AN UPDATE ON THE STATUS OF WET FOREST STREAM-DWELLING FROGS OF THE EUNGELLA REGION

MEYER, E. A.[1], HINES, H. B.[2], CLARKE, J. M.[3] & HOSKIN, C. J.[4]

Eungella's wet forests are home to a number of stream-breeding frogs including three species endemic to the Eungella region: the Eungella dayfrog (*Taudactylus eungellensis*), Eungella tinkerfrog (*T. liemi*), and northern gastric brooding frog (*Rheobatrachus vitellinus*). During the mid-1980s, *T. eungellensis* and *R. vitellinus* suffered dramatic population declines attributable to amphibian chytridiomycosis, a disease caused by the amphibian chytrid fungus (*Batrachochytrium dendrobatidis* or Bd). While surveys in the late 1980s failed to locate *T. eungellensis* or *R. vitellinus*, populations of the former were located on a handful of streams surveyed by researchers in the mid-to-late 1990s. Between January 2000 and November 2015, additional surveys targeting these and other wet forest frog species were conducted at 114 sites within Eungella National Park and adjoining areas of State Forest. During these surveys, we located *T. eungellensis* at many more sites than surveys in the 1990s. Abundances of *T. eungellensis* at these sites were typically low, however, and well below abundance levels prior to declines in the mid-1980s. As with surveys in the 1990s, *T. eungellensis* was scarce at high-elevation sites above 600 metres altitude. Numbers of this species do not appear to have increased significantly since the mid-1990s, suggesting recovery of *T. eungellensis* populations is occurring slowly, at best. In contrast with *T. eungellensis*, *T. liemi* was frequently recorded at high-elevation sites, albeit at low densities. As with previous surveys, surveys during 2000–2015 were unsuccessful in locating *R. vitellinus*. Further frog surveys and monitoring (including disease surveillance) are needed to better assess the status of stream frogs at Eungella, and to understand the influence of Bd on the abundance and distribution of threatened stream-dwelling frogs at Eungella.

Keywords: Eungella, frogs, conservation status

[1] *5 Luscombe Street, Runcorn, Queensland, Australia (ed_meyeroz@yahoo.com.au)*
[2] *Ecological Assessment Unit, Queensland Parks and Wildlife Service, Department of Environment and Science, PO Box 15187, City East, Queensland, Australia*
[3] *Regional Projections, CSIRO Climate Science Centre, Private Bag 1, Aspendale, Victoria, Australia*
[4] *College of Science & Engineering, James Cook University, Townsville, Queensland, Australia*

INTRODUCTION

The wet forests of Eungella are home to a number of stream-dwelling frogs including three species endemic to the Eungella region: the northern gastric brooding frog (*Rheobatrachus vitellinus*), Eungella dayfrog (*Taudactylus eungellensis*), and Eungella tinkerfrog (*T. liemi*). Once common in areas of suitable habitat, *R. vitellinus* and *T. eungellensis* suffered dramatic population declines in the mid-1980s, and neither species could be located during surveys in the late 1980s and early 1990s (McDonald, 1990). Numbers of another more widely distributed species, the tusked frog (*Adelotus brevis*), may also have declined at sites north of Eungella township in the mid-1980s. No declines were noted in *T. liemi* or any other stream-dwelling frog species known from the Eungella region at this time (McDonald, 1990); however, data on these species are sparse. More recently, Anstis (2013) reported a possible decline in *T. liemi* numbers at Eungella, but provided little in the way of evidence to support this claim.

The sudden population declines at Eungella during the 1980s are likely attributable to amphibian chytridiomycosis, a disease caused by the amphibian chytrid fungus (*Batrachochytrium dendrobatidis* or Bd), which has also been implicated in declines affecting other stream-breeding species in south-eastern Queensland and the Wet Tropics region of northern Queensland during the late 1970s and late 1980s/early 1990s (Richards *et al*., 1993; Retallick *et al*., 2004; Scheele *et al*., 2017; Berger, 2000; Murray *et al*., 2010). This fungus and disease were only described in the late 1990s and were unknown at the time that declines affecting *T. eungellensis* and *R. vitellinus* took place.

Before its disappearance in the mid-1980s, *R. vitellinus* was known from rocky rainforest streams above 405 m altitude (Figure 7C) with animals commonly encountered in shallow water amongst rocks in riffle zones and around cascades (McDonald, 1990). At this time, *R. vitellinus* was known from first, second and third order streams within the catchments of Finch Hatton, Urannah, Cattle and Owens Creeks (McDonald, 1990; Figures 1A and 2). *Taudactylus eungellensis* was more broadly distributed at Eungella, and while present on some of the same streams inhabited by *R. vitellinus*, was more commonly encountered on larger (third, fourth and fifth order) streams, including streams at lower elevation (below 405 m altitude) (McDonald, 1990). Unlike *R. vitellinus*, *T. eungellensis* was also present in wet forest areas south of the township of Eungella, within the Broken River and Cattle Creek (South Branch) catchments (McDonald, 1990; Liem & Hosmer, 1973; Figures 1B and 2). According to McDonald (1990), both species were common across their range until January 1985, when declines were first noted at lower-altitude sites (around 400–500 m altitude). Thereafter, numbers of *T. eungellensis* and *R. vitellinus* declined dramatically, and neither species could be located after 1986 despite repeated surveys throughout the late 1980s (McDonald, 1990).

In 1992, six years after *T. eungellensis* was last sighted in the wild, a single subadult animal was seen and photographed on Boulder Creek in the east of Eungella National Park (Couper, 1992; P. Couper, Queensland Museum, *pers. comm.*). Surveys led by James Cook University researchers Jean-Marc Hero and Richard Retallick the following year located *T. eungellensis* on a small number of streams in the south and east of Eungella National Park; however, no *R. vitellinus* were seen or heard at this time (McNellie & Hero, 1994). Subsequent surveys and monitoring conducted by Retallick during the mid-to-late 1990s yielded additional records of *T. eungellensis*, as well as data on the abundance and population trends of *T. eungellensis* and other stream-dwelling frogs in the south and east of the Clarke Range (R. Retallick, *pers. comm.*, unpublished report). Despite targeted surveys, no *R. vitellinus* were located at this time either (McDonald & Alford, 1999; Northern Queensland Threatened Frogs Recovery Team, 2001). A more recent unsuccessful survey targeting *R. vitellinus* was mentioned by Moore (2014), but no details of areas searched or observations of other frog species were provided.

In this paper, we present data from coordinated surveys and monitoring targeting *T. eungellensis*, *T. liemi* and *R. vitellinus* carried out by Queensland Parks and Wildlife Service staff and volunteers (including the authors) through 2000–2006, and subsequent surveys led by Conrad Hoskin. This includes survey results from sites in remote and difficult-to-access parts of Eungella National Park not previously surveyed for frogs, as well as resurveys of historical sites for *R. vitellinus* and *T. eungellensis*. Surveys targeting these species also yielded data on other wet forest and stream-associated frogs (*A. brevis*, *Litoria revelata*, *Litoria chloris*, *Litoria wilcoxii/jungguy*, *Mixophyes fasciolatus*), some of which are highly localised in the Eungella region and may also have been impacted by the emergence of chytridiomycosis, albeit to a lesser extent than *R. vitellinus* or *T. eungellensis*. Collectively, these data provide the most comprehensive and up-to-date assessment of the status of wet forest stream-dwelling frogs at Eungella currently available.

MATERIALS AND METHODS

Nomenclature and Terminology

The nomenclature in this paper follows that used in the Queensland Government's WildNet database. Although genetically distinct, the northern and eastern stony creek frog (*Litoria jungguy* and *L. wilcoxii*, respectively) are very similar in appearance and difficult to separate in the field (Donnellan & Mahony, 2004). Records of these species have therefore been combined. In this paper, the term 'site' refers to a section of stream between confluences as mapped on the 1:50,000 topographic map sheets available at the time surveys were undertaken.

Data Sources

The data presented in this paper are from two main sources: (1) surveys and standardised monitoring coordinated by Queensland Parks and Wildlife Service (QPWS) through 2000–2006 (comprising the 'QPWS dataset'); and (2) surveys undertaken by Conrad Hoskin and colleagues through 2009–2015 (comprising the 'Hoskin dataset'). Details of these surveys and associated datasets are provided below, while the location of survey and monitoring sites is shown in Figure 2A.

