FROGS AS PREDATORS OF ORGANISMS OF AQUATIC ORIGIN IN THE MAGELA CREEK SYSTEM, NORTHERN TERRITORY.

by

Michael Cappo B. Sc. (Hons)

A thesis submitted for the degree of
Master of Science
in the Department of Zoology,
University of Adelaide.
1986.

DECLARATION

I certify that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text.

Michael Cappo.

ACKNOWLEDGEMENTS

The preparation of this thesis has occurred in diverse situations, from the floodplains of the Magela Creek. system to the decks of fishing boats. Along the way I have greatly enjoyed the co-operation, encouragement and company of my peers, fellow students and employers. Here I wish to acknowledge the contribution of some small number of them.

To my supervisor, Mike Tyler, I am grateful for guidance, encouragement and sound advice. On occasion he was joined in this role of mentor by Steven Morton (Office of the Supervising Scientist), Ian Sommerville and Alan Butler (University of Adelaide).

For the collation and processing of my results on electronic data bases I relied heavily on the expertise and patience of Phil Leppard.

During the field component of my study I was ably assisted by the staff, and use of facilities, at the Alligator Rivers Region Research Institute of the Office of the Supervising Scientist. The project was supported, in part, by a grant from this body.

Laboratory work was carried out at the University of Adelaide.

Ken Marshall and David Williams, the laboratory managers at each institution, provided prompt and valuable support whilst Ruth Evans prepared the illustrations and Judy Semets typed the manuscript.

Finally, I am indebted to my fellow students for discussion and encouragement, in particular, Janet Brooks, Helen Chernoff, Graeme Crook, Andy Davis, Chris Humphrey, Lesley Hurley and Mike Thompson.

To my parents,

Margaret and Jack Cappo,

who encouraged an urchin's obsession with nature.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF APPENDICES

SUMMARY

The patterns of distribution and diets of the anuran fauna of the Magela Creek system of the Northern Territory have been examined. Frogs may be potentially important in the transfer of contaminants away from aquatic ecosystems to terrestrial ecosystems through food webs by virtue of their role as prey and predator, their life histories and their colonisation of local mining sites.

The aim of this study was to predict which species of frogs are most important in this transfer through ingestion of prey with wholly or partially aquatic life histories. The 16 study species comprised six genera. Seven faunal groupings were recognised: aquatic frogs (*Litoria dahlii*); arboreal frogs (*L. rothii*, *L. bicolor*, *L. rubella*); ground hylids (sensu Moore, 1961) (*L. pallida*, *L. inermis*, *L. nasuta*, *L. tornieri*, *L. wotjulumensis*); wide-mouthed burrowing frogs (*Cyclorana australis*, *C. longipes*, *Limnodynastes ornatus*, *L. convexiusculus*); narrow-mouthed burrowing frogs (*Notaden melanoscaphus*); toadlets (*Uperoleia inundata*); and froglets (*Ranidella bilingua*).

The patterns of spatial distribution of this fauna were surveyed to determine which species forage in aquatic macrohabitats, these species being considered most likely to encounter prey of aquatic origin. Stomach contents were classified to the lowest level necessary to determine the nature of their origin and quantified to compare the relative occurrence of prey of aquatic origin.

Macrohabitats in close vicinity to waterbodies were found to be important as foraging areas for only the aquatic frogs *Litoria dahlii*, the arboreal frogs *L. rothii* and *L. bicolor*, the ground hylids and froglets. However, all species may encounter prey of aquatic origin during at least two stages of their post-metamorphic ontogeny, as juvenile frogs leaving the larval habitat and as adults visiting waterbodies for breeding purposes.

Biases in sampling techniques enforced inclusion in stomach content analyses of species which forage in terrestrial macrohabitats. The occurrence of prey of aquatic origin was not significant in the stomachs of these frogs. An index of food consumption (stomach distention) was significantly influenced by breeding activity of frogs collected at waterbodies and it is proposed that breeding activities are placed at a premium over foraging activities by adults at breeding sites. Juveniles of most species were collected rarely at waterbodies.

The frequency of occurrence of aquatic prey orders in stomachs containing food was low; less than 12% for 12 species, and less than 50% for aquatic and arboreal species examined in stomach content analyses. It is concluded that the aquatic frog, *Litoria dahlii*, ingests the greatest amounts of prey of aquatic origin in terms of frequency of occurrence, number of items and biovolume. Larval and adult forms of the Odonata, Zygoptera, Trichoptera, and aquatic Coleoptera and Hemiptera, were common in stomachs of this species, which forages within waterbodies and their littoral zones. The arboreal species, *Litoria rothii* and *L. bicolor*, consumed alate prey predominately, and are considered of secondary importance in predation upon organisms with wholly or partially aquatic life histories.

The levels of consumption of these prey types by Litoria dahlii were shown to vary widely with seasonal, micro-temporal and spatial factors in the Magela Creek system.

1.1 INTRODUCTION.

The Magela Creek system drains a large catchment on the western border of the Arnhem Land plateau and supports a diverse and abundant flora and fauna. Of major significance to any study of the area is the fact that a uranium mine, processing plant and mining settlement are located at Jabiru in its watershed.

Activities associated with the extraction and processing of uranium ore, and construction of a mining township, produce pollutants including heavy metals, sources of ionising radiation, herbicides and pesticides (Jeffree and Williams, 1980, Tyler and Crook, 1980). The bioaccumulation of such materials in aquatic organisms can occur when the materials are directed selectively to specific cells which take in more than they release. Similarly, trophic accumulation in aquatic ecosystems can occur as each step of a typical food chain may increase tissue concentrations of these materials several orders of magnitude above that of preceding lower levels.

Bioaccumulated materials may leave aquatic ecosystems through food chains. Firstly, terrestrial animals may directly consume aquatic flora and fauna as food. Secondly, arthropods and frogs may disperse from aquatic larval habitats upon metamorphosis into adult form, and subsequently be consumed by terrestrial predators.

Tyler and Crook (1980) surveyed the distribution, reproductive biology and natural levels of skeletal abnormalities of the poorly known frog fauna in the Magela Creek system. Their studies indicated that frogs were likely to persist in or recolonise the mine sites at Jabiru, and were seasonally so abundant that they constituted a significant food source for other vertebrates in the area. Therefore, frogs may be particularly important in the transfer of material away from aquatic ecosystems to terrestrial ecosystems as both prey and predator.

The major objective of my study is to predict which of 16 species of frogs are most important in this transfer of material through ingestion of prey with wholly or partially aquatic life histories.

This objective has been addressed in two main ways. Firstly, the spatial and temporal distributions of the frog fauna were studied to determine which species forage in, or near, natural and artificial water bodies. Secondly, stomach content analyses of species collected from major natural and artificial habitats in the Magela Creek system were used to represent the ingestion of prey of aquatic origin.

