



Technical Memorandum 19

Frogs of the Magela Creek system

M. J. Tyler and G. A. Crook

Supervising Scientist for
the Alligator Rivers Region

Supervising Scientist for the
Alligator Rivers Region

TECHNICAL MEMORANDUM 19

FROGS OF THE MACELA CREEK SYSTEM

M.J. Tyler & G.A. Crook

Australian Government Publishing Service

Canberra 1987

Supervising Scientist for the
Alligator Rivers Region
PO Box 387, Bondi Junction
N.S.W. 2022, Australia

January 1987

©Commonwealth of Australia 1987

ISSN 0810-9532
ISBN 0644 01353 2

This Technical Memorandum was prepared by:
Michael J. Tyler and Graeme A. Crook
Department of Zoology, University of Adelaide

acting as consultant to the Supervising Scientist
for the Alligator Rivers Region

The Supervising Scientist for the Alligator Rivers Region manages the Alligator Rivers Region Research Institute, which conducts, co-ordinates and integrates research relating to the effects on the environment of uranium mining in the Alligator Rivers Region. Research findings of projects carried out under contract to the Supervising Scientist or undertaken by the Supervising Scientist's own staff may be published in the Research Report or Technical Memorandum series. Views expressed by authors do not necessarily reflect the views and policies of the Supervising Scientist, the Commonwealth Government or any collaborating organisation.

CONTENTS

ABSTRACT	v
1 INTRODUCTION	1
2 SIGNIFICANT ENVIRONMENTAL PARAMETERS	3
2.1 Physical environment	3
2.2 Climate	4
3 METHODS	7
3.1 Collection and transport	7
3.2 Studies of live material	7
4 FROG FAUNA OF MAGELA CREEK	9
4.1 <i>Cyclorana australis</i> (Gray)	9
4.2 <i>C. longipes</i> Tyler and Martin	11
4.3 <i>Litoria bicolor</i> (Gray)	11
4.4 <i>L. caerulea</i> (White)	12
4.5 <i>L. coplandi</i> (Tyler)	13
4.6 <i>L. dahliei</i> (Boulenger)	15
4.7 <i>L. inermis</i> (Peters)	15
4.8 <i>L. pallida</i> Davies, Watson & Tyler	16
4.9 <i>L. meiriana</i> (Tyler)	17
4.10 <i>L. microbelos</i> (Cogger)	18
4.11 <i>L. nasuta</i> Tschudi	18
4.12 <i>L. personata</i> Tyler, Davies & Martin	19
4.13 <i>L. rothii</i> (de Vis)	20
4.14 <i>L. rubella</i> (Gray)	21
4.15 <i>L. tornieri</i> (Nieden)	21
4.16 <i>L. wotjulumensis</i> (Copland)	22
4.17 <i>Limodynastes convexiusculus</i> (Macleay)	23
4.18 <i>L. ornatus</i> (Gray)	23
4.19 <i>Megistolotes lignarius</i> Tyler, Martin and Davies	24
4.20 <i>Notaden melanoscapus</i> Hosmer	25
4.21 <i>Ranidella bilinea</i> Martin, Tyler & Davies	26
4.22 <i>Sphenophryne robusta</i>	26
4.23 <i>Uperoleia arenicola</i> Tyler, Davies and Martin	26
4.24 <i>U. inundata</i> Tyler, Davies and Martin	27
5 IDENTIFICATION	28
5.1 Key to frog eggs found upon escarpment	28
5.2 Key to tadpoles found upon escarpment	29
5.3 Key to adult frogs found upon escarpment	30
5.4 Key to lowland frog eggs	31
5.5 Key to lowland tadpoles	32
5.6 Key to lowland adult frogs	34
6 ACTIVITY PATTERNS AND REPRODUCTIVE BEHAVIOUR	36
7 PREDATION STUDIES	37
8 EFFECTS OF URANIUM MINING UPON DIVERSITY AND SIZE OF FROG POPULATIONS	37

9	REFERENCES	40
---	------------	----

TABLES

1	Monthly rainfall at Jabiru in millimetres: July 1971 - June 1980	6
2	Distribution and abundance of the frog fauna of the Magela Creek area	10
3	Vertebrate predators of frogs inhabiting the Magela Creek system	39

FIGURES

1	The Alligator Rivers Region	2
2	Habitat types encountered during the study	5
3	1978-1979 Jabiru rainfall compared with average	8
4	1979-1980 Jabiru rainfall compared with average	8
5	Growth gradients of tadpoles of various species of <i>Litoria</i>	14
6	Growth gradients of tadpoles of various species of frogs	27
7	Wet season activity	38

ABSTRACT

Tyler, M.J. & Crook, G.A. (1987). Frogs of the Magela Creek system. Technical Memorandum 19, Supervising Scientist for the Alligator Rivers Region.*

Facets of the reproductive biology of 24 species of frogs from the Magela Creek system were examined over two Wet seasons. Data are presented for the onset, duration and termination of activity, calling and breeding, and are correlated with temperature and relative humidity.

Most species breed at the onset of the Wet season before the flood plain is completely inundated. For each species the eggs and form of the spawn clump are described.

* Most of this report has previously been published as part of: M.J. Tyler, G.A. Crook & M. Davies (1983), 'Reproductive biology of the frogs of the Magela Creek System, Northern Territory', *Rec. S. Aust. Mus.* 18(18), 415-440.

1 INTRODUCTION

Preamble

Frogs, because of the semipermeable nature of their skin and the vulnerability of their aquatic eggs and tadpoles, have been used in various studies of toxicology and, more recently, as indicators of environmental contamination.

The frog fauna of Australia is incompletely known, and up till now studies have centred upon fundamental problems of taxonomy, nomenclature, evolution, biogeography and speciation: the fauna of even the most intensely studied geographic area (the southeast of the continent) still includes species awaiting description. Therefore, almost any applied study of frogs necessitates, initially, the gathering of the most fundamental biological and ecological data.

The investigation reported here was initiated following a report based on a brief visit to the area (Fig. 1) by M.J. Tyler and M. Davies in November-December 1977. They predicted that several species of frogs could breed in the planned Retention Ponds and tailings dam at the Ranger uranium mine, and they drew attention to the high incidence of frog predators in the area.

Available data

Every biological program initiated by the Office of the Supervising Scientist has been faced with the existence of a very rich fauna about which little is known. As a consequence, a common feature of most programs has been simply to establish the nature of that fauna.

There was limited data on frogs, but the data were insufficient to permit even the most fundamental experimental work. Museum collections were sparse and a high proportion of their contents were erroneously identified. In consequence the Northern Territory reference specimens published in the results of the Smithsonian Museum--National Geographic--South Australian Museum Expedition of 1948 were largely in error.

The studies undertaken by the Alligator Rivers Region Environmental Fact Finding Study set new standards, and their studies on the relatively rich frog fauna highlighted some of the areas of taxonomic deficiency. Despite these reasonable baseline data, the frog data subsequently included in the Environmental Impact Statements for the mining companies were generally of a low standard, and of no value to our work.

It follows that our initial objective was simply to attempt to establish the diversity and relative abundance of the fauna, and to identify the fauna.

The problem was compounded by the fact that the aquatic phases of the frog (the eggs in their spawn clumps and the tadpoles) were unknown. Thus, we had to induce breeding in captivity between known pairs, or rear unknown spawn to resultant frogs.

Of the 24 species that we now know to occur in the area, the tadpoles of only six species could be associated with their respective adults when we commenced the survey. The spawn of none of the species could be identified with any degree of certainty.

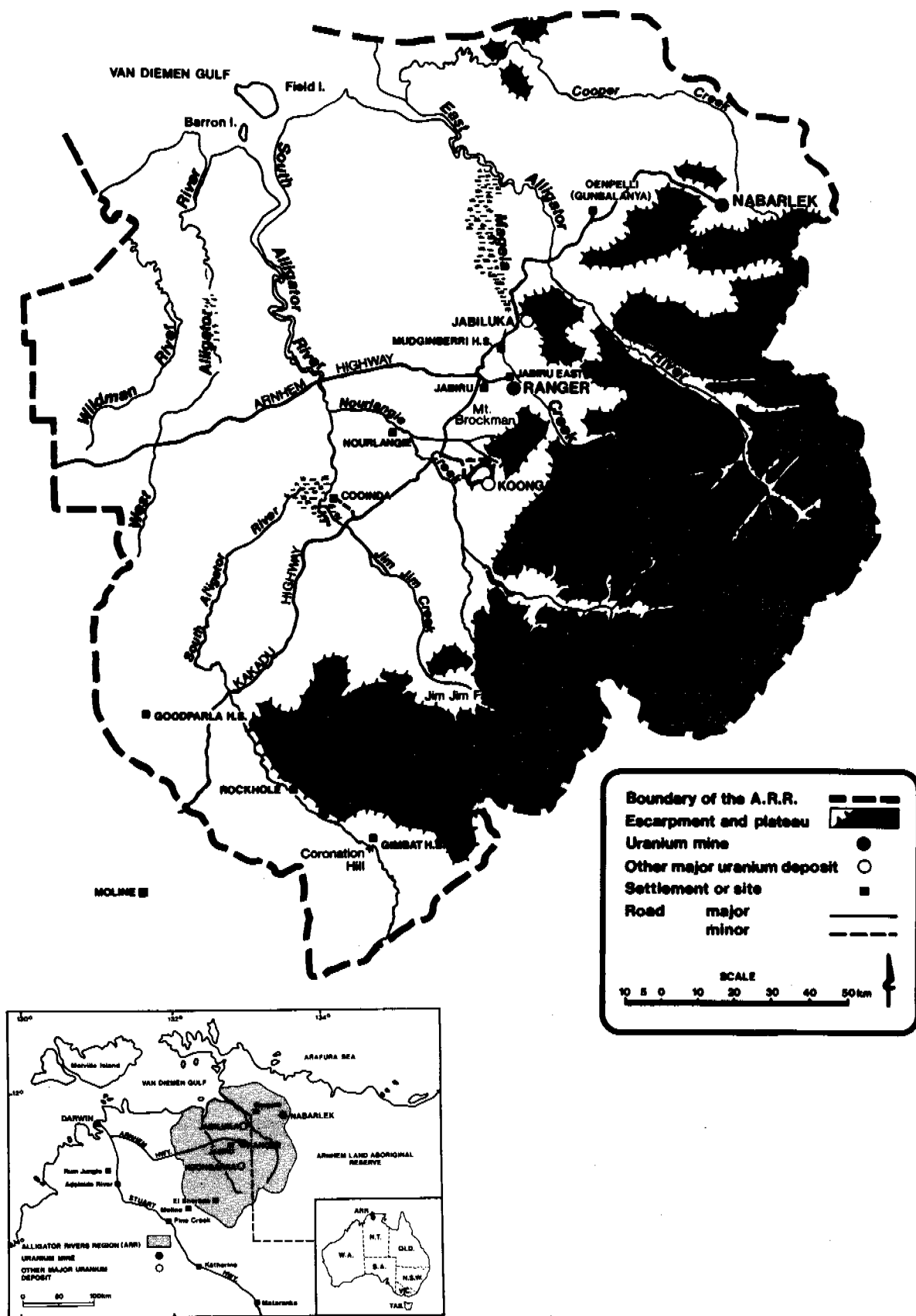


Figure 1. The Alligator Rivers Region

Objectives

The objectives of the study were:

- to provide a basic ecological description of the Magela Creek system with regard to those amphibians (in particular, frogs) likely to prove useful to the future monitoring of the possible ecological effects of uranium mining in the Alligator Rivers Region;
- to indicate how such information may best be applied to monitoring the environmental impact of uranium mining operations in the Region; and
- at the completion of the study, or from time to time during the study, to recommend further studies that should be undertaken to assist in defining practical monitoring programs.

2 SIGNIFICANT ENVIRONMENTAL PARAMETERS

2.1 Physical environment

There is a lack of uniformity in the nomenclature and delineation of plant communities in the area surrounding Magela Creek. The system that we have adopted is applicable to frog communities, and involves the following seven units, each of which is meaningful in an ecological sense, and significant in the diversity and sequence of breeding sites there:

- 1) sandstone scrub and woodland in escarpment country;
- 2) sandstone rainforest remnants;
- 3) open sclerophyll forest;
- 4) inundated grassland;
- 5) fringes of billabongs;
- 6) flood plains; and
- 7) artificial pools, scrapes, ponds etc.

Data on dominant plant species within the units are from Christian & Aldrick (1977).

Sandstone scrub and woodland in escarpment country. The breeding sites on the escarpment vary from pools on the open rock face to streams through deep crevices in the sandstone (Fig. 2a). Tadpoles have been found in shallow depressions on exposed rock faces where the water temperatures reach up to 45°C and where there is little, if any, algal growth in the water. These pools fill with rainwater early in the Wet season, and are utilised at that time. Further storms cause overflowing, and the water runs over the rocks and into small, scrub-lined streams which flow only during these storms. For the remainder of the time the stream beds are a series of pools among sandstone rocks with spinifex, sedges and wiry grasses along the banks. These small streams run into deeper, sandy-bottomed streams, cut out of the sandstone, which remain for much longer after the Wet season has ended. The gorges created by these streams are often very deep and steep-sided, and the water is cold (< 10°C). The larger streams support a woodland with eucalypts such as *E. dichromophloia*, *E. phoenicea*, and *E. miniata*, smaller trees such as *Owenia*, *Xanthostemon* and *Erythrophleum*, with wiry grasses and spinifex in the understorey.

Sandstone rainforest remnants. These forests differ from the woodlands through domination by *Allosyncarpia ternata*, a myrtaceous evergreen tree species which grows up to 22 m high. Other non-eucalypt trees are present and the understorey is sparse. The leaf litter is thick and moist. These forests occur in the broken terrain of sandstone plateau and escarpment,

usually in narrow gorges at the base of the escarpment. The streams usually have defined channels with rocky bottoms and are permanent, flowing for most of the year. This forest appears to be a relic. The frogs utilise the pools in small side streams which flow only after storms.

Open sclerophyll forest. The open forest is dominated by *Eucalyptus tetradonta* and *E. miniata* with the occasional *Erythrophleum*. The understorey is varied and includes *Livistonia*, *Xanthostemon*, *Planchonia*, *Buchanania*, *Grevillea*, *Melaleuca* and *Acacia*. Annual and perennial grasses are also present. In the Wet season, shallow depressions in this woodland provide ideal breeding sites for several frog species. Heavy storms inundate the whole forest floor, so creating a host of microhabitats in which frogs abound.

Inundated grasslands. In the open sclerophyll forest and along the creeks are large, clear areas of annual and perennial grasses. These areas have sandy soil, and the depressions in them fill with water early in the Wet season providing breeding sites for several frog species. Complete inundation of these areas occurs once the Wet season has set in (usually in early January). More frog species then utilise the areas of shallow water outside the deeper depressions.

