledge has not emerged alone, in peril of becoming a fad, but into a community that is partially knowledgeable and so partially skilled to act for Sloane’s Froglet.

7.4 CONCLUSION

I have developed a framework for applied, disciplinary research called “intentional ecology” based in the disciplines of conservation biology, systems theory and contemporary feminist thought. I have demonstrated how the framework can be used by describing its application to the case for Sloane’s Froglet. In so doing, I have found that the framework is strengthened by incorporating knowledge from the fields of adaptive management and knowledge exchange. I believe this approach provides hope for understanding complex social-ecological systems and applying that understanding, and so hope for a continued complex, dynamic, diverse and beautiful world.
**Thesis aim:** Provide new knowledge about the ecology of Sloane’s Froglet and explore the relationship between new knowledge and environmental practice using a transdisciplinary case study approach

**Chapter 1**
General Introduction, thesis overview and literature review

**Aim 1:** Investigate the distribution and habitat of Sloane’s Froglet

**Chapter 2**
Where is Sloane’s Froglet?

**Chapter 3**
What are the habitat characteristics of waterbodies occupied by calling Sloane’s Froglets?

**Chapter 4**
Which parts of the waterbody does Sloane’s Froglet use in peak calling periods?

**Aim 2:** Investigate the factors that enable and constrain the use of new knowledge by environmental practitioners in regional Australia focussing on the Sloane’s Froglet case study

**Chapter 5**
How is the case for Sloane’s Froglet (as I experienced it) relevant to questions of knowledge exchange and applied transdisciplinary enquiry?

**Chapter 6**
What constrains and enables the use of new knowledge in environmental practice in regional Australia? (Focussing on the case for Sloane’s Froglet)

**Aim 3:** Explore the foundations for and value of combining applied ecological and social research in one case study

**Chapter 7**
What framework or model can support my applied and transdisciplinary enquiry and so expand and complement traditional research and practice approaches? What are the outcomes of applying this framework to the Sloane’s Froglet case study?

**Thesis aim and aims 1, 2 and 3**

**Chapter 8**
Conclusion. Summary of results and recommendations for future research
Chapter 8  Conclusion
8.1 INTRODUCTION

This thesis describes a journey in which a case study of the ecology of a small and unknown frog informs and generates bigger questions about the ways that ecological knowledge is applied and contextualised in complex social-ecological systems. In this final chapter of the *Case for Sloane’s Froglet*, I provide a brief summary of the main research findings and recommendations for future research.

8.2 SUMMARY OF MAIN FINDINGS

The main conclusions from my research into the case for Sloane’s Froglet are summarised and discussed below.

8.2.1 Intentional ecology

Intentional ecology offers a theoretical framework in which the complex interrelationships between ecological research and the contexts within which it can become applied are supported. It does this by providing a basis for reflection; a call to action; an acknowledgement of care; and, the acceptance of the use of multiple methodologies which may be incorporated in transdisciplinary research.

Adaptive management and the insights of knowledge exchange research are important for connecting transdisciplinary understandings and the application of new knowledge.

Environmental practitioners are able to offer great insights into knowledge exchange and effective advocacy approaches. These insights include wisdom about the nature of knowledge; methods for communication between researchers and practitioners; the implications of internally held values, the filters of external factors such as societal norms; and, the interactions between them.

Advocacy based on newly generated ecological knowledge can be difficult and ineffective. Success in mobilising new knowledge may rely on the support of an influential person or organisation, the use of networks, the ability to extend beyond established networks, the ability to use new media, and be limited by a variety of external constraints including institutional processes.

8.2.2 What I have learned about Sloane’s Froglet

Distribution surveys undertaken by me and presented in Chapter 2 show that an extant population of Sloane’s Froglet occurs in southern NSW and northern Victoria,
congruent with within Australia’s Murray-Darling Basin and the Grassy-Box Woodland. This landscape, well documented as the most over-cleared landscape in Australia also has also modified water availability and movement. Adding to the pressures on Sloane’s Froglet is that in southern NSW, the population occurs predominantly in peri-urban areas that are currently undergoing more intensive settlement and urbanisation. It is likely that the documented decline in recordings of Sloane’s Froglet is a real reflection of the condition of the population and that the decline is related to landscape-scale threats.

Little was known about the detection of Sloane’s Froglet prior to my research and there have been some difficulties associated with its identification. In Chapter 3, I established that Sloane’s Froglets have a peak calling and associated breeding period in winter (June, July and August).

Sloane’s Froglet may not be detected during non-targeted amphibian surveys when it may indeed be present at a site. This may result from three factors:

1. it may not be calling during Spring, Summer and Autumn when the majority of frog diversity surveys are undertaken;
2. it is difficult to detect at these times, as the calls of other frog species mask it; and/or
3. surveyors do not recognize the call and are unable to correctly identify Sloane’s Froglet when in the hand.

In order to conserve the species it is important that parameters for its detection are clarified and made available to ecologists undertaking surveys and research that input into planning and management decisions. Detection probability analysis suggested that visiting a site three times in peak calling period is effective in establishing presence and absence of Sloane’s Froglets.

In Chapter 3 I established that Sloane’s Froglets use a wide variety of waterbodies, large and small, constructed and natural, permanent and temporary during peak breeding season. Vegetated littoral zones, aquatic vegetation, shallow water depths, gentle bank slopes and especially the presence of an adjacent ephemeral overflow have an interacting effect that correlates with Sloane’s Froglet occurrence in waterbodies.
Sloane’s Froglets were shown in Chapter 4 to use the very shallow parts of the waterbodies that they occur in. Sloane’s Froglets situate themselves within the waterbody, not on the bank. Sloane’s Froglets arrange themselves in the waterbodies in relation to other males of their species and other males of other species that are calling at the same time. Within-waterbody use is not just dependent on microhabitat availability but may relate to breeding behaviour. This suggests there is a complex interaction between resource use and inter and intra specific behaviour.