A concomitant aim of my study was to supply, to the Office of the Supervising Scientist for the Alligator Rivers region, baseline quantitative data on patterns of frog abundance and diet. This statutory office has a mandate to develop, co-ordinate and undertake programs of research in relation to the effects of uranium mining operations on the environment of the region. Priorities in ecological research carried out by the Office have been given to determining the major pathways of potential contamination and to the selection of biological monitoring points along these pathways. My study directly complements other studies on the trophic relationships of birds, reptiles, mammals and fish. To permit the Office to model energy flows through the anuran link in food chains, I sought to quantify stomach contents in terms of frequency of occurrence, number of individuals and volume occupied by prey taxa in a sample.

Fundamental to my discussion of the use of lists of stomach contents is a review of the literature on the food and feeding habit of adult Anura.

1.2 LITERATURE REVIEW - THE FOOD AND FEEDING HABITS OF ADULT ANURA.

There is a paucity of information on the food and feeding habits of Australian anurans, and no studies have been published on the species included in the present study. Consequently, the few Australian investigations have been carried out simply to describe the stomach contents of a range of species, without attempting to examine the mechanics behind observed intraspecific and interspecific differences (e.g. Lee, 1967, Pengilley, 1971). The species examined and numbers involved are presented as Appendix (1.1). Only a single study has compared the availability of arthropod prey against stomach contents to establish the existence of any resource partitioning between species with respect to food (MacNally, 1983).

Elsewhere, the abundance of frogs and the nature of their feeding process have resulted in a proliferation of literature on their prey and feeding habits. From a survey of papers on the food and feeding habits of anurans I established that frogs which live in close association with waterbodies ingest large amounts of prey of aquatic origin. Examples of the studies documenting this phenomenon are given in Table (1.1). Representatives of the Ranidae figure prominently, partly because of their world-wide distribution and partly because of a lack of studies of other species occupying similar niches in tropical and subtropical areas. Few studies have analysed anuran stomach contents with the specific aim of determining the aquatic component of diet. Exceptions are Stewart and Sandison (1972), Johnson and Christiansen (1976), and Corse and Metter (1980).

In this review of the literature I do not dwell on the wide range of prey items recorded from frog stomachs. Rather, I document the evolution of a presistent paradigm of anuran foraging, discuss the discriminatory powers of the anuran in prey selection, and outline a new holistic view of ecological, behavioural and physiological correlates to anuran foraging mode. Finally, the factors influencing the accuracy of lists of stomach contents in representing diet are reviewed.

Detailed documention of the prey of a diverse range of anuran families began to appear in the late nineteenth century (e.g. Kirkland, 1897), as biologists took advantage of improved microscopes and an expansion in the classifica-

AUTHOR	SPECIES	FAMILY
Hamilton (1948)	*Rana clamitans*	Ranidae
Cohen and Howard (1958)	*Rana catesbeiana*	"
Tyler (1958)	*Rana esculenta*	"
Turner (1959)	*Rana pretiosa pretiosa*	"
Berry (1966)	*Amolops larutenis*	"
Jenssen and Klimstra (1966)	*Rana clamitans*	"
Hedeen (1971)	*Rana septentrionalis*	"
	Rana pipiens	"
Stewart and Sandison (1972)	*Rana septentrionalis*	"
	Rana clamitans	"
	Rana catesbeiana	"
Bruggers (1973)	*Rana catesbeiana*	"
Blackith and Speight (1974)	*Rana temporaria*	"
Durant and Dole (1974)	*Atelopus oxyrhynchus*	Atelopodidae
Elliott and Karunakaran (1974)	*Rana cancrivora*	Ranidae
Johnson and Christiansen (1976)	*Acris crepitans*	Hylidae
Kramek (1976)	*Rana septentrionalis*	Ranidae
Hulse (1978)	*Lepidobatrachus llanensis*	Leptodactylidae
Corse and Metter (1980)	*Rana catesbeiana*	Ranidae

Table (1.1); Published accounts of ingestion of prey of aquatic origin by frogs.

tion of arthropods. Studies of anuran food were carried out to evaluate the role of anurans as predators on specific prey such as pest insects, to examine intra-specific variation in feeding habits and to investigate patterns of resource partitioning within anuran communities. Examples of these three types of studies, and the species investigated, are presented in Table (1.2).

1.2.1 THE APPEARANCE OF A PERSISTENT PARADIGM.

The ease of studying anuran diets afforded biologists the opportunity to speculate upon why certain organisms were present or absent in stomach contents. From early in this century (Cott, 1932) until relatively recently (Greding and Hellebuyck, 1980) even the briefest summaries

Table (1.2); Examples of three types of studies of anuran food and feeding habits.

1. A SEARCH FOR SPECIFIC PREY TYPES IN STOMACH CONTENTS.	
Perez (1951)	Rana catesbeiana
Hamilton (1954)	Bufo spp.
Hinckley (1962)	Bufo marinus
Bailey (1976)	Bufo marinus
Corse and Metter (1980)	Rana catesbeiana
2. THE DOCUMENTATION OF INTRASPECIFIC VARIATION IN STOMACH CONTENTS.	
Tyler (1958)	Rana esculenta
Berry (1966)	Amolops larutensis
Houston (1973)	Rana temporaria
Labanick (1976)	Acris crepitans
3. AN EXAMINATION OF RESOURCE PARTITIONING BETWEEN SPECIES.	
Berry (1965)	Rana sp., Rhacophorus sp., Leptobatrachium sp., Microhyla spp.
Inger and Greenberg (1974)	Rana sp.
Toft (1981)	Dendrobatidae, Bufonidae, Leptodactylidae
MacNally (1983)	Ranidella signifera, R. parinsignifera
Toft (1985)	Review Paper

of anuran stomach contents were accompanied by speculation upon the role of prey choice in the anuran feeding response. Some of these studies are summarised in Table (1.3).

Most authors considered that ranids, hylids and bufonids are indiscriminate, opportunistic predators. In general terms, the anuran was considered to be a visual carnivore whose diet is governed by prey abundance, habitat utilisation, predator agility and foraging period rather than predator choice (e.g. Labanick, 1976). It was presumed that the existence of any prey discrimination is based on prey movement and size alone (e.g. Clarke, 1974); although in most cases the range of "acceptable" prey is

Table (1.3); Speculation upon the role of prey choice from stomach content analyses of anurans.

AUTHORS	SPECIES	ESTIMATION OF PREY AVAILABILITY	ROLE OF PREY CHOICE
Berry (1970)	Bufo asper	Qualitative reference to some taxa.	"Feeding depends on the abundance and availability of prey taxa although selection for prey of certain size exists".
Bruggers (1973)	Rana catesbeiana	Qualitative reference to some taxa.	"An opportunistic carnivore - prey utilization seeming to parallel prey availability".
Berry (1966)	Amolops larutensis	Qualitative survey of abundance of some prey taxa.	"Prey consumed is governed largely by its availability although a preference exists for prey within a certain size range".
Brown (1974)	Hyla cinerea, Bufo woodhousei, Gastrophryne carolinensis	No data on prey abundance presented.	"Anurans appear to have a degree of food selection based upon the species and its habits".
Bailey (1976)	Bufo marinus	Qualitative reference made for some taxa.	"The diversity of taxa in the gut contents is consistent with the hypothesis that toads of the genus Bufo are indiscriminate feeders".