Fringes of billabongs. The main body of water is not a very important habitat. The major areas are the pools and grassy areas on the fringes among *Melaleuca* and *Pandanus* (Fig. 2b). These areas fill up with water in the early Wet season and predatory fishes are excluded long enough for tadpoles to complete metamorphosis. This occurs before the billabongs overflow later in the Wet season.

Flood plains. These are large expanses of sedgeland which are inundated for two to six months of the year. The principal plant genera here are *Cyperus*, *Eleocharis*, *Fuirena*, and *Sesbania* with some grasses. A wide variety of herbaceous plants and water lilies occur in areas where there is inundation for six to eight months (Fig. 2c). The frogs usually inhabit the edges of the flood plains, and occupy small islands of rock and vegetation when the flood plains are inundated.

Artificial ponds, scrapes, ponds etc. Buffalo wallows are important breeding sites on the flood plains and inundated grasslands in the early months of the Wet season. Artificial gravel scrapes beside the roads are important throughout the Wet season, providing shallow temporary pools in areas where such pools would not occur naturally. The soil is gravelly and the vegetation is sparse. The large cleared areas around the pools provide a larger number of potential calling sites for males than the surrounding open forest. Dams, drainage ditches and even pools on the road surface are used as breeding sites by some species. Indeed any disturbance of the environment causing the formation of pools increases the breeding potential of frogs in the area, and tailings dams, Retention Ponds, siltation pools and other earthworks have to be considered in a similar sense (Fig. 2d).

2.2 Climate

Very few species of frogs breed exclusively in large flowing rivers or in deep water upon flood plains. Such sites are inhabited by diverse fishes and, as indicated in Section 7, the fish in the Magela Creek system eat tadpoles with alacrity. It follows that successful completion of metamorphosis requires the existence of breeding sites lacking predatory



Figure 2. Habitat types encountered during the study: (a) pool in escarpment country; (b) fringe of a billabong; (c) edge of the flood plain; and (d) Retention Pond 1.

Table 1. Monthly rainfall at Jabiru, July 1971 - June 1980

All figures are in mm

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
1971-72	0.0	0.0	0.7	44.7	108.2	168.4	192.0	236.9	343.7	10.5	17.6	0.0	1120.7
1972-73	0.0	0.0	0.0	1.7	182.9	153.0	436.6	116.8	470.3	48.6	6.8	0.0	1443.7
1973-74	0.0	0.0	0.0	43.4	332.3	165.4	463.0	256.4	348.1	73.0	24.6	0.0	1706.1
1974-75	0.0	60.4	0.0	77.4	173.4	217.8	270.3	432.5	303.1	203.8	0.3	0.0	1739.0
1975-76	0.0	0.4	0.6	257.4	114.0	387.6	394.4	502.8	590.4	34.2	0.0	0.0	2281.8
1976-77	0.0	0.0	0.0	52.2	182.4	141.6	341.7	188.7	372.6	94.2	13.4	0.0	1386.8
1977-78	0.0	0.0	0.0	5.8	93.8	408.2	328.8	442.6	124.2	22.6	13.4	0.0	1439.4
1978-79	5.0	0.0	26.8	19.6	204.2	301.5	469.6	323.5	153.8	3.6	3.0	0.0	1508.8
1979-80	0.0	0.0	0.0	26.4	118.2	138.6	505.6	767.9	268.4	64.2	5.4	0.0	1894.7

fishes. During the Northern Territory Dry season, most species are totally inactive and there is no breeding of any species.

Rainfall figures for Jabiru from 1971-80 (Table 1) indicate that in most years the Wet season starts in November. Our two-year observations on frog biology include an atypical year in which the onset was delayed, and was then followed by the highest monthly total on record (February 1980, 767.9 mm) (Figs 3 and 4).

Most of the rain falls in storms which can be fierce, but localised. Aseasonal rains are significant only upon the escarpment, where they fill pools and create breeding sites immediately.

We have not plotted other climatic parameters, because rainfall is the single most significant factor in permitting frog dispersal and initiating breeding activity.

3 METHODS

Researchers were based in Jabiru during the northern Wet seasons from October 1978 to April 1979 and from October 1979 to March 1980.

3.1 Collection and transport

Spawn, tadpoles and frogs were collected throughout the periods of their availability. They were transported in water in polyethylene bags inflated with expired air and then sealed against leakage. The bags were carried in large aluminium boxes insulated with polyurethane sheeting. Water or ground temperatures were recorded at the site of capture using a Schultheis rapid-reading thermometer. Wet and dry bulb readings were obtained with a whirling hygrometer.

In most instances, spawn was obtained at night and transported to Darwin early the following morning. At the airport, the containers were stored in an air-conditioned area (20-25°C) for four hours prior to departure by air to Adelaide. Upon arrival in Adelaide the livestock was transferred to a 30°C room at the Department of Zoology, University of Adelaide. Spawn and small quantities of tadpoles were placed in white, 'Advance', plastic containers and aerated. Denser aggregations or large sized tadpoles were kept in 5 L glass aquaria.

3.2 Studies of live material

Life history studies were undertaken at the University of Adelaide. Water used was passed through a commercial softener and filter, followed by passage through an activated charcoal dechlorinator and a bacterial filter. Water was allowed to stand in the plastic containers or glass aquaria for 24 h prior to use to equilibrate to room temperature; it was changed daily. The light regime of the room was controlled to be similar to that at Jabiru.

Tadpoles were fed on washed and boiled lettuce leaves.

Tadpoles were sampled regularly and preserved in Tyler's (1962) tadpole fixative. Selection of specimens for preservation followed the attainment of the progressive developmental stages of Gosner (1960). Specimens were subsequently measured with a microscope eyepiece micrometer or dial calipers.

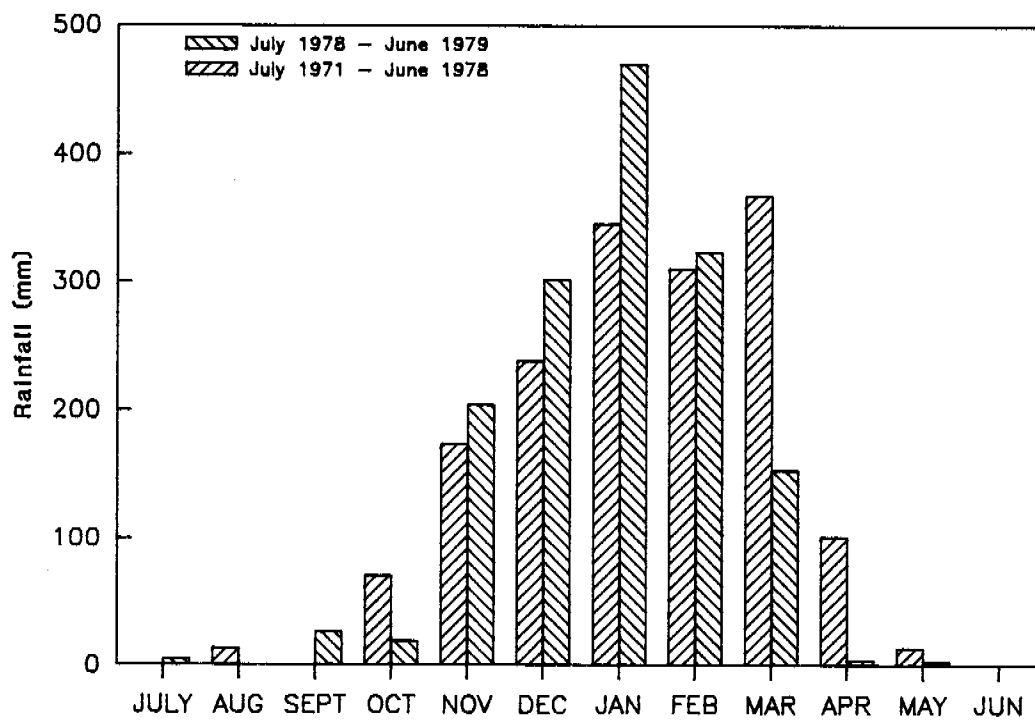


Figure 3. 1978-79 rainfall figures for Jabiru compared with average

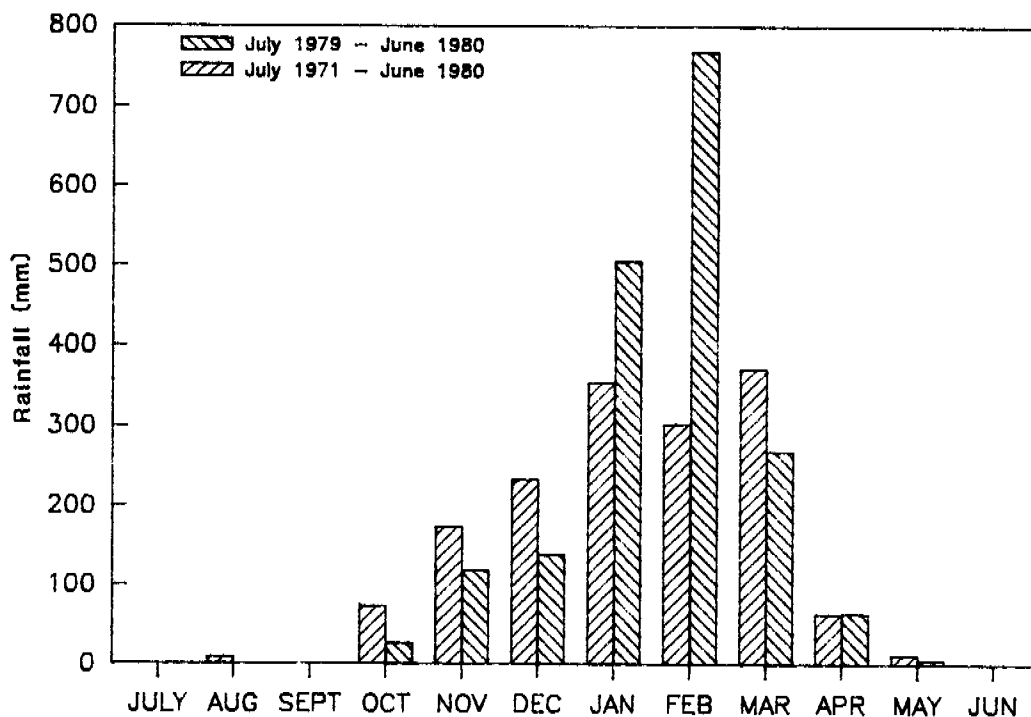


Figure 4. 1979-80 rainfall figures for Jabiru compared with average

4 FROG FAUNA OF MAGELA CREEK

As a means of placing the frog fauna of the Magela Creek area in perspective, it is worth noting the diversity and extent of the Australian and Northern Territory frog faunas.

Within Australia, about 160 species are currently recognised, but numerous new species are known to await discovery. The native fauna represents the families Hylidae, Leptodactylidae, Microhylidae and Ranidae and (by our estimate) includes 26 genera. Of these 26 genera, nine have been reported from the Northern Territory.

Twenty-four species, representing eight genera, have been found in the Magela Creek area. Two species, *Litoria personata* and *Uperoleia arenicola* of Tyler et al. (1980) were discovered along the edge of the escarpment east of the Magela Creek, and are still known only from those few specimens. An additional five species were undescribed when we commenced our survey. These and the above taxa were reported in the following papers: Tyler et al. (1978); Martin et al. (1979); and Tyler et al. (1979).

Table 2 lists the composition of the fauna species, indicates their distribution and gives an assessment of their relative abundance.

In the following species account, summarising our field and laboratory observations, the sequence of species is alphabetical.

4.1 *Cyclorana australis* (Gray)

Definition. The largest frog in the area, *C. australis* is a robust species, grey-brown and 60-100 mm in snout to vent length. Generally this species is fossorial, spending the day and the Dry season underground, usually at the base of trees or under logs. It is active at night from October to April, although the number of active adults drops sharply after January, being replaced by metamorphosing juveniles.

Breeding biology. Large numbers of males congregate early in the Wet season in breeding choruses. On warm nights during and after rain, the males call from open areas or from the base of grass tussocks near water. Amplexus occurs at temperatures of 24.5-28.5°C and relative humidities of 78.5-96%. Spawn is deposited at the edge of temporary pools as a surface layer, which sinks to the bottom during early development. The clump is loosely attached and breaks up when disturbed. At deposition sites the water temperature is 31-33.5°C and the water depth 5-100 cm. The eggs are laid in clumps of up to 7000, although 100 to 1000 is the usual number. The eggs have a dark brown animal pole and a white vegetal pole. Two membranes surround the ovum. The mean capsule diameter is 2.5 mm (2.3-2.8 mm) and mean ovum diameter is 1.6 mm (1.5-1.8 mm).

Developmental history. Development reaches stage 17 in 1-2 days. The tadpoles are robust with a rotund body, elongate snout and deep fins. The anus is dextral and the spiracle sinistral. The tooth row formation is 2/3 and there is a well-developed, elevated border of papillae surrounding strong jaws. The border is separated anteriorly by a median gap. There is a nasal groove present from stage 32 to 41. No stage 37 of Gosner could be found, as the metatarsal tubercle appears concurrently with differentiation, so combining the features used to distinguish 37 and 38. The tadpoles reach a length of up to 70 mm in stage 41 (mean 54.8 mm; range 40.9-68.2 mm). The spawn of *C. australis* and *C. longipes* are often mixed

Table 2. Distribution and abundance of the frog fauna of the Magela Creek area

	Escarpment: sandstone scrub & woodland	Escarpment: rainforest remnants	Inundated grassland	Open sclerophyll forest	Billabong fringes	Flood plains	Artificial pools, gravel scrapes
0 Absent							
1 Rare							
2 Common							
3 Abundant							
<i>Litoria bicolor</i>	0	0	2	0	3	2	0
<i>L. caerulea</i>	2	2	1	1	1	1	0
<i>L. coplandi</i>	3	2	0	0	0	0	0
<i>L. dahliei</i>	0	0	1	0	2	3	1
<i>L. inermis</i>	0	0	1	0	2	0	3
<i>L. pallida</i>	0	0	3	0	2	1	3
<i>L. meiriana</i>	3	3	0	0	0	0	0
<i>L. microbelos</i>	0	0	1	0	3	2	0
<i>L. nasuta</i>	0	0	3	2	2	0	1
<i>L. personata</i>	2	0	0	0	0	0	0
<i>L. rothii</i>	0	0	2	1	2	2	2
<i>L. rubella</i>	0	0	2	1	2	2	3
<i>L. tornieri</i>	0	0	3	0	2	1	3
<i>L. wotjulumensis</i>	2	2	1	0	0	0	2
<i>Cyclorana australis</i>	0	0	2	1	2	2	3
<i>C. longipes</i>	0	0	1	0	1	1	3
<i>Limnodynastes convexiusculus</i>	1	0	2	0	2	3	0
<i>L. ornatus</i>	2	0	2	1	0	0	3
<i>Notaden melanoscaphus</i>	0	0	3	3	0	0	0
<i>Megistolotis lignarius</i>	2	2	0	0	0	0	0
<i>Ranidella bilinea</i>	0	0	3	1	2	2	0
<i>Uperoleia arenicola</i>	1	0	0	0	0	0	0
<i>U. inundata</i>	0	0	3	2	0	0	0
<i>Sphenophryne robusta</i>	0	2	0	0	2	0	0

together; the tadpoles form dense and very active aggregations. Tadpoles constantly rise to the surface, gulp air and then submerge, so producing the impression of boiling water. The tadpoles prefer the cooler lower waters but low oxygen saturation levels cause them to rise to the surface. Metamorphosing juveniles are found from December to April (mean size 21.3 mm; range 19.8-25.4 mm) usually at the edge of pools where they feed on insects and other frogs. Many juveniles are emerald green.