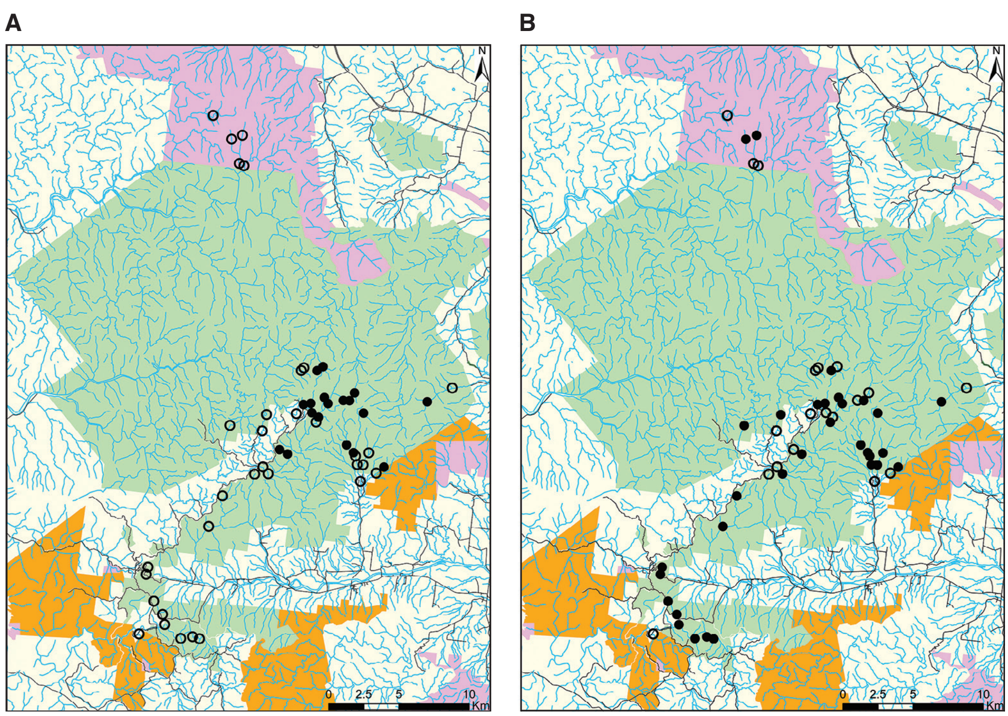
QPWS Surveys and Data

The QPWS dataset comprises data from annual surveys and standardised monitoring undertaken by QPWS staff and trained volunteers from January 2000 through to December 2006 (JC, EM and/or HH were the key personnel involved in planning and implementing these surveys). Annual surveys run by QPWS were undertaken during the 1999–2000, 2000–2001, 2001–2002, 2003–2004, and 2005–2006 wet seasons (see Table 1 for details regarding the timing of surveys). During these surveys, wet forest streams of the Clarke Range, principally within Eungella National Park and also nearby areas of State Forest (including Crediton and Cathu State Forest), were surveyed for frogs and tadpoles by teams of 3–4 observers. In most cases, streams were surveyed by day and night (in the afternoon and early evening), with observers using headlamps and dipnets to locate frogs and tadpoles along and adjacent to streams.

During annual surveys, QPWS staff and volunteers surveyed 84 stream sites within the catchments of Broken River, Finch Hatton, Cattle (North and South Branches), upper Urannah, Boulder, upper St Helens, Rawsons, Amelia, Massey, Quandong, Cathay and Tree Fern Creeks (Figure 2). This included historical sites that *T. eungellensis* and *R. vitellinus* were known from prior to declines in the 1980s, sites surveyed by Retallick and Hero in the early-to-mid 1990s, and a number of sites not previously surveyed for frogs. A significant proportion (~75%) of these were surveyed on multiple occasions through 2000–2006. In between annual surveys, QPWS staff and volunteers undertook additional censuses at a number of monitoring transects established by Retallick and Hero (Retallick *et al*., 1997, unpublished), including sites on Rawsons, Tree Fern, Finch Hatton, and Mt William and Mt David Creeks (the latter two in the upper Cattle Creek North Branch catchment) (Figure 2; Table 2). Details regarding the timing of these additional censuses are provided in Table 1.

For each diurnal and nocturnal survey, the following information was recorded on a pro forma: (1) the number of each species observed; (2) the age/life stage and reproductive condition of animals observed; (3) how animals were observed (i.e. whether animals were heard, seen or handled/captured); (4) the presence of sick, moribund or dead animals; (5) stream flow and water quality; (6) the nature and extent of any pig or fire damage; (7) the date, start and end times for each survey; (8) the length of stream surveyed; (9) weather conditions during and preceding surveys; (10) the names of the observers; and (11) site and transect location.

FIGURE 1. Map of the Eungella area showing the historical distribution of (A) *Rheobatrachus vitellinus* and (B) *Taudactylus eungellensis* at sites surveyed by McDonald (1990), prior to catastrophic declines in the mid-1980s. Presence sites represented by closed circles (●), absence sites by open circles (○). After McDonald (1990). Refer Figure 2 for further details of the study area.



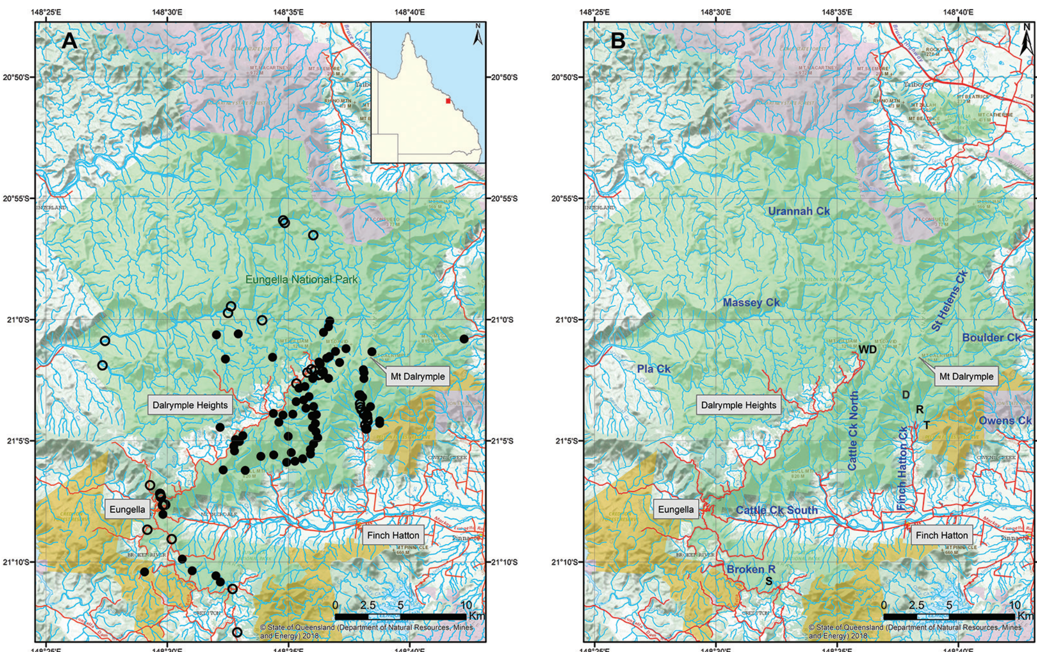


FIGURE 2. Maps of the Eungella area showing: (A) the location of survey sites included in QPWS and Hoskin datasets from 2000–2015, with QPWS sites represented by closed circles (●) and Hoskin sites by open circles (○); (B) major creek catchments and the location of QPWS monitoring transects (WD = Mount William and Mount David Creeks, D = Dooloomai Falls, R = Rawsons Creek, T = Tree Fern Creek and S = Sunrise Creek). In these figures, Eungella National Park is shaded light green, forest reserves brown and state forests pink. Major drainage lines are shown in blue and roads in red. The townships of Eungella and Finch Hatton are labelled, as well as the locality of Dalrymple Heights and Mount Dalrymple, the highest point in the study area at 1260 metres altitude. Base map sourced from http://qtopo.dnrm.qld.gov.au

In addition to records from the aforementioned surveys, the QPWS dataset includes additional opportunistic observations through 2000–2009 from EM and members of the Mackay Bushwalkers' Club (confirmed by HH and EM from field notes and/or photographs).

Hoskin Surveys and Data

The Hoskin dataset includes georeferenced data from a number of smaller surveys led by CH from 2009 to 2015 (see Table 1 for details). While some of the sites surveyed by CH overlap with sites surveyed by QPWS (e.g. sites in lower Finch Hatton Creek, and headwater streams of Cattle Creek North Branch), the majority were on streams not surveyed by QPWS through 2000–2006. This includes a number of remote and difficult-to-access streams at low-to-mid elevation in the lower Pla Creek and Massey Creek, and mid/upper Urannah Creek catchments, most of which appear not to have been surveyed for frogs previously. For the most part, CH recorded only the frog species present and relative abundance of species present at each survey site.

Disease Management and Surveillance

As discussed earlier, frog population declines at Eungella during the mid-1980s are likely attributable to the emergence of amphibian chytridiomycosis, a disease implicated in the decline and disappearance of stream frogs in other parts of Queensland. To understand the current impact of this disease on frog species at Eungella, QPWS survey teams were asked to keep a record of any sick and/or dead animals encountered during surveys. A subset of sick/moribund animals were swabbed and tested for amphibian chytrid fungus using techniques described in Murray *et al*. (2010). Apparently healthy frogs and tadpoles were also tested for amphibian chytrid fungus at a handful of survey sites.

TABLE 1. Summary of survey effort showing the timing and location of stream frog surveys coordinated by QPWS and C. Hoskin from 2000 to 2015, including the number of sites surveyed in each creek catchment.

