CENTRE FOR ABORIGINAL ECONOMIC POLICY RESEARCH

THE AUSTRALIAN NATIONAL UNIVERSITY

Catching *Kordbolbok*: From Frog Survey to Closing the Gap in Arnhem Land

E. Ens, G. Vallance, S. Namundja, V. Garlngarr, B. Gurwalwal, P. Cooke and K. McKenzie

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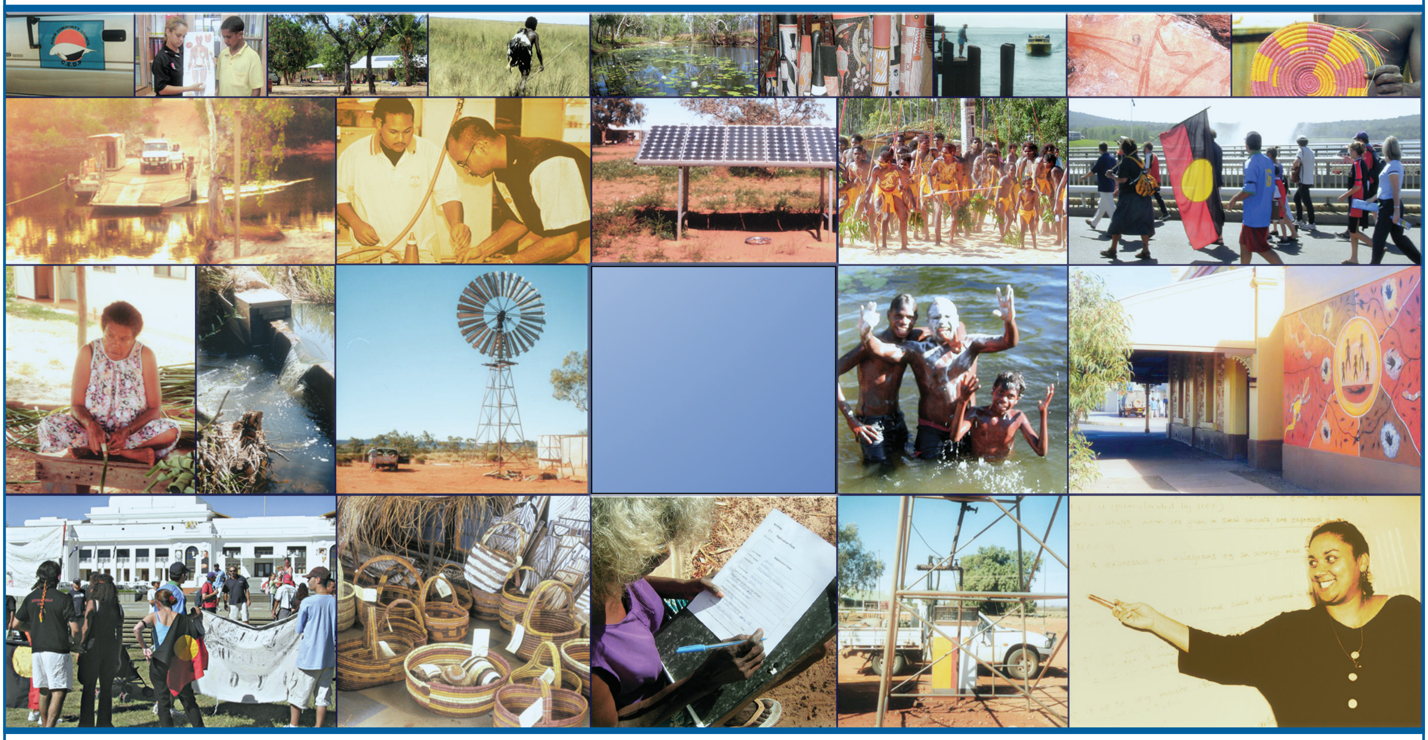

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ABSTRACT

This working paper introduces the first frog survey of the Arnhem Plateau, as far as we know, which was conducted by the Warddeken Indigenous Rangers and a western scientist employed by CAEPR. The survey methodology and outcomes are presented in conjunction with some comment on the socioeconomic benefits of such surveys in remote outstations of the Northern Territory. Thirteen native frog species known to western science were found, including one species that as far as we know is previously undescribed—as well as the exotic cane toad (*Bufo marinus*). This exercise highlighted the significant role already played by traditional owners in the management of Indigenous-owned Arnhem Land. A greater monitoring role—for example, through frog surveys—could be pursued given the right tools and training.