Bush and Menhinnick(1962)	*Bufo woodhousei fowleri*	No data on prey abundance presented.	"Interspecific differences in diet are dependent on the seasonal availability of insects, relative abundance of prey items and the kinds of habitats from which the toads were collected".
Blackith and Speight (1974)	*Rana temporaria*	No data on prey abundance presented.	"Unselective and sedentary in its feeding habits, selection by frogs for prey of a certain size range.
Berry and Bullock (1962)	*Bufo melanostictus*	No data on prey abundance presented.	"Apparently entirely unselective, including noxious forms such as centipedes and scorpions".
Berry (1965)	*Rana* sp., *Rhacophorus* sp., *Leptobrachium* sp., *Microhyla* spp.	No data on prey abundance presented.	"Wide variation exists in the degree of selection of prey by Singapore anurans and diet depends on the prey available in a particular habitat, on the size of prey animals, on frog size and especially mouth gape".
Clarke (1974)	*Bufo* spp.	No data on prey abundance presented.	"The range of gut contents of toads of the genus *Bufo* reflects availability of food of appropriate size".
Christian (1982)	*Pseudacris triseriata*	Quantitative survey of abundance of prey taxa.	"The selective foraging strategy of *P. triseriata* is based on prey size and varies with predator size".

governed by upper and lower physical limits imposed by mouth gape and visibility of small prey (Berry and Bullock, 1962).

Blackith and Speight (1974) liken the feeding process of Rana temporaria to the "action of an un-baited pit fall trap"; while Zug and Zug (1979) conclude that Bufo marinus "will eat almost any animate object they can catch", both studies emphasising the importance of prey movement as an ingestion stimulus. For many years this popular view of anuran feeding behaviour remained simplistic, inaccurate and unproductive, being based largely upon speculation and, until recently, remaining untested.

This situation arose from a combination of three main factors. In comparison with the extensive body of literature on items ingested by anurans, there is a relative lack of data on the cues and motivational states involved in eliciting a feeding response. The theory on anuran feeding behaviour outstripped the empirical data on how anurans feed. The feeding response itself has been poorly documented for the majority of anurans. Finally, there has been widespread misuse of lists of stomach contents alone to speculate upon the roles of prey discrimination and predator choice without considering diet in relation to availability of prey in the field (Ingle, 1971, Smith, 1981, Freed, 1982).

The lack of obvious morphological correlates to feeding in the Anura also may have contributed to the popular belief that, in general, they are not specialist feeders

(Emerson, 1976, 1985, Brown, 1974, Drewes and Roth, 1981).

1.2.2 THE ANURAN FEEDING RESPONSE - WHAT CUES ARE USED IN FEEDING?

Central to the persistent view that anurans are indiscriminate feeders was the belief that the cues utilised during feeding are simple, visual stimuli.

The basic feeding response of most phaneroglossan anurans consists of a sequence of three major components involving orientation toward a prey stimulus, approach toward the prospective prey item (if the item is outside of striking range) and prey capture. Capture of the item involves a lunge with open mouth and use of the adhesive tongue to a greater or lesser extent (Fite, 1973, Heatwole and Heatwole, 1968, Kramek, 1976, Regal and Gans, 1976).

Movement of objects within a range of acceptable sizes has been supposed widely to be the primary releaser of such behaviour (see Table (1.3) for examples). However, experimental work by Ingle (1971) and Freed (1980, 1982) has shown that anurans respond differently to different types of prey movement. Anurans can discriminate between prey types on the basis of prey activity patterns, and this discrimination can be quite subtle.

In behavioural studies, Ingle and McKinley (1978) showed that the configuration of a moving stimulus is an important prey selection parameter. Horizontal length adds to the "quality" of a feeding stimulus, and worm-like forms prove better feeding stimuli for toads than similarly moving square objects. These experimental stimulus movements represent crude simplifications when compared with the repertoire of activity patterns of natural prey.

Subsequently, Freed (1980, 1982) combined studies on treefrog feeding ecology with laboratory preference experiments utilising natural prey items to determine the mechanisms whereby treefrogs select food items. He showed that Hyla cinerea consistently is capable of selecting specific prey. Although prey length is an important cue utilised by the frog, it can be overshadowed by the cues provided by prey activity. H. cinerea differentially selects prey in relation to the proportion of time a prey species remains active, as well as the types of activity most often displayed. Flies (Musca sp.), which devoted the greatest proportion of their time to the activity patterns of greatest stimulus value (crawling, flying), were consumed much more frequently than mosquitoes, which remained motionless for over 60% of the observed time.

An increasing body of information suggests that olfactory and auditory stimuli may also play a role in the anuran feeding response. It has been demonstrated that some anurans are attracted to prey odour and exhibit a feeding response toward prey odour alone, in the absence of any other visual or tactile stimuli. Bufo boreas and Rana pipiens responded only towards odour of prey taxa on which they had fed previously, and were able to discriminate between these odours; blinded R. pipiens proved adept at locating and capturing prey by using olfaction alone (Shinn and Dole, 1978, 1979, Dole, Rose and Tachiki, 1981).

Rossi (1983) suggested that the extrusion of the tongue by toads excited by prey odour may have had a sensory role as terrestrial anurans are known to possess well-developed Jacobsen's organs.

In nature, the odour of prey items may provide information in addition to the cues supplied by visual stimuli. It is known that anurans may modify their criterion for optimal size of prey, when excited by the odour of familiar prey items, and snap at stationary objects or very large objects that normally they would avoid (Ingle, 1971).

Learning is involved in the use of olfactory cues but there may also be some innate response to chemical compounds of arthropods and organic materials. This may explain the otherwise puzzling ingestion of vegetable matter, carrion, faeces and canned dog food by members of some populations of Bufo marinus and other anura (Berry and Bullock, 1962, Alexander, 1965, Zug, Lindgren and Pippet, 1975, Zug and Zug, 1979).

Despite the sensitive phonotactic responses exhibited by anurans in breeding aggregations (Robertson, 1982), there has been little speculation upon the possibility of the existence of a role for auditory cues in the anuran feeding response.

Zug and Zug (1979) suggested that Bufo marinus recognises the sounds made by prey. They found that toads were attracted to the sounds made by ants repairing a dissected nest, and subsequently fed on the ants. Similarly, toads were observed occasionally to locate breeding aggregations of *Physalaemus pustulosus* for feeding purposes by following the calls of males in the choruses (Jaeger, 1976, Zug and Zug, 1979).