Year	Month	Dataset	No. of sites	Amelia Creek	Bee Creek	Boulder Creek	Broken River	Cathay Creek	Cattle Creek North	Cattle Creek South	Endeavour Creek	Finch Hatton Creek	Hazelwood Creek	Massey Creek	Pla Creek	Quandong Creek	Rawsons Creek	St Helens Creek	Tree Fern Creek	Urannah Creek
2000	10	QPWS	3									2					1			
2000	12	QPWS	21			1	4	1	4	1	1	3	1			2	2		1	
2001	5	QPWS	5							1		2					2			
2001	11	QPWS	30	1		1	3		12	1		6		2			2	1	1	
2002	9	QPWS	5									2					2		1	
2002	11	QPWS	13				1		7			3					1		1	
2002	12	QPWS	21				1		12			1		2			2			3
2003	5	QPWS	2									2								
2003	9	QPWS	1														1			
2004	1	QPWS	23				3		12	1		2					3		2	
2004	4	QPWS	4									2					1		1	
2004	7	QPWS	4									2					1		1	
2004	10	QPWS	4						1			1					1		1	
2005	2	QPWS	6						1			2					2		1	
2005	5	QPWS	5						1			2					2			
2005	9	QPWS	3									2					1			
2005	10	QPWS	5						1			1		1			2			
2006	1	QPWS	4									2					1		1	
2006	2	QPWS	5						2			1					1		1	
2006	9	QPWS	1														1			
2006	10	QPWS	2									2								
2006	12	QPWS	30				2		21	1		2		1			2		1	
2008	2	QPWS	1														1			
2009	9	Hoskin	2											1	1					
2010	12	QPWS	1						1											
2012	2	QPWS	1						1											
2012	10	Hoskin	10		4		2		1			2		1						
2014	3	Hoskin	5				3		1			1								
2015	11	Hoskin	22				1		4	3		7		3			1			3

TABLE 2. Frog monitoring sites surveyed by QPWS staff and trained volunteers from 2000 through to 2006.

Location	Altitude (m)	Distance (m)
Rawsons Creek	330	200
Dooloomai Falls (Right-hand Side), Finch Hatton Creek catchment	550	200
Dooloomai Falls (Left-hand Side), Finch Hatton Creek catchment	550	200
Mt David Creek: Upper tributary of Cattle Creek (North Branch) draining from western slopes of Mt David	940	700
Mt William Creek: Upper tributary of Cattle Creek (North Branch) on southern slopes of Mt William	980	400
Tree Fern Creek	230	200
Sunrise Creek: Tributary of Broken River approximately 3.5 km east-south-east of the QPWS base at Broken River	790	200

Because of the threat posed by amphibian chytridiomycosis and other diseases, hygiene protocols were adopted to reduce the risk of spreading pathogens to and from the Eungella region, as well as amongst survey sites. To reduce the risk of pathogen spread between sites, footwear and dipnets were cleaned and disinfected when moving between subcatchments. In order to reduce the risk of disease transmission between animals, frogs and tadpoles were also handled using separate disposable gloves and freezer bags.

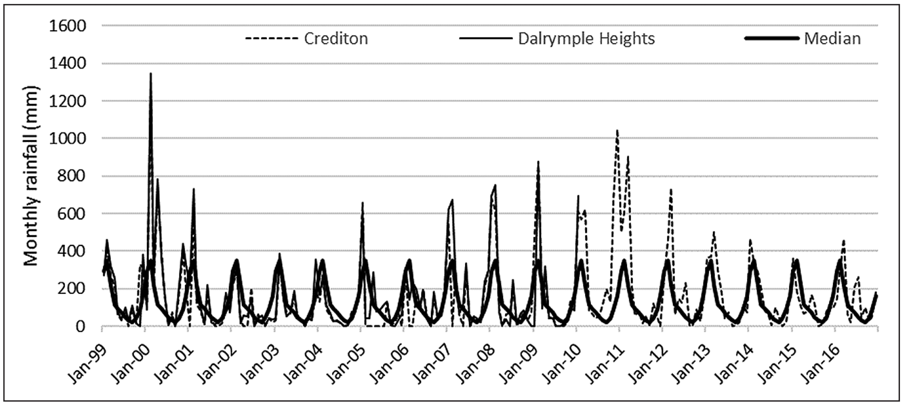
Climatic Conditions During Surveys

Monthly rainfall data for the Eungella area over the period in which surveys were undertaken are presented in Figure 3. The data in this figure show significant variation in wet season rainfall from 1999 to 2016, with above-median falls during the 1999–2000 and 2000–2001 wet seasons and below-median rainfall during subsequent wet seasons up until, and including, the 2005–2006 wet season. Rainfall totals for subsequent wet seasons were above or well above median up until 2013–2014, after which wet season rainfall was at median or below-median levels (Figure 3). While surveys in the very early 2000s coincided with above-median wet season rainfall, most of the surveys discussed in this paper were conducted in wet seasons with below-median rainfall.

Data Collation and Analysis

The QPWS dataset was managed using a Microsoft Access database. HH and EM vetted the data for suspect records (where the identification of frogs or tadpoles appeared doubtful and could not be verified).

FIGURE 3. Monthly rainfall totals for Crediton (south of Eungella township) and Dalrymple Heights weather stations from January 1999 to December 2016 (sourced from Bureau of Meteorology website http://www.bom.gov.au/climate/data/index.shtml accessed 15 July 2018). Median rainfall figures are based on data collected at Crediton over the period 1953–2018.



Presence records were used to generate distribution maps for each of the wet forest species encountered, as well as the introduced cane toad *Rhinella marina*, and to investigate altitudinal variation in site occupancy. Count data were also used to investigate altitudinal variation in frog abundance at presence sites. To account for variation in transect length, counts of post-metamorphic (adult and subadult) frogs recorded during surveys were standardised to 100 m. We used Microsoft Excel to plot maximum standardised counts for each site against altitude, and undertook regression analyses to investigate the relationship between frog abundance and altitude for all rainforest species encountered during surveys, except the whirring tree frog (*Litoria revelata*), which was only recorded at three sites between 930 and 980 m altitude. For the purposes of this analysis, site altitude was inferred from topographic maps using the approximate centre point of each site.

Long-term trends in the abundance of *T. eungellensis* and *T. liemi* at monitoring transects through 2000–2006 were investigated by plotting raw count data from standardised surveys against time and conducting regression analyses on these data.

RESULTS

Fifteen frog species were recorded on streams surveyed by QPWS and CH from 2000 to 2015. Table 3 summarises the number, altitudinal distribution and proportion of survey sites occupied by each species. More detailed information on the distribution and abundance of frog species recorded during surveys is provided below.

Northern Gastric Brooding Frog (Rheobatrachus vitellinus)

Despite searches of historical sites and numerous other rainforest streams above 400 m altitude, no *R. vitellinus* were recorded on any of the 114 sites surveyed through 2000–2015.

TABLE 3. Altitudinal distribution of frog species recorded during the current survey (QPWS and Hoskin datasets combined), 2000–2015.

Species	Number of presence sites	Altitudinal range (m)	Site occupancy (proportion of survey sites where species recorded)			
			<350 m altitude (n=28)	350–600 m altitude (n=20)	601–850 m altitude (n=37)	>850 m altitude (n=29)
Adelotus brevis	19	230–940	0.07	0.25	0.24	0.10
Limnodynastes peronii	9	230–980	0.11	0.00	0.14	0.03
Limnodynastes terraereginae	1	680	0.00	0.00	0.03	0.00
Litoria chloris	45	130–1020	0.29	0.45	0.41	0.45
Litoria fallax	4	220–980	0.04	0.00	0.00	0.10
Litoria gracilenta	2	680–790	0.00	0.00	0.05	0.00
Litoria inermis	1	130	0.04	0.00	0.00	0.00
Litoria latopalmata	1	980	0.00	0.00	0.00	0.03
Litoria wilcoxii/jungguy	60	130–980	0.61	0.75	0.54	0.28
Litoria revelata	4	930–980	0.00	0.00	0.00	0.14
Mixophyes fasciolatus	38	130–1000	0.18	0.35	0.38	0.41
Taudactylus eungellensis	32	190–1050	0.32	0.50	0.19	0.21
Taudactylus liemi	63	230–1050	0.25	0.45	0.65	0.79
Uperoleia fusca	2	880–940	0.00	0.00	0.00	0.07
Rhinella marina	21	130–790	0.39	0.30	0.11	0.00

Eungella Dayfrog (Taudactylus eungellensis)

During our surveys, we recorded *T. eungellensis* at 32 sites across five catchments, including Finch Hatton, Rawsons, Cattle (North Branch), Tree Fern and upper Urannah Creeks (Figure 4A). Sites with *T. eungellensis* ranged in altitude from 190 m to 1050 m, with the majority of presence sites below 700 m altitude. Site occupancy was highest below 600 m altitude, with *T. eungellensis* present at 50% of sites surveyed between 350–600 m altitude (Table 3).