The tadpoles of *C. australis* are indistinguishable from those of *C. longipes* until stage 41 when the mottled pattern on the back of the latter species makes its first appearance.

Dates of ecological events:

First seen: 19 October 1978; 27 October 1979.
Last seen: 18 April 1979; 11 March 1980.
First calling: 1 November 1978; 27 October 1979.
Last calling: 25 January 1979; 10 February 1980.
First breeding chorus: 1 November 1978; 27 October 1979.
First breeding: 18 November 1978 (tadpoles were collected 11 November 1978; 2 November 1979)
Last breeding: 8 January 1979; 9 January 1980.

4.2 *Cyclorana longipes* Tyler and Martin

Definition. Attains a snout to vent length of up to 55 mm. The habits of this species are similar to those of *C. australis* from which it is distinguished by its smaller size and densely mottled back pattern.

Breeding biology. As in *C. australis*, males congregate in large breeding choruses. Breeding occurs from November to mid-December at temperatures of 23-28.5°, and relative humidities of 85-96%. Spawn is laid in loosely-attached clumps of 50-2000 eggs on the surface of water at the edge of temporary pools, at water temperatures of up to 40°C and a depth of 100 cm. The eggs sink to the bottom in early development. The eggs are brown with a white vegetal pole, and have two jelly envelopes. The mean capsule diameter is 2.2 mm (1.9-2.5 mm) and ovum diameter 1.4 mm (1.2-1.5 mm).

Developmental history. The tadpoles are identical in form and habits to *C. australis* but attain a smaller maximum size: 59.5 mm at stage 42 (mean 42.3 mm; range 32.8-59.5 mm). Maximum growth occurs during stages 25-28, extending from a mean of 7.7 mm (6.8-8.3 mm) in stage 24 to 28.2 mm (24.6-30.5 mm) in stage 28. The tadpoles possess numerous long gill filaments in stages 22-24. At 30°C juveniles metamorphosed after 40 days. Juveniles were collected on 12 December 1978 in Jabiru, in an area where the first pools did not appear until after 1 November 1978, so leaving a maximum of 42 days for complete development. At metamorphosis juveniles have a mean snout to vent length of 20 mm (19.1-21.1 mm).

Dates of ecological events:

First seen: 1 November 1978; 2 November 1979.
Last seen: 8 January 1979; 9 January 1980.
First calling: 1 November 1978; 2 November 1979.
Last calling: 8 January 1979; 9 January 1980.
First breeding chorus: 1 November 1978; 2 November 1979.
First breeding: 18 November 1978 (tadpoles collected 11 November 1978); 2 November 1979.
Last breeding: 23 November 1978; 19 December 1979.

4.3 *Litoria bicolor* (Gray)

Definition. A small, green tree frog bearing a white stripe on each side of the head and body. Commonly found on vegetation surrounding billabongs

and streams. It is a nocturnal species and spends the day hidden at the base of leaves of *Pandanus*. Early in the Wet season males call during the day.

Breeding biology. From November to April males call from the stems of grass, bushes and small trees in or immediately around water. This species appears to alter the nature of its breeding sites during the Wet season, being found near the billabongs in the early Wet season (October-December) but later it is found in temporary pools by the roadside and in swamps (provided there are sufficient calling sites for the males). There are huge choruses in the early Wet season, but much fewer males call at the latter sites. It breeds at air temperatures of approximately 26°C, at humidities of 92-96%. The eggs are deposited in temporary pools with emergent vegetation. Eggs are small (mean capsule diameter 2.5 mm; range 1.9-2.9 mm) and mean ovum diameter 1.0 mm) with a black animal and white vegetal pole. They are laid in small clumps of 10-20 eggs below the surface, attached to submerged vegetation. There are three jelly envelopes surrounding the ovum.

Developmental history. The eyes are widely spaced, the anus is dextral and the spiracle sinistral. The dorsum is mottled brown in the early stages with pigmentation increasing with development until at stage 41 the tadpole is a uniform brown. At stage 38 a white patch appears just posterior of the eye and develops laterally in the following stages, until at 41 it appears as a broad white stripe from the eye to the groin. Also by stage 41 another white stripe has appeared antero-ventral to the eye, passing beneath the eye and terminating just dorsal and posterior of the shoulder region. The ventral surface is white in these later stages. The tail muscle has stripes of pigment laterally and on the dorsal and ventral edges, the tail fins becoming increasingly pigmented as age increases, the fin edges becoming very dark in later stages. From stages 25-28 a conspicuous band of white muscle is present at the posterior end of the abdomen. The remainder of the abdomen is dark brown. The tooth row formation is 2/3 surrounded by a well-developed, elevated border of small papillae, separated anteriorly. The tadpoles reach a maximum length at stage 42 (mean 33.7 mm; range 27.4-40.1 mm) with maximum growth occurring between stages 25 and 27: length at stage 25 is 11.2 mm (6.4-19.6 mm), length at stage 27 is 21.8 mm (20.3-22.7 mm) (Fig. 5). At 30°C the tadpoles metamorphosed at 77 days; no comparative data are available for populations in the field.

Dates of ecological events:

First seen: 24 October 1978; 24 November 1979.

Last seen: 13 April 1979; 22 March 1980.

First calling: 6 November 1978; 24 November 1979.

Last calling: 13 April 1979; 22 March 1980.

First breeding chorus: 6 November 1978; 24 November 1979.

First breeding: 9 January 1979; well developed tadpoles 10 February 1980.

Last breeding: 13 February 1979.

4.4 *Litoria caerulea* (White)

Definition. This is a large, green tree frog commonly found in dwellings in the area, and consequently familiar to every resident. It spends the day hidden in crevices and hollows.

Breeding biology. This species does not form large breeding choruses; instead the males call from exposed elevated surfaces (e.g. walls, fences) individually or in small groups. Calling occurs during or immediately after rain at night in the Wet season (from October to March). Breeding occurs from November to February at air temperatures of 24-25°C and a humidity of about 96%. Eggs are deposited in small, temporary pools, with or without emergent vegetation. The water temperature at deposition sites varies from 28° to 38°C and the water depth from 5 and 50 cm. The spawn is laid as a surface film of brown eggs with a white vegetal pole. The number of eggs in the clutch varies from 200 to 350. The eggs have two envelopes. The capsule has a mean diameter of 2.5 mm (2.2-2.9 mm); the ovum has a mean diameter of 1.3 mm (1.1-1.4 mm).

Developmental history. Eggs hatch at stage 18, and attain a mean length of 8.1 mm (7.4-8.5 mm) by stage 24. A period of maximum growth follows, the embryo reaching 28.5 mm (25.6-31.2 mm) by stage 29. Growth continues at a steady rate until maximum size is reached at stage 41 (Fig. 5): mean 41.0 mm (38.6-43.6 mm). The tadpoles are of the typical lentic *Litoria* type. The eyes are widely spaced, anus dextral and spiracle sinistral. At stage 22 the tadpoles have well-developed gills. The tooth row formation is 2/3 with a well-developed, elevated border with large papillae on the posterior edge. The border does not extend anterior of the first upper labial tooth row. The tadpoles are mottled brown with increasing pigmentation as development proceeds. There are two brown caudal stripes, a lateral one extending halfway along the tail and one along the dorsal edge of the muscle for nearly the length of the tail. Pigmentation of the tail fin increases as development occurs, but is only light. The ventral surface is dark, becoming lighter with development. At 30°C one juvenile metamorphosed at 18 mm after 38 days.

Dates of ecological events:

First seen: 1 November 1978; 27 October 1979.
Last seen: 12 April 1979; 22 March 1980.
First calling: 1 November 1978; 27 October 1979.
Last calling: 26 February 1979; 22 March 1980;.
First breeding chorus: 23 November 1978; 24 November 1979.
First breeding: 23 November 1978; 27 November 1979.
Last breeding: 19 February 1979.

4.5 *Litoria coplandi* (Tyler)

Definition. A medium-sized dark-brown frog measuring up to 40 mm snout to vent length. It is commonly found at night on sandstone boulders in and around streams in the escarpment. The Dry season is spent in aggregations in crevices and in caves in the sandstone.

Breeding biology. The males call from open sandstone rock faces near water, after rain, early in the Wet season (September-December). Little is known of the deposition sites or the structure of the eggs, which are laid singly or in small clumps on the bottom of rock pools.

Developmental history. The dark brown tadpoles have a conspicuous white abdominal muscle layer at the posterior end of the abdomen which allows easy field identification. This layer becomes less conspicuous after stage 36 when the entire ventral surface becomes white. There is heavy pigmentation of the tail muscle over the entire surface at the posterior end of the tail, but only over the dorsal half at the anterior end. The

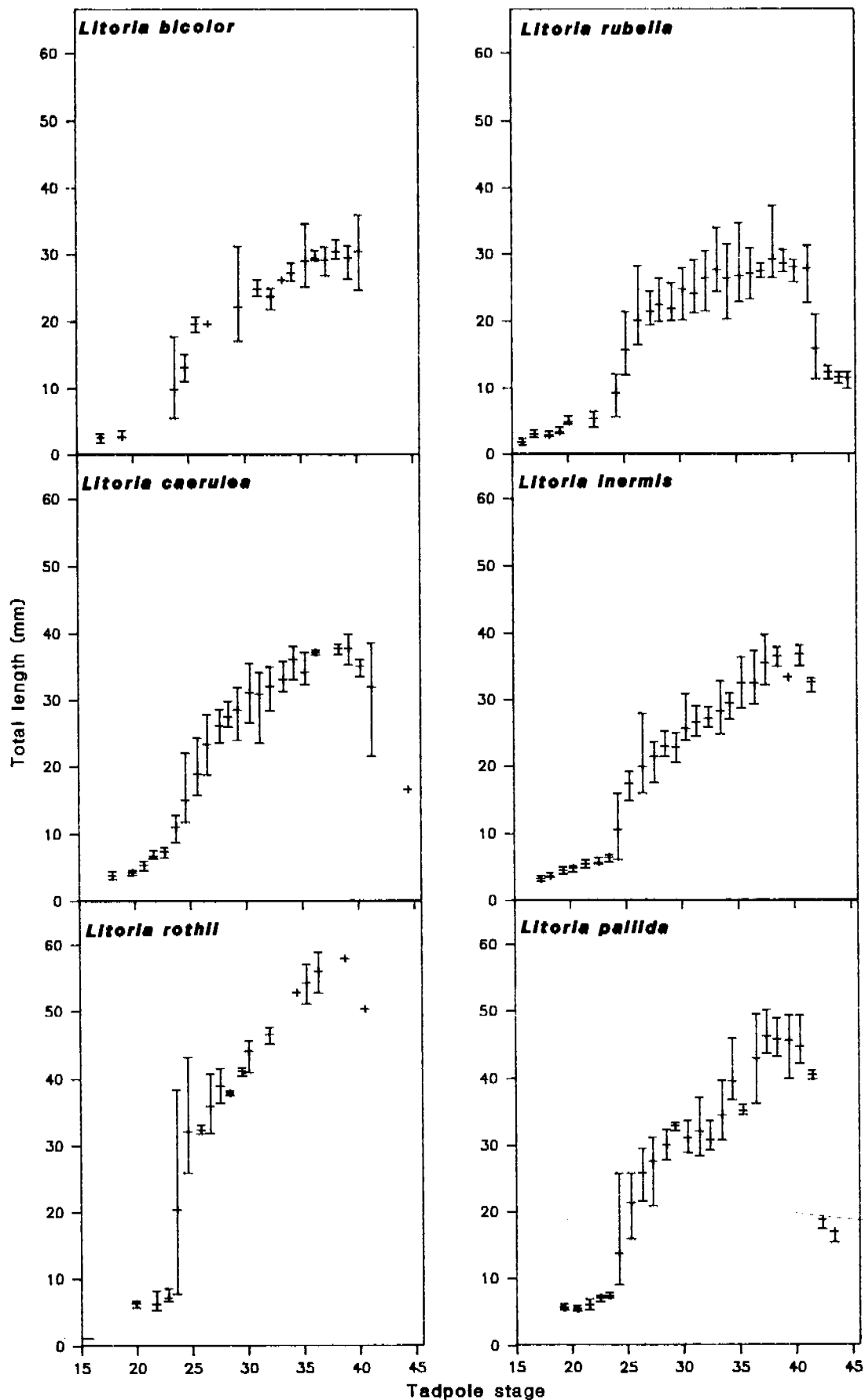


Figure 5. Growth gradients of tadpoles of various species of *Litoria*

tail fin is lightly pigmented. A nasal groove to the eye appears at stage 37 but disappears by 41. The anus is dextral and the spiracle sinistral. The tooth row formation is 2/3 with a complete, well-developed, elevated border of small papillae. The jaws are well-developed. The tadpoles reach a length of more than 45 mm. The juveniles metamorphose at a mean length of 15.8 mm (13.6-18.6 mm). The duration of development is unknown, but metamorphosing specimens found on 21 February 1980 were collected in an area where sufficient amounts of rain had fallen only since the first days of January, leaving a maximum of 52 days.

Dates of ecological events:

First seen: 7 November 1978; 24 October 1979.

Last seen: 19 April 1979.

First calling: 7 November 1978; 28 October 1979.

First breeding chorus: 7 November 1978; 28 October 1979.

First breeding: tadpoles found 11 November 1978; 29 October 1979
(tadpoles approximately 7 days).

4.6 *Litoria dahlui* (Boulenger)

Definition. An aquatic species of the flood plain, *L. dahlui* is a large frog measuring up to 70 mm snout to vent length. It is green with brown and olive back markings. It spends the Dry and early Wet seasons in cracks and crevices in the soil. When the plains are flooded, it emerges and can be seen in shallower vegetated parts of the flooded areas, or basking at the perimeter of buffalo wallows.

Breeding biology. Although abundant on the flood plains, little is known of its breeding habits. Males were observed calling from a floating position in the water when rain was falling during periods of rising floods on the flood plains (I. Morris pers. comm.). Spawn is unknown.