Observation on the use of auditory cues in location of prey are not restricted to *B. marinus*. Smith (1977) found that individuals of *Rana catesbeiana* were attracted to, and greatly excited by, the distress calls of *R. pipiens* and juvenile conspecifics. The frogs were also attracted by tape recordings and human imitations of the calls from distances of over 12 metres.

It is clear that sounds and odours produced by prey taxa largely have been overlooked in the development of a model for the anuran feeding response. The ability to use olfactory and auditory cues alone, or combined with visual cues, could be of considerable use to anurans feeding in darkness. However, the cues utilised by anurans which feed underground or underwater are unknown (Calaby, 1960, Avila and Frye, 1978, Brown, 1978).

1.2.3 THE ROLE OF PREY SELECTION - AN HOLISTIC MODEL OF ANURAN FORAGING.

Many studies of anuran feeding habits have documented "resource partitioning" (Schoener, 1974) of food between syntopic anurans (reviewed by Toft, 1985), or attempted to determine the role of prey choice (see Table (1.3) for examples) from lists of stomach contents alone.

Without comparing stomach contents with the availability of prey taxa in the field, it is impossible to determine the existence of prey selection, and thus to investigate the causal mechanisms behind interspecific partitioning of food. Widespread speculation upon the role of prey choice from lists of stomach contents has been a major factor in persistence of the simplistic view of anuran feeding behaviour outlined earlier.

Studies by Labanick (1976), Toft (1980a and b, 1981), Christian (1982), Freed (1982) and McNally (1983) have compared some quantification of stomach contents with a measure of prey abundance in the field to derive an "electivity index" (Ivlev, 1961) to represent predator choice for different prey taxa. In each case, abundance was used directly to estimate availability of prey taxa to the predator. However, Freed (1982) has shown that the "functional density" (Werner and Hall, 1974), or actual availability of a prey taxon to the anuran, is not related directly to the field abundance of that taxon. Functional density will vary between taxa, depending upon the specific activity patterns utilised as cues for prey capture by the anuran. Freed found also that, depending on the number of prey families included in the statistical analysis of electivity indices, it is possible to conclude that either: Hyla cinerea is : (1) a non-selective feeder, or (2) a discriminating forager.

Despite these basic problems in analysis of prey preference, there is firm evidence that anurans preferentially select prey taxa in natural situations (Toft, 1980a, 1980b, 1981, Freed, 1982). More importantly, recent studies of ecological, physiological and behavioural correlates of foraging modes of anurans, and of other ectothermal vertebrates, have revealed a complex suite of interrelated characters leading to a new, holistic view of anuran foraging (Taigen and Pough, 1983, Toft, 1985).

Studies on feeding habits of diurnal litter inhabiting anurans in Amazonian Peru and Panama (Toft, 1980 a, 1981) showed that species of litter frogs form a continuum from species that specialise in feeding on ants and mites to species that avoid these items. Modes of foraging, anti-predator defence and taxa of litter frogs are correlated with position along the continuum.

Toft recognised three feeding guilds (sensu Root, 1967) common to the same ecological association of anurans composed from two different faunas in different environments. Two specialist guilds are present: dendrobatids and bufonids that eat hard-bodied, slow-moving arthropods such as ants and mites (ant specialists); and, leptodactylids that eat soft-bodied, mobile arthropods, primarily orthopterans and large spiders. Generalist species are recognised also for Peru: Dendrobates femoralis which takes prey in proportions not significantly different from those in the leaf litter, and for Panama; Colostethus spp. which eat ants and soft-bodied arthropods.

Ant specialists search for prey, foraging constanly over wide areas and eating many small prey per unit time. Prey are captured with little effort by leaning forward and snapping up the item with the tongue. In contrast, non-ant specialists sit and wait for prey whilst hiding beneath leaf litter. Typically they wait for prey to move by on the surface of adjacent leaves and leap or lunge at the item with open mouth. Only a few large prey are taken per day, and ants are eaten rarely. Ant specialists take smaller prey for a given mouth width than do non-ant specialists, and generalists are intermediate (Toft, 1980 a).

The anti-predator defences employed within the three guilds also are correlated with foraging mode. Actively foraging ant specialists are more visible to predators, and nearly all are poisonous, possessing skin toxins (*Dendrobates*, *Phyllobates*) or poisons in parotoid glands (bufonids). Both generalist dendrobatids and leptodactylid members of the "non-ant specialist" guild are not known to be poisonous, and rely instead on cryptic colouration and motionless concealment beneath leaf litter to hide them from predators.

Toft (1980a, 1981) and Emerson (1976) predicted that the different foraging modes of specialist anuran predators would entail differing physiological costs. They considered that sit-and-wait foragers have lower energetic costs in searching for prey, which come by them, and lesser physiological costs in digesting large, soft-bodied prey. Conversely, higher energetic costs are entailed in capturing and handling large, active prey which must be subdued with mouth and forelimbs. Ant or termite specialists which forage widely may be advantaged by an increased probability of encountering individuals of dispersed but abundant prey, or of finding a concentration of prey, such as an ant nest. The major direct cost of active foraging is the energetic expense of extensive movement. A smaller cost of capture per item is incurred; but active foragers must capture many more of the small, chitinous prey-which are presumably more difficult to digest. Risks of predation are higher for active foragers, and the production and deposition of toxins presumably involve energy expenditure.

These generalisations lead to the prediction that metabolic capacities also will be correlated with feeding habits. Taigen and Pough (1983) tested this hypothesis by analysing interspecific differences in oxygen consumption and capacity for anaerobic metabolism. The species studied included taxa in Toft's (1980a, 1981) feeding guilds. In accordance with earlier predictions, they found that predation on ants and termites is correlated with high aerobic capacity, low anaerobic capacity and high resting metabolism. Conversely, specialisation on larger, more mobile prey such as orthopterans and coleopterans is associated with low aerobic capacity, high anaerobic capacity and low resting metabolism.

Sit-and-wait foragers such as the leptodactylids are capable of bursts of muscular activity, such as leaping rapidly away from predators (Emerson, 1976) or seizing and subduing prey, but they tire easily. Active foragers like the bufonids are less capable of these rapid movements but can sustain activity for long periods.

The current paradigm gives an holistic view of the ecological, behavioural and physiological factors involved in anuran foraging, through a multi-disciplinary approach. Two extremes are presented: active searchers and sit-and-wait foragers; but it is certain that the lack of intermediates or other specialisations indicates only a lack of quantitative data. To date, the model has been applied only to communities of diurnal litter anurans and awaits further testing in other communities. Similar correlates to anuran foraging are certain to be found elsewhere. It is also possible that foraging mode and its correlates may be exclusive to different taxonomic groups on a general basis. For example, Clarke (1974) reviewed literature on feeding in bufonids from a wide range of habitats and concluded that, as a group, they could be considered to be ant specialists.