Keywords: Frogs, Indigenous land and sea management, Arnhem Plateau, Closing the Gap, Warddeken Land Management Limited

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INTRODUCTION

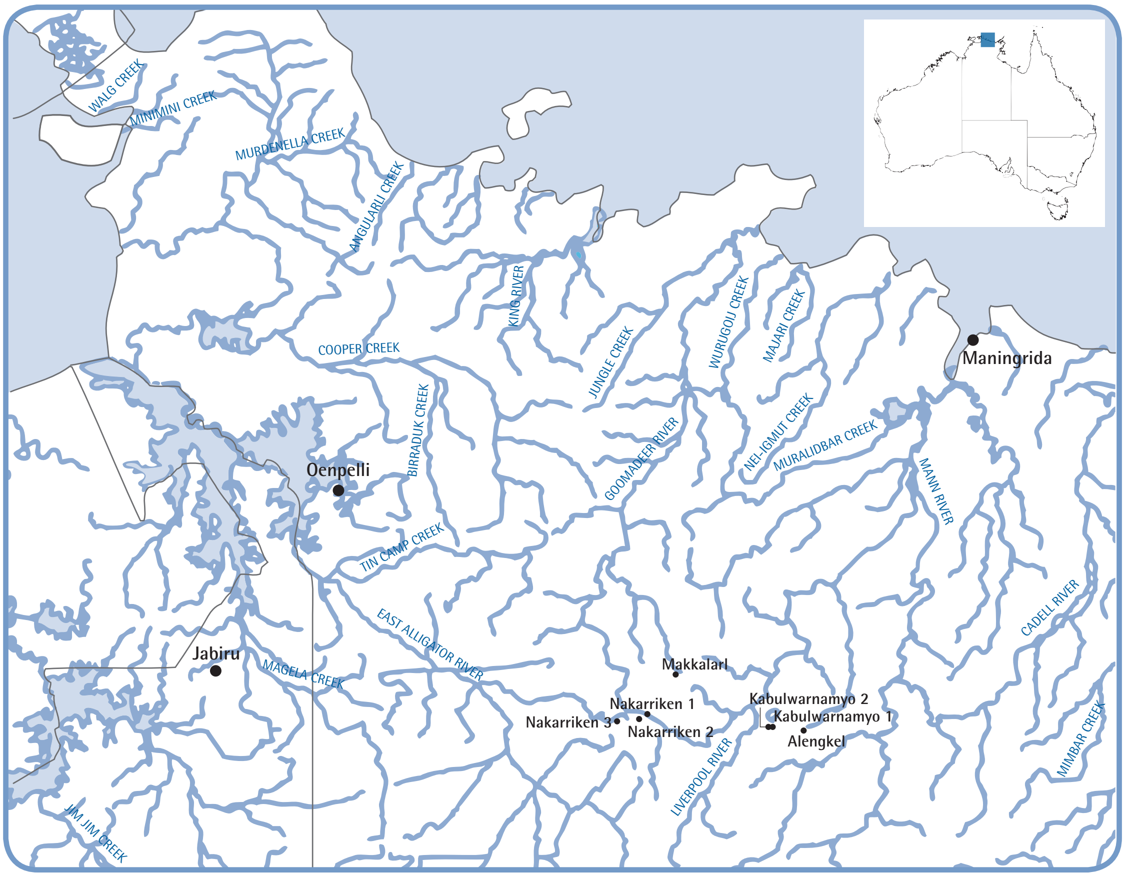
Funding bodies and the broader Indigenous and non-Indigenous community are increasingly demanding more detailed and quantitative monitoring and evaluation of the outcomes of natural resource management projects (Australian Government 2009). For Indigenous land and sea management groups these requirements present accentuated burdens and problems due to the lower English literacy and numeracy level of Australia's Indigenous population and poor service delivery to remote communities (Kral 2009; Kral & Schwab 2003; Westbury & Sanders 2000). The educational and socioeconomic gap between Indigenous and non-Indigenous Australians is increasingly flagged in government policy and in the media, with caveats highlighting the enormity and complexity of the task (Altman, Biddle & Hunter 2008). Research suggests that closing some of the gaps will take a long time, possibly 100 years or more (Altman, Biddle & Hunter 2008). Most proposed solutions to 'closing the gap' draw on the need to build capacity, resilience, infrastructure and increased property rights into Indigenous communities (Altman, Biddle & Hunter 2008). Delivery of these solutions is further complicated by the geographical distribution and demography of Australia's approximately 1,200 Indigenous communities, which are scattered primarily throughout remote areas of Australia. Of these, 900 communities have a population of less than 50 people (Altman, Buchanan & Larsen 2007). Pragmatic approaches to this goal will therefore require innovative, sustained and long term commitment by both Indigenous and non-Indigenous people.

Commentators and people working with Indigenous communities advise that the movement toward closing the gap must come from within communities if it is to be sustainable (Chino & DeBruyn 2006; Hunt 2005). Traditional top-down bureaucratic and often highly ideological and 'technical transfer' approaches have repeatedly proved to be ineffective in attaining their objectives (Hunt 2005; Nair 2003). Sustained small steps from within both Indigenous and non-Indigenous communities must be initiated to facilitate the building of bigger steps towards cross cultural understanding and collaboration in order to address the socioeconomic divide that exists within Australia. According to Hunt (2005) there are two dominant emergent approaches to capacity development: the neoliberal economic rationalist approach and the human or social capital approach. The neoliberal approach relates to 'hard' capacity development of infrastructure and finances, whereas the social capital approach refers to 'soft' capacities involving initiative, motivation and community momentum which are seen as critically important (Baser & Morgan 2008). The present project focuses on soft capacity development in the short-term that may lead to economic development as a longer term objective.