Developmental history. The tadpoles have a bulbous, elongate body. The eyes are dorso-lateral, the anus is median and the spiracle sinistral. The dorsal pattern is one of strong mottling on a dark background, developing into the characteristic stripe pattern of the adult by stage 41. The ventral surface is dark, lightening to white by stage 42. The tail muscle is pigmented with a broad lateral stripe and one along the dorsal edge. Some pigmentation of the tail fin. The tooth row formation is 2/3. There is a well-developed, elevated border of small papillae, widely separated anteriorly. The jaws are well-developed. The tadpoles reach a length of 35 mm by stage 26, increasing to a mean of 52.6 mm (44.4-56.7 mm) at stage 38. At stage 43 the metamorphlings measured a mean of 28.2 mm (23.2-32.5 mm).

Dates of ecological events:

First seen: 5 November 1978; 30 January 1980.

Last seen: 10 February 1979; 19 March 1980.

4.7 *Litoria inermis* (Peters)

Definition. A pale grey to brown, medium sized (up to 40 mm snout to vent length) ground-dwelling frog with slightly expanded terminal digital discs. One of three closely related 'ground hylid' species found in the

area. It can be distinguished by its extremely warty dorsal skin, relative limb length and reproductive strategy.

Breeding biology. Males call from open areas (usually steeply-sloping banks) from November to March. The largest choruses take place early in the Wet season. Breeding occurs throughout this time in a temperature range of 23.5-28°C and relative humidity range of 92-96%. Deposition sites are temporary pools with little or no emergent vegetation, gravelly or sandy soil with cover within one metre of the water. Breeding occurs at a water temperature of 33-35°C, in water of 5-60 cm depth. The eggs are laid in clumps of 96-330, free-floating, on the surface. The capsule is the largest of the frogs in the area with a mean diameter of 6.1 mm (5.8-5.8 mm). The ovum measures 1.33 mm (1.3-1.4 mm) and is brown with a white vegetal hemisphere. There are three jelly envelopes in the capsule.

Developmental history. The tadpoles are of the typical *Litoria* lentic water form with an elongate, oval-shaped body. The anus is dextral and the spiracle sinistral. The tadpoles are mottled brown on the dorsum, and the abdomen is dark, lightening during development. The tail muscle is mottled, and the tail fin edges become very dark in late developmental stages. There is a well-developed, elevated border of small papillae separated anteriorly around well-developed jaws, and a tooth row formula of 2/3. In the laboratory, a small patch of brown pigment is present on the tip of the tail in stage 25, but this disappears by stage 26. The period of maximum growth is from stage 25-27, with the total length increasing from a mean of 6.3 mm (6.0-6.6 mm) at stage 24, to 21.2 mm (16.7-30.3 mm) at stage 27. There is a gradual increase after this period until the mean maximum length of 40.3 mm (38.3-43.5 mm) (see Fig. 5). At 30°C juveniles metamorphosed after 74 days. However, there is no comparative field data.

Dates of ecological events:

First seen: 21 October 1978; 18 October 1979.
Last seen: 18 April 1979; 11 March 1980.
First calling: 14 November 1978; 30 November 1979.
Last calling: 4 February 1979; 11 March 1980.
First breeding chorus: 14 November 1978; 7 December 1979.
First breeding: 17 November 1978; 9 January 1980.
Last breeding: 7 December 1979; 7 March 1980.

4.8 *Litoria pallida* Davies, Watson & Martin

Definition. Another of the 'ground hylid' species, this species has a well-defined eye stripe and a smooth dorsum. It is pale grey to brown; in the breeding season this species is mottled brown on the dorsum.

Breeding biology. Males call in large choruses from open areas within 1 metre of water from October to April. Breeding has been observed from November to March, at temperatures of 24-28°C and a relative humidity of 89-96%. Spawn is deposited in temporary pools; at the time of collection the water temperature was 33.6-41.2°C, and the water depth was up to 100 cm. The eggs are brown with a white vegetal pole and are laid as a surface layer, becoming clumped when even slightly disturbed. There are 50-350 eggs laid with a mean capsule diameter of 3.6 mm (3.4-3.9 mm), and mean ovum diameter of 1.3 mm (1.2-1.3 mm). The ovum is enveloped by three jelly envelopes.

Developmental history. The tadpoles are mottled brown on the dorsum and have a dark abdomen which lightens to white by stage 41. The mottled pattern overlays the dark flanks. The tail muscle is heavily pigmented and mottled, and the tail fin is pigmented. The tadpole is of the typical *Litoria* form with the anus dextral and the spiracle sinistral. The tooth row formula is 2/3 and the papillary border is elevated and well-developed, with the small papillae separated anteriorly. The tadpoles hatch at stage 18. The maximum growth occurs between stages 25 and 27 with total length increasing from an average of 6.2 mm (6.0-6.3 mm) at stage 24 to 24.4 mm (20.1-28.5 mm) at stage 27. There is then continued growth and the maximum length is reached at stage 38 with a mean total length of 44.8 mm (42.1-48.9 mm) (see Fig. 5). This length is maintained until absorption of the tail begins at stage 42. Two metamorphlings measured 14.8 and 16.1 mm respectively at stage 44. At 30°C juveniles metamorphosed after 87 days. In the field juveniles were collected on 28 February 1980 in an area where suitable pools had been available since 5 January giving a maximum of 54 days for development.

Dates of ecological events:

First seen: 20 October 1978; 18 October 1979.
Last seen: 18 April 1979; 19 March 1980.
First calling: 7 November 1978; 2 November 1979.
Last calling: 7 March 1979; 19 March 1980.
First breeding chorus: 7 November 1978; 2 November 1979.
First breeding: 25 November 1978.
Last breeding: 25 January 1979; 5 March 1980.

4.9 *Litoria meiriana* (Tyler)

Definition. A small brown or mottled slate frog reaching a maximum snout to vent length of 25 mm. It is active during the day in leaf-litter alongside streams in the sandstone escarpment. The Dry season is spent in crevices and caves in the sandstone.

Breeding biology. In the early Wet season the males call from leaf-litter and open rock faces at the edge of streams in the escarpment. Breeding occurs from October to December. Amplexed pairs have been found at temperatures of 26.5-27.0°C and relative humidities of 85-88.5%. Spawn is deposited in a film of small clumps attached to sandstone rocks in small temporary pools in sandy stream beds in the escarpment. The eggs are small and light brown. One clutch contained 39 eggs.

Developmental biology. The tadpoles are brown with the anus dextral and the spiracle sinistral. The tail muscle is mottled brown with a dark brown stripe along the dorsal edge. The upper tail fin is pigmented. The ventral surface lightens during development until it is white at stage 42. The tadpoles have the typical *Litoria* tooth row formation and a well-developed, elevated border of small papillae. The border is narrowly separated anteriorly. The jaws are well-developed. The maximum growth period is from stage 25 to 27, length increasing from a mean of 4.05 mm (3.9-4.2 mm) at stage 22 to 6.2 mm (3.7-12.6 mm) at 25, and up to 21.1 mm (15.9-25.1 mm) at stage 27. Growth is then very slight, increasing only to a mean of 25.4 mm (25.3-25.6 mm) at stage 41 (Fig. 6). At 30°C tadpoles reached stage 42 in 45 days. At Ngarradj Warde Djobkeng (Birndu) juveniles were found in large numbers on 30 November 1978. The first appreciable rains in the area and observations of calling and spawning were in

the first days of November (Greg Miles pers. comm.), thus giving a maximum of 30 days for development.

Dates of ecological events:

First seen: 20 October 1978; 28 October 1979.
Last seen: 19 April 1979.
First calling: 7 November 1978; 28 October 1979.
Last calling: 30 November 1978.
First breeding chorus: 7 November 1978; 28 October 1979.
First breeding: 7 November 1978.

4.10 *Litoria microbelos* (Cogger)

Definition. The smallest species in the area, little is known of its habits. It reaches a maximum snout to vent length of 20 mm. It is dark brown, and is found among long grass at the edges of pools and streams. The day is spent under logs, stones and vegetation near streambeds or flooded grassland.

Breeding biology. Males call, from October to February, from the base of grass tussocks or on grass stems during or immediately following rain. In the early Wet season this species and *L. bicolor* have large breeding choruses in pools at the edge of billabongs. Where *L. bicolor* is present, *L. microbelos* males call from the base of the grass tussocks; however, if *L. bicolor* is absent, *L. microbelos* calls from the grass stems which *L. bicolor* normally occupies. The eggs are deposited in small clumps among grass stems. The mean ovum diameter is 0.8 mm (0.8-0.9 mm) and the eggs have a brown animal and a cream vegetal pole. No complete jelly capsules were found.

Developmental history. The embryos hatch at stage 20 at a total length of 3.0 mm (2.8-3.1 mm). At stage 24 the total length is 4.1 mm (4.0-4.2 mm) increasing to 11.4 mm (10.8-12.0 mm) at stage 27. No data are available for later stages. There is dark pigmentation on the dorsal surface, and a dark eye and lateral stripe. There are bands of pigment on the tail muscle. The tail is lightly pigmented. The tooth rows are 2/3. The papillae are relatively large and the border is well-developed, elevated and widely separated anteriorly. The jaws are rather weakly developed.

Dates of ecological events:

First seen: 21 October 1978; 27 October 1979.
Last seen: 26 February 1979; 5 March 1980.
First calling: 14 November 1978; 27 October 1979.
Last calling: 26 February 1979; 5 March 1980.
First breeding chorus: 14 November 1978; 27 October 1979.

4.11 *Litoria nasuta* Tschudi

Definition. This species is an exceptionally long-legged, streamlined frog which has the common name 'Rocket Frog'. It is brown with dark brown and white laterally orientated back markings, and a conspicuous dark eye stripe. It is abundant everywhere except upon the escarpment.

Breeding biology. Males call from open areas between grass tussocks within one metre of water from November to March. Breeding occurs from

November to February. Amplexed pairs have been found at temperatures of 25-26.5°C, at relative humidities of 96%. The spawn is deposited in small temporary pools on inundated grassland, usually with sparse emergent vegetation. At spawn deposition sites water temperatures were 30.5-41.2°C, and water depths were 15-30 cm. The eggs are dark brown with cream vegetal hemispheres. The spawn is laid as a surface film which becomes a clump when disturbed. There are 50-100 eggs laid in a clump, with a mean capsule diameter of 3.4 mm (3.2-3.7 mm) and ovum diameter of 1.1 mm (1.0-1.3 mm). There are three jelly envelopes around the ovum.

Developmental history. The tadpole is of typical *Litoria* form in lentic water. The anus is dextral and the spiracle is sinistral. The tooth row formula is 2/3 with a well-developed, elevated papillary border, separated anteriorly. The tadpoles are mottled brown with the ventral surface whitening during development. The tail muscle is mottled and the tail fin pigmented. The characteristic, striped, back pattern of the adults becomes evident at stage 42. At stage 41, the length and striped pattern of the legs and toe-webbing distinguish this species from closely related species. The eggs hatch at stage 18 at a mean length of 1.9 mm (1.8-1.9 mm). They reach a length of 6.0 mm (5.2-6.3 mm) by stage 24, whereupon there is maximum growth until stage 28, 33.3 mm (29.0-38.3 mm). Growth continues steadily until a maximum mean length of 48.8 mm (44.8-55.7 mm) is reached at stage 39. The tadpoles remain at this size until absorption of the tail commences at stage 43. At 30°C juveniles metamorphose at a mean length of 18.7 mm (17.3-21.6 mm) after 31 days.

Dates of ecological events:

First seen: 23 October 1978; 18 October 1979.

Last seen: 24 April 1979; 5 March 1980.

First calling: 7 November 1978; 24 November 1979.

Last calling: 5 March 1979; 5 March 1980.

First breeding chorus: 7 November 1978; 24 November 1979.

First breeding: 25 November 1978; 19 December 1979.

Last breeding: 3 February 1979; 18 January 1980.

4.12 *Litoria personata* Tyler, Davies & Martin

Definition. A newly-discovered, small, rock-dwelling species, reaching a maximum of 35 mm snout to vent length. It is brown or grey with a conspicuous dark eye stripe. The Dry season is spent in cracks and crevices in the escarpment.

Breeding biology. Males call from open rock faces and elevated positions at the edge of streams in the escarpment from November to late January. The eggs are unknown.

Developmental history. Tadpoles are found in pools upon, and at the base of, the escarpment. The tadpoles are highly distinctive, being dark brown dorsally with gold to yellow dorso-lateral stripes. The ventral surface is creamy-white. There is a dark grey band between the eyes, and an arrow-head-shaped dark grey patch anteriorly. The body shape is typical of other *Litoria* from lotic habitats. The body is flattened, the tail muscle is powerful and the fins narrow. The tooth row formula is 2/3, with a complete, elevated papillary border. The jaws are weakly developed. The anus is dextral and the spiracle sinistral. Tadpoles measured 41.8-55.1 mm at stages 41 to 45. They form aggregations and are often seen floating in a horizontal position at a depth of 5-10 cm.

Dates of ecological events:

First seen: 7 November 1978; 29 January 1980.
Last seen: 20 January 1979.
First calling: 7 November 1978.
Last calling: 20 January 1979; 29 January 1980.
First breeding chorus: 7 November 1978.
First breeding: (tadpoles 7 November 1978).

4.13 *Litoria rothii* (de Vis)

Definition. *L. rothii* is a large brown tree frog reaching 60 mm snout to vent length. This species has bright yellow and black markings in the groin and posterior of the thigh. It is commonly seen on buildings in the area.

Breeding biology. From November to March males call from elevated positions near water after rain. Breeding occurs from November to March at temperatures of 27.5-28.5°C, at relative humidities of around 96%. The spawn is deposited in small clumps in temporary pools with or without emergent vegetation. The eggs are dark brown with a cream vegetal pole and have a mean ovum diameter of 1.4 mm (1.3-1.4 mm). The outer capsule is fragile and easily ruptured, it measures 4.6-5.4 mm. There are three jelly envelopes surrounding the ovum.

Developmental history. The tadpoles are pale yellow on the dorsal surface and white ventrally when they hatch at stage 18. There are dark brown stripes dorsally and dorso-laterally, and a bright yellow spot is visible on the dorsal surface just anterior to the eyes. At stage 23 there are external gill filaments present. The dark brown stripes are a dorsal one which branches forward anterior of the eyes and one either side of the body running from the nostril to the end of the tail. The anus is dextral and the spiracle sinistral. The body is of the typical *Litoria* lentic water form, but the tail fins are much deeper than in other species in the area. The stripes fade and the dorsal and lateral surfaces become mottled brown. The dorsal surface of the head becomes very flat. The tooth row formation is 2/3. The third lower row of labial teeth is absent or reduced to a small, median structure bearing less than ten teeth. The border is well-developed, elevated and separated anteriorly. The papillae are large and the jaws are well-developed. The tadpoles undergo a maximum growth period at stage 25, increasing in total length from a mean of 7.0 mm (6.8-7.4 mm) at stage 24 to 19.9 mm (7.2-38.2 mm) at stage 25 to 31.4 mm (25.3-43.0 mm) in stage 26. A maximum length of 58.2 mm was measured in a stage 40 tadpole (Fig. 5). At 30°C a juvenile metamorphosed after 146 days; in the field, however, a large juvenile was collected on 11 March 1980 in an area where water was not present until after 5 January 1980. This gives a maximum of 65 days for development.