While not a formal finding from my research it would appear that Sloane’s Froglet is a dynamic and mobile species. Supporting evidence for Sloane’s Froglets’ mobility comes from distribution work in 2010, 2011 and 2012 and limited distribution surveys undertaken in 2013 (as detailed in Chapter 2) as well as my pilot study undertaken prior to the commencement of the PhD research in 2009 (data not shown) resulting in data for five years. My observations suggest that it moves between waterbodies within and between years (Plates 8.1 and 8.2).
Plate 8.1. A Sloane’s Froglet on the ground at the Corowa golf course in June 2013 (Joanne Diver)

Plate 8.2. A Sloane’s Froglet in the car park at Charles Sturt University, Albury (Ashlee Bowen)
8.3 RECOMMENDATIONS FOR FUTURE RESEARCH

8.3.1 Research for Sloane’s Froglet

If management of this Vulnerable species is considered to be the main driver for research into it, then I suggest that future research should be directed towards: increasing knowledge of Sloane’s Froglet distribution; establishing and applying an appropriate monitoring and evaluation protocol; the peri-urban context of existing populations; movement, connectivity and dispersal; use of habitat in non-breeding periods; and, life history.

8.3.1.1. Distribution and detection

As current knowledge of Sloane’s Froglet is limited to southern Australia, especially southern NSW, further distribution studies need to be undertaken in Victoria, northern NSW and southern Queensland to locate any extant populations of Sloane’s Froglets. Such studies could confirm the extent of any population decline and provide a sound basis for intervention efforts.

Surveys in southern Australia should be undertaken in July and August during peak calling period. In northern NSW and southern Qld a peak calling period has not been established. Given the likelihood of mistaken identification, the studies should be undertaken by experienced researchers who are familiar with Sloane’s Froglet and are able to differentiate it from other species. A minimum of three site visits should be undertaken if intending to establish the absence of Sloane’s Froglet from a site.

8.3.1.2. Establishing and applying an appropriate monitoring and evaluation protocol

As the extant populations of Sloane’s Froglet are in areas where land use is rapidly changing, a suitable method for monitoring and evaluating the distribution and abundance of Sloane’s Froglet needs to be developed. The method then needs to be applied and reviewed, in order to ensure it is adequate. Undertaking monitoring and evaluation within an adaptive management framework would assist in having the results of monitoring incorporated into future management.

8.3.1.3. The peri-urban context of existing populations

There are no established reasons for Sloane’s Froglets’ occurrence in peri-urban areas and the following suggestions are purely speculative. One factor may be the
availability of constructed wetlands. The density and proximity of dams in landscapes with many small acreage landholdings is higher than many other parts of the landscape. There are also high nutrient and regulated waterbodies within close proximity to one another. In preliminary research undertaken in 2009, Sloane’s Froglets were found in waterbodies close to regulated sources such as sewerage treatment ponds. The availability of such regulated waterbodies in peri-urban areas may also be greater than within the surrounding rural landscape.

Another consideration is the limits placed on agricultural pesticide and herbicide use within peri-urban areas. Agricultural chemical use may have an effect on frog viability (Mann et al., 2009) and application of such chemicals changes between rural and peri-urban areas. In particular, in the study region within NSW, aerial spraying of rural areas with Fenithrothion and Fipronil and ground spraying with Chlorpyrifos occurs frequently as the region is subject to attack by Australian Plague Locusts, Chortoicetes terminifera, (NSW Department of Primary Industries, 2014; Story et al., 2005). These chemicals are known to have deleterious effects on Australian native birds and honeybees (e.g. Story et al., 2007), but their effects on amphibians has not been tested (Story et al., 2005). Peri-urban areas are not aerially sprayed. Nothing is known of the susceptibility of Sloane’s Froglet to agricultural chemicals or other toxins. Further research into the affects of agricultural chemicals on Sloane’s Froglet is warranted.

8.3.1.4. Movement, connectivity and dispersal

As little is known about movement of Sloane’s Froglet further research should be focussed on the space between individual waterbodies, because frogs, like many other group of animals do not just use one place to live their entire life.

It seems likely that the viability of Sloane’s Froglet populations is dependant not just on individual wetland characteristics, but also on broader habitat features including the proximity and abundance of breeding and refuge habitat and the variety and availability of dispersal routes across the landscape. Determining these requirements requires carefully designed research. This research has been and continues to be undertaken for other species in Australia where they are listed as nationally endangered, for instance, the Growling Grass Frog (Hale et al., 2013) and involves surveying many sites over a number of years. For Sloane’s Froglet no research has been undertaken into refuge habitat; the habitat used during dry months; the
populations ability to disperse; or, metapopulation dynamics. Given the context of aggressive development within the region within which Sloane’s Froglet is distributed, and the concurrence of habitat destruction, this research is of a high priority.

8.3.1.5. **Use of habitat in non-breeding periods**

Within the study region, winters are cool and wet and summers are hot and dry. Many of the waterbodies that Sloane’s Froglet uses for breeding have ephemeral or seasonal hydroperiods and dry up in the summer. As yet we have no knowledge of the habitat that Sloane’s Froglet uses for refuge during dry periods or across dry years. For instance, whether it uses permanent waterbodies, can remain viable in dryer areas for a period of time or whether it uses some specific microhabitat feature such as deep clay cracks are questions that remain unanswered. Investigation into the habitat characteristics of areas used in non-breeding periods may provide valuable information for holistic and connectivity management as well as for management in drought periods.