From the literature reviewed here, it is clear that anurans should be considered as efficient predators capable of subtle discrimination and selection of prey types. Their feeding response is governed by complex interrelated factors, and consequently stomach content analyses should be used with restraint in studying feeding habits.

1.2.4 FACTORS INFLUENCING THE ACCURACY OF LISTS OF STOMACH CONTENTS IN REPRESENTING ANURAN DIET.

Lists of stomach contents present a picture of diet which is stationary in both space and time and refers, in real terms, only to those animals included in the sample. However, prey abundance is known to vary considerably with spatial and temporal factors,and anuran feeding habits vary with developmental stage.

The premium placed on foraging activities during the anuran life history,and the size of prey ingested, vary with post-metamorphic ontogeny. During juvenile phases the range of available prey will depend on predator size;and in some studies it has been concluded that juveniles occupy food niches differing from adults (Clarke, 1974, Christian, 1982). During juvenile phases,foraging is placed at a high premium to maximise growth; but later food consumption is closely related to reproductive cycles and cycles of fat body production. During the breeding season,males place a premium on attracting mates and maintaining calling sites over foraging activities. Food consumption is lowered until late in the breeding season when energy reserves are most depleted (Jenssen and Klimstra, 1966, Christian, 1982, MacNally, 1983). As eggs enlarge in the female, food consumption rises and fat bodies are depleted, until the end of the breeding season when energy demands decrease and food intake is directed toward fat deposition (Jenssen and Klimstra, 1966, Johnson and Christiansen, 1976). Males and females paired in amplexus have been reported to contain less food than unpaired frogs (Durant and Dole, 1974).

The nature and amount of stomach contents have been shown to vary intraspecifically with time and site of collection of samples on both fine and coarse grain scales.

The foraging microhabitats occupied by juveniles and calling males often differ from those occupied by other developmental stages (Martof, 1953). In the case of juveniles, such spatial separation may be maintained to avoid predation by larger, cannibalistic conspecifics (Tyler, 1958). On a wider scale, the stomach contents of species assumed to be less selective in their foraging, such as ranids, have been shown to vary markedly between sites within the species' range (Hamilton, 1948, Corse and Metter, 1980).

Seasonal and daily variation in stomach contents have been documented mainly for species inhabiting microhabitats closely associated with waterbodies; such as the ranids. The availability of insect prey of aquatic origin changes seasonally with water level,and in the shorter term,during vast "hatches" characterising the life histories of these insects (Hamilton, 1948, Jenssen and Klimstra, 1966, Hedeen, 1972, Houston, 1973, Corse and Metter, 1980). Frogs often fill their stomachs with spent naiads during the emergence cycles of these insects, which are not recorded again from stomach contents in time series (Turner, 1959). Stomach contents vary also with the daily activity patterns of predator and prey. For example, it has been demonstrated that aquatic insects and freshwater crayfish are ingested more frequently at night by Rana clamitans, which feeds both diurnally and nocturnally (Hamilton, 1948).

The level of satiation of the anuran has been shown to modify its response to potential prey items in both laboratory and field observations (Heatwole and Heatwole, 1968, Kramek, 1976). As satiation is approached, there is a lowering of the upper size-threshold of acceptable prey. The level of satiation may govern the identity and number of prey selected and consequently recorded in stomach contents.

As the feeding habits of anurans are dynamic, and governed by these inter-related factors, stationary pictures of diet obtained from stomach content analysis will be biased. Further bias can be introduced by the quantifications used in analysing stomach contents. Rare, large prey will dominate analyses of biomass or biovolume; and, conversely, small, very abundant items will overshadow other items in numerical analyses. Frequency of occurrence of prey items in stomachs gives only an indication of presence or absence, and does not give an index of abundance of prey. Independent of these analyses is the bias introduced by differential rates of digestion of prey items. Large prey with heavily chitinous exoskeletons persist in stomach contents more than small, soft-bodied prey such as mosquitoes. Hence, rapidly digested prey are under-represented in stomach content analyses.

Despite these biases, lists of stomach contents remain useful tools in describing diets of anurans if specific questions are addressed and appropriate quantifications are selected for the questions at hand. The potential for variability must be recognised and accounted for by appropriate sampling of populations.

2. THE STUDY AREA.

2.1.1; GEOGRAPHIC LOCATION.

The study area encompasses the lower catchment and floodplain zones of the Magela Creek system within the area defined by Christian and Aldrick (1977) as the Alligator Rivers Region of the Northern Territory. My studies were concerned mainly with the habitats in and adjacent to the Ranger uranium project area at Jabiru.

Jabiru is located at 12° 40' S; 132° 54' E at an elevation of 25.0 m a.s.l., approximately 250 km East of Darwin. The location of the study area is shown in Figure (2.1).

2.1.2; CLIMATE.

The dominant feature of the climate in the study area is the marked seasonality of rainfall producing distinct, annual wet and dry seasons.

High temperatures are sustained throughout the year, with a mean annual temperature of approximately 27°C and a range between mean monthly temperatures of only 5.6°C. Day length also varies little from a mean minimum of 11.2 hours in June to a mean maximum of 12.7 hours in January (Christian and Aldrick, 1977).

Rainfall is not only markedly seasonal, but its monthly distribution pattern within the wet season also varies


ALLIGATOR RIVERS REGION
Northern Territory
Queensland
Western Australia
South Australia
New South Wales
Victoria
Tas.
130°
132°
134°
136°
12°
14°
DARWIN
Oenpelli
Mudginberri
JABIRU
Nhulunbuy
Adelaide River
ARNHEM LAND
Pine Creek
Katherine

greatly from year to year and, to some extent, between sites.

The wet season varies in length but generally is confined to the period November - March, with January, February and March being the wettest months. Equatorial or monsoonal troughs, and the convection systems associated with them, produce widespread rainfall during the wet season. Localised falls of high intensity and thunderstorms are produced by tropical cyclones and local convection systems.

The monthly rainfall recorded at Jabiru during the period January 1971 to December 1982 is shown in Table (2.1). The total rainfall recorded during the study did not differ markedly from the average annual rainfall (1560 mm) reported by Christian and Aldrick (1977).

Virtually no rain falls during the dry season which is considered to extend from May to September and represents a period of intense annual drought. The average annual evaporation in the region has been estimated at about 2200 mm, rising from approximately 100 mm in February to 260 mm in October, and exceeding the average annual rainfall by some 640 mm. As a result relative and absolute humidities are high during the dry season. Soils dessiccate rapidly in the dry season, and ephemeral vegetation dies off and is burnt in widespread wild fires (Christian and Aldrick, 1977).

2.1.3; <u>THE HYDROLOGICAL REGIME IN THE STUDY AREA</u>.