Dates of ecological events:

First seen: 21 October 1978; 2 November 1980.
Last seen: 8 March 1979; 11 March 1980.
First calling: 7 November 1978; 2 November 1979.
Last calling: 8 March 1979; 11 March 1980.
First breeding chorus: 7 November 1978; 2 November 1979.
First breeding: 5 December 1978 (tadpoles found 18 November 1978, early stage 25); 26 November 1979.
Last breeding: 7 March 1980.

4.14 *Litoria rubella* (Gray)

Definition. A small brown tree frog measuring a maximum of 40 mm snout to vent length; it is abundant throughout the area except in the escarpment. The day is spent in hollows, under logs and rocks in dry streambeds, and on banks.

Breeding biology. Males call from a variety of areas near water ranging from open grassy areas to elevated sandy hillocks, usually on the ground. Silent males and amplexed pairs are often found within 0.3 m of a calling male. Calling and breeding occur from November to April, though both activities appear concentrated early and late in this period. Amplexus occurs at temperatures of 25-26.5°C and relative humidities of 92-96%. Spawn is deposited in temporary pools with or without emergent vegetation. Water temperatures of up to 40°C have been recorded at the deposition site, the water depth was 30-100 cm. The eggs have a brown animal pole and cream vegetal pole, and are laid as a surface film. There are 40-300 eggs in a clump with a mean capsule diameter of 2.1 mm (1.9-2.3 mm), and mean ovum diameter of 1.0 mm (1.0-1.1 mm). There are three jelly envelopes enclosing the ovum.

Developmental history. At 30°C the eggs hatch within three days at stage 21. The tadpoles attain maximum growth during stages 25-27, increasing in total length from 5.9 mm (4.5-6.9 mm) at stage 23 to 22.2 mm (17.9-30.9 mm) at stage 27. Maximum length of 31.2 mm (25.3-34.8 mm) is reached at stage 42 (Fig. 5). The tadpoles have a 2/3 tooth formation, small papillae in a well-developed elevated border which is separated anteriorly. The jaws are well-developed. The spiracle is left ventrolateral and the anus right median. The body is rotund and mottled brown on the dorsum, white on the ventral surface. The mottling becomes darker during development. There is dark pigmentation on the tail muscle in three stripes, a lateral one and along the dorsal and ventral extremities. This pigmentation also occurs on the outer edge of the tail fin becoming increasingly darker during development. A shallow nasal groove from eye to nose is present in later stages. At stage 41, a broad, white lateral stripe and vertebral stripe appears and is retained until after metamorphosis. There is also a white patch anterior and below the eye. The rest of the dorsum is uniformly brown. At 30°C the juveniles metamorphose after 38 days. A collection of tadpoles with metamorphlings present was made on 10 February 1980. The pool the collection was made in could not have been filled before 5 January 1980 leaving a maximum of 37 days for complete development.

Dates of ecological events:

First seen: 21 October 1978; 2 November 1979.

Last seen: 7 March 1979; 22 March 1980.

First calling: 8 November 1978; 2 November 1979.

Last calling: 7 March 1979; 22 March 1980.

First breeding chorus: 8 November 1978; 2 November 1979.

First breeding: 8 November 1978.

Last breeding: 13 February 1979; 22 March 1980.

4.15 *Litoria tornieri* (Nieden)

Definition. Another of the 'ground hylids', this species is distinguished by a fine brown stripe on the anterior of the tibio-fibula. The colour in

the breeding season is orange-red with a conspicuous dark brown eye stripe. This species reaches up to 40 mm snout to vent length.

Breeding biology. Males call from cover, either under leaves or at the base of grass tussocks within 3 metres of water. Calling occurs from October to April, breeding has been observed from November until March. The call is distinctive from the other members of the 'ground hylid' group. Breeding occurs at temperatures of 25.0-26.5°C and relative humidities of 92-96%. The eggs are laid in temporary pools in inundated grassland where the depth of water is less than 100 cm. The dark brown eggs have a white vegetal pole and are laid as a surface layer which clumps when disturbed. The mean capsule diameter is 3.4 mm (3.2-3.7 mm) and the ovum diameter is 1.4 mm. There are two jelly envelopes.

Developmental history. The tadpoles are mottled brown on the dorsum and have a dark abdomen which lightens to white during development. The tail muscle is mottled and the tail fin pigmented. The tadpole is of typical *Litoria* form for lentic waters. The anus opens right of median and the spiracle left lateral. The tooth row formation is 2/3 and the border is well-developed, elevated and separated anteriorly. The papillae are small. Jaws are strongly developed. The tadpoles hatch at stage 18 and reach a mean total length of 6.5 mm (6.1-7.1 mm) at stage 24. A period of accelerated growth occurs, increasing the mean total length to 26.4 mm (23.2-29.9 mm) at stage 27. Growth increases slowly until it reaches a maximum of 38.8 mm (34.6-44.0 mm) at stage 38. One juvenile metamorphosed at a length of 15.1 mm. At 30°C tadpoles reached stage 40 in 44 days.

Dates of ecological events:

First seen: 20 October 1978; 18 October 1979.

Last seen: 18 April 1979; 7 March 1980.

First calling: 7 November 1978; 5 December 1979.

Last calling: 5 March 1979; 7 March 1980.

First breeding chorus: 5 December 1979.

First breeding: 7 December 1978; 9 January 1980.

Last breeding: 23 December 1978; 28 February 1980.

4.16 *Litoria wotjulumensis* (Copland)

Definition. This species can be distinguished from the other ground-dwelling hylids by its larger size (reaching 70 mm snout to vent length), elongate body, extensive webbing of the hind limbs and broad, dark conspicuous eye stripe. Its call is a variety of rattles and chuckles.

Breeding biology. The males call from open areas on the water's edge facing the water. Calling occurs from October to March with breeding occurring in the early months of the Wet season. Breeding has been recorded at temperatures of 25-27°C and relative humidities of 75-92%. The spawn is laid in temporary pools in sandy or gravelly soil. Eggs were found at water temperatures of 32-33°C and in water 10-50 cm deep. The dark brown eggs have a cream vegetal pole and are deposited as a floating clump of 30-200 eggs, sometimes attached to surface vegetation. The mean capsule diameter is 4.6 mm (4.2-4.9 mm) and ovum diameter 1.75 mm (1.6-1.9 mm). There are three jelly envelopes surrounding the ovum.

Developmental history. The tadpoles have well-developed external gills from stages 20 to 24. The body is typical of *Litoria* of lentic waters. The tadpole is mottled dark brown with the ventral surface white. The

anus is dextral and the spiracle sinistral. The tail muscle is heavily mottled and the upper tail fin pigmented. The tooth row formation is 2/3 with a well-developed, elevated border of small papillae. The border is separated anteriorly. The jaws are strongly developed. At stage 25 the mean total length is 12.6 mm (8.2-21.2 mm) increasing to a maximum of 40.5 mm (39.3-42.3 mm) at stage 41. Juveniles metamorphosed at a mean length of 17.0 mm (15.5-18.0 mm). At 30°C tadpoles reached stage 42 after 53 days.

Dates of ecological events:

First seen: 1 November 1978; 28 October 1979.

Last seen: 19 April 1979; 9 January 1980.

First calling: 1 November 1978; 28 October 1979.

Last calling: 8 March 1979; 9 January 1980.

First breeding chorus: 1 November 1978; 28 October 1979.

First breeding: 18 November 1978; 18 December 1979. (Tadpoles found 30 October 1979; well developed. Metamorphosing juveniles present.)

Last breeding: 11 December 1978; 18 December 1979.

4.17 *Limodynastes converiusculus* (Macleay)

Definition. A large broad-bodied frog with a mottled pattern on its back. It is common in swampy areas and abundant on the flood plains. It is found among long grass usually in small hollows or burrows. It is cryptic in its habits.

Breeding biology. From October until April the males call from small hollows among long grass near water. Little is known of the eggs except that they are laid in a foam nest.

Developmental history. The tadpoles are a distinctive, jet black with long, deep tail fins. The opening is median and the spiracle lateral. The tooth row formula is 5/3 and there is an elevated border of large papillae which is widely separated anteriorly. The jaws are rather weakly developed. The body is robust and the dorsal surface slightly flattened. The tadpoles do not occur in large numbers. They attain a maximum length of 70 mm.

Dates of ecological events:

First seen: 5 November 1978; 18 October 1979.

Last seen: 24 April 1979; 19 March 1980.

First calling: 7 November 1978 (near Jabiru 12 December 1978);
24 November 1979 (near Jabiru).

Last calling: 25 March 1979; 19 March 1980.

First breeding chorus: 12 December 1978; 26 November 1979.

4.18 *Limodynastes ornatus* (Gray)

Definition. A rotund, burrowing frog up to 45 mm snout to vent length with a highly variable back pattern. This species has no preferred habitat (although it is uncommon in the larger billabongs) and is abundant in the area.

Breeding biology. The males call whilst free-floating in water. Calling occurs from October to March, breeding from November to February. Breeding

has been recorded at air temperatures of around 26°C and at relative humidities of 88.5-96%. Any pool from 2 cm in depth can be used for breeding, including ditches newly dug for sewer pipes and shallow, water-filled depressions on the road surface. At deposition sites water temperatures were 27-38°C. The eggs are deposited in a foam nest floating on the surface of the pool. The number of eggs per clump is 155-1630 with a mean of 645. The ovum is black with a white vegetal pole and has a mean diameter of 1.2 mm (1.0-1.3 mm). The eggs have one jelly envelope, and the mean capsule diameter is 1.6 mm (1.45-1.8 mm).

Developmental history. The foam nest collapses as the embryos develop. The embryos hatch after 18 hours at stage 20 at a mean length of 4.4 mm (4.0-4.7 mm). Long filamentous gills are present from stage 22 to 24. Growth is steady throughout development. The tadpoles are brown on the dorsal surface with a darker patch between the eyes and on the tail muscle. The eyes are dorsal and close together giving the tadpole a distinctive appearance. The anus opens medially and the spiracle is sinistral. The body is flattened dorso-ventrally. The tooth row is variable from 2/3 to 5/3. The border is well-developed, elevated and has large papillae. It is widely separated superiorly. The jaws are weakly developed. The tadpoles form dense and active aggregations and cannibalism is prevalent, especially in ephemeral pools (presumably due to inadequate nutrients there). A maximum length of 31.0 mm (29.5-32.8 mm) is reached at stage 39 and juveniles metamorphosed at a mean of 10.3 mm (6.5-11.6 mm). At 30°C metamorphosis was completed after 26 days. In the field spawn laid on 28 November 1977 developed to stage 46 on 23 December 1977: a total of 25 days.

Dates of ecological events:

First seen: 26 October 1978; 2 November 1979.
Last seen: 26 February 1979; 4 March 1980.
First calling: 7 November 1978; 2 November 1979.
Last calling: 26 February 1979.
First breeding chorus: 7 November 1978; 2 November 1979.
First breeding: 7 November 1978; 7 December 1979.
Last breeding: 13 February 1979.

4.19 *Megistolotis lignarius* Tyler, Martin and Davies

Definition. A moderate-sized (60 mm snout to vent length) robust species with short muscular limbs. It inhabits scree slopes and escarpments and hides beneath rocks and boulders.

Breeding biology. The males call from under boulders in or near stream-beds on the escarpment. The creamy-yellow eggs are deposited in a foam nest under rocks.

Developmental history. Hatching occurs at stage 21. The body and fins are intense black. The anus opens medially and the spiracle is sinistral. The tadpoles have highly efficient suctorial mouthparts. The tooth row formation is variable from 4/3 to 6/3. The border is well-developed, elevated and narrowly separated superiorly. The papillae are small and jaws are strongly developed. Cannibalism has been noted in the laboratory. The tadpoles reach a length of over 50 mm by stage 42. In the laboratory a juvenile metamorphosed after 65 days and measured 23.3 mm.

Dates of ecological events:

First seen: 7 November 1978; 28 October 1979.

Last seen: 20 January 1979.

First calling: 7 November 1978; 28 October 1979.

Last calling: 30 November 1978.

First breeding chorus: 7 November 1978; 28 October 1979.

First breeding: 7 November 1978 (spawn observed by G. Miles on 5 November 1978).

4.20 *Notaden melanoscaphus* Hosmer

Definition. A medium-sized, robust, burrowing frog with short limbs. This species is found in grasslands throughout the area. It is pale brown with large dark blotches on its back, and when seized exudes a copious amount of sticky, yellow secretion from large dorsal glands. It spends the day buried in sandy soil.

Breeding biology. The males call during or immediately after rain from shallow, water-filled depressions. Calling occurs from December to March, breeding from early January to March. Air temperature range 23-26.5°C; relative humidity 96-100%. The spawn is deposited as a surface film in shallow ephemeral pools in inundated grassland. Water temperatures range from 27 to 36°C and depth from 1 to 30 cm. The eggs have a black animal pole and a white vegetal pole. The number of eggs varies from 500 to 1000 with a mean of 833. The eggs have individual capsules joined by a sticky, loose layer of jelly. There is one jelly envelope enclosing the ovum. The mean capsule diameter is 2.7 mm (2.6-2.9 mm) and ovum diameter 1.4 mm (1.3-1.45 mm).

Developmental history. The eggs sink as they develop and hatch at stage 20 at a mean length of 5.8 mm (5.0-6.8 mm). External gills are present from stages 22 to 24. The anus opening is dextral and the spiracle is sinistral and lateral (visible from a dorsal view). Dorsal pigmentation is dark brown with the adult back pattern becoming apparent during stage 41. The ventral surface is dark brown becoming lighter as development proceeds. The tail muscle is dark brown and the tail fins are pigmented. The upper tail fin is much deeper than the lower rows. The tooth row formation is 2/3 with 1 complete upper and 2 complete lower rows. The third lower tooth row is reduced to median structure of ten teeth. The papillae are large and the border is not well-developed and is widely separated superiorly. The jaws are very weakly developed. The tadpoles increase in total length from a mean of 7.25 mm (6.1-8.1 mm) at stage 24 to 17.2 mm (13.7-19.2 mm) at stage 26. A stage 42 tadpole measured 35.4 mm (Fig. 6). The tadpoles live in very shallow water (1.5 cm) in inundated grassland. Water temperatures of over 41°C have been recorded. There is heavy flocculent material on the bottom and the tadpoles spend most of the time lying in this layer. In the field a juvenile was found on 26 February 1979 in an area where *Notaden* were not present before 4 January 1979, giving a maximum of 53 days for complete development.

Dates of ecological events:

First seen: 21 October 1978; 13 January 1980.

Last seen: 8 March 1979; 19 March 1980.

First calling: 10 December 1978; 13 January 1980.