8.3.1.6. **Life history**

Very little is yet known about the life history of Sloane’s Froglet. Life history features are inextricably linked with habitat use and can lead to better understanding of the implications of management actions. Building on the work undertaken by Anstis, (2013) to better understand the length of time from egg-laying to metamorphosis could underpin understanding of the use of ephemeral waterbodies by Sloane’s Froglets. Knowledge of Sloane’s Froglet life expectancy would help with understanding potential threats that may lead to local extirpation as well as potential interventions to mitigate the possibilities of extinction. Understanding the energy requirements and use of this very small species which breeds at the coldest time of the year would also be of great interest.

8.3.1.7. **Predation pressure**

While in this study the presence of fish and their potential impact upon Sloane’s Froglet was not investigated, many studies have shown that fish predation impacts tadpole populations (e.g. Baber and Babbit, 2004; Shulse, Semlitsch & Trauth, 2013). *Gambusia holbrooki* and *Cyprinus carpio*, both significant pest species within the study area (Morgan & Buttemer, 1996; Pyke & White, 2000; Reynolds, 2009), were observed...
in waterbodies that Sloane’s Froglet was present and absent in. Further research into controlling pest fish species in waterbodies occupied by Sloane’s Froglet may be warranted.

8.3.2 Intentional ecology and knowledge exchange

My research indicates, however, that none of this potential work will provide any gain for Sloane’s Froglet unless it is situated within a broader context of knowledge exchange and use. Any further research would greatly benefit from taking an intentional ecology approach.

As mentioned in the discussion in Chapter 6, (Fazey et al., 2013) have provided an exhaustive list of future research questions (80 in total) for the area of environmental knowledge exchange which covers topic areas such as “defining and conceptualising” knowledge exchange (p. 24), exploring its “efficiency and effectiveness” (p. 24) and the “role of power in influencing” knowledge exchange (p. 25). The case study of knowledge exchange that I provided in Chapter 6 has been developed in the context of themes evident through the data. Other researchers might view the data differently and construct a different story, perhaps one that more overtly acknowledges the relationship between knowledge and power (for instance, after Foucault, 1980). I believe that multiple methodological approaches that include the exploration of practitioners’ knowledge and experience as well as the reflection of those researchers and practitioners involved in the coproduction and application of new knowledge, will greatly contribute to this field.

The application of intentional ecology to other case studies than the Sloane’s Froglet one presented here, and a review of its success and effectiveness would benefit other attempts to develop transdisciplinary applied ecological research. I believe such research would also strengthen the discipline of conservation biology and provide a basis and framework for those researchers who are interested in furthering the discussion of the role of advocacy, knowledge exchange and their responsibilities in their work.
8.4 CONCLUDING REMARKS

If, as has been asserted (Gannon, 2006), a PhD thesis is the opportunity to present your mastery over one discipline, then where does my expertise lie? I have moved from autoecological distribution and habitat studies to a discussion of my advocacy journey, through a social science process and on to a framework developed through a theoretical approach. As stated at the beginning of the thesis the methodologies undertaken are plural and the approach taken transdisciplinary purposefully. Multiple approaches are suitable for complex social-ecological systems. But are they suitable for the study of inconspicuous Froglets? I hope that my thesis has demonstrated that even the autoecological study of small Froglets can reveal complex problems and elicit value-laden research and practice scenarios.

I have pondered where my expertise does lie, in ecology? In social research methods? In environmental philosophy? I feel that I can approach all in an informed and effective manner. It seems likely that my expertise lies in case study research; both ecological and social, and in using that case study to illustrate a bigger story and way of understanding the world. Shrader-Frechette & McCoy, (1993) propose that ecology may be useful when framed as a case study discipline and most certainly social research uses the case study approach frequently.

I have, however, a stronger claim to expertise.

My expertise lies in the inconspicuous and forgotten frog, Sloane’s Froglet, in its ecology and in understanding and making visible the complex and value-laden social and political factors surrounding it. And so, I present to you, Sloane’s Froglet.
Plate 8.3. A male Sloane’s Froglet from Corowa (Alexandra Knight)
References


Environment Protection and Biodiversity Conservation Act 1999 (Australia)


Alexandra Knight


Terms and Charges - From 1 April 2014. Interviews and focus groups. 12 May 2014 from www.smartdocs.com.au


Alexandra Knight


Appendix
## Appendix Generalised linear models

### Table A3.1. Generalised linear models for habitat characteristics of Sloane’s Froglet unoccupied and occupied waterbodies (Chapter 3). Table includes Akaike Information Criteria (AIC), number of parameters (K), Minus 2 log likelihood, Akaike’s Information criteria adjusted for small sample sizes (AICc), percent of unoccupied (0) and occupied (1) sites correctly predicted by the model, pseudo R squared, difference in AICc (Δi), and Akaike weights (ωi).