Capacity development includes dimensions of participation, leadership, social support, sense of community, access to resources and skills, and development and empowerment of local coalitions to make their own informed decisions (Chino & DeBruyn 2006; Nair 2003). Chino and DeBruyn (2006: 559) suggest that capacity building within Indigenous communities must go beyond the western concepts of action planning and developing leadership to incorporate indigenous ways of knowing with the life skills many western people take for granted, 'in a way that is comfortable, familiar and respectful of different cultures and traditions'. Additionally, a movement towards ownership of capacity away from notions of partnership and participation is advocated as an optimal goal which must be accompanied by mechanisms that facilitate sustainability and longevity of that capacity (Hunt 2005).

Here we present the initial outcomes of collaborative work between an Indigenous community and a western scientist which aimed to build community natural resource management monitoring and reporting capacity. There are very few published examples of collaboration between Indigenous and non-Indigenous people in the environmental sciences and further understanding is needed to guide sustainable development of Indigenous communities which are engaging in community natural resource management activities (Carter 2008). (See, however, Fordham et al. forthcoming for a recent case study in development

Fig. 1. Location of Arnhem Plateau study sites showing main drainage lines



of sustainable wildlife enterprises in remote Indigenous communities, utilising both Indigenous ecological knowledge and western science knowledge systems.) We report on the initial findings of a frog survey initiated as a biodiversity inventory exercise with a small Indigenous traditional owner community on the Arnhem Plateau, Northern Territory, Australia. The community is based at the Kabulwarnamyo outstation, a small outstation located some 100 kilometres east of Jabiru, the main township in Kakadu National Park (see Fig. 1). Kabulwarnamyo is different to many small outstations as it is also the base for the Indigenous Rangers of Warddeken Land Management Limited (WLML). WLML has become a viable Indigenous land management organisation mainly through its development and implementation of the Western Arnhem Land Fire Abatement (WALFA) project (Whitehead et al. 2008). Location of the land management base at Kabulwarnamyo offers employment and related socioeconomic benefits (Burgess et al. 2005) to residents of the community, which primarily comprises traditional owners of the plateau. The aim of the present project is to further develop the monitoring and evaluation skills of the Indigenous rangers, particularly those not heavily involved in the fire management project, as well as attempting to draw other members of the community into community natural resource management activities. Therefore, we offer a first hand account of an initially successful collaboration between Indigenous and non-Indigenous people that we anticipate will deliver not only ecological and land management outcomes in terms of biodiversity inventory and monitoring, but also greater community engagement and ownership of land management activities. It is the intention of the primary author to develop additional, similar, small-scale projects with local outcomes with other traditional owner groups, which may result in broader scale and

WLML: Warddeken Land Management Limited

WALFA: Western Arnhem Land Fire Abatement

Fig. 2. Areas surveyed for frogs

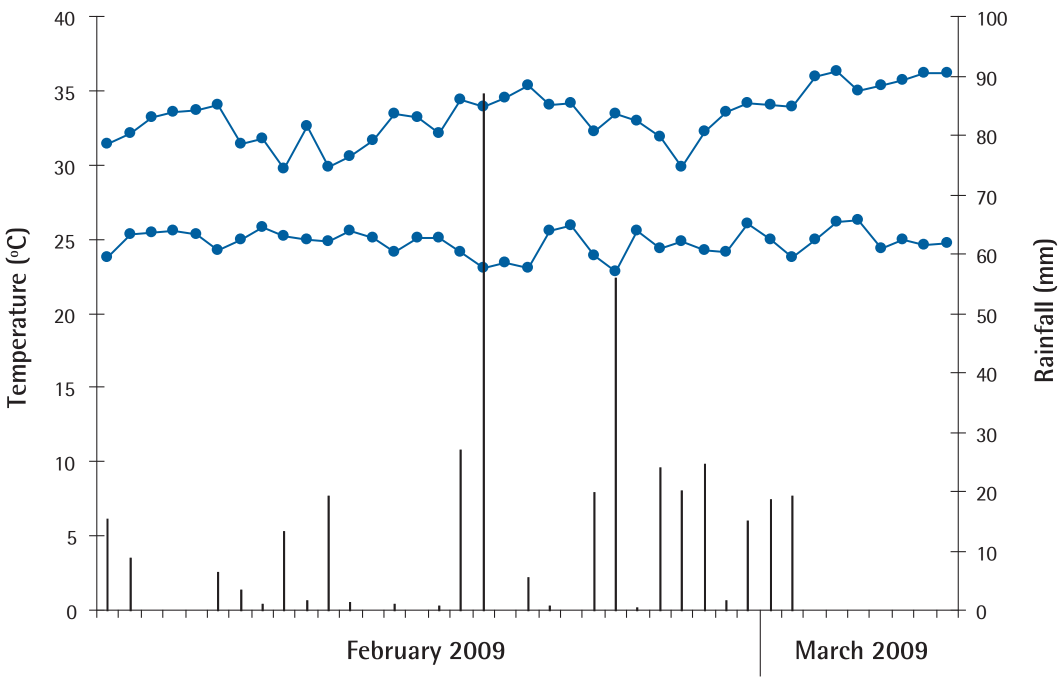
Above: Kabulwarnamyo spring (2a), Nakaldurrk (2b), Seraine Namundja at Alengkel (2c), and Emmanuel Namarnyilk at Makkalarl (2d).

multidimensional benefits in the long term. In this paper we outline the methodology used to survey the frog fauna in several locations around Kabulwarnamyo outstation, and discuss the immediate and proposed longer-term ecological and socioeconomic benefits afforded to the local and broader community. Issues of sustainability and factors affecting continual development of such projects are raised in conclusion.