Last calling: 7 March 1979; 19 March 1980.
First breeding chorus: 4 January 1979; 13 January 1980.
First breeding: 4 January 1979; 17 January 1980.
Last breeding: 26 February 1979.

4.21 *Ranidella bilingua* Martin, Tyler and Davies

Definition. A small species measuring a maximum of 25 mm and inhabiting grasslands which are inundated in the Wet season. It is brown with variable darker markings on its back. The Dry season is spent on the soil, under logs and rocks.

Breeding biology. This species appears to have no definite breeding season. Instead, the males will call and mating will occur whenever sufficient rain falls, even in Dry season showers. Males call from the base of grass tussocks in or around water. The eggs are laid in small clumps and attached to vegetation. The animal pole is dark brown and the vegetal pole creamy white. There is a single jelly envelope. The capsule diameter is 1.74 mm (± 0.16 mm) and ovum diameter is 1.17 mm (± 0.04 mm).

Developmental history. The eggs hatch at stage 20 and have a total length of 4.0-4.5 mm. There are no external gills present. At stage 25 the total length is about 6.5 mm, increasing to 24.5 mm by stages 40-41. The tadpoles are dark brown with the myotomes and ventral surface white. Upper and lower fins are pigmented. The tooth row formation is 2/3 with the third lower row very short. Few large papillae border the lateral area of the mouth, but are completely absent superiorly. Posteriorly there are just two papillae flanking the third short tooth row. The jaws are strongly developed. Juveniles metamorphosed at a length of 7.8 to 8.3 mm after 13-14 days.

Dates of ecological events:

First seen: 24 October 1978; 5 December 1979.
Last seen: 19 April 1979; 22 March 1980.
First calling: 10 December 1978; 5 December 1979.
Last calling: 19 April 1979; 22 March 1980.
First breeding chorus: 4 January 1979; 5 December 1979.

4.22 *Sphenophryne robusta* (Fry)

Definition. A very small brown cryptic species found in 'paperbark swamps', rainforest remnants and on the escarpment. It inhabits the leaf litter.

Breeding biology. Little is known of its biology, but if it behaves similarly to other sphenophryne microhylids, then the eggs would be laid on land, and the tadpoles would develop inside the egg capsule.

4.23 *Uperoleia arenicola* Tyler, Davies and Martin

Definition. A small squat species which has only been found in a sandy streambed on the escarpment at Birndu (Ngarradj Warde Djobkeng) near Ja Ja. It is variable in colour from pale grey to a dark slate with bronze glands on the shoulders. The specimens were found on steep-sided sandy banks of the stream.

Breeding biology. The males call without moving from their burrows and while still covered with fine sand. Nothing else is known of the biology of this species.

4.24 *Uperoleia inundata* Tyler, Davies and Martin

Definition. A moderate-sized species of up to 30 mm snout to vent length. It is grey with highly variable dark brown dorsal markings. It inhabits grasslands inundated in the Wet season.

Breeding biology. From January to April the males call from shallow water at the base of grass tussocks, under leaves and logs, and from grass stems in deeper water. Large breeding choruses are formed. Breeding occurs during January and February, at temperatures of 24.5-29.0°C and relative humidities of 89-100%. The spawn is deposited in shallow inundated grasslands. Water temperatures were 27.2-28.6°C; the depth of water was 2-5 cm. The eggs are laid either in small clumps (< 5) or individually, and

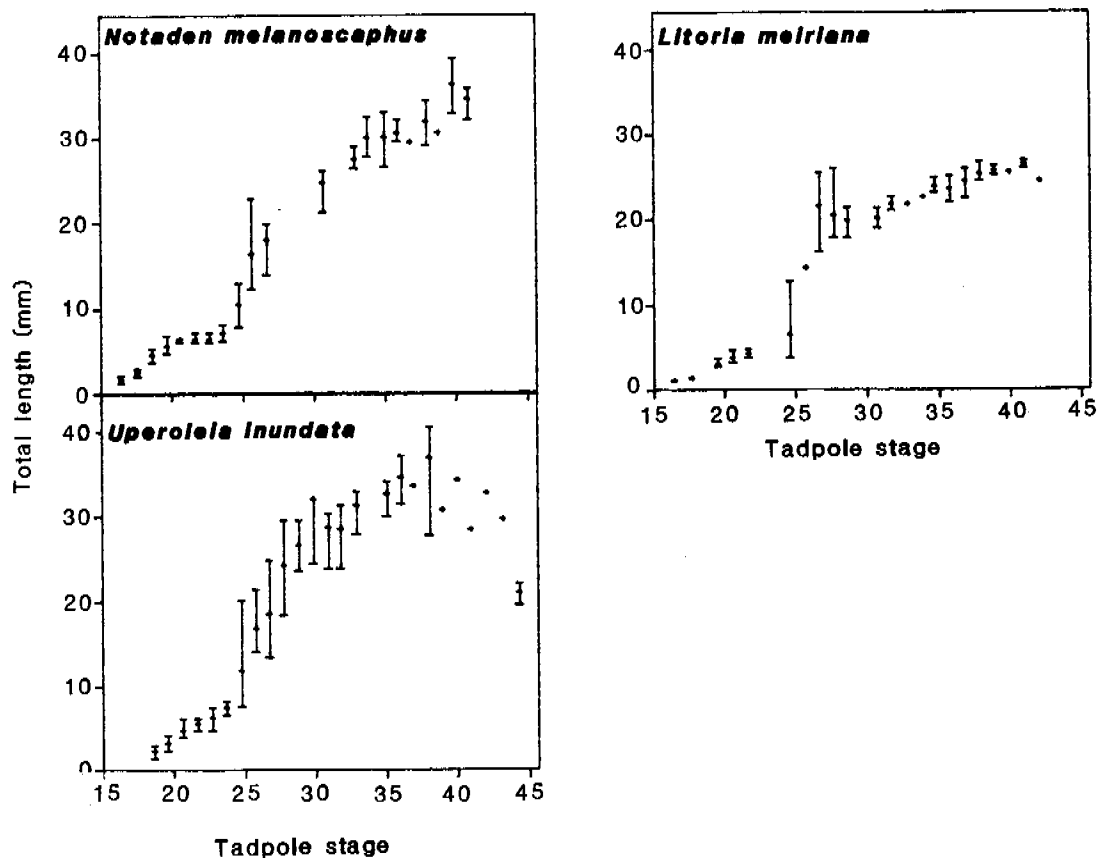


Figure 6. Growth gradients of tadpoles of various species of frogs

immediately sink to the bottom. They have a sticky, tough outer layer which quickly accumulates a covering of particles which acts as camouflage. The egg has a dark brown animal pole with a light brown vegetal pole. There is one jelly envelope in the capsule which has a mean diameter of 1.9 mm (1.5-2.0 mm). The mean ovum diameter is 1.4 mm (1.1-1.4 mm).

Developmental history. The embryos hatch at stage 20 at a mean total length of 2.7 mm (2.5-2.8 mm). External gills are absent. At stage 25 the mean total length is 10.4 mm (6.6-17.1 mm). The tadpoles are dark brown on the dorsal and lateral areas, and mottled red-purple and white on the ventral surface. The anus is dextral and the spiracle is sinistral and is visible from above. The tail muscle is mottled brown and the upper tail fin is pigmented. The tooth row formation is 2/3 with the upper row divided. The papillae are large and the border is poorly developed, widely separated superiorly and inferiorly. The jaws are weakly developed. The tadpoles grow to a mean maximum length of 31.0 mm (23.25-33.9 mm). At stage 44 the tadpoles had a size range of 16.0-17.7 mm (Fig. 6). Juveniles were collected on 2 March 1979 in an area where water had not been present until 10 January 1979. This gives a maximum of 51 days for metamorphosis.

Dates of ecological events:

First seen: 21 October 1978; 9 January 1980.
 Last seen: 19 April 1979; 19 March 1980.
 First calling: 4 January 1979; 9 January 1980.
 Last calling: 19 April 1979; 19 March 1980.
 First breeding chorus: 4 January 1979; 9 January 1980.
 First breeding: 8 January 1979; 13 January 1980.
 Last breeding: 30 January 1979; 18 January 1980.

5 IDENTIFICATION

To permit identification in the field we have prepared dichotomous keys to spawn, tadpoles and adults. To assist the identification procedures we have divided the total fauna into two groups: species found on the escarpment, and those found elsewhere (which we term 'lowland' for want of a more appropriate all-embracing word). Within the 'escarpment' category we have included species such as *Limnodynastes ornatus* and *convexiusculus*, which are in no way adapted to that environment, but occasionally penetrate its fringe.

Excellent colour photographs of many of the species appear in handbooks of the frogs of Australia by Barker & Grigg (1977) and by Cogger (1979). However, because there are so many additional species, and confusion about the use of some names, we recommend that their photographs be used to confirm identifications reached here, rather than as primary sources for identification.

5.1 Key to frog eggs found upon the escarpment

1. Eggs terrestrial, laid in leaf litter.....*Sphenophryne robusta*
 Eggs laid in water.....2
2. Eggs deposited in foam nest.....3
 Eggs not in foam nest.....5

3. Eggs barely pigmented or unpigmented; foam nest in concealed sites.....4
 Eggs black with white vegetal pole, foam nest floating on surface of pools.....*Limnodynastes ornatus*
 4. Foam nest under boulders in streambeds or pools; creamy-yellow.....*Megistolotis lignarius*
 Foam nest in small hollows among grass tussocks; white.....*Limnodynastes convexiusculus*
 5. Large number of brown/white eggs laid as surface film.....*Litoria caerulea*
 Eggs laid singly or in clumps.....6
 6. Eggs floating.....*L. wotjulumensis*
 Eggs below surface of water.....7
 7. Eggs laid as small clumps or film firmly attached to sandstone rock face.....*L. meiriana*
 Eggs laid singly or in small clumps on bottom of rock pools.....*L. coplandi*
- The eggs of *Uperoleia arenicola* and *Litoria personata* are unknown.

5.2 Key to tadpoles found upon the escarpment

1. With distinctive gold or yellow dorso-lateral stripes.....*L. personata*
 Lacking gold or yellow dorso-lateral stripes.....2
2. Body flattened dorso-laterally, eyes dorsal, narrowly separated.
 Papillae border widely separated anteriorly.....*Limnodynastes ornatus*
 Body not flattened dorso-laterally, eyes dorso-lateral.....3
3. Black colour.....4
 Brown colour.....5
4. Papillae border narrowly separated anteriorly; small papillae; 4/3, 5/3, 6/3 labial tooth rows; strong jaws.....*Megistolotis lignarius*
 Papillae border widely separated anteriorly; large papillae; 5/3 labial tooth rows; jaws weakly developed.....*Limnodynastes convexiusculus*
5. Dark brown; conspicuous white patch near base of abdomen.....*Litoria coplandi*
 Lacking white patch near base of abdomen.....6
6. Papillae border widely separated medially; jaws rather weakly developed. Tail fin lightly pigmented; tail muscle pigmentation in two stripe: one lateral halfway along tail, one along dorsal edge...*Litoria caerulea*

- Jaws strongly developed. Upper tail fin pigmented. Tail muscle heavily pigmented.....7
7. Tadpoles small (< 26 mm); border narrowly separated anteriorly. Ventral surface dark, becoming lighter. Dark brown stripe along dorsal edge of tail muscle.....*L. meiriana*
- Tadpoles medium (< 45 mm); border separated anteriorly. Ventral surface light from stage 26.....*L. wotjulumensis*
- It is assumed that *Sphenophryne robusta* has no free-swimming tadpole.

5.3 Key to adult frogs found upon the escarpment

1. Green or olive, large (up to 100 mm); expanded discs on toes, conspicuous toe webbing.....*Litoria caerulea*
Not green or olive.....2
2. Tympanum not visible.....3
Tympanum distinctly visible.....6
3. Very small (up to 25 mm length).....4
Size within range of 25-75 mm.....5
4. Brown with dark stripe on side of head sometimes extending along sides; cylindrical toe discs. Found in leaf litter only.....*Sphenophryne robusta*
Brown to slate grey with orange parotoid glands; no toe discs. Metatarsal tubercle enlarged. Found in sand streambeds.....*Uperoleia arenicola*
5. Inner metatarsal tubercle enlarged; usually sandy with darker back patterns, rounded snout; < 45 mm in length. Slight web on toes.....*Limodynastes ornatus*
Inner metatarsal tubercle not enlarged; grey or olive with dark mottling on dorsal, slightly elongate snout; up to 65 mm in length. Conspicuous cream supralabial gland. No webbing.....*L. convexiusculus*
6. Robust; large, prominent, oval inner, but no outer metatarsal tubercle. Toe discs absent. Hindlimbs short; males have black nuptial spines.....*Megistolotis lignarius*
Not robust; no large, prominent, oval inner metatarsal tubercle. Toe discs present. Long hindlimbs.....7
7. Feet with trace of webbing. Small (< 35 mm). Conspicuous eye stripe. Toe disc expanded.....*Litoria personata*
Hindlimbs with conspicuous webbing.....8
8. Conspicuous eye stripe finishing midway along body, toe discs small. Large size (up to 70 mm SV length).....*L. wotjulumensis*
Toe discs well developed. No eye stripe.....9

9. Small (< 25 mm), diurnal and nocturnal. Heavy mottled dark brown band on legs, dorsal pattern.....*L. meiriana*
Up to 400 mm, nocturnal. Mottled dorsal pattern, large inner metatarsal tubercle.....*L. coplandi*

5.4 Key to lowland frog eggs

1. Terrestrial, found in leaf litter in *Melaleuca* swamps.....*Sphenophryne robusta*
Deposited in water.....2
2. Deposited in foam nest.....3
Not deposited in foam nest.....4
3. Barely pigmented; foam nest in concealed areas in inundated grassland.....*Limnodynastes convexiusculus*
Black with white vegetal pole; foam nest conspicuous, floating on surface of pools.....*L. ornatus*
4. In large loosely attached clumps on bottom of pools.....5
Not in large loosely attached clumps.....6
5. Brown, ovidiameter 1.2-1.5 mm; capsule diameter 1.9-2.5 mm.....*Cyclorana longipes*
Brown, ovidiameter 1.3-1.6 mm; capsule diameter 2.5-2.8 mm.....*C. australis*
6. Laid singly or in small clumps on bottom of pools in inundated grassland.....*Uperoleia inundata*
Not laid singly or in small clumps on bottom of pools in inundated grassland.....7
7. Laid as free-floating clumps.....8
Not laid as free-floating clumps.....10
8. Capsule large (6.1 mm); brown and white egg; 3 jelly envelopes.....*Litoria inermis*
Capsule medium (4.5-5.5 mm); dark brown and white egg.....9
9. Ovum diameter 1.6-1.9 mm.....*L. wotjulumensis*
Ovum diameter 1.3-1.4 mm.....*L. rothii*
10. In small clumps (of < 20 eggs) attached to vegetation.....11
Not in small clumps (of < 20 eggs) attached to vegetation.....13
11. Very small ovum (0.8-0.9 mm) brown and cream.....*L. microbelos*
Small ovum (1.0-1.2 mm) dark brown and cream.....12