During QPWS surveys, the abundance of *T. eungellensis* at presence sites was generally low, with numbers of post-metamorphic *T. eungellensis* rarely exceeding 10 animals per 100 m of stream transect. Counts of post-metamorphic *T. eungellensis* were generally higher below 700 m altitude, with the highest abundance (60 per 100 m of stream transect) recorded on Rawsons Creek, at 330 m altitude (Figure 5). In contrast with sites below 700 m altitude, counts of *T. eungellensis* at sites above 700 m altitude were consistently low, with no more than three animals recorded per 100 m of stream transect (Figure 5). Qualitative abundance data from surveys undertaken by Hoskin are broadly consistent with those from QPWS surveys, with *T. eungellensis* occurring at higher densities on lower elevation streams (<600 m altitude) compared with streams at higher elevation.

Summary statistics of *T. eungellensis* counts from QPWS monitoring transects over the period 2000–2006 are provided in Table 4. Counts at monitoring transects varied considerably between censuses and there was no clear or consistent trend in *T. eungellensis* numbers during this period, other than an apparent increase at Dooloomai Falls (Figure 6). On average, counts of *T. eungellensis* at monitoring transects were higher during diurnal surveys than nocturnal surveys (Table 4).

During our surveys, *T. eungellensis* were mostly recorded from larger, more open streams strewn with large rocks and boulders (Figure 7A). During diurnal surveys, adult and subadult *T. eungellensis* were mostly seen resting on wet rocks and boulders near areas of cascading water (Figure 7B). However, at night, animals were also observed sitting out on low vegetation (palm seedlings, sapling trees and fallen palm fronds) beside streams. Tadpoles of *T. eungellensis* were mainly recorded from deeper pools with slow-flowing water.

Only a small number of moribund/dead *T. eungellensis* were located during surveys, including two adult animals at Rawsons Creek (at 330 m altitude), one at Tree Fern Creek (at 230 m altitude) and one near Mt David Creek in the upper Cattle Creek North Branch catchment (at 1050 m altitude). Sick/moribund *T. eungellensis* were found sitting out in exposed situations (e.g. on bare rock) in various states of decomposition. One of the animals from Rawsons Creek was confirmed as being infected with chytridiomycosis (Murray *et al*., 2010).

Eungella Tinkerfrog (Taudactylus liemi)

During our surveys, *Taudactylus liemi* was recorded at 63 sites across 11 creek catchments, including Broken River, Amelia, Cattle (North and South Branches), Endeavour, Finch Hatton, Massey, Rawsons, St Helens, Tree Fern, and Urannah Creeks (Figure 4B). Sites where *T. liemi* was recorded ranged in altitude from 230 m to 1050 m above sea level. In contrast with *T. eungellensis*, *T. liemi* was more commonly encountered on streams above 600 m altitude than streams below 600 m, with *T. liemi* recorded at 65% of survey sites between 600 m and 850 m altitude (Table 3). The proportion of sites occupied by this species was even higher above 850 m altitude, where *T. liemi* was present at almost 80% of sites surveyed.

TABLE 4. Summary statistics and the results of linear regression analyses for count data from surveys undertaken at QPWS *T. eungellensis* monitoring transects from 2000 through to 2006. Regression analyses returning a non-significant result ($p > 0.05$) are denoted by the letters 'N.S.'. These data are based on counts of post-metamorphic animals from standardised censuses.

Site	**Maximum count**	**Median count**	**Mean diurnal count (mean ± s.e.m.)**	**Mean nocturnal count (mean ± s.e.m.)**	**Results of regression analysis**	**Number of standardised surveys (diurnal/nocturnal)**
Rawsons Creek	121	62.5	70.5 ± 6.00	45.36 ± 7.87	N.S.	44 (22/22)
Dooloomai Falls (LHS)	12	2	3.33 ± 1.02	1.93 ± 0.48	$p < 0.05$	30 (15/15)
Dooloomai Falls (RHS)	2	0	0.33 ± 0.19	0.11 ± 0.11	N.S.	21 (12/9)
Tree Fern Creek	11	1	2.38 ± 0.97	2.00 ± 1.20	N.S.	15 (8/7)
Mt William Creek	0	0	0	0	N.S.	20 (11/9)
Mt David Creek	1	0	0.0 ± 0.0	0.33 ± 0.33	N.S.	7 (4/3)

FIGURE 4. Distribution of frog species recorded during surveys from 2000 to 2015: (A) *T. eungellensis*; (B) *T. liemi*; (C) *A. brevis*; and (D) *L. chloris*. Presence sites represented by closed circles (●), absence sites represented by open circles (○). Refer to Figure 2 for a description of the features of the base map.

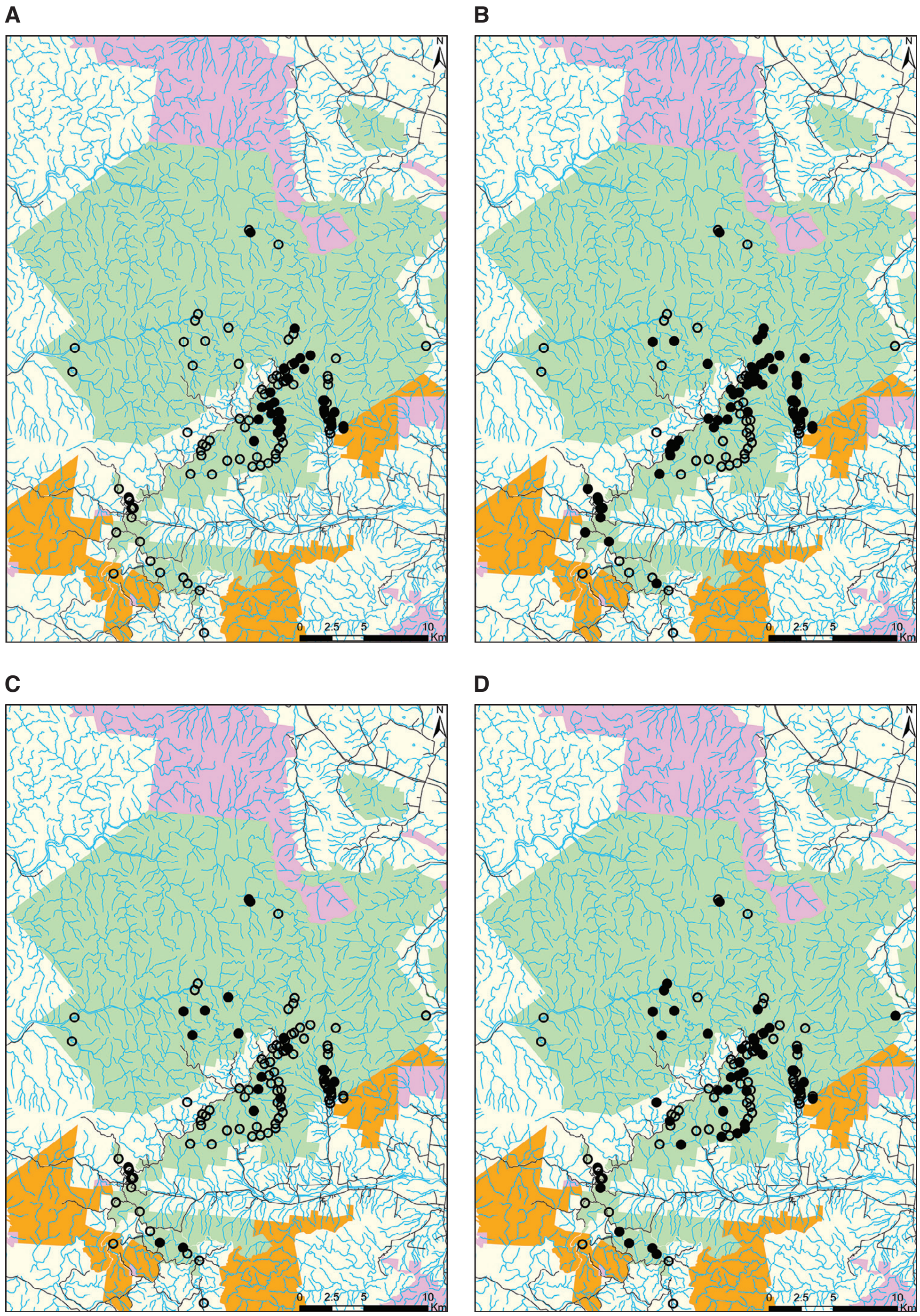
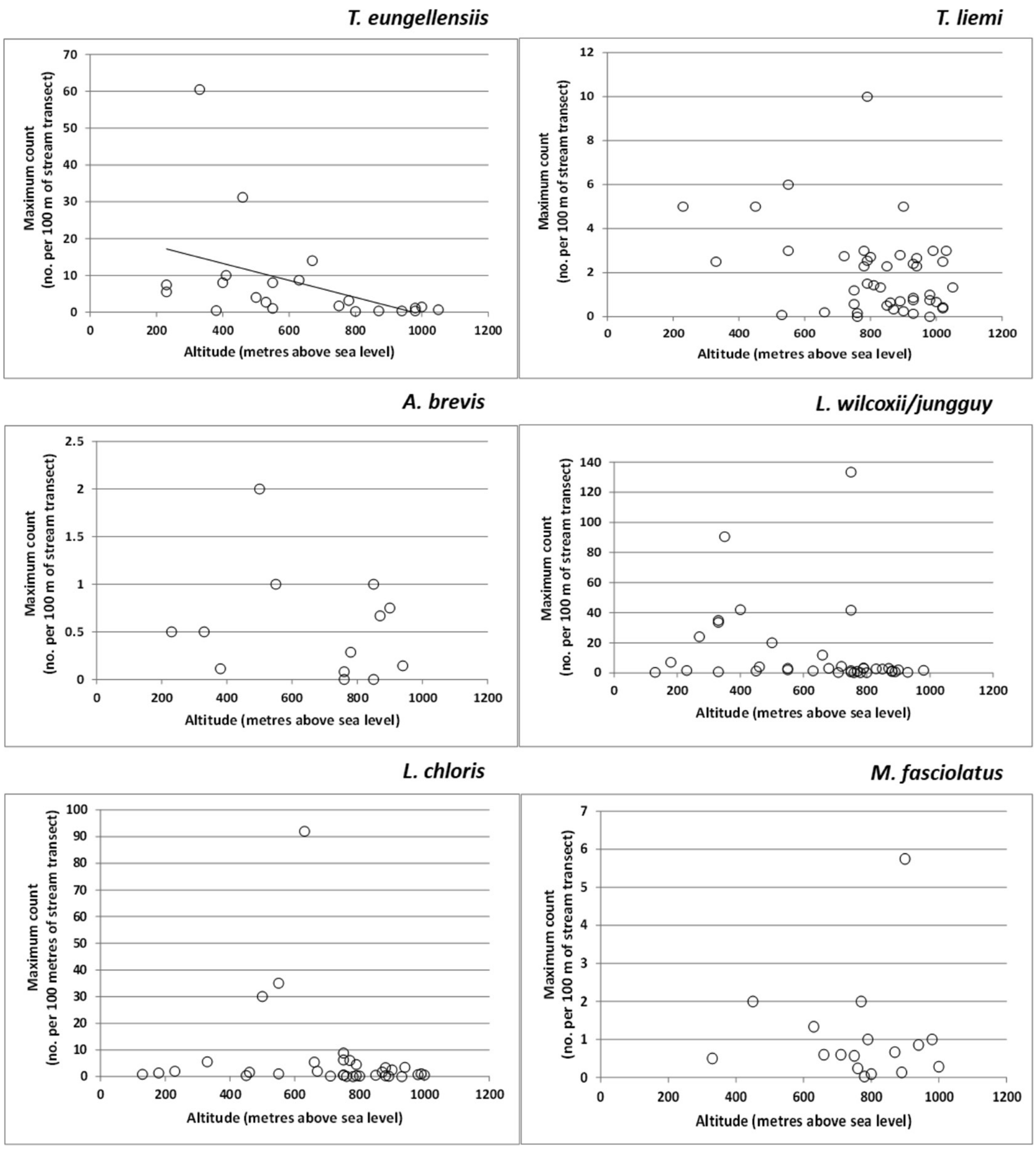