CATCHING *KORDBOLBOK*

The primary focus of this project was to conduct a preliminary survey of the frog fauna in various habitats of the Warddeken land management area. Prior to this survey, no specific frog survey had been conducted on the eastern Arnhem Plateau. The work was designed to be both exploratory and adaptive—a training, inventory and engagement exercise involving both Indigenous and non-Indigenous collaborators. The Indigenous rangers were involved in the entire project from study design to data collection, analysis and interpretation. It was also intended that this preliminary species survey work would be fed into a more systematic future monitoring program that will assess potential changes in frog community composition in response to climate change, feral animal invasion—including cane toads (Altman, Griffiths & Whitehead 2003), pigs (Edwards et al. 2004) and buffalo (Edwards et al. 2004)—and other land management activities conducted by the rangers.

Fig. 3. Daily rainfall and minimum and maximum temperatures in the month preceding and during the frog survey



Source: Data from recording station at Jabiru Airport (12° 39′ 35″ S 132° 53′ 31″ E) 1984–2009, Bureau of Meteorology 2009.

METHODOLOGY

STUDY SITES

In the vicinity of Kabulwarnamyo (see Fig. 1 map), five fresh water points were selected by the rangers and visited during 4–11 March 2009: Kabulwarnamyo spring; Nakaldurrk; Kunkebngarrng; Alengkel; and Makkalarl. Each water point differed in terms of habitat type.

Kabulwarnamyo spring (Fig. 2a) is a perennial freshwater spring flat which lies approximately 100 metres from Kabulwarnamyo outstation, which has a variable population of 20–50 people. At the time of this study, the spring was frequented by Kabulwarnamyo residents, camp dogs and two feral Asian water buffalo (*Bubalis bubalis* Lydekker). Vegetation of the spring was characterised by a stand of *Melaleuca* spp. in the central flowing section of the spring-fed creek and was surrounded by a sedgeland dominated by *Fimbrystylis* spp and *Cyperus* spp. We surveyed Kabulwarnamyo spring for frogs twice: once on 4 March 2009 in the early evening (6.30–7.30 p.m.) and once on 6 March 2009 later in the evening (9.00–10.00 p.m.).

Nakaldurrk is a section of a perennial creek infrequently traversed by vehicles. A large flat rock characterised the area where the creek broadens out to be approximately 1 centimetre–1 metre deep, and 2–10 metres wide (Fig. 2b). Nakaldurrk is a relatively open section of the creek with few surrounding trees compared to the contiguous area. We surveyed Nakaldurrk once on 5 March 2009 (6.00–7.00 p.m.).

Table 1. Species list for each study site, Arnham Plateau frog survey, 2009

	Sites				
Species	Kabulwarnamyo	Alengkel	Nakaldurrk	Kunkebngarrng	Makkalarl
Bufo marinus (cane toad)	sound[b]	photo[a]		photo[b]	sound[b]
Crinia remota (Remote froglet)	photo[b]				sound[b]
Crinia bilingua (Bilingual frog)	photo[a b] sound[a b]	photo[b] sound[a b]	sound[a]	sound[b]	photo[b]
Cyclorana australis (giant frog)	sound[a b] old photo (PC)	sound[a b]			
Limnodynastes convexiusculus (marbled frog)		caught[b]			
Litoria bicolor					photo[b] sound[b]
Litoria meiriana (rockpool frog)		photo[b]	photo[a]		
Litoria microbelos	photo[b]		photo[a]		photo[b]
Litoria personata (masked rock frog)		photo	tadpole	photo[b]	photo[b]
Litoria rothii (brown tree frog)					photo[b]
Litoria tornieri					photo[b]
Notaden melanoscaphusc	photo[b]	photo sound			photo[b]
Uperoleia inundata	photo[b]				
Litoria rubella					photo[b]
Unidentified tadpoles			1 species[a]	1 species[b]	

Notes: a. Early evening survey.
b. Late evening survey.
c. See discussion below regarding identification.

Kunkebngarrng was (opportunistically) searched for frogs on the way back to camp from Nakaldurrk (7.30–8.00 p.m.). Kunkebngarrng is an ephemeral sand bed creek which crosses a dirt road. The area was well-vegetated, with understorey and canopy tropical riparian vegetation species.

Alengkel—the fourth site surveyed—is an area of spring flat inhabited by approximately 20 feral buffalo. The buffalo had disturbed patches of the spring by wallowing and trampling (Ens et al. forthcoming); the edge of a buffalo wallow can be seen in Fig. 2c. Alengkel is situated at the upper reach of Kabulwarnamyo spring, before the water goes underground and resurfaces as Kabulwarnamyo spring. The area surveyed at Alengkel had scattered *Melaleuca* spp. trees and *Pandanus spiralis*, and the ground cover was dominated by *Fimbrystylis* spp. and *Cyperus* spp. (Fig. 2c). Two surveys were conducted at Alengkel: one in the early evening of 6 April 2009 (6.30–7.30p.m.) and one later in the evening of 10 March 2009 (9.00–10.00 p.m.).