12. Ovum diameter 1.0 mm; capsule 2.5 mm (1.9-2.5 mm); 3 jelly envelopes.....*L. bicolor*
Ovum diameter 1.2 mm; capsule diameter 1.7 mm; 1 jelly envelope
.....*Ranidella bilingua*
13. Surface film in shallow water (< 5 cm) in inundated grassland. Black animal pole, white vegetal pole; discrete jelly envelope around ovum with loose sheet of jelly enclosing all eggs.....*Notaden melanoscaphus*
.....*Notaden melanoscaphus*
Surface film in ephemeral or temporary pools. Not black animal pole. Discrete jelly capsules.....14
14. Dark brown.....15
Pale brown.....17
15. Surface film of 200-350 eggs; capsule 2.2-2.9 mm.....*Litoria caerulea*
Surface film or clump; < 100 eggs laid; capsule 3.2-3.7 mm.....16
16. Ovum diameter 1.0-1.3 mm; 3 jelly envelopes.....*L. nasuta*
Ovum diameter 1.4 mm; 2 jelly envelopes.....*L. tornieri*
17. Ovum diameter 1.0-1.1 mm; capsule 1.9-2.3 mm*L. rubella*
Ovum diameter 1.2-1.3 mm; capsule 3.4-3.9 mm.....
.....*L. pallida*

5.5 Key to lowland tadpoles

1. Black, large (up to 70 mm), 6/3 labial tooth rows.....*Limnodynastes converiusculus*
.....*Limnodynastes converiusculus*
Not black.....2
2. Tooth rows vary 2/3 to 6/3; eyes dorsal, narrowly separated; body dorso-ventrally flattened.....*L. ornatus*
Tooth rows always 2/3; eyes dorso-lateral.....3
3. Large (up to 70 mm). Bulbous bodies, usually dense and active in aggregations.....4
Medium (up to 50 mm). Not in dense and active aggregations.....6
4. Lacking nasal groove. Dorsal pattern strong mottling, tail muscle with broad lateral stripe and along dorsal edge. Striped back pattern develops at stage 41. Papillae border widely separated anteriorly.....*Litoria dahliei*
Nasal groove in stages 32-41; tail muscle mottled; papillae border not widely separated anteriorly.....5
5. At stage 41 back pattern with well-defined dark patches.....*Cyclorana longipes*
.....*Cyclorana longipes*
At stage 41 back lacking dark patches; longitudinal rows of small glands present.....*C. australis*

6. Papillae border separated posteriorly.....7
 Papillae border not separated posteriorly.....8
7. Papillae large in lateral area. Absent anterior and just two at posterior, flanking short third labial tooth row; jaws strong; ventral surface white. Small (< 25 mm).....*Ranidella bilingua*
 Papillae large, widely separated anteriorly, separated posteriorly; jaws weakly developed; ventral surface mottled red-purple and white. Small (< 34 mm).....*Uperoleia inundata*
8. Third lower row of labial teeth reduced to median structure of approx. 10 teeth.....9
 Third lower row of labial teeth not reduced.....10
9. Papillae large, border not well-developed and widely separated anteriorly. Jaws very weakly developed. Tadpoles < 38 mm in length Dark brown dorsal. Ventral surface dark brown becoming lighter. Very shallow water in inundated grassland.....*Notaden melanoscaphus*
 Papillae large, border well-developed and separated anteriorly. Jaws well-developed. Tadpoles up to 58 mm long; early stages pale yellow dorsal with dark brown dorsal and dorso-lateral stripes; during later development (after 27) the stripes fade and the dorsal and lateral surfaces become mottled brown with the pale yellow background. Dorsal surface of head becomes flattened. In temporary pools.....*Litoria rothii*
10. Conspicuous band of white muscle on posterior of abdomen until stage 38. At 38 white patch develops just posterior of eye and develops into broad white stripe from eye to groin. Another white stripe anterior and below eye passing beneath eye and ends behind shoulder. Tadpole mottled brown early, uniform brown on dorsum later.....*L. bicolor*
 No conspicuous band of white muscle on posterior of abdomen.....11
11. Tail muscle pigmentation not in broad bands. > 25 mm.....12
 Tail muscle pigmentation in broad bands, very small (< 20mm); jaws weakly developed. Papillae border widely separated. Dark dorsal pattern and dark eye and lateral stripe.....*L. microbelos*
12. Papillae border widely separated anteriorly; jaws rather weakly developed; tail fin lightly pigmented; tail muscle pigmentation in two stripes: one lateral halfway along tail, one along dorsal edge.....*L. caerulea*
 Papillae separated anteriorly; jaws well developed.....13
13. a. Tail muscle has three stripes; one lateral, one on dorsal and ventral edges. Tail fin edge becomes darker with development. Small tadpoles (< 35 mm). In stage 41 broad, white lateral stripe and narrow vertebral stripe appear. White patch anterior to and below eye.....*L. rubella*
 b. Tadpoles mottled brown. Tail muscle mottled brown. Up to 50 mm.Ground-dwelling hylids

(*L. wotjulumensis*, *L. nasuta*, *L. tornieri*, *L. pallida*,
L. inermis).

Further specific identification is only possible from stage 41 onwards as follows:

At stage 41

- (i) a. Toes strongly webbed.....ii
- b. Toe webbing not well developed.....iii
- (ii) a. Striped back pattern, long hindlimbs with longitudinal
 stripes.....*L. nasuta*
- b. Brown back pattern, broad conspicuous dark eye stripe.....
 *L. wotjulumensis*
- (iii) a. Continuous dark brown stripe on posterior edge of
 tibia.....*L. tornieri*
- No continuous stripe.....*L. inermis* & *L. pallida*

Specific identification of these species is only possible after stage 46.

At stage 46

- Warty dorsal surface, indistinct head stripe, some flecking
on the dorsal surface.....*L. inermis*
- Smooth dorsal skin, distinct head stripe.....*L. pallida*

5.6 Key to lowland adult frogs

- 1. Inner metatarsal tubercle enlarged.....2
- Inner metatarsal tubercle not enlarged.....6
- 2. Medium to large size (> 35 mm). Outer metatarsal tubercle
 absent or not enlarged.....3
- Small (to 35 mm). Enlarged outer metatarsal tubercle. Stout-
 bodied; short, stocky limbs; conspicuous parotoid glands and
 glands at corner of mouth; grey with highly variable dark brown
 dorsal markings. Found in inundated grassland
 *Uperoleia inundata*
- 3. Inner metatarsal tubercle not black.....4
- Inner metatarsal tubercle black. Rounded snout. Stout body, short
 robust limbs. Pale brown with dark brown dorsal markings. When
 seized, exudes copious quantities of yellow sticky secretion from
 large number of dorsal glands. Found in inundated grassland.
 *Notaden melanoscaphus*
- 4. Belly smooth. Rounded snout. Medium-sized (up to 45 mm). Sandy
 with variable dark dorsal markings. Toes one-third webbed.
 Tympanum not visible. Males have nuptial pads on first two
 fingers and conspicuous lateral fringes on toes. Calling occurs

- while free-floating in water.....*Limnodynastes ornatus*
- Belly granular. Slightly elongated snout. Large size (50-110 mm).
Toes slightly webbed. Tympanum visible. Male nuptial pads on
first finger only. Calling occurs on land.....5
5. Medium sized (to 55 mm). Well-defined dark patches on dorsal
surface, usually with a vertebral stripe.....*Cyclorana longipes*
- Very large (to 110 mm). Pale brown with patches. A contrasting
dark brown eye stripe from snout to shoulder.....*C. australis*
6. Toe discs conspicuous - expanded to twice width of digit.....7
- Toe discs absent or inconspicuous.....10
7. Small (< 30 mm) and green; thin brown strip along flanks; white
stripe present from nose to groin.....*Litoria bicolor*
- Medium to large size (35-110 mm).....8
8. Brown or grey, 35-60 mm snout to vent length.....9
- Very large green or olive frog (up to 110 mm). Common around
dwellings.....*L. caerulea*
9. Large (to 60 mm). Extensive toe webbing. Yellow and black
markings in the groin and posterior of thigh. Elongate
limbs.....*L. rothii*
- Medium (to 45 mm). Webbing halfway up toes. Broad eye stripe
from nose to shoulder, sometimes continuing along flanks
Short, robust limbs.....*L. rubella*
10. Small (< 25 mm).....11
- Medium to large (> 30 mm).....13
11. Slender body; granular belly.....12
- Robust body; smooth belly; mottled brown; dark eye stripe occasion-
ally continuing along flanks; toe discs small and cylindrical;
tympanum not visible; no webbing on toes; found in leaf litter
in *Melaleuca* swamps.....*Sphenophryne robusta*
12. Up to 25 mm. Brown with variable dark markings on back. No toe
discs. Unwebbed toes.....*Ranidella bilingua*
- Up to 20 mm. Brown with darker lateral stripes; dark eye stripe
from nose to midway along flank; beneath this, white stripe from
nose to shoulder. Toe discs present. Toes slightly webbed.....
.....*Litoria microbelos*
13. Toes at least partly webbed.....14
- Toes unwebbed; large (to 65 mm); grey or olive with discrete dark
patches on dorsal surface; conspicuous cream supralabial gland;
stout body; tympanum not visible. Found in inundated grassland
and flood plains.....*Limnodynastes convexiusculus*
14. Toes fully webbed; large (to 85 mm).....15
- Toes less than fully webbed; medium (to 50 mm).....16

15. Up to 85 mm; green with brown and olive back markings, cream patches on posterior of thigh. Belly smooth and white. Eyes prominent and dorsal. Found on flood plain; mostly aquatic.....*Litoria dahlii*
- Up to 70 mm; brown, contrasting broad dark eye stripe continuing along sides of body. Belly granular and cream. Eyes dorso-lateral.....*L. wotjulumensis*
16. Striped dorsal pattern absent.....17
- Conspicuous brown and white longitudinal stripes on back. Broad dark eye stripe. Streamlined shape with elongated snout and extremely long legs. Black and yellow markings on posterior of thigh. Stripes and dark patches on legs. Toes half-webbed.....*L. nasuta*
17. Continuous dark brown stripe on anterior of tibia; red-brown dorsal in breeding season; pale brown to grey in the Dry season.....*L. tornieri*
- No continuous tibial stripe; brown dorsal surface in breeding season.....18
18. Usually indistinct head stripe; warty dorsal skin; some mottling; no thigh markings. Males call from open areas usually on steeply sloping banks.....*L. inermis*
- Distinct head stripe; smooth dorsal skin; occasional mottling; back and yellow markings on posterior of thigh; males call from open areas among grass tussocks adjacent to water.....*L. pallida*

6 ACTIVITY PATTERNS AND REPRODUCTIVE BEHAVIOUR

In general the frogs of Magela Creek area exhibit a clear seasonal dichotomy of behaviour. During the Dry season the majority of species are totally inactive, and at least nine species remain beneath the surface of the ground. Some of these are fossorial species, but others simply descend down deep cracks in the hardened mud at the edge of billabongs. Whether a species actively digs or enters an existing crevice, the result is similar and probably equally successful in the short-term.

The date of onset of the Wet season is variable (Table 1). The release of those species that have buried themselves requires sufficient rain to penetrate to the depths at which they occur, and so soften the intervening zone (probably 1-2m) of baked soils. For these species the rainfall has to be fairly substantial, and it is likely that temporary pools for breeding purposes will have formed by the time that the frogs emerge. The non-fossorial species, those that simply seek ground cover to avoid dehydration, are equally dependent upon the formation of the same breeding sites. It follows that although the latter group may have an advantage in commencing their activity at an earlier date, and thus have first access to food sources, they have no advantage in terms of access to breeding resources. In fact our data (Fig. 7) indicate that three of the first four species to breed are fossorial (*Cyclorana australis*, *C. longipes* and *Limnodynastes ornatius*).

Upon the escarpment breeding may be of a more opportunistic nature. Because the rock surfaces are impervious and smooth, even slight falls of rain rapidly fill most depressions used for breeding purposes, and also saturate the cracks down which so many species hide. Thus it is possible for breeding to occur upon the escarpment following even the most localised rainfall in the Dry season.

7 PREDATION STUDIES

As a fundamental step to determine the role of frogs in vertebrate food chains, frogs and tadpoles were fed to various fishes, reptiles and birds. These data were supplemented by literature records and the personal observations of colleagues. The principal objective was to establish whether any of the predators fed selectively, eating some species and not others, or whether they were indiscriminate feeders. The studies tended to support the latter concept (Table 3).

Few specific records are available for birds. Lea & Gray (1935) list unidentified frogs eaten by a variety of water birds and Miller (1979) reports frogs in the stomachs of cormorants. J. McKean (pers. comm.) states that frogs comprise 10-20% of the diet of 13 species of cormorants, darters, herons and egrets listed elsewhere as occurring in the general area of the mining leases and adjacent lands. We have observed kingfishers eating frogs.

Amongst the native mammals *Dasyurus* sp. (little native cat), *Hydromys* sp. (water rat), *Xeromys* sp. (water rat) and *Canis familiaris* (dingo) are all known to eat frogs. However specific identifications of frogs eaten by birds and mammals at the site are not available.

The role of adult frogs in invertebrate food chains is minor. Australian records are summarised by Tyler (1976). Subsequent reports include predation upon frogs by a preying mantid (Ridpath 1977), beetles (Littlejohn & Wainer 1978) and even green ants (Davies, Tyler & Martin 1979). Tadpoles are eaten by numerous invertebrates as well as the vertebrates listed above.

8 EFFECTS OF URANIUM MINING UPON DIVERSITY AND SIZE OF FROG POPULATIONS

With the available data on frog ecology and, in particular, the knowledge of the Dry season refuges and Wet season breeding sites, it has been possible to assess the likely impact of the mining program.

In our earlier studies we set out to discover which species would be suitable for long-term monitoring purposes. We argued that the species with highly specialised niches would be displaced during the construction phase of the mining operation, and several of these species would not reappear there. In contrast, most of the species breeding in static water would increase in numbers during and immediately following the completion of the construction activities. In particular it was considered that the tailings dam and Retention Ponds would provide significant additional breeding sites.