FIGURE 5. Altitudinal variation in counts of post-metamorphic animals at presence sites during QPWS surveys. The data points in these plots represent the maximum counts for each site standardised to 100 m of stream transect. Trendlines are included only for linear regression analyses with a *p* value less than 0.05.



During QPWS surveys, the abundance of *T. liemi* at presence sites was generally low, with numbers of post-metamorphic individuals rarely exceeding four animals per 100 m of stream transect (Figure 5). The relationship between altitude and abundance of *T. liemi* during these surveys (Figure 5) was unclear. On average, however, counts of *T. liemi* at sites above 800 m elevation were lower than counts at sites below 800 m altitude. Qualitative abundance data from the Hoskin surveys were consistent with the trends in the QPWS dataset.

Summary statistics for *T. liemi* counts from QPWS monitoring transects over the period 2000–2006 are provided in Table 5. Numbers of *T. liemi* at these transects varied considerably between censuses and there was no clear or consistent trend in count data during this period, with regression analyses returning non-significant results.

The majority of *T. liemi* records from our surveys were of animals calling from rock piles and crevices along smaller (first and second order) streams, or seepage areas and drainage lines adjoining larger streams. Numbers of *T. liemi* did not vary consistently between nocturnal or diurnal surveys (Table 5). During QPWS surveys, tadpoles of *T. liemi* were commonly sighted in shallow, silt-laden pools along smaller, gently flowing streams (Figure 7D). On occasion, *T. liemi* tadpoles were sighted on larger streams, though only in very low numbers and only during periods of low or basal flow. Spawn of *T. liemi* was not recorded during surveys; however, on one occasion early-stage tadpoles (Gosner stage 24–25) were located in seepage water in a narrow rock crevice. Although no sick or moribund *T. liemi* were observed during surveys, a number of animals collected for captive breeding in the late 2000s did test positive for amphibian chytrid fungus (Taudactylus Research and Husbandry Team, 2012).

Tusked Frog (Adelotus brevis)

During surveys, we recorded *A. brevis* at nineteen sites across five catchments, including Broken River, Cattle (North Branch), Finch Hatton, Massey and Rawsons Creek catchments (Figure 4C). Sites with *A. brevis* were situated between 230 m and 940 m altitude, with the majority of presence sites located between 350 m and 850 m altitude. Counts of *A. brevis* along QPWS stream transects were generally very low, with a maximum abundance of two animals per 100 m, and there was no clear relationship between altitude and the abundance at presence sites during surveys (Figure 5).

Whilst conducting surveys, *A. brevis* was recorded calling from isolated streamside pools in bedrock and seepage-fed pools adjoining streams, or occasionally the backwaters of large, slow-moving pools. Spawn and tadpoles of *A. brevis* were rarely seen, and no sick or moribund animals were observed.

Southern Orange-eyed Treefrog (Litoria chloris)

During surveys, *L. chloris* was recorded from 45 sites and 13 of the 16 creek catchments surveyed through 2000–2015 (Figure 4D). Sites at which *L. chloris* was recorded during surveys ranged in altitude from 130 m to 1020 m, with the majority of records above 500 m altitude. *Litoria chloris* was present at over 45% of sites above 350 m elevation, compared with 21% of sites below this altitude (Table 3).

During QPWS surveys, the abundance of *L. chloris* at presence sites ranged from one to 92 animals per 100 m of stream transect; however, numbers at most sites were low (<8 animals per 100 m). The very high counts of *L. chloris* recorded at some sites represent aggregations of calling males during irruptive breeding events. Sites with higher numbers were situated between 500 and 700 m elevation. Overall, however, there was no clear relationship between abundance and altitude in this species (Figure 5).

FIGURE 6. Count data for *T. eungellensis* from the QPWS monitoring transect at Dooloomai Falls (Left-hand Side) from 2000 through to 2006. This transect is situated at 550 m altitude in Finch Hatton Creek catchment (shown as 'D' in Figure 2B).

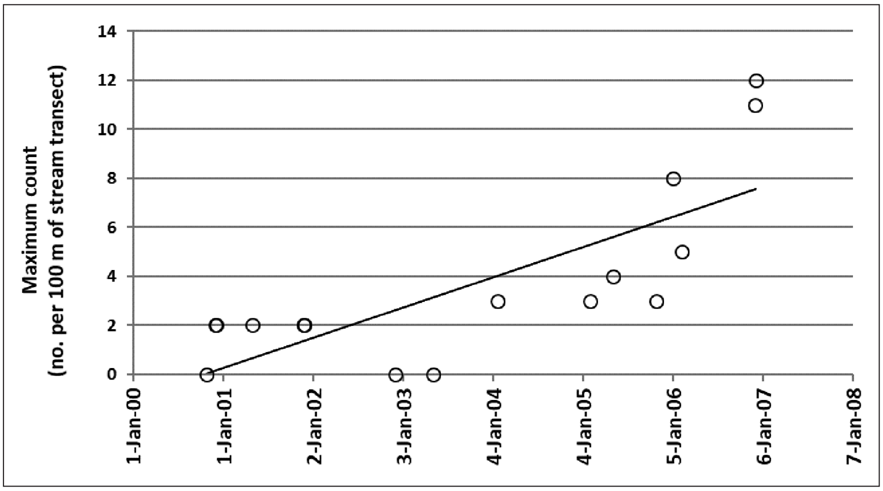


TABLE 5. Summary statistics and the results of linear regression analyses for count data from surveys undertaken at QPWS *T. liemi* monitoring transects from 2000 through to 2006. Regression analyses returning a non-significant result ($p > 0.05$) are denoted by the letters 'N.S.'. These data are based on counts of post-metamorphic animals from standardised censuses.