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<th>AICc</th>
<th>Percent correctly predicted</th>
<th>Pseudo R sq</th>
<th>Δi</th>
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<td>100.7655</td>
<td>50</td>
<td>0=67.5%</td>
<td>1=77.8%</td>
<td>0.2141</td>
<td>7.1734</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(BKSL OPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>108.0952</td>
<td>7</td>
<td>94.0952</td>
<td>75</td>
<td>0=72.5%</td>
<td>1=79.6%</td>
<td>0.2661</td>
<td>7.3559</td>
</tr>
<tr>
<td>factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>107.2686</td>
<td>9</td>
<td>98.2686</td>
<td>15</td>
<td>0=70%</td>
<td>1=75.9%</td>
<td>0.3038</td>
<td>7.3699</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>108.3994</td>
<td>6</td>
<td>94.3994</td>
<td>18</td>
<td>0=72.5%</td>
<td>1=77.8%</td>
<td>0.2638</td>
<td>7.6602</td>
</tr>
<tr>
<td>percSUBTA+factor(BKSL OPE)+EVNooflayers+EVBareground</td>
<td>107.6455</td>
<td>9</td>
<td>98.6455</td>
<td>84</td>
<td>0=67.5%</td>
<td>1=75.9%</td>
<td>0.3008</td>
<td>7.7468</td>
</tr>
<tr>
<td>emVeg+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>109.5559</td>
<td>3</td>
<td>103.5559</td>
<td>26</td>
<td>0=70%</td>
<td>1=75.9%</td>
<td>0.1923</td>
<td>7.9310</td>
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<td>emVeg+factor(BKSL OPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>109.0125</td>
<td>6</td>
<td>97.0125</td>
<td>80</td>
<td>0=75%</td>
<td>1=75.9%</td>
<td>0.2434</td>
<td>7.9364</td>
</tr>
<tr>
<td>percSUBTA+factor(BKSL OPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>108.3488</td>
<td>8</td>
<td>92.3488</td>
<td>29</td>
<td>0=70%</td>
<td>1=79.6%</td>
<td>0.2798</td>
<td>8.0013</td>
</tr>
<tr>
<td>emVeg+EVBareground</td>
<td>109.2240</td>
<td>6</td>
<td>97.2240</td>
<td>95</td>
<td>0=65%</td>
<td>1=83.3%</td>
<td>0.2417</td>
<td>8.1480</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(BKSL OPE)+EVNooflayers</td>
<td>109.6335</td>
<td>5</td>
<td>99.6335</td>
<td>53</td>
<td>0=70%</td>
<td>1=81.5%</td>
<td>0.2229</td>
<td>8.2737</td>
</tr>
<tr>
<td>factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>109.9877</td>
<td>4</td>
<td>101.9877</td>
<td>71</td>
<td>0=70%</td>
<td>1=74.1%</td>
<td>0.2046</td>
<td>8.3955</td>
</tr>
<tr>
<td>factor(BKSL OPE)+factor(OVERFLOW)+EVNooflayers</td>
<td>110.3663</td>
<td>3</td>
<td>104.3663</td>
<td>30</td>
<td>0=55%</td>
<td>1=87%</td>
<td>0.1860</td>
<td>8.5914</td>
</tr>
<tr>
<td>factor(BKSL OPE)+factor(OVERFLOW)+EVNooflayers</td>
<td>110.2921</td>
<td>4</td>
<td>102.2921</td>
<td>15</td>
<td>0=67.5%</td>
<td>1=81.5%</td>
<td>0.2022</td>
<td>8.6999</td>
</tr>
<tr>
<td>emVeg+EVNooflayers+EVBareground</td>
<td>109.5808</td>
<td>7</td>
<td>95.5808</td>
<td>31</td>
<td>0=70%</td>
<td>1=79.6%</td>
<td>0.2545</td>
<td>8.8415</td>
</tr>
<tr>
<td>factor(OVERFLOW)+EVBareground</td>
<td>109.3664</td>
<td>8</td>
<td>93.3664</td>
<td>31</td>
<td>0=70%</td>
<td>1=74.1%</td>
<td>0.2718</td>
<td>9.0189</td>
</tr>
<tr>
<td>factor(BKSL OPE)+factor(OVERFLOW)</td>
<td>110.2134</td>
<td>6</td>
<td>98.2134</td>
<td>89</td>
<td>0=70%</td>
<td>1=75.9%</td>
<td>0.2340</td>
<td>9.1373</td>
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<tr>
<td>Model (factor((PA))^2)</td>
<td>AIC</td>
<td>(K)</td>
<td>Minus 2 log likelihood</td>
<td>AICc</td>
<td>Percent correctly predicted</td>
<td>Pseudo (R^2)</td>
<td>(\Delta)</td>
<td>(\omega_i)</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------</td>
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<td>------</td>
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</tr>
<tr>
<td>factor(BKSLOPE)+factor(WATDEPTH)+EVBareground</td>
<td>110.3188</td>
<td>6</td>
<td>98.3188</td>
<td>111.28</td>
<td>0=67.5%</td>
<td>1=79.6%</td>
<td>0.2332</td>
<td>9.2427</td>
</tr>
<tr>
<td>percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>111.1772</td>
<td>2</td>
<td>107.1772</td>
<td>111.30</td>
<td>0=75%</td>
<td>1=64.8%</td>
<td>0.1641</td>
<td>9.2675</td>
</tr>
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<td>emVeg+factor(BKSLOPE)+factor(WATDEPTH)</td>
<td>109.6483</td>
<td>8</td>
<td>93.6483</td>
<td>111.34</td>
<td>0=75%</td>
<td>1=79.6%</td>
<td>0.2696</td>
<td>9.3008</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)</td>
<td>110.7416</td>
<td>5</td>
<td>100.7416</td>
<td>111.42</td>
<td>0=67.5%</td>
<td>1=77.8%</td>
<td>0.2143</td>
<td>9.3818</td>
</tr>
<tr>
<td>emVeg</td>
<td>110.5187</td>
<td>6</td>
<td>98.5187</td>
<td>111.48</td>
<td>0=72.5%</td>
<td>1=75.9%</td>
<td>0.2316</td>
<td>9.4427</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)</td>
<td>111.5462</td>
<td>4</td>
<td>103.5462</td>