The Magela Creek system is a northward - flowing tribu-

Table (2.1); Rainfall in millimetres by year and month at Station 014198. Jabiru. (Data from the Bureau of Meteorology, Darwin).

	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
	1971						0	0	1	51	109	169	-	
	1972	193	238	345	11	18	0	0	0	0	2	232	114	1153
	1973	461	117	465	49	7	-	0	0	0	44	332	167	
	1974	468	256	348	73	22	0	0	60	0	77	173	218	1695
	1975	276	433	302	170	*	0	0	*	6	-	113	-	
	1976	476	536	-	-	-	-	-	-	-	-	-	-	
	1977	-	-	-	-	-	-	-	-	-	-	94	414	
	1978	329	429	124	23	10	0	5	0	27	20	204	302	1473
	1979	470	324	154	4	3	0	0	0	0	26	118	139	1238
	1980	506	768	268	64	5	0	0	0	0	25	49	348	2033
STUDY PERIOD	1981	325	386	457	18	16	*	0	3	26	41	227	264	1813
	1982	364	228	288	2	*	0	0	-	-	-	-	-	-
Means and Medians for the period 1971 - 1982 (all available data).														
Mean Rainfall		387	371	306	46	9	*	1	7	7	36	170	237	1577
Median Rainfall		412	355	302	23	7	0	0	0	0	34	146	218	1584

"-" = Missing observation

"*" = Rainfall between 0.1 and 0.4 mm

tary of the East Alligator River and drains an area of 1600 km^2 (Williams, 1979). Its headwaters arise from the Arnhem land plateau and descend through a precipitous escarpment to adjacent lowlands. The major features of the Magela Creek system are shown in Figure (2.2). Flow occurs only in the wet seasons, and consists of a series of flood peaks superimposed on a base flow which begins normally during mid-December and ceases about the end of June (Hart and McGregor, 1980). Rising floodwaters run down the Magela Creek to the floodplain, connecting ponds, swamps and waterholes in the lowlands which are isolated in the dry season. This flow, combined with onshore winds and high tides, causes extensive flooding of the plains, forming a vast sheet of water up to 150 km^2 (Williams, 1979). Poorly drained areas in the lowlands are also inundated by concentrated rainfall and increases in the level of the water table.

These patterns of inundation provide, during the wet seasons, a diverse range of breeding sites and foraging habitats for anurans

2.2.1; ANURAN HABITATS IN THE STUDY AREA.

Tyler and Crook (1980) adopted seven units to describe the habitats utilised by breeding anurans in the Magela Creek system. Habitats on the Arnhem land plateau and the escarpment region were described as "sandstone scrub and woodland in escarpment" and "sandstone rainforest remnants". In the adjoining lowlands "open sclerophyll forest", "inundated grassland", "fringes of billabongs" and

Figure (2.2); Major features of the Magela Creek system.

"floodplains" were recognised as important anuran habitats. "Artificial pools, scrapes and ponds" were also considered to be significant in providing larval habitats for many species.

The present study is restricted to the five natural and artificial units described for the lowland portions of the Magela Creek system. Habitats in these lowlands, on the Magela Creek floodplain and at the Ranger uranium mining project are considered here separately.

2.2.2; LOWLAND HABITATS

This description is essentially brief as a detailed survey of vegetation and soil types and drainage patterns within the study area is provided elsewhere (Chapter 4.1.8).

Material eroded from the escarpment and Arnhem Land plateau has been deposited on the surrounding lowlands forming the present land surface of low, undulating hills and ridges. In general, soils are sandy or loamy and highly susceptible to erosion.

Major assemblages of vegetation in the lowlands include open eucalypt woodland with a variable understorey of shrubs, grasses and sedges interspersed with expanses of perennial and ephemeral grassland. Seasonally inundated areas bordering the Magela Creek channel are characterised by stands of *Melaleuca* spp. and sedge/grass herbfields.

2.2.3; FLOODPLAIN HABITATS

The floodplain of the Magela Creek system consists of poorly drained paperbark swamps, open perennial and annual swamps, lagoons and grass/sedge herbfields (Williams, 1979).

Intense blooms of macrophytes and emergent sedges and grasses occur after inundation of the floodplain. As water levels decline, this vegetation dies and breaks away from the substrata forming dense floating mats. During the dry season these same areas dry to form deeply cracked clay pans and black soil plains.

Perennial lagoons on the floodplain (billabongs), are bordered by clumps of screw palms (*Pandanus aquaticus*) and freshwater mangrove (*Barringtonia acutangula*). Macrophytes, such as the water lily *Nymphaea gigantea*, grow in shallows at the billabong margins.

2.2.4; ARTIFICIAL HABITATS

Feral animals and activities associated with the extraction and processing of uranium ore have altered the landscape markedly in localised areas of the Magela Creek system. These alterations have destroyed some anuran habitats and created others in the form of artificial waterbodies.

The wallows and pug marks of feral water buffalo are widespread on the Magela floodplain and along the creek channel in swampy areas, and provide breeding sites for anurans. The physical effects of mining are localised and more intense.

A plan of the Ranger uranium mining project area at Jabiru is shown in Figure (4.2).

Large amounts of contaminated water are associated with the mining and processing of uranium ore at Jabiru. Run-off and seepage from ore stock piles and waste rock dumps, and water pumped from the mine pits is held in three retention ponds. Water containing wastes and by-products of the uranium milling process is stored in a large tailings dam.

The development of a regional urban centre at Jabiru also has resulted in the formation of artificial habitats for anurans. Gravel scrapes excavated to supply materials for road construction are flooded in the wet season and provide breeding sites for many anurans. Eutrophic ponds at the Jabiru sewerage treatment works afford an ideal habitat for anuran larvae, and provide a perennial habitat for frogs normally associated with waterbodies. New habitats also may have arisen from clearing of land, erection of buildings and siting of vehicle tracks in and around the project area.

3. THE ANURAN FAUNA OF THE MAGELA CREEK SYSTEM.

3.1.1; THE ANURAN FAUNA.

The anuran fauna of the Magela Creek system is notable for both its diversity and abundance. During an extensive survey of the area in 1980, Tyler and Crook found 24 species of frogs representing eight genera and three families. Of these taxa, seven were hitherto undescribed. They found anurans in natural and artificial habitats throughout the floodplains, lowlands and escarpment regions constituting the Magela Creek system, and considered them to be the most abundant form of terrestrial vertebrate present in the area during the wet seasons.

It is worth noting that within Australia as a whole about 180 native species of frogs are currently recognised, comprising 26 genera in the families Hylidae, Leptodactylidae, Microhylidae and Ranidae.

Table (3.1) lists the species comprising the anuran fauna of the Magela Creek system and indicates their distribution and abundance according to Tyler and Crook (1980). Species included in the present study are marked with an asterisk.