Site	Maximum count	Median count	Mean diurnal count (mean ± s.e.m.)	Mean nocturnal count (mean ± s.e.m.)	Results of regression analysis	Number of standardised surveys (diurnal/nocturnal)
Dooloomai Falls (LHS)	8	1	2.38 ± 0.53	1.63 ± 0.34	N.S.	37 (21/16)
Dooloomai Falls (RHS)	6	1	1.77 ± 0.43	0.56 ± 0.29	N.S.	21 (12/9)
Tree Fern Creek	12	1	0.63 ± 0.26	2.71 ± 1.60	N.S.	15 (8/7)
Mt William Creek	15	2	3.44 ± 1.09	4.60 ± 1.37	N.S.	20 (10/10)
Mt David Creek	4	2	3.00 ± 1.00	2.67 ± 0.88	N.S.	8 (5/3)
Sunrise Creek	3	0	0.75 ± 0.41	0.50 ± 0.50	N.S.	14 (8/6)

L. chloris was most commonly recorded along streams with exposed bedrock containing isolated pools. Spawn and tadpoles were often found in these pools, while adult frogs were seen sitting out on rocks and vegetation along streams. On occasion (during periods of low or basal flow), tadpoles of *L. chloris* were also recorded from larger mid-stream pools. Three sick or dead *L. chloris* were recorded below 400 m altitude on Cattle (North Branch) and Rawsons Creeks during QPWS surveys. Sick *L. chloris* encountered at this time exhibited lethargy, but no other symptoms typical of amphibian chytridiomycosis.

Northern/Eastern Stony Creek Frog (Litoria jungguy/wilcoxii)

L. jungguy and/or *L. wilcoxii* were recorded at 60 sites between 130 m and 980 m altitude across fourteen of the sixteen creek catchments surveyed through 2000–2015 (Figure 8A). The abundance of post-metamorphic animals at presence sites ranged from one to 135 animals per 100 m of stream transect, with abundance levels at most sites low (<8 animals per 100 m of stream transect) (Figure 5). There was no obvious relationship between altitude and the abundance of *L. jungguy* and/or *L. wilcoxii* recorded at presence sites during surveys. On average, however, numbers at sites above 800 m altitude were lower than counts below 800 m (Figure 5). Due to problems separating *L. jungguy* and *L. wilcoxii* in the field, it is unclear how the current distribution and abundance of these species at Eungella might differ.

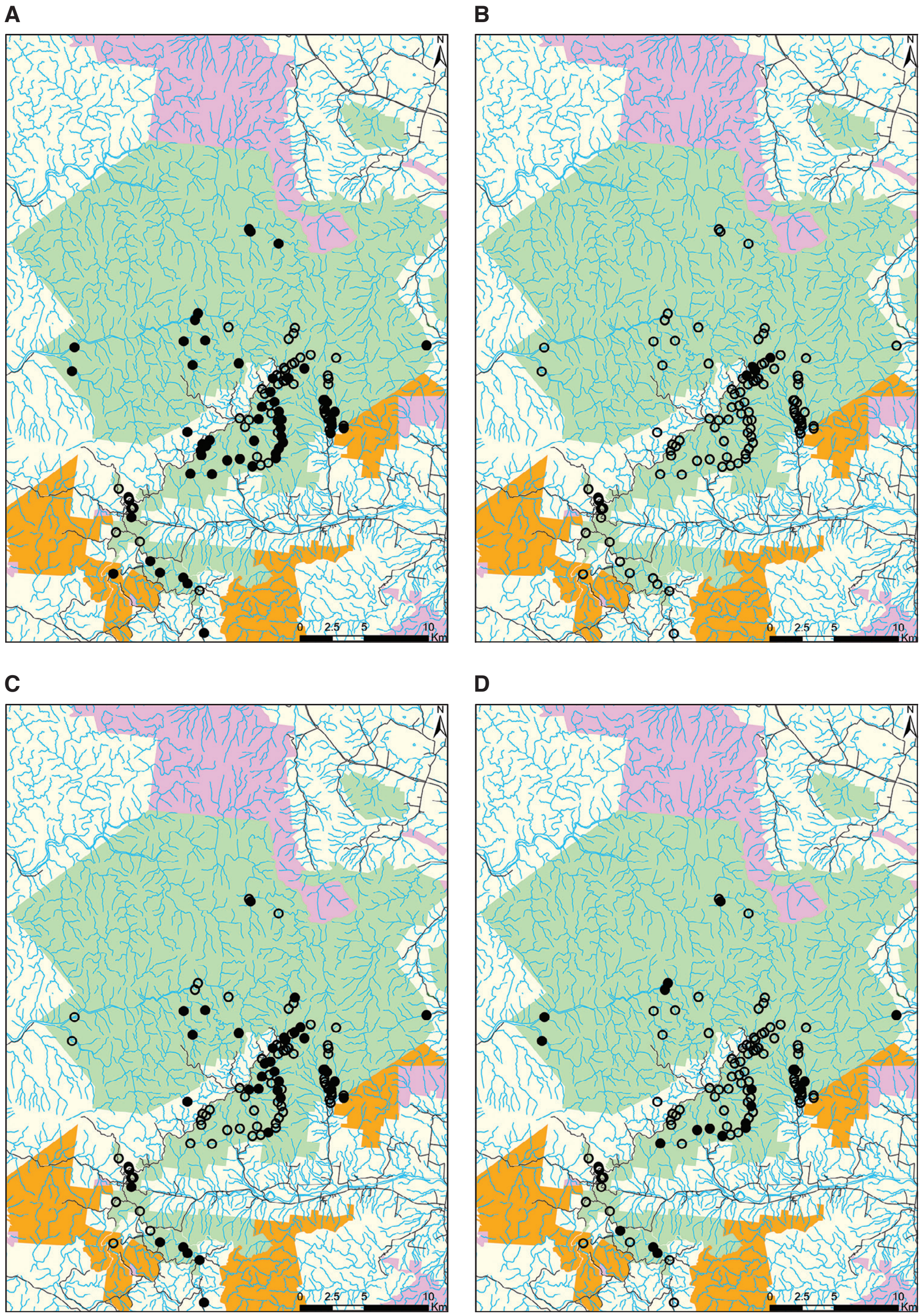
During surveys, *L. jungguy* and/or *L. wilcoxii* were recorded mainly from larger (third, fourth and fifth order), more open streams with animals seen sitting out on rocks, boulders and vegetation beside streams. Aggregations of breeding males were occasionally recorded at mid-altitude sites on more open streams/creeks, and tadpoles of *L. jungguy* and/or *L. wilcoxii* were occasionally recorded in slower-flowing sections of streams. Eight sick, moribund or dead *L. jungguy* and/or *L. wilcoxii* were recorded during QPWS surveys. Included in this tally were an adult and subadult found dead on Boulder Creek (at 260 m altitude); four sick and dead animals on Rawsons Creek (at 330 m altitude); and two animals at sites EU073 and EU076 in the lower Cattle Creek catchment (between 270 and 340 m altitude). In most cases, dead/moribund *L. jungguy* and/or *L. wilcoxii* were found sitting out in the open on rocks and boulders near streams. A number of sick and moribund *L. jungguy/wilcoxii* recorded during surveys exhibited symptoms consistent with amphibian chytridiomycosis, including lethargy, pallor and turgid (swollen) thighs, and one of these was confirmed as having chytridiomycosis (Berger, 2001).

Whirring Treefrog (Litoria revelata)

During surveys, we recorded *L. revelata* in low abundance (<3 animals per 100 m of stream transect) at just four sites, all above 900 m elevation in the headwaters of Cattle Creek North Branch (Figure 8B). Adult animals were mostly observed sitting out on low vegetation beside streams, with spawn and tadpoles recorded mainly from isolated pools in bedrock adjoining streams. Higher densities of *L. revelata* were recorded around farm dams in areas above 900 m elevation at Dalrymple Heights, adjoining Eungella National Park and in close proximity to stream sites occupied by this species.

FIGURE 7. (A) *T. eungellensis* habitat at Dooloomai Falls. (B) Adult *T. eungellensis* in splash zone of cascade on Rawsons Creek. (C) *R. vitellinus* habitat on Mt William Creek in the upper reaches of Cattle Creek (North Branch). (D) *T. liemi* habitat on first order stream in the upper reaches of Cattle Creek (North Branch). Photos A, C, D by E. Meyer; photo B by H. Hines.

FIGURE 8. Distribution of frog species recorded during surveys from 2000 to 2015: (A) *L. wilcoxii/jungguy*; (B) *L. revelata*; (C) *M. fasciolatus*; and (D) *R. marina*. Presence sites represented by closed circles (●), absence sites represented by open circles (○). Refer to Figure 2 for a description of the features of the base map.



Great Barred Frog (Mixophyes fasciolatus)

M. fasciolatus was recorded at 34 sites across eight creek catchments, including Broken River, Amelia, Cattle (North and South Branches), Finch Hatton, Hazlewood, Massey and Rawsons Creeks (Figure 8C). During surveys, this species was recorded at sites between 300 m and 1000 m altitude. The proportion of sites with *M. fasciolatus* below 350 m was low (18%) compared with sites above 350 m altitude, where this species was present at 35–41% of sites surveyed (Table 3). The abundance of *M. fasciolatus* at presence sites was very low (<3 animals per 100 m of stream transect) irrespective of altitude (Figure 5).