The fifth location visited was an ephemeral wetland near Makkalarl billabong which we surveyed for frogs on 7 March 2009 (8.30–10.30 p.m.). The wetland had a maximum depth of approximately 1 metre in the centre, was dominated by emergent sedge vegetation (Fig. 2d), and surrounded by savanna woodland.

Rain fell in the preceding nine afternoons/evenings of the survey period and after the first survey at Kabulwarnamyo spring on 4 March 2009 (Fig. 3). No rain fell during the remainder of the survey period. Monthly rainfalls for February 2009 (335.2mm) and March 2009 (209.8mm) were lower than the long-term average for February (364.7mm) and March (322.4mm) in this region.

THE FROG SURVEYS

We initially surveyed Kabulwarnamyo spring, Nakaldurrk, Kunkebngarrng and Alengkel just after dusk for approximately one hour (6.00–7.00 p.m.) and found only a few frogs. We then surveyed Kabulwarnamyo spring at 9.00 p.m. and found much greater frog activity. Surveys were thereafter conducted from 9.00 p.m. at Makkalarl and Alengkel. Frogs were also incidentally recorded on different days at Ngalkombarli at midday (11 March) and in Kabulwarnamyo outstation at 10.00 p.m. (10 March). The water pH and temperature were recorded at each site. Frog species present were identified from sound recordings, photographs and captured frogs (Table 1.).

CDEP: Community Development and Employment Program

CRIO: Consortium for Research and Information Outreach

The frog surveys involved eight people: two full time Warddeken Indigenous Rangers (one male aged 50 and one female aged 23) who are funded by the Australian Government 'Working on Country' program; two part-time Warddeken Indigenous Rangers (one male aged 28 and one female aged 38) who are funded through the Australian Government's Community Development and Employment Program (CDEP) and are paid 'top-up' money by WLML if they work more than 20 hours per week; the non-Indigenous Warddeken Chief Executive Officer (male aged 59) who attended one survey trip; a non-Indigenous field biologist from the Centre for Aboriginal Economic Policy Research (CAEPR) at The Australian National University (ANU) (female aged 32); a non-Indigenous casual field assistant paid by WLML (female aged 26); and the Director of the Consortium for Research and Information Outreach (CRIO) at ANU who attended two survey trips (male aged 60). Different survey tasks were rotated among participants each evening. The tasks were to record frog calls using a Zoom H4® audio recording devices (we used two of these per night), try and catch frogs, take photos of frogs, take water quality measurements, and watch out for buffalo! On the morning following each survey, sound and image data were uploaded onto computers and specimens were photographed. Frogs were identified according to recorded calls using the *Frogs of the Northern Territory* CD ROM (Northern Territory Frogs Database 2003), images in *Frogs of the Northern Territory* (Tyler & Davies 1986) and *Reptiles and Amphibians of Australia* (Cogger 2000), and related distribution, habitat and anatomical descriptions. The aim of our survey work was to record the different types of frogs at each location. A systematic monitoring regime was not implemented because the aim of the exercise was to undertake a successful collaborative effort, create an enjoyable and informative experience for all participants, and determine which methods would be best used to document the frog diversity on the Arnhem Plateau with the available skill and resource set.

CREATING THE DATABASE

The survey data was organised and documented using FileMaker® Pro 10 database software. Individual records of each frog species identify the location and time of collection. An informal workshop on how to use FileMaker® was run by Kim McKenzie, Director of CRIO, at Kabulwarnamyo, and all survey participants attended this workshop. This covered how to upload photos and sounds (after clipping), enter specific information, and construct drop-down lists for species and locations. Participants were encouraged into hands-on experience as the workshop progressed.

Table 2. Mean temperature and pH readings at each site, Arnham Plateau frog survey, 2009

	Site				
	Kabulwarnamyo	Alengkel	Nakaldurrk	Kunkebngarrng	Makkalarl
Temperature (°C)	25	25	25	25	25
pH	4.90	4.61	4.89	4.85	5.15

RESULTS

Over 25 search hours at five sites, a total of 13 native frog species and one exotic species (*Bufo marinus* cane toad) were recorded (Table 1), and tadpoles of three different species were found. The highest frog diversity was found at Makkalarl. *Crinia bilingua* was found at all sites and *Litoria personata* and *Bufo marinus* were found at four of the five sites. Water temperature and pH readings were similar across sites (Table 2).

INDIGENOUS KNOWLEDGE OF FROGS OF THE ARNHEM PLATEAU

Kordbolbok is the generic Bininj Kun-wok word for frogs. Bininj Kun-wok is a language group term for six similar dialects originating from the area bound by Kakadu National Park, down to Pine Creek and across to eastern Arnhem Land to the Mann, Liverpool and Cadell River districts (Evans 2003; Garde 2002). During our survey, junior and senior rangers based at Kabulwarnamyo suggested that *kordbolbok* was the only word used to describe frogs, of any type. However local linguist Murray Garde confirmed that he had heard senior people use other words to describe different frogs through depictions in art, attendance at ceremonies, seeing frogs in the bush and in general discussion (Garde 2002). For example, the golf ball frog or Northern spadefoot toad (*Notaden melanoscaphus*) has been referred to as *kurlbung-kurlbung* in Kune (Bininj Kun-wok dialect) and *ngoyongoyo* as a general Bininj Kun-wok term (M. Garde, pers. comm.). However according to Garde (pers. comm.), no systematic effort to document frog associated words has been undertaken on the Arnhem Plateau.