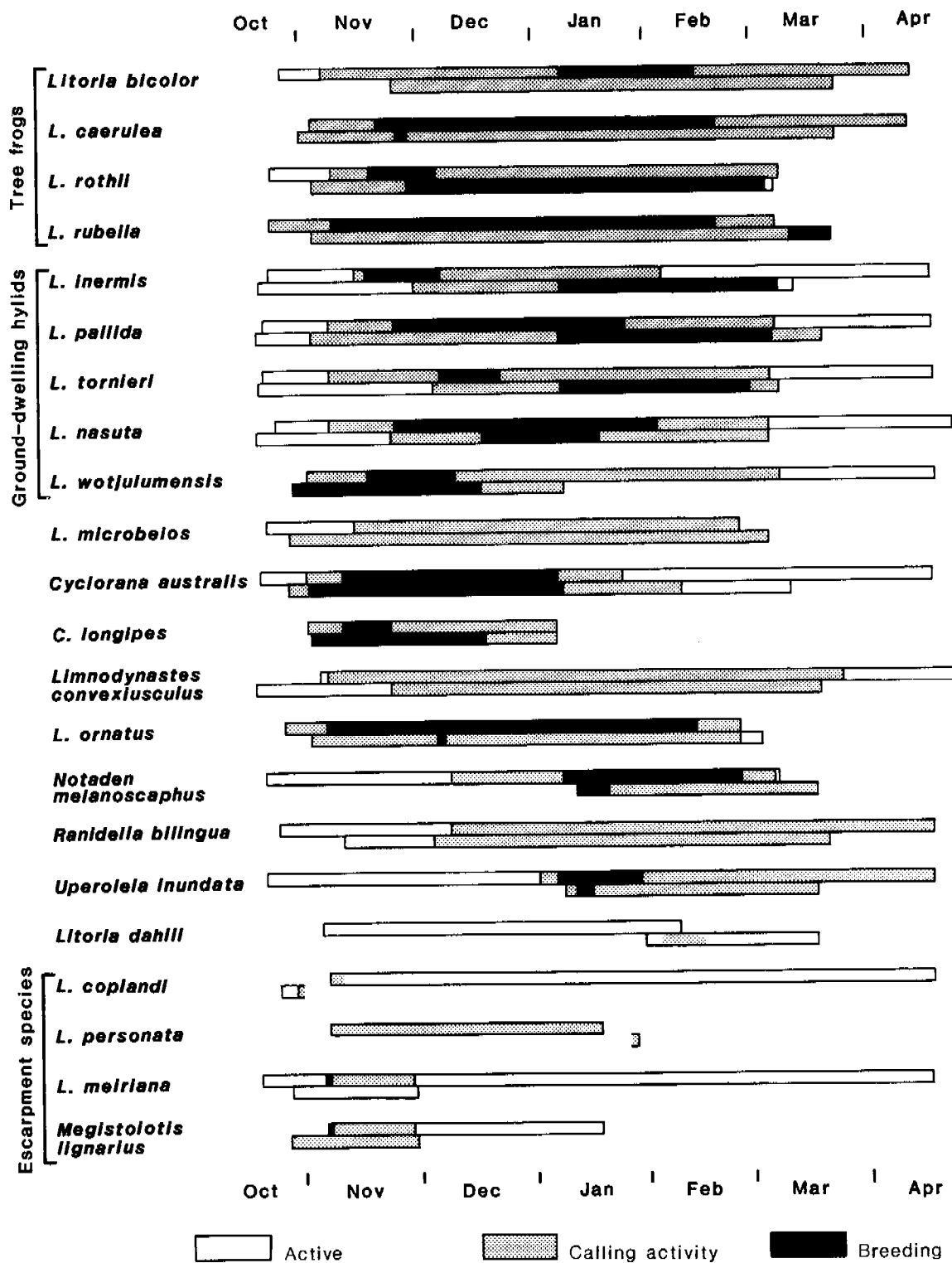


Figure 7. Wet season activity (for each species the upper trace represents data derived from the 1978-79 season and the lower trace data derived from the 1979-80 season)

Table 3. Vertebrate predators of frogs inhabiting the Magela Creek system

Predator	Prey
(A) FISH	
<i>Nematocentris maculata</i> Sunfish	<i>Litoria pallida</i> , <i>L. nasuta</i> , <i>L. tornieri</i> , <i>Uperoleia</i> sp., <i>L. rubella</i>
<i>Leiiotherapon unicolor</i> Spangled grunter	<i>Litoria pallida</i> , <i>L. nasuta</i> , <i>L. tornieri</i> , <i>Uperoleia</i> sp., <i>L. dahlia</i> (tadpoles), <i>Ranidella</i> <i>bilingua</i>
<i>Hexanematichthys leptaspis</i> Fork-tailed catfish	<i>Litoria pallida</i> , <i>L. nasuta</i> , <i>L. tornieri</i> , <i>Uperoleia</i> sp., <i>Cyclorana australis</i> (tadpoles), <i>L. dahlia</i> (tadpoles)
<i>Toxotes chatareus</i> Archerfish	<i>Litoria pallida</i> , <i>L. nasuta</i> , <i>L. tornieri</i> , <i>Uperoleia</i> sp., <i>Cyclorana australis</i> (tadpoles), <i>L. dahlia</i> (tadpoles)
<i>Scleropages jardini</i> Saratoga	<i>Litoria pallida</i> , <i>L. nasuta</i> , <i>L. tornieri</i> , <i>Uperoleia</i> sp.,
<i>Lates calceifer</i> Barramundi	<i>Cyclorana australis</i> (tadpoles)
<i>Neosilurus</i> sp. Fork-tailed catfish	<i>Cyclorana australis</i> (tadpoles), <i>Litoria dahlia</i> (tadpoles)
<i>Hephaestes fuliginosus</i> Black bream	<i>Litoria pallida</i> (adults and tadpoles), <i>L. bicolor</i> , <i>Cyclorana</i> <i>australis</i> , (juveniles and tadpoles) <i>Notaden melanoscaphus</i> , <i>Uperoleia</i> sp., <i>L. nasuta</i> (juveniles and tadpoles), <i>Limnodynastes ornatus</i> (tadpoles), <i>C. longipes</i> (tadpoles), <i>L. dahlia</i> (adult and tadpoles), <i>L. tornieri</i> , <i>L. inermis</i>
<i>Amniataba percoides</i> Banded grunter	<i>Litoria dahlia</i> (tadpoles)
(B) REPTILES	
<i>Amphiesma mairii</i> Freshwater snake	<i>Limnodynastes ornatus</i> ^a <i>Litoria rubella</i> , <i>L. inermis</i> <i>L. bicolor</i> , <i>L. pallida</i> , <i>C. australis</i> (juvenile) <i>L. rothii</i> , <i>L. coplandi</i>
<i>Dendrelaphis punctulatus</i> ^a Green tree snake	<i>Litoria rothii</i>
<i>Varanus timorensis</i> ^a	<i>Litoria rothii</i>

^a Data from Cogger & Lindner (1974)

The eight species likely to recolonise the mining sites are: *Cyclorana australis*, *C. longipes*, *Litoria caerulea*, *L. nasuta*, *L. rothii*, *L. rubella*, *L. wotjulumensis* and *Limnodynastes ornatatus*.

Locally, at least, the population density of each species will increase substantially above pre-mining levels, simply because of the vast increase in water there. The crushed rock walls provide numerous refuges. In fact, in the absence of any preventative plans by Ranger, the existing tailings dam and Retention Ponds constitute a new biological resource to which animals will be attracted from outside the mine lease area. Following breeding some of the frogs will disperse away from the area. Nevertheless the mine site frog population is likely to remain high.

9 REFERENCES

- Barker, J. & Grigg, G.C. (1977). A field guide to Australian frogs. Rigby, Sydney.
- Christian, C.S. & Aldrick, J.M. (1977). A review of the Alligator Rivers Region environmental fact-finding study. AGPS, Canberra.
- Cogger, H.G. (1979). Reptiles and Amphibians of Australia. (Second edition). Reed, Sydney.
- Cogger, H.G. & Lindner, D. (1974). Frogs and reptiles, in H.J. Frith & J.H. Calaby (eds) 'Fauna survey of the Port Essington District, Cobourg Peninsula, Northern Territory of Australia', CSIRO, Melbourne.
- Davies, M., Tyler, M.J. & Martin, A.A. (1979). Frogs preyed on by ants? *Vict. Nat.* 97.
- Gosner, K.L. (1960). A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* 16, 183-90.
- Lea, A.M. & Gray, (1935). Food of Australian birds: an analysis of stomach contents in 3 parts. *Emu* 34, 275-292.
- Littlejohn, M.J. & Wainer, J.W. (1978). Carabid beetle preying on frogs. *Vict. Nat.* 95, 251-2.
- Martin, A.A., Tyler, M.J. & Davies, M. (1979). A new species of *Ranidella* (Anura: Leptodactylidae) from Northwestern Australia. *Copeia* 1980 1, 93-99.
- Miller, B. (1979). Ecology of the Little Black Cormorant, *Phalacrocorax sulcirostris*, and Little Pied Cormorant, *P. melanoleucos*, in Inland New South Wales. I. Food and Feeding Habits. *Aust. Wildl. Res* 6, 79-95.
- Ridpath, M.G. (1977). Predation on frogs and small birds by *Hierodula werneri* (Giglio-Tos) (Mantidae) in tropical Australia. *J. Aust. Ent. Soc.* 16, 153-54.
- Tyler, M.J. (1962). On the preservation of Anuran tadpoles. *Aust. J. Sci.* 5, 222.
- Tyler, M.J. (1976). Frogs. William Collins, Sydney.
- Tyler, M.J., Davies, M. & Martin, A.A. (1978). A new species of hylid frog from the Northern Territory. *Trans. R. Soc. S. Aust.* 102, 151-57.

- Tyler, M.J., Davies, M. & Martin, A.A. (1980). Australian frogs of the leptodactylid genus *Uperoleia*. *Aust. J. Zool.*, *Suppl. Ser.* **79**.
- Tyler, M.J., Martin, A.A. & Davies, M. (1979). Biology and systematics of a new limnodynastine genus (Anura: Leptodactylidae) from north-western Australia. *Aust. J. Zool.* **27**, 135-50.

SUPERVISING SCIENTIST FOR THE ALLIGATOR RIVERS REGION

RESEARCH PUBLICATIONS

Alligator Rivers Region Research Institute Research Report 1983-84

Alligator Rivers Region Research Institute Annual Research Summary 1984-85

Research Reports (RR) and Technical Memoranda (TM)

- | | | | |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| RR 1 | The macroinvertebrates of Magela Creek, Northern Territory.
April 1982 | (pb, mf - 46 pp) | Marchant, R. |
| RR 2 | Water quality characteristics of eight billabongs in the Magela Creek catchment.
December 1982 | (pb, mf - 60 pp) | Hart, B.T. & McGregor, R.J. |
| RR 3 | A limnological survey of the Alligator Rivers Region. I. Diatoms (Bacillariophyceae) of the Region.
August 1983 | (pb, mf - 160 pp) | Thomas, D.P. |
| | A limnological survey of the Alligator Rivers Region. II. Freshwater algae, exclusive of diatoms.
1986 | (pb - 176 pp) | Ling, H.U. & Tyler, P.A. |
| RR 4 | Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Volume 1. Outline of the study, summary, conclusions and recommendations.
1986 | (pb - 63 pp) | Bishop, K.A., Allen, S.A., Pollard, D.A. & Cook, M.G. |
| TM 1 | Transport of trace metals in the Magela Creek system, Northern Territory. I. Concentrations and loads of iron, manganese, cadmium, copper, lead and zinc during flood periods in the 1978-1979 Wet season.
December 1981 | (pb - 27 pp) | Hart, B.T., Davies, S.H.R. & Thomas, P.A. |
| TM 2 | Transport of trace metals in the Magela Creek system, Northern Territory. II. Trace metals in the Magela Creek billabongs at the end of the 1978 Dry season.
December 1981 | (pb - 23 pp) | Davies, S.H.R. & Hart, B.T. |
| TM 3 | Transport of trace metals in the Magela Creek system, Northern Territory. III. Billabong sediments.
December 1981 | (pb - 24 pp) | Thomas, P.A., Davies, S.H.R. & Hart, B.T. |
| TM 4 | The foraging behaviour of herons and egrets on the Magela Creek flood plain, Northern Territory.
March 1982 | (pb, mf - 20 pp) | Recher, H.F. & Holmes, R.T. |
| TM 5 | Flocculation of retention pond water.
May 1982 | (pb, mf - 8 pp) | Hart, B.T. & McGregor, R.J. |
| TM 6 | Dietary pathways through lizards of the Alligator Rivers Region Northern Territory.
July 1984 | (pb, mf - 15 pp) | James, C.D., Morton, S.R., Braithwaite, R.W. & Wombey, J.C. |
| TM 7 | Capacity of waters in the Magela Creek system, Northern Territory, to complex copper and cadmium.
August 1984 | (pb, mf - 42 pp) | Hart, B.T. & Davies, S.H.R. |
| TM 8 | Acute toxicity of copper and zinc to three fish species from the Alligator Rivers Region.
August 1984 | (pb, mf - 31 pp) | Baker, L. & Walden, D. |
| TM 9 | Textural characteristics and heavy metal concentrations in billabong sediments from the Magela Creek system, northern Australia.
October 1984. | (pb, mf - 39 pp) | Thomas, P.A. & Hart, B.T. |
| TM 10 | Oxidation of manganese(II) in Island Billabong water.
October 1984 | (pb, mf - 11 pp) | Hart, B.T. & Jones, M.J. |
| TM 11 | In situ experiments to determine the uptake of copper by the aquatic macrophyte <i>Najas tenuifolia</i> R.Br.
December 1984 | (pb, mf, - 13 pp) | Hart, B.T., Jones, M.J. & Breen, P. |
| TM 12 | Use of plastic enclosures in determining the effects of heavy metals added to Gulungul Billabong.
January 1985 | (pb, mf - 25 pp) | Hart, B.T., Jones, M.J. & Bek, P. |
| TM 13 | Fate of heavy metals in the Magela Creek system, northern Australia. I. Experiments with plastic enclosures placed in Island Billabong during the 1980 Dry Season: heavy metals.
May 1985 | (pb, mf - 46 pp) | Hart, B.T., Jones, M.J. & Bek, P. |

pb = available as paperback; mf = available as microfiche

- | | | |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| TM 14 | Fate of heavy metals in the Magela Creek system, northern Australia. II. Experiments with plastic enclosures placed in Island Billabong during the 1980 Dry season: limnology and phytoplankton.
May 1985 | Hart, B.T., Jones, M.J.,
Bek, P. & Kessell, J.

(pb - 32 pp) |
| TM 15 | Use of fluorometric dye tracing to simulate dispersion of discharge from a mine site. A study of the Magela Creek system, March 1978.
January 1986 | Smith, D.L., Young P.C. &
Goldberg R.J.

(pb - 51 pp) |
| TM 16 | Diets and abundances of aquatic and semi-aquatic reptiles in the Alligator Rivers Region. July 1986 | Shine, R.

(pb - 57 pp) |
| TM 17 | Plants of the Alligator Rivers Region, Northern Territory.
August 1986 | Cowie, I.E. &
Finlayson, C.M.

(pb - 54 pp) |
| TM 18 | The taxonomy and seasonal population dynamics of some Magela Creek flood plain microcrustaceans (Cladocera and Copepoda)
September 1986 | Julli, M.E.

(pb - 74 pp) |