<td>111.99</td>
<td>0=70%</td>
<td>1=74.1%</td>
<td>0.2847</td>
<td>9.8138</td>
</tr>
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<td>perfSUBTA+factor(OVERFLOW)+EVBareground</td>
<td>110.8165</td>
<td>5</td>
<td>100.8165</td>
<td>111.49</td>
<td>0=72.5%</td>
<td>1=75.9%</td>
<td>0.2137</td>
<td>9.4568</td>
</tr>
<tr>
<td>factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>110.8611</td>
<td>7</td>
<td>96.8611</td>
<td>111.81</td>
<td>0=75%</td>
<td>1=79.6%</td>
<td>0.2473</td>
<td>9.7725</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>111.5407</td>
<td>6</td>
<td>99.5407</td>
<td>112.04</td>
<td>0=77.5%</td>
<td>1=77.8%</td>
<td>0.2642</td>
<td>9.8402</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>112.2864</td>
<td>3</td>
<td>106.2864</td>
<td>112.55</td>
<td>0=77.5%</td>
<td>1=79.6%</td>
<td>0.2237</td>
<td>10.4646</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>111.9874</td>
<td>5</td>
<td>101.9874</td>
<td>112.16</td>
<td>0=77.5%</td>
<td>1=75.9%</td>
<td>0.2446</td>
<td>10.1219</td>
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<tr>
<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>110.2438</td>
<td>9</td>
<td>92.2438</td>
<td>112.38</td>
<td>0=70%</td>
<td>1=79.6%</td>
<td>0.2806</td>
<td>10.3451</td>
</tr>
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<td>emVeg+percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>111.1914</td>
<td>7</td>
<td>97.1914</td>
<td>112.49</td>
<td>0=65%</td>
<td>1=83.3%</td>
<td>0.2420</td>
<td>10.4522</td>
</tr>
<tr>
<td>emVeg+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>111.5407</td>
<td>6</td>
<td>99.5407</td>
<td>112.50</td>
<td>0=75%</td>
<td>1=79.6%</td>
<td>0.2237</td>
<td>10.4646</td>
</tr>
<tr>
<td>emVeg</td>
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<td>5</td>
<td>101.9874</td>
<td>112.66</td>
<td>0=70%</td>
<td>1=74.1%</td>
<td>0.2046</td>
<td>10.6276</td>
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<tr>
<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>112.3610</td>
<td>4</td>
<td>104.3610</td>
<td>112.81</td>
<td>0=55%</td>
<td>1=87%</td>
<td>0.1861</td>
<td>10.7688</td>
</tr>
<tr>
<td>emVeg+factor(WATDEPTH)+factor(OVERFLOW)</td>
<td>112.2000</td>
<td>5</td>
<td>102.2000</td>
<td>112.88</td>
<td>0=67.5%</td>
<td>1=81.5%</td>
<td>0.2029</td>
<td>10.8402</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>111.4411</td>
<td>8</td>
<td>95.4411</td>
<td>113.13</td>
<td>0=70%</td>
<td>1=72.2%</td>
<td>0.2556</td>
<td>11.0937</td>
</tr>
<tr>
<td>percSUBTA+factor(OVERFLOW)+EVBareground</td>
<td>112.8752</td>
<td>3</td>
<td>106.8752</td>
<td>113.14</td>
<td>0=75%</td>
<td>1=72.2%</td>
<td>0.1665</td>
<td>11.1002</td>
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<tr>
<td>Model</td>
<td>AIC</td>
<td>K</td>
<td>Minus 2 log likelihood</td>
<td>AICc</td>
<td>Percent correctly predicted</td>
<td>Pseudo R sq</td>
<td>Δi</td>
<td>ωi</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------</td>
<td>----</td>
<td>------------------------</td>
<td>---------</td>
<td>----------------------------</td>
<td>-------------</td>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td>percSUBTA+factor(BKSL OPE)+factor(OVERFLOW)</td>
<td>112.9029</td>
<td>3</td>
<td>106.9029</td>
<td>113.16</td>
<td>0=72.5%</td>
<td>1=66.7%</td>
<td>0.1662</td>
<td>11.1280 0.0004</td>
</tr>
<tr>
<td>percSUBTA+factor(BKSL OPE)+factor(WATDEPTH)+EVNooflayers +EVBareground</td>
<td>112.6533</td>
<td>5</td>
<td>102.6533</td>
<td>113.33</td>
<td>0=72.5%</td>
<td>1=75.9%</td>
<td>0.1994</td>
<td>11.2935 0.0004</td>
</tr>
<tr>
<td>factor(BKSL OPE)</td>
<td>112.9237</td>
<td>4</td>
<td>104.9237</td>
<td>113.37</td>
<td>0=75%</td>
<td>1=72.2%</td>
<td>0.1817</td>
<td>11.3315 0.0004</td>
</tr>
<tr>
<td>emVeg+percSUBTA</td>
<td>112.1254</td>
<td>7</td>
<td>98.1254</td>
<td>113.42</td>
<td>0=70%</td>
<td>1=75.9%</td>
<td>0.2347</td>
<td>11.3861 0.0004</td>
</tr>
<tr>
<td>emVeg+factor(WATDEPTH)+EV Bareground</td>
<td>112.4222</td>
<td>7</td>
<td>98.4222</td>
<td>113.72</td>
<td>0=72.5%</td>
<td>1=77.8%</td>
<td>0.2324</td>
<td>11.6830 0.0003</td>
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<td>factor(BKSL OPE)+EVNooflayers</td>
<td>112.7837</td>
<td>6</td>
<td>100.7837</td>
<td>113.74</td>
<td>0=65%</td>
<td>1=83.3%</td>
<td>0.2140</td>
<td>11.7076 0.0003</td>
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<tr>
<td>emVeg+percSUBTA+factor(BKSL OPE)+factor(WATDEPTH)</td>
<td>112.9066</td>
<td>6</td>
<td>100.9066</td>
<td>113.87</td>
<td>0=72.5%</td>
<td>1=74.1%</td>
<td>0.2130</td>
<td>11.8305 0.0003</td>
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<tr>
<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVBareground</td>