In our surveys we found two very distinct small round burrowing frogs which we had preliminarily identified as *Notaden melanoscaphus* and *Uperoleia arenicola* (Jabiru toadlet) (see Fig. 4). Both types were called *kordbolbok* by the rangers, along with all other frogs found. After viewing photos taken during our field work, Associate Professor Mike Tyler, an Australian frog expert from the University of Adelaide, was unsure of the identification of the frog we had called *N. melanoscaphus* although suggested that we had most likely correctly identified *U. arenicola.* To aid identification of the frogs of the Arnhem Plateau, we are currently collecting voucher specimens to facilitate correct identification as it has been suggested that the species we had identified as *N. melanoscaphus* may in fact be a new *Uperoleia* species that has not been described by western scientists (M. Tyler, pers. comm.).

The knowledge of only one generic term for all frogs by the younger people suggests that there are obstacles to the transfer of Indigenous ecological knowledge by senior people. However, we expect that each species, according to the western definition, is unlikely to have a unique name in Bininj Kun-wok, based on the lack of usefulness and/or cultural meaning of specific frogs. Frogs do not feature prominently in the mythology and resources of Warddeken (rock country of the Arnhem Plateau) people as they do for central Australian clans (M. Garde, pers. comm.) where they are significant food and water resources

Fig. 4. Unknown *Uperoleia* species dorsal (4a) and ventral (4b) views; and *Uperoleia arenicola* (4c).

(Bayly 1999; Bourne 1953). However, Warddeken people do use frogs for bait (M. Garde & E. Naminyilk, pers. comm.). Frogs and their calls may have also been used as indicators of impending rainfall as they have been noted by Roth (1897, cited by Krappe 1940). In nearby north eastern Arnhem Land, Boll (2004) has documented the occurrence of frogs in Aboriginal mythology, paintings, songs and stories and frogs as a totemic animal of Gurrumurru (north eastern Arnhem land). Boll was also told by a senior Aboriginal man that Galiwin'ku is a frog dreaming area (Boll 2004). The Indigenous uses and mythological representation of frogs on the Arnhem Plateau therefore warrants further investigation.

WESTERN KNOWLEDGE OF FROGS ON THE ARNHEM PLATEAU

Frogs are globally documented as sensitive indicators of ecosystem health based on their physiological absorption of water and solutes through their skin, complex life cycles across terrestrial and aquatic habitats, and specialised use of microhabitats (Cogger 2000). A global decline in frog populations has been quantified (Houlahan et al. 2000) and is broadly attributed to anthropogenic environmental impacts such as water pollution, air pollution, climate change, habitat modification and livestock trampling (Boyer & Grue 1995). For example, a reduction in frog species richness and some species abundances were associated with increased livestock trampling throughout wetlands of the Murrumbidgee River in New South Wales (Jansen & Healey 2003). Similar threats to the frog populations of Arnhem Land are expected although likely to be minimal at this time due to low human population levels and less intensive anthropogenic disturbance. Frog diversity is expected to be high in this area and species lists are likely to continue to increase as more frog surveys are conducted and new species described (Finlayson et al. 2006). New species have been described as recently as 1997 and 2001 (Northern Territory Frogs Database 2003).

Within Arnhem Land, only two documented surveys have been conducted on the mainland and another two on off-shore islands, although several surveys have been conducted in nearby Kakadu National Park. Yibarbuk et al. (2001) studied frog fauna as part of a broader fauna and flora survey on the Dukaladjarranj estate on the north eastern rim of the Arnhem Plateau in the upper catchment of the Cadell River. Across the riparian fringe and river habitats studied, 11 species of frog have been recorded (Table 3) and none

Table 3. Frog species previously recorded in Arnhem Land, nearby off-shore Islands and Kakadu National Park

	Locations of previous surveys				
Species	Kakadu National Park[a]	Dukaladjarranj[b]	Roper River[c]	Wessel/ English Company Islands[d]	Groote Eylandt[e]
Bufo marinus			✓		
Crinia remota			✓		✓
Cyclorana australis	✓		✓		
Limnodynastes convexiusculus	✓	✓	✓		✓
Limnodynastes ornatus	✓	✓	✓	✓	✓
Litoria bicolour		✓	✓	✓	✓
Litoria caerulea	✓		✓		✓
Litoria coplandi	✓	✓			
Litoria inermis	✓	✓	✓	✓	
Litoria meiriana	✓	✓			
Litoira nasuta	✓	✓	✓	✓	✓
Litoria pallida	✓		✓		
Litoria personata		✓			
Litoria rothii	✓		✓		✓
Litoria rubella	✓		✓		✓
Litoria tornieri	✓	✓		✓	✓
Litoria wotjulumensis	✓	✓	✓	✓	✓
Megistolotis lignarius	✓				
Unknown *Uperoleia* species			✓		
Ranidella bilingua	✓	✓			
Sphenophryne adelphe				✓	
Uperoleia arenicola	✓				
Uperoleia inundata	✓		✓	✓	✓
Uperoleia lithomoda	✓		✓		✓
Species richness	24	11	16	8	13