Whilst conducting surveys, *M. fasciolatus* was primarily encountered on larger (third, fourth and fifth order streams) where adults were mostly heard and/or seen near water. Tadpoles of *M. fasciolatus* were observed mostly in deeper mid-stream pools and slow-flowing sections of stream. No sick, moribund or dead *M. fasciolatus* were recorded during surveys. However, small cysts containing trematode worms (*Fibricola* sp.) were noted on the tail and body of one tadpole that also tested positive for chytrid fungus (Berger, 2001; Murray *et al*., 2010). A separate series of five tadpoles collected in 2002 from Mt William Creek in the headwaters of Cattle Creek North Branch also tested positive for amphibian chytrid fungus (Symonds *et al*., 2007).

Other Frog Species

During surveys, a number of dry forest and/or pond-breeding frog species were occasionally recorded on stream transects, including the striped marshfrog (*Limnodynastes peronii*), scarlet-sided pobblebonk (*Limnodynastes terraereginae*), eastern sedgefrog (*Litoria fallax*), bumpy rocketfrog (*Litoria inermis*), broad-palmed rocketfrog (*Litoria latopalmata*), dusky gungan (*Uperoleia fusca*), and the introduced cane toad (*Rhinella marina*). The most commonly encountered of these species was *R. marina*, which was recorded at 39% of survey sites below 350 elevation, but only 11% or less of sites above 600 m altitude. Abundances of this and other dry forest species at presence sites were extremely low (<2 animals per 100 m of stream transect), and none of the aforementioned species were recorded breeding on stream transects during surveys. We recorded *R. marina* at 21 sites ranging in altitude from 130 to 790 m (Figure 8D). Densities of post-metamorphic *R. marina* at presence sites were very low (<2 animals per 100 m of stream transect) across all altitudes (Figure 5).

DISCUSSION

Status of R. vitellinus *and* T. eungellensis *at Eungella*

As with previous surveys in the 1980s and 1990s, we were unable to locate *R. vitellinus* on any of the stream sites surveyed through 2000–2015. With the last confirmed sighting of *R. vitellinus* over 30 years ago and repeated failure of surveys to locate this species, the likelihood of *R. vitellinus* surviving in the wild appears extremely low (but see 'Future Surveys', below).

In contrast with *R. vitellinus*, surveys were highly successful in locating *T. eungellensis*, with animals recorded at 32 sites within Eungella National Park. This represents a significant increase in the number of known presence sites compared with the mid-to-late 1990s. While potentially reflecting recovery of *T. eungellensis*, this increase is more likely the result of greater survey effort (increased number of survey sites and increased number and frequency of surveys) through 2000–2015.

During our surveys, *T. eungellensis* was recorded from many of the same creek catchments where Retallick (*pers. comm*., unpublished report) recorded this species in the 1990s, including Cattle Creek (North Branch), Finch Hatton Creek, Rawsons Creek and Tree Fern Creek. In addition to these catchments, *T. eungellensis* were also recorded from sites on Urannah Creek and Massey Creek, most of which are unlikely to have been surveyed for frogs previously. In contrast with surveys in the mid-to-late 1990s, we were unable to locate *T. eungellensis* at survey sites within the Boulder and St Helens Creek catchments. Additional surveys are therefore needed to assess the status of *T. eungellensis* in these catchments.

As with surveys in the mid-to-late 1990s, *T. eungellensis* was recorded across a broad altitudinal range (from 230 to 1050 m altitude), with the majority of presence sites situated below 600 m. Abundances of *T. eungellensis* during our surveys were also similar to those recorded in the 1990s and, with the exception of Rawsons Creek, well below abundance levels recorded prior to declines affecting this species and *R. vitellinus* in the mid-1980s (R. Retallick, *pers. comm*., unpublished report).

Numbers of *T. eungellensis* at monitoring transects through 2000–2006 were broadly similar to those recorded in the 1990s, with the notable exception of Dooloomai Falls (Left-hand Side) where numbers were much lower compared with those recorded by R. Retallick in the mid-1990s (R. Retallick, *pers. comm.*, unpublished report). While the reasons for this decline are unclear, numbers of *T. eungellensis* at this site appeared to be increasing slowly through 2000–2006. Whether numbers at this site have subsequently recovered to mid-1990s levels (when Retallick recorded counts as high as 70 animals over 200 m of stream transect) is unknown. Count data at other monitoring transects did not show any obvious increase or decrease in numbers of *T. eungellensis* through 2000–2006. Whether the abundance of *T. eungellensis* at these sites has changed significantly since then is unclear, as regular monitoring and surveys at Eungella were discontinued after 2006.

While the persistence of *T. eungellensis* at sites within Eungella National Park is encouraging, numbers of *T. eungellensis* at most sites remain low compared with pre-decline levels, and recovery of this species appears to be occurring very slowly, at best. The continued absence of *T. eungellensis* at many historical sites, the consistently low abundance of animals at sites above 600 m, and apparent instability of populations at mid-to-high altitude sites, moreover, suggest the scope for future/ongoing recovery of *T. eungellensis* may be limited. Further surveys, monitoring and research are needed to determine whether this is actually the case or not, and if/how the recovery of *T. eungellensis* can be assisted (e.g. through translocations or by augmenting or re-establishing populations with captive-bred animals).

Status of Taudactylus liemi

During surveys through 2000–2015, *T. liemi* was recorded on numerous smaller streams at mid-to-high altitude (>600 m elevation) within Eungella National Park. The abundance of *T. liemi* at presence sites during this period was generally low, with numbers rarely exceeding 4 animals per 100 m of stream transect. How these numbers compare with abundance levels prior to 2000 is unclear, as abundance data for *T. liemi* from previous surveys are lacking.

Anstis (2013) stated that numbers of *T. liemi* at Eungella had declined since the late 1990s, but provided no data or references to support this claim. QPWS data from monitoring and surveys through 2000–2006 provide no clear evidence for such a decline, while subsequent observations/surveys by EM and CH through 2008–2015 are equivocal in this regard. Available evidence therefore does not appear to support Anstis' (2013) claim of a decline in numbers of *T. liemi* since the 1990s.

Status of Other Stream-dwelling Frogs at Eungella

During our surveys, *L. chloris* and *L. wilcoxii* and/or *L. jungguy* were commonly encountered at survey sites within Eungella National Park, as was the case during surveys and monitoring in the mid-to-late 1990s. In comparison, *M. fasciolatus* and *A. brevis* were encountered at relatively few sites during surveys, and only at very low densities (<2 animals per 100 m of stream transect). Although comparatively low, the number of sites supporting *A. brevis* during surveys through 2000–2015 greatly exceeds that during surveys in the mid-to-late 1980s, suggesting a possible recovery in *A. brevis* populations following an apparent decline in the mid-to-late 1980s (McDonald, 1990). It is possible, however, that the increased detectability of *A. brevis* at Eungella during surveys is the result of increased survey effort.

In contrast with other stream-dwelling hylids encountered during our surveys, *L. revelata* was recorded from only a handful of high-elevation streams in the headwaters of Cattle Creek North Branch and, incidentally, a small number of nearby farm dams at Dalrymple Heights. These few high-elevation sites are the only locations from which this enigmatic species is known in mid-eastern Queensland, with the next nearest populations of *L. revelata* occurring 500 km to the north, on the Atherton Tableland, and about 900 km south, along the Queensland/New South Wales border. Given the apparent paucity of sites supporting *L. revelata* in mid-eastern Queensland, more effort should be put into surveys and monitoring of this species at Eungella.

Due to difficulties differentiating between *L. wilcoxii* and *L. jungguy* in the field, the current status of these species at Eungella remains unclear. Widespread genotyping of stony creek frogs at Eungella is needed to better understand the distribution and abundance of these species at Eungella.

The Occurrence and Impact of Amphibian Chytrid Fungus at Eungella

The population declines documented at Eungella during the mid-1980s are almost certainly attributable to amphibian chytridiomycosis – an apparently exotic disease implicated in amphibian population declines elsewhere in eastern Australia and many other parts of the world (Retallick *et al*., 2004; Murray *et al*., 2010; Scheele *et al*., 2017). During our surveys, we encountered a number of animals exhibiting symptoms consistent with this disease, including lethargy, pallor, and turgor of the thighs, a subset of which tested positive for Bd (the cutaneous fungal pathogen responsible for amphibian chytridiomycosis). Although the number of animals exhibiting signs/symptoms of chytridiomycosis was low, laboratory testing of sick and healthy frogs and tadpoles (e.g. Berger, 2001; Murray *et al*., 2010; Symonds *et al*., 2007) suggests this fungal pathogen is widespread at Eungella, with Bd detected in a range of frog species across a broad altitudinal range (from 330 to 980 m altitude).