<td>112.0297</td>
<td>4</td>
<td>106.0297</td>
<td>114.47</td>
<td>0=77.5%</td>
<td>1=63%</td>
<td>0.1731</td>
<td>12.4375 0.0002</td>
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<tr>
<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers</td>
<td>112.7938</td>
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<td>96.7938</td>
<td>114.48</td>
<td>0=77.5%</td>
<td>1=75.9%</td>
<td>0.2451</td>
<td>12.4464 0.0002</td>
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<tr>
<td>factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>113.3192</td>
<td>7</td>
<td>99.3192</td>
<td>114.62</td>
<td>0=75%</td>
<td>1=79.6%</td>
<td>0.2254</td>
<td>12.5799 0.0002</td>
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<td>114.5315</td>
<td>4</td>
<td>106.5315</td>
<td>114.98</td>
<td>0=77.5%</td>
<td>1=63%</td>
<td>0.1691</td>
<td>12.9394 0.0002</td>
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<td>114.0645</td>
<td>6</td>
<td>102.0645</td>
<td>115.03</td>
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<td>12.9884 0.0002</td>
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<td>factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers</td>
<td>114.7056</td>
<td>4</td>
<td>106.7056</td>
<td>115.15</td>
<td>0=75%</td>
<td>1=72.2%</td>
<td>0.1678</td>
<td>13.1135 0.0002</td>
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<tr>
<td>emVeg+factor(WATDEPTH)</td>
<td>114.7808</td>
<td>5</td>
<td>104.7808</td>
<td>115.46</td>
<td>0=75%</td>
<td>1=72.2%</td>
<td>0.1828</td>
<td>13.4210 0.0001</td>
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<td>factor(BKSL OPE)+factor(WATDEPTH)+factor(OVERFLOW)</td>
<td>114.6533</td>
<td>6</td>
<td>102.6533</td>
<td>115.61</td>
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<td>0.1994</td>
<td>13.5772 0.0001</td>
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<td>percSUBTA+factor(BKSL OPE)</td>
<td>115.4090</td>
<td>5</td>
<td>105.4090</td>
<td>116.09</td>
<td>0=72.5%</td>
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<td>0.1779</td>
<td>14.0493 0.0001</td>
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<td>114.9010</td>
<td>7</td>
<td>100.9010</td>
<td>116.20</td>
<td>0=75%</td>
<td>1=74.1%</td>
<td>0.2131</td>
<td>14.1618 0.0001</td>
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<td>emVeg+percSUBTA+factor(WATDEPTH)+EVBareground</td>
<td>115.2245</td>
<td>8</td>
<td>99.2245</td>
<td>116.91</td>
<td>0=75%</td>
<td>1=79.6%</td>
<td>0.2261</td>
<td>14.8770 0.0001</td>
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<tr>
<td>emVeg+factor(WATDEPTH)+EVNooflayers</td>
<td>116.3125</td>
<td>5</td>
<td>106.3125</td>
<td>117.22</td>
<td>0=75%</td>
<td>1=64.8%</td>
<td>0.1709</td>
<td>14.9527 0.0001</td>
</tr>
<tr>
<td>emVeg+percSUBTA+factor(WATDEPTH)+EVNooflayers+EVBareground</td>
<td>116.5448</td>
<td>5</td>
<td>106.5448</td>
<td>117.22</td>
<td>0=75%</td>
<td>1=72.2%</td>
<td>0.1690</td>
<td>15.1850 0.0001</td>
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<tr>
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<td>115.9812</td>
<td>7</td>
<td>101.9812</td>
<td>117.28</td>
<td>0=67.5%</td>
<td>1=81.5%</td>
<td>0.2046</td>
<td>15.2420 0.0001</td>
</tr>
<tr>
<td>Model (factor(PA))**</td>
<td>AIC</td>
<td>K</td>
<td>Minus 2 log likelihood</td>
<td>AICc</td>
<td>Percent correctly predicted</td>
<td>Pseudo R sq</td>
<td>Δ</td>
<td>ω_i</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----</td>
<td>---</td>
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<td>-----</td>
<td>-----------------------------</td>
<td>-------------</td>
<td>---</td>
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</tr>
<tr>
<td>emVeg+percSUBTA+factor(WATDEPTH)</td>
<td>117.0773</td>
<td>3</td>
<td>111.0773</td>
<td>117.34</td>
<td>0=72.5% 1=66.7%</td>
<td>0.1337</td>
<td>15.3024</td>
<td>0.0001</td>
</tr>
<tr>
<td>factor(BKSLOPE)+factor(WATDEPTH)</td>
<td>116.4725</td>
<td>6</td>
<td>104.4725</td>
<td>117.43</td>
<td>0=75% 1=72.2%</td>
<td>0.1852</td>
<td>15.3964</td>
<td>0.0001</td>
</tr>
<tr>
<td>percSUBTA+factor(BKSLOPE)+factor(WATDEPTH)+factor(OWFLOW)</td>
<td>117.7041</td>
<td>2</td>
<td>113.7041</td>
<td>117.83</td>
<td>0=72.5% 1=66.7%</td>
<td>0.1132</td>
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<tr>
<td>factor(OWFLOW)+EVNooflayers</td>
<td>118.4336</td>
<td>4</td>
<td>110.4336</td>
<td>118.88</td>
<td>0=70% 1=79.6%</td>
<td>0.1387</td>
<td>16.8415</td>
<td>0.0000</td>
</tr>
<tr>
<td>factor(WATDEPTH)+factor(OVERFLOW)+factor(BKSLOPE)+factor(WATDEPTH)+factor(OWFLOW)+EVNooflayers</td>
<td>118.7505</td>
<td>6</td>
<td>110.7505</td>
<td>118.93</td>
<td>0=75% 1=72.2%</td>