Notes and sources: a. Woinarski & Gambold 1992.
b. Yibarbuk et al. 2001.
c. Catling et al. 1999.
d. Woinarski et al. 1999.
e. Tyler, Davies & Watson 1986.

recorded in the woodland or sandstone habitats (Yibarbuk et al. 2001). As part of a cane toad biodiversity impact study during the 1995/1996 wet season, six species of frogs were recorded in habitat just south of Arnhem Land near the Roper River, described as eucalypt woodland with a grassy understorey adjacent to permanent billabongs and/or rivers (Catling et al. 1999). During ad hoc observations recorded over about 20 years and a more systematic survey during the dry seasons between 1993 and 1996, Woinarski et al. (1999) documented six species on the Wessel and English Company groups of Islands which lie north of Arnhem Land. Additionally, Tyler, Davies and Watson (1986) recorded 13 species on Groote Eylandt.

These few reports suggest that up to 24 species of frogs could occur in Arnhem Land. From comparison of records from within nearby Kakadu National Park and from the rest of tropical monsoonal Australia, we suggest that more species are likely to occur in Arnhem Land—some of which may not have been described by western scientists. We base this suggestion on the remoteness of the country, diversity of habitats, the highly dissected landscape of the Arnhem Plateau, inaccessibility and the restricted access to non-Indigenous people. According to Woinarski and Gambold (1992) the 24 frogs recorded in Kakadu National Park fell into four distinct assemblages based on substrate and moisture availability: sandstone, clay-flat, wet forest and two species with idiosyncratic niches. Within the Arnhem Plateau, which is classed as the sandstone habitat (Woinarski and Gambold 1992), there is a diversity of geographically isolated patches of unique freshwater microhabitats which may host distinct assemblages due to differences in substrate and water availability. Different habitats include perennial spring flats, rivers with or without gorges, perennial creeks with or without jungle vegetation, ephemeral water systems, and billabongs.

DISCUSSION

The Arnhem Plateau frog survey delivered a mixture of ecological, social and educational benefits to the Kabulwarnamyo community. Following continuation of this project and other similar projects, potential longer-term ecological, social, educational and economic benefits are identifiable. This is significant in that it specifically relates outcomes of this project to the natural resource management monitoring, evaluation and reporting improvement framework recently proposed by the Australian Government (2009).

From an ecological perspective, 13 native frog species were recorded in an area which had not been surveyed previously for frogs. Additionally, we may have found one species not previously described by western science. These data contribute preliminary baseline information on the frog diversity of the Arnhem Plateau. Continued monitoring of species abundance and associated habitat features will allow us to predict the impacts of current ecological threat such as cane toads, feral animals, mining and climate change.

Soaks, spring and plateau pools have been suggested as priority habitat types for monitoring of cane toad impact in northern Australia (van Dam, Walden & Begg 2002). Cane toads have established in low densities on the Arnhem Plateau, where the human population is currently far lower than elsewhere in the Top End (P. Cooke, pers. comm.). A number of native frog species are thought to feed on and possibly die from consuming cane toad tadpoles. *Litoria bicolor* tadpoles demonstrated 100 per cent mortality after eating cane toad eggs (Crossland et al. 2008). Other native tadpoles which eat frog eggs or tadpoles may also be at risk: the giant frog (*Cyclorana australis*), green tree frog (*Litoria caerulea*), Dahl's aquatic frog (*Litoria dahlii*), Roth's (brown) tree frog (*Litoria rothii*), and the marbled frog (*Limnodynastes convexiusculus*) (Catling et al. 1999; Tyler & Cappo 1983). It has also been suggested that *Litoria inermis, L. microbelos, L. meiriana, L. nasuta, L. personata, L. tornieri, L. wotjulumensis, Notaden melanoscaphus, Crinia bilingua, Uperoleia arenicola* and *U. inundata* may be affected (van Dam, Walden & Begg 2002). Many of these species were found in the present survey. It has been hypothesised that the cane toad is more likely to have an adverse impact on larger sized native frog species such as the giant frog (*Cyclorana australis*) and the marbled frog (*Limnodynastes convexiusculus*) (Freeland & Kerin 1988). While this may be possible, aestivation during the dry season effectively removes these species from competition during the period of the year when resources are most likely to be limiting (Freeland & Kerin 1988).

There is evidence to suggest that frog species decline increases with the grazing intensity of ungulates in Australian freshwater systems (Jansen and Healey 2003). Buffalo and pigs, both feral ungulates of northern Australia, have been shown to reduce the health of floodplain, billabong and springs of northern Australia through their trampling, grazing, wallowing and migration activities (Ens et al. forthcoming; Fordham et al. 2006; Friend & Taylor 1984; Petty et al. 2007; Skeat, East & Corbett 1996; Taylor & Friend 1984). This damage, however, was not related to significant declines in frog diversity (abundance or richness) of the floodplains in Kakadu National Park (Friend & Cellier 1990). Moreover, some species appeared to show significant positive associations with buffalo wallows, which was attributed to the trapping of early rains and promotion of successful early frog breeding (Friend & Cellier 1990). Further research is required to elucidate whether ecological damage by feral animals affects frog dynamics of Arnhem Plateau wetlands.