The occurrence of Bd at Eungella was documented in a previous study by Retallick *et al*. (2004), who detected Bd in populations of *T. eungellensis* and *L. wilcoxii/jungguy* at sites between 230 and 550 m altitude during the mid-1990s, including the largest known population of *T. eungellensis* on Rawsons Creek (Retallick *et al*., 2004). These authors concluded that populations of *T. eungellensis* at Eungella are now persisting with stable endemic infections of amphibian chytrid fungus. While monitoring data from lower-altitude sites support this view, data from higher-altitude streams are more equivocal in this regard, with *T. eungellensis* remaining scarce or absent at most high-altitude sites surveyed during the 1990s and 2000s. Monitoring data from Dooloomai Falls showing a sharp decline in numbers since the late 1990s are also equivocal in this regard, raising doubts about the stability of chytrid infections at mid-altitude sites. Further research on the prevalence of Bd infection amongst *T. eungellensis* populations across an altitudinal gradient is needed to better understand the influence of Bd on survival and recruitment of this species at mid- and high-altitude stream sites.

Although occurrence/abundance of *T. eungellensis* at higher-altitude sites may be heavily influenced by Bd, this does not appear to be the case for *T. liemi*, which, despite testing positive for Bd, was commonly encountered at mid- and high-altitude sites through 2000–2015, albeit at low densities. Whether the low abundances of *T. liemi* recorded during surveys are the result of Bd or other factors is unclear, as data on the abundance of this species before the mid-1980s are scarce. Given the involvement of Bd in declines of both the northern and Kroombit tinkerfrog (*T. rheophilus* and *T. pleione*), however, it seems unlikely that numbers of *T. liemi* would not have been impacted by Bd either now or in the past (Scheele *et al*., 2017). Further research investigating the prevalence of Bd infection in *T. liemi* is needed to determine what, if any, impact Bd might have on the abundance of this species.

In contrast with *R. vitellinus* and *T. eungellensis*, there are insufficient data to assess the past and current impact of Bd on other stream-dwelling frogs at Eungella. Data on the prevalence and impact of Bd infection in these species are needed to better understand the influence of Bd on their distribution and abundance at Eungella.

Future Surveys

While surveys through the 1990s and 2000s have so far failed to locate *R. vitellinus*, many kilometres of stream habitat within Eungella National Park remain unsurveyed, so the persistence of this species should not be ruled out. As well as relict populations of *R. vitellinus*, unsurveyed streams within Eungella National Park could also support additional populations of *T. eungellensis* at similar densities to that observed on Rawsons Creek. Further surveys in remote and difficult-to-access parts of Eungella, focusing on streams at the lower altitudinal limit for both *T. eungellensis* and *R. vitellinus* (i.e. between 350 m and 550 m altitude), therefore should be encouraged. In particular, future surveys at Eungella should focus on westerly-aspect streams with low canopy cover (e.g. streams in the middle and upper reaches of Massey and Urannah Creeks) because these have acted as disease refuges for populations of stream frogs impacted by Bd in the Wet Tropics region (Puschendorf *et al*., 2011). The impact of Bd on these streams may be limited because average conditions are warmer than is optimal for growth and reproduction of Bd (Puschendorf *et al*., 2011). Additional areas to focus on include the St Helens Creek and Northern Urannah Creek catchments north to Mt MacCartney, where considerable areas of rainforest stream habitat have received very little survey attention, either historically (see Figure 1) or recently (see Figure 2).

The rediscovery and persistence of *T. eungellensis* on streams at Eungella offer hope for the continued existence of the sharp-snouted dayfrog (*Taudactylus acutirostris*) in the Wet Tropics of North Queensland. Like *T. eungellensis*, this once-common species suffered significant declines attributable to chytridiomycosis in the late 1980s and early 1990s and has not been sighted in the wild since 1997 (Marshall, 1997; Northern Queensland Threatened Frogs Recovery Team, 2001). Given the extent of unsurveyed stream habitat in the Wet Tropics, more effort should be put into locating relictual populations of this species. As with future surveys targeting *T. eungellensis*, surveys for *T. acutirostris* should target more open streams near the lower altitudinal limit reported for this species (i.e. around 350 m altitude, Hoskin & Hero, 2008).

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LITERATURE CITED

Anstis, M. (2013). *Tadpoles and Frogs of Australia*, New Holland, Sydney.

Berger, L. (2001). *Diseases in Australian Frogs*, PhD Thesis, James Cook University.

Couper, P. (1992). Hope for our missing frogs. *Wildlife Australia* **29**, 10–11.

Donnellan, S. C. & Mahony, M. J. (2004). Allozyme, chromosomal and morphological variability in the *Litoria lesueuri* species group (Anura: Hylidae), including a description of a new species. *Australian Journal of Zoology* **52**, 1–28.

Hines, H. B., Mahony, M. & McDonald, K. R. (1999). An assessment of frog declines in wet subtropical Australia. *In*: (A. Campbell, ed.), *Declines and Disappearances of Australian Frogs*, Department of the Environment and Heritage, Canberra, pp. 44–65.

Hoskin, C. J. & Hero, J-M. (2008). Rain Forest Frogs of the *Wet Tropics, North-East Australia*, Griffith University, Gold Coast, Queensland.

Liem, D. S. & Hosmer, W. (1973). Frogs of the genus *Taudactylus* with descriptions of two new species (Anura: Leptodactylidae). *Memoirs of the Queensland Museum* **16**, 435–57.

Marshall, C. J. (1998). The reappearance of *Taudactylus* (Anura: Myobatrachidae) on north Queensland streams. *Pacific Conservation Biology* **4**, 39–41.

McDonald, K. R. (1990). *Rheobatrachus* Liem and *Taudactylus* Straughan & Lee (Anura: Leptodactylidae) in Eungella National Park, Queensland: distribution and decline. *Transactions of the Royal Society of South Australia* **114**, 187–194.

McDonald, K. R. & Alford, R. (1999). A review of declining frogs in northern Queensland. *In*: (A. Campbell, ed.), *Declines and Disappearances of Australian Frogs*, Department of the Environment and Heritage, Canberra, pp. 14–22.

McNellie, M. & Hero, J-M. (1994). Mission amphibian: the search for the missing rainforest frogs of Eungella. *Wildlife Australia* **31**, 22–23.

Moore, R. (2014). *In Search of Lost Frogs*, Bloomsbury Publishing, London.

Murray, K., Retallick, R., Mcdonald, K. R., Mendez, D., Aplin, K., Kirkpatrick, P., Berger, L., Hunter, D., Hines, H. B., Campbell, R., Pauza, M., Driessen, M., Speare, R., Richards, S. J., Mahony, M., Freeman, A., Phillott, A. D., Hero, J-M., Kriger, K., Driscoll, D., Felton, A., Puschendorf R. & Skerratt, L. F. (2010). The distribution and host range of the pandemic disease chytridiomycosis in Australia, spanning surveys from 1956–2007. *Ecology* **91**, 1557–1558.

Newell, D. A., Goldingay, R. L. & Brooks, L. O. (2013). Population recovery following decline in an endangered stream-breeding frog (*Mixophyes fleayi*) from subtropical Australia. *PLoS ONE* **8**, e58559.

Northern Queensland Threatened Frog Recovery Team. (2001). *Recovery Plan for the Stream-dwelling Rainforest Frogs of the Eungella Region of Mid-eastern Queensland 2000–2004*. (Queensland Environmental Protection Agency, Brisbane).

Retallick, R., Hero, J-M. & Alford, R. A. (1997). *Adult Population Monitoring and Larval Ecology of the Stream-dwelling Frogs at Eungella National Park*. Unpublished Report prepared for Environment Australia and Queensland Department of Environment).

Retallick, R. (1998). *Population Monitoring of Stream-dwelling Frogs at Eungella National Park*. Unpublished Report prepared for Environment Australia and Queensland Department of Environment.

Retallick, R. W., McCallum, H. & Speare, R. (2004). Endemic infection of amphibian chytrid fungus in a frog community post-decline. *PLoS Biology* **2**, e351: 1966–1971.

Richards, S. J., McDonald, K. R. & Alford, R. A. (1994). Decline in populations of Australian endemic tropical rainforest frogs. *Pacific Conservation Biology* **1**, 66–77.

Scheele, B. C., Skerratt, L. F., Grogan, L. F., Hunter, D. A., Clemann, N., McFadden, M., Newell, D., Hoskin, C. J., Gillespie, G. R., Heard, G. W., Brannelly, L., Roberts, A. A. & Berger, L. (2017). After the epidemic: ongoing declines, stabilizations and recoveries in amphibians afflicted by chytridiomycosis. *Biological Conservation* **206**, 37–46.

Symonds, E. P., Hines, H. B., Bird, P. S., Morton, J. M. & Mills, P. C. (2007). Surveillance for *Batrachochytrium dendrobatidis* using *Mixophyes* (Anura: Myobatrachidae) larvae. *Journal of Wildlife Diseases* **43**, 48–60.

Taudactylus Research and Husbandry Team. (2012). Taudactylus *Research and Husbandry summary: 2009–2012*. Unpublished report for ARAZPA.