The spatial and temporal heterogeneity in precipitation, land forms and floral assemblages characteristic of the area affords a wide variety of anuran habitats, and has resulted in a striking diversity in form and function within the local anuran fauna.

Table (3.1); Distribution and abundance of the frog fauna of the Magela Creek area (after Tyler and Crook, 1980).

0 Absent
1 Rare
2 Common
3 Abundant

	Species	Authority	1	2	3	4	5	6	7
*	Litoria bicolor	(Gray)	0	0	2	0	3	2	0
	L. caerulea	White	2	2	1	1	1	1	0
	L. coplandi	(Tyler)	3	2	0	0	0	0	0
*	L. dahlii	(Boulenger)	0	0	1	0	2	3	1
*	L. inermis	(Peters)	0	0	1	0	2	0	3
*	L. pallida	Davies, Martin & Watson	0	0	3	0	2	1	3
	L.meiriana	(Tyler)	3	3	0	0	0	0	0
	L. microbelos	(Cogger)	0	0	1	0	3	2	1
*	L. nasuta	Tschudi	0	0	3	2	2	0	1
	L. personata	Tyler, Davies & Martin	2	0	0	0	0	0	0
*	L. rothii	(de Vis)	0	0	2	1	2	2	2
*	L. rubella	(Gray)	0	0	2	1	2	2	3
*	L. tornieri	(Nieden)	0	0	3	0	2	1	3
*	L. wotjulumensis	(Copland)	2	2	1	0	0	0	2
*	Cyclorana australis	(Gray)	0	0	2	1	2	2	3
*	C. longipes	Tyler & Martin	0	0	1	0	1	1	3
*	Limnodynastes convexiusculus	(MacLeay)	1	0	2	0	2	3	0
*	L. ornatus	(Gray)	2	0	2	1	0	0	3
	Megistolotis lignarius	Tyler, Martin & Davies	2	2	0	0	0	0	0
*	Notaden melanoscaphus	Hosmer	0	0	3	3	0	0	0
*	Ranidella bilingua	Martin, Tyler & Davies	0	0	3	1	2	2	0
	Uperoleia arenicola	Tyler, Davies & Martin	1	0	0	0	0	0	0
*	Uperoleia inundata	Tyler, Davies & Martin	0	0	3	2	0	0	0
	Sphenophryne robusta	(Fry)	0	2	0	0	2	0	0

1 Escarpment: Sandstone and woodland
2 Escarpment: Rainforest remnants
3 Inundated grassland
4 Open sclerophyll forest
5 Billabong fringes
6 Floodplains
7 Artificial pools, gravel scrapes

* SPECIES INCLUDED IN THE CURRENT STUDY.

Many of the typical morphological features attributed to anurans occupying xeric, mesic, aquatic and arboreal habitats throughout the world are readily recognisable amongst the species living in the Magela Creek area.

Despite these differences, all of the species recorded from the Magela Creek area (with the exception of Sphenophryne robusta) share a common dependence on perennial or ephemeral water bodies for breeding purposes. Breeding activities occur on an opportunistic basis in the wet seasons, depending upon the spatial and temporal variation in rainfall. Larval life histories are short.

During seasonal periods of drought, the frogs avoid desiccation in burrows or by sheltering in the crevices and interstices afforded by rocky outcrops, plant litter, or cracking clay soils.

3.2.1; TARGET SPECIES

The choice of species to be included in the current study involved a number of factors.

Time available for fieldwork was limited to less than 11 months, over two wet seasons. The number and nature of anuran habitats available for study also was limited due to the curtailment of vehicular travel in the region during the wet seasons.

Consequently, species inhabiting remnants of monsoonal rainforest, the Arnhem Land escarpment and other isolated, inaccessible areas were excluded from this study.

Of the species studied, the range of sizes and number of individuals available for research purposes varied according to the natural patterns of distribution and abundance of each species, and my ability to collect them. As a result, examination of rare, flighty or cryptic species was restricted to relatively few individuals, and juvenile and sub-adult material was lacking for the more common species.

After consideration of the above factors, 16 species representing six genera were included in the present study. These species were sub-divided further into seven faunal groupings on the basis of their functional morphology and taxonomic status.

A list of the target species in faunal groups is presented in Table (3.2).

3.2.2; AQUATIC FROGS

Litoria dahlii was the only species included in this faunal group. It is a large frog (up to 80 mm snout to vent length (S.V.L.)) and 45 g weight. It is a powerful swimmer with muscular hind limbs and fully webbed toes. The eyes and nares are situated high atop the flat head; and superficially, L. dahlii bears a resemblance to other species closely associated with water, such as L. raniformis of south eastern Australia.

Table (3.2); Target species in faunal groupings.

FAUNAL GROUP	SPECIES
Aquatic frogs	*Litoria dahlii*
Arboreal frogs	*Litoria rothii* *Litoria bicolor* *Litoria rubella*
Ground hylids (sensu Moore (1961))	*Litoria pallida* *Litoria inermis* *Litoria nasuta* *Litoria tornieri* *Litoria wotjulumensis*
Wide-mouthed, burrowing frogs	*Cyclorana australis* *Cyclorana longipes* *Limnodynastes ornatus* *Limnodynastes convexiusculus*
Narrow-mouthed, burrowing frogs	*Notaden melanoscaphus*
Toadlets	*Uperoleia inundata*
Froglets	*Ranidella bilingua*

Adults and juveniles were observed readily at night and during the day at the margins of billabongs and the floodplain, but seldom were sighted away from water.

3.2.3; ARBOREAL FROGS

The three species comprising this faunal group are proficient climbers possessing expanded digital discs, long slender limbs and large mouths characteristic of most "tree frogs".

Litoria rothii is the largest of these lightly built species, growing to 55 mm S.V.L. in the study area. A frog of this length may weigh as little as 5 g. Litoria rubella and L. bicolor are smaller, growing to 40 mm and 30 mm respectively in snout to vent length. All three species can be observed at night on vegetation near streams and billabongs, and on the walls of human dwellings in the area, where they forage near electric lights.

3.2.4; GROUND HYLIDS

Five species, possessing essentially similar morphological features, were characterised as ground hylids in the sense of Moore (1961). All are ground-dwellers with slender bodies, long, triangular snouts and long, muscular hind limbs. They are all strong leapers, capable of several long, high jumps in rapid succession.

Litoria wotjulumensis and L. nasuta are the two largest species, growing to 75 mm and 55 mm respectively in snout to vent length. Both are capable of executing leaps far exceeding one metre. Although L. wotjulumensis has extensively webbed toes, and can swim powerfully, it was rarely found in water.

The other three species in this faunal group are so similar that close examination is required to separate them. Litoria tornieri can be distinguished on the basis of a well defined dark line along the anterior margin of the tibia and fibia, L. inermis has comparatively "warty" skin on the dorsum, and L. pallida differs in the colour pattern of the thighs and eye stripe. Each species ranges from 30 mm to 35 mm in maximum snout to vent length and up to about 6 g in total weight.