<td>0.1703</td>
<td>17.3104</td>
<td>0.0000</td>
</tr>
<tr>
<td>factor(WATDEPTH)+factor(OVERFLOW)+factor(OVERFLOW)+EVNooflayers</td>
<td>119.0253</td>
<td>5</td>
<td>109.0253</td>
<td>119.32</td>
<td>0=52.5% 1=70.4%</td>
<td>0.1497</td>
<td>17.6655</td>
<td>0.0000</td>
</tr>
<tr>
<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers</td>
<td>119.4169</td>
<td>4</td>
<td>111.4169</td>
<td>119.86</td>
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<td>6</td>
<td>109.5134</td>
<td>119.83</td>
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<td>0.1497</td>
<td>17.6655</td>
<td>0.0000</td>
</tr>
<tr>
<td>factor(WATDEPTH)+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>120.1437</td>
<td>5</td>
<td>110.1437</td>
<td>120.82</td>
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<td>0.1410</td>
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<td>factor(WATDEPTH)+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>120.2061</td>
<td>2</td>
<td>118.2061</td>
<td>121.99</td>
<td>0=52.5% 1=70.4%</td>
<td>0.1497</td>
<td>19.9492</td>
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<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
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<td>3</td>
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<td>122.09</td>
<td>0=45% 1=81.5%</td>
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<td>20.0541</td>
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<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>120.6304</td>
<td>4</td>
<td>118.6304</td>
<td>122.33</td>
<td>0=40% 1=83.3%</td>
<td>0.0781</td>
<td>20.2963</td>
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<tr>
<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>124.0895</td>
<td>3</td>
<td>118.0895</td>
<td>124.36</td>
<td>0=40% 1=83.3%</td>
<td>0.0789</td>
<td>22.3236</td>
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<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>124.1830</td>
<td>4</td>
<td>118.1830</td>
<td>124.63</td>
<td>0=42.5% 1=79.6%</td>
<td>0.0939</td>
<td>22.5909</td>
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<td>percSUBTA+factor(WATDEPTH)+factor(OVERFLOW)+EVNooflayers+EVBareground</td>
<td>127.4670</td>
<td>3</td>
<td>121.4670</td>
<td>127.73</td>
<td>0=67.5% 1=51.9%</td>
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<td>4</td>
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<td>AIC</td>
<td>K</td>
<td>Minus 2 log likelihood</td>
<td>AICc</td>
<td>Percent correctly predicted</td>
<td>Pseudo R sq</td>
<td>Δi</td>
<td>ωi</td>
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</tr>
<tr>
<td>percSUBTA+EVNooflayers+EVBaround</td>
<td>128.7260</td>
<td>4</td>
<td>120.7260</td>
<td>129.17</td>
<td>0=75% 1=57.4%</td>
<td>0.0584</td>
<td>27.1338</td>
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<td>119.2678</td>
<td>129.94</td>
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<tr>
<td>factor(WATDEPTH)+EVNooflayers</td>
<td>130.9656</td>
<td>2</td>
<td>126.9656</td>
<td>131.09</td>
<td>0=45% 1=70.4%</td>
<td>0.0098</td>
<td>29.0558</td>
<td>0.0000</td>
</tr>
<tr>
<td>percSUBTA+factor(WATDEPTH)</td>
<td>131.0308</td>
<td>2</td>
<td>127.0308</td>
<td>131.16</td>
<td>0=20% 1=85.2%</td>
<td>0.0093</td>
<td>29.1211</td>
<td>0.0000</td>
</tr>
<tr>
<td>percSUBTA+factor(WATDEPTH) +EVNooflayers</td>
<td>131.9189</td>
<td>3</td>
<td>125.9189</td>
<td>132.18</td>
<td>0=17.5% 1=88.9%</td>
<td>0.0179</td>
<td>30.1440</td>
<td>0.0000</td>
</tr>
<tr>
<td>percSUBTA</td>
<td>130.9655</td>
<td>2</td>
<td>126.9655</td>
<td>130.96</td>
<td>Only one class fit = bad model</td>
<td>0.0098</td>
<td>30.2262</td>
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<tr>
<td>EVNooflayers</td>
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<td>2</td>
<td>127.0307</td>
<td>131.03</td>
<td>0=20% 1=85.2%</td>
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<td>30.2915</td>
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</tr>
<tr>
<td>percSUBTA+EVNooflayers</td>
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<td>3</td>
<td>125.9189</td>
<td>132.18</td>
<td>0=17.5% 1=88.9%</td>
<td>0.0179</td>
<td>31.1796</td>
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</table>
Table A4.1. Generalised linear models for sites within waterbodies which are unoccupied and occupied by Sloane’s Froglet (chapter 4). Table includes, Akaike Information Criteria (AIC), number of parameters (K), Minus 2 log likelihood, Akaike’s Information criteria adjusted for small sample sizes (AICc), percent of unoccupied (0) and occupied (1) sites correctly predicted by the model, pseudo R squared, difference in AICc (Δ), and Akaike weights (ω).