Modification of freshwater wetland characteristics could also result from climate change and mining activities in the region. Anthropogenic climate change is predicted to cause sea level rise in northern Australia (Bayliss et al. 1997; Eliot, Finlayson & Waterman 1999) which may lead to saltwater intrusion into floodplains and billabongs in Arnhem Land (Eliot, Finlayson & Waterman 1999; Mulrennan & Woodroffe 1998), thus rendering them unsuitable for frog survival (Boyer & Grue 1995).

Additional longer-term ecological benefits could arise out of such surveys as a result of increased exposure and engagement of traditional owners to biodiversity auditing. Not only are the participants likely to remember why and how we conducted the survey, but they are also likely to tell other people of their experiences. Therefore, direct participation or indirect exposure to the study may encourage people to pursue or continue either informal biodiversity studies and observation or formal biodiversity monitoring. Increased interest in frog species and observations occurred throughout the present survey. Kabulwarnamyo community members who previously had not really participated in ranger activities voluntarily engaged with this frog survey. They spoke to us about frogs they had seen around the outstation, and of other places where they had seen many frogs. These places will be incorporated into future surveys. Discussions continued to invoke mention of other types of animals such as lizards, snakes and insects. During our two-week survey, interest developed from discussion to participation, when non-ranger community members participating in frog survey trips. Many outstation residents were discussing the frog surveys and catching frogs. Frog survey trips continued after the western scientist left the camp, and more are planned for next wet season. Such discussion and direct or indirect participation in the survey has the added social benefits of fostering community cohesion, communication and building human bonds to nature. Community or local stakeholder engagement is recognised as central to effective capacity development (Chino & DeBruyn 2006; Hunt 2005; Land, Hauck & Baser 2009).

Educational benefits from such community-based activities may also become apparent. The present frog survey involved both basic ecological survey training and inter-generational and cross-cultural discussion about why people would want to survey biodiversity, the need to protect country from ecological threats, and current technologies. Participants' investigative skills were also developed by searching through audio, visual and written references to frogs and cross referencing these with our data; and subsequently discussing potential species identification and the supporting reasons—something many participants had not done before. This was an interesting process which built communication bridges between rangers and community members, and between generations. As more species were identified, participants confidence in and ability to read English and discuss findings grew. Furthermore, our data was entered into a Filemaker® database on the computer, which required development of digital photographic image, audio editing and English writing skills. The adaptive nature of the exercise was designed to encourage participant suggestions and alterations to methods used in the frog survey itself and in later documentation of our findings. This adaptive and inclusive approach was seen as imperative to facilitate uptake and ownership of the study, which is advocated by current capacity building principles (Hunt 2005; Land, Hauck & Baser. 2009). Most participants engaged in the documentation activity, although some were apprehensive because of poor English and computer literacy skills. Nevertheless, some initially apprehensive participants did begin to type in words and manipulate digital photos, initially with support and assistance, but later independently. Therefore, some progress was made in regard to administration and documentation skills development of all participants. For some participants, it was the first time they had used water quality testing kits and digital audio-visual technologies (camera, sound recording device, video camera). Again, despite initial apprehension, all participants were using these pieces of equipment with confidence by the end of the survey.

Although this is admittedly a snapshot example, we saw the potential for substantial community development through increased community activity and novel mental stimuli. Further extension of this program along with development of other work programs is likely to continue to build these relationships and experiences, and possibly even offer economic opportunities through the creation of additional land management jobs. Indigenous people own approximately 20 per cent of Australia's land mass (Altman, Buchanan & Larsen 2007), and there is ample opportunity for increased Indigenous involvement in natural resource management on these lands, particularly in environmental monitoring.

Of additional importance was the growth in confidence observed in some participants. Some people who did not previously engage with the ranger program, or speak to the western scientist on previous visits, voluntarily approached the survey team and engaged in the activity. They also expressed interest in becoming more involved in future surveys, not only for mere participation and escape from boredom, but also for health reasons. The majority of Kabulwarnamyo women and some men, have been diagnosed with diabetes and other weight-related issues. Australian Indigenous people have among the highest rates of diabetes in the world (Daniel et al. 1999). Increased participation in natural resource management based activities, such as biodiversity surveys, allows people to get out on country, walk around and increase their exercise levels. The health benefits of increased involvement in natural resource management activities by Indigenous people is an expanding research field (see Burgess et al. 2005).

The present survey was a foundation exercise designed to identify frog species occurring in several wetlands of the Arnhem Plateau and to build ranger capacity to monitor and document biodiversity. Initial successes were evident in terms of a comparable species list for this region and social, cross-cultural and educational benefits. The longer-term benefits of continued biodiversity surveys and ecological monitoring are likely to incorporate socioeconomic, educational, ecological and health issues, as previously discussed. Sustained government and non-government financial and operational support of Indigenous land and sea management programs which facilitate the meshing of Indigenous and non-Indigenous methods is crucial to achieving these goals, while at the same time assisting the broader policy aims of closing the gap in Indigenous disadvantage.

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