<table>
<thead>
<tr>
<th>Model (FRSPcod)**</th>
<th>AIC</th>
<th>K</th>
<th>Minus 2 log likelihood</th>
<th>AICc</th>
<th>Percent correctly predicted</th>
<th>Pseudo R sq</th>
<th>Δ</th>
<th>ω</th>
</tr>
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<tbody>
<tr>
<td>wataver+DISTSAME+DISTOTHER</td>
<td>91.2420</td>
<td>5</td>
<td>81.2420</td>
<td>91.8134</td>
<td>0=76.6%</td>
<td>1=84.1%</td>
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<td>92.5670</td>
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<td>1=79.5%</td>
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<td>0.7536</td>
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<td>81.0619</td>
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<td>1=79.5%</td>
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<td>4</td>
<td>86.3220</td>
<td>94.6993</td>
<td>0=70.2%</td>
<td>1=81.8%</td>
<td>0.3152</td>
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<td>79.7557</td>
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<td>1=79.5%</td>
<td>0.3673</td>
<td>3.0297</td>
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<td>85.0406</td>
<td>95.6121</td>
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<td>1=84.6%</td>
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<td>85.1604</td>
<td>95.7318</td>
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<td>1=86.4%</td>
<td>0.3244</td>
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<td>87.4746</td>
<td>95.8520</td>
<td>0=72.3%</td>
<td>1=79.5%</td>
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<td>90.2380</td>
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<td>1=79.5%</td>
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<td>88.2760</td>
<td>96.6534</td>
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<td>86.3066</td>
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<td>1=86.4%</td>
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<tr>
<td>Model (FRSPcod)~</td>
<td>AIC</td>
<td>K</td>
<td>Minus 2 log likelihood</td>
<td>AICc</td>
<td>Percent correctly predicted</td>
<td>Pseudo R sq</td>
<td>Δ</td>
<td>ω</td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
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<td>------------------------</td>
<td>---------</td>
<td>----------------------------</td>
<td>-------------</td>
<td>-----</td>
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</tr>
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<td>5</td>
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<tr>
<td>Model (FRSPcod)**</td>
<td>AIC</td>
<td>K</td>
<td>Minus 2 log likelihood</td>
<td>AICc</td>
<td>Percent correctly predicted</td>
<td>Pseudo R sq</td>
<td>Δi</td>
<td>ω</td>
</tr>
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<td>106.1656</td>
<td>116.7370</td>
<td>0=63.5%</td>
<td>1=83%</td>
<td>0.2706</td>
<td>6</td>
</tr>
<tr>
<td>wataver+SUBPLCOV+EMRDHTMAX+DISTSAME</td>
<td>116.4128</td>
<td>4</td>
<td>108.4128</td>
<td>116.7901</td>
<td>0=65.4%</td>
<td>1=84.9%</td>
<td>0.2552</td>
<td>7</td>
</tr>
<tr>
<td>BANKAREA+SUBPLCOV+EMRDHTMAX+DISTSAME</td>
<td>116.2326</td>
<td>5</td>
<td>106.2326</td>
<td>116.8040</td>
<td>0=65.4%</td>
<td>1=81.1%</td>
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<td>wataver+SUBPLCOV+DISTOTHER</td>
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<td>4</td>
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<td>0=65.4%</td>
<td>1=84.9%</td>
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<td>EMRDHTMAX+DISTSAME</td>
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<td>111.2519</td>
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<td>1=84.9%</td>
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<td>4</td>
<td>109.2931</td>
<td>117.6705</td>
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<td>1=84.9%</td>
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<tr>
<td>wataver+SUBPLCOV+EMRDHTMAX+DISTOTHER</td>
<td>117.2233</td>
<td>5</td>
<td>107.2233</td>
<td>117.7947</td>
<td>0=65.4%</td>
<td>1=66.7%</td>
<td>0.1996</td>
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<td>122.4981</td>
<td>3</td>
<td>116.4981</td>
<td>122.7224</td>
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<td>1=77.8%</td>
<td>0.1304</td>
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<tr>
<td>BANKAREA+SUBPLCOV+DISTOTHER</td>
<td>124.2506</td>
<td>4</td>
<td>116.2506</td>
<td>124.6280</td>
<td>0=50%</td>
<td>1=75.6%</td>
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</tr>
<tr>
<td>DISTOTHER</td>
<td>124.6056</td>
<td>2</td>
<td>120.6056</td>
<td>124.7167</td>
<td>0=46.2%</td>
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<td>4</td>
<td>116.4951</td>
<td>124.8725</td>
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<tr>
<td>SUBPLCOV+DISTOTHER</td>
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<td>119.9998</td>
<td>126.2241</td>
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<tr>
<td>EMRDHTMAX+DISTOTHER</td>
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<td>3</td>
<td>120.3920</td>
<td>126.6163</td>
<td>0=53.8%</td>
<td>1=73.3%</td>
<td>0.1013</td>
<td>8</td>
</tr>
<tr>
<td>BANKAREA+SUBPLCOV+EMRDHTMAX+DISTOTHER</td>
<td>126.2413</td>
<td>5</td>
<td>116.2413</td>
<td>126.8127</td>
<td>0=50%</td>
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<td>SUBPLCOV+EMRDHTMAX+DISTOTHER</td>
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<td>4</td>
<td>119.9457</td>
<td>128.3231</td>
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<td>138.0772</td>
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<td>1=70.4%</td>
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<td>4</td>
<td>137.0636</td>
<td>145.4410</td>
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<td>137.6163</td>
<td>145.9936</td>
<td>0=61.4%</td>
<td>1=72.2%</td>
<td>0.1052</td>
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<td>5</td>
<td>136.8997</td>
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<td>1=68.5%</td>
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<td>Model (FRSPcod)</td>
<td>AIC</td>
<td>K</td>
<td>Minus 2 log likelihood</td>
<td>AICc</td>
<td>Percent correctly predicted</td>
<td>Pseudo R sq</td>
<td>Δ</td>
<td>ω</td>
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<td>-------</td>
<td>----------------------------</td>
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</tr>
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<td>wataver+SUBPLCOV</td>
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<td>144.5094</td>
<td>150.7337</td>
<td>0=52.6% 1=72.2%</td>
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<td>58.920</td>
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<td>wataver+EMRDHTMAX</td>
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<td>145.6380</td>
<td>151.8623</td>
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<td>149.2341</td>
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<td>149.0871</td>
<td>155.3114</td>
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<td>157.4955</td>
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<td>159.4239</td>
<td>0=73.7% 1=33.3%</td>
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