The ground hylids were found in a wide variety of terrestrial microhabitats often far from free water.

3.2.5; WIDE-MOUTHED, BURROWING FROGS

Four species of Cyclorana and Limnodynastes were placed in this category. All are strong burrowers with robust bodies, muscular limbs and capacious mouths.

The largest of the four species is Cyclorana australis which attains a snout to vent length of 100 mm and a body weight of about 100 g. Limnodynastes ornatus, C. longipes and L. convexiusculus grow to 45 mm, 55 mm and 60 mm respectively in snout to vent length.

The inner metatarsal tubercle is modified for digging in C. australis, C. longipes and L. ornatus, being horny and shovel shaped. This feature is lacking in L. convexiusculus, which also differs in having many low flat glands in the skin on the dorsum. These glands express a milky fluid when the frog is grasped, which dries to form a sticky film.

3.2.6; NARROW-MOUTHED, BURROWING FROGS

This faunal grouping was erected for Notaden melanoscaphus alone on the basis of its specialised morphology and habits.

Notaden melanoscaphus is a globular, robust frog with short limbs, a truncated snout and "warty" skin. It is a powerful burrower possessing a black inner metatarsal tubercle of hard keratin which is shovel-like in profile.

This species reaches a maximum snout to vent length of about 55 mm and a weight of 20 g. The skin of the dorsum is extensively glandular, and when grasped the frog exudes copious quantities of a viscous, yellow fluid which dries to form an adhesive mass of rubbery consistency (pers. obs.).

In comparison with other species of similar size, the mouth of N. melanoscaphus is small, and the mandible, maxilla and premaxilla are poorly ossified and flexible in life. The method of locomotion of this frog also differs markedly from that of the other species studied. N. melanoscaphus does not leap, but walks or runs.

3.2.7; TOADLETS

The toadlet, *Uperoleia inundata*, is a small, stout frog with short, stubby limbs attaining 30 mm in snout to vent length and 4 g in weight. Because of its short limbs, this species is an inefficient jumper and often walks with a gait similar to that of *N. melanoscaphus*. Like *N. melanoscaphus*, the toadlet can produce small amounts of a milky secretion from parotoid, coccygeal and inguinal glands on the dorsum. *U. inundata* is also a capable burrower, possessing well developed inner and outer metatarsal tubercles.

3.2.8; FROGLETS

The froglet, *Ranidella bilingua*, is the smallest of the species included in the current study, growing to 25 mm in snout to vent length and to about one gram in weight.

It is a terrestrial species with a slender body and relatively long toes lacking webbing.

4. MATERIALS AND METHODS.

4.1.1; FIELD STUDIES.

Field studies were undertaken during the periods January - April 1981, August 1981 and October 1981 - May 1982. The 11 months spent at Jabiru included two wet seasons, when frogs are most active and abundant, together with a short period in the middle of a dry season. Each field component was designed to address a separate objective.

4.1.2; FIELD STUDIES (JANUARY - APRIL 1981).

The main aim of the first period of field work was to collect numbers of frogs of a range of species from diverse natural and artificial habitats in the study area. Sampling took place at night, with commencement times ranging from 2100 hours to 0430 hours.

To ensure maximum returns, in terms of numbers and species of frogs captured, collections were made amongst congregations of calling males at spawning sites. Such congregations were located by visiting customary spawning sites, or by listening for the specific calls of desired species in inundated areas. Frogs in such congregations were caught by hand with the aid of a torch. Other specimens were located upon the surface of wet roads in the lights of a slowly moving vehicle.

The dates, locations and times of collection of frogs are shown in Table (4.1)

4.1.3; INHERENT BIAS IN SAMPLING PROCEDURE, (JANUARY-APRIL 1981)

Frogs, including rare and cryptic species, were captured readily by making collections at spawning sites. However, this procedure introduced considerable bias into samples of frogs retained for stomach content analyses.

By virtue of their vocal advertisement, male frogs were far more susceptible to capture at spawning sites than silent females. It is also possible that at these times advertisement and other activities associated with spawning are placed at a premium over feeding activities. If so, the stomach of a calling male is likely to contain less food than a frog not calling.

By sampling around breeding sites, the size distribution of collections comprised mature adults and recently metamorphosed juveniles which had not yet dispersed from the larval habitat.

As a result of these sampling biases, female frogs and subadult specimens were lacking in collections made in the first period of field work.

It was also recognised that, whereas all of the target species approach water bodies for spawning purposes, the majority do not aggregate there for feeding. Hence the stomach contents of frogs collected at such sites may not

TABLE (4.1)

COLLECTING ACTIVITIES JANUARY - APRIL 1981

Date	Time	Sampling Location
14 Jan.	2300	Jabiru Airstrip
16 Jan.	2200	Retention Pond No. 1
20 Jan.	2100	Retention Pond No. 2
20 Jan.	2200	Tailings Dam
21 Jan.	2230	Boonjinnie Road, creek crossing
22 Jan.	2130	Minesite pool near Tailings Dam
22 Jan.	2330	Tailings Dam
23 Jan.	2130	Road - West end of Jabiru Airstrip
23 Jan.	2230	Roadside pool, Jabiru East/turnoff Arnhem Highway
23 Jan.	2300	Arnhem Highway
23 Jan.	2330	Roadside Pool, 800 m West of Gulungul Creek
26 Jan.	2100	Jabiru East roads
26 Jan.	2200	West end of Jabiru Airstrip
26 Jan.	2300	Jabiru Airstrip
28 Jan.	2130	2.6 Km West of Jabiru, Borrow Pit
28 Jan.	2300	12.1 Km West of Jabiru, Borrow Pit
29 Jan.	2200	Retention Pond No. 1
29 Jan.	2340	Jabiru Sewerage Treatment Works
30 Jan.	2130	Gulungul Swamp, Roadside
30 Jan.	2300	800 m West of Gulungul Creek Roadside
30 Jan.	2350	4.4 Km West of Jabiru, Borrow Pit
31 Jan.	2120	2.6 Km West of Jabiru, Borrow Pit
31 Jan.	2100	Road, West end of Airstrip
31 Jan.	2430	4.4 Km West of Jabiru, Borrow Pit
2 Feb.	2200	Roads, Jabiru East
2 Feb.	2200	Boonjinnie Road
2 Feb.	2300	12.5 Km West of Jabiru, Borrow Pit
2 Feb.	2400	Western end of lake, New Townsite
3 Feb.	0100	Western end of lake, New Townsite roads
5 Feb.	0200	Roadside Pool, Jabiru East turnoff
27 Mar.	1200	Floodplain edge, Nankeen Billabong
11 Apr.	0430	Floodplain edge, Nankeen Billabong

be representative of the normal range of items ingested in foraging areas.

These collections provided a large sample of frogs for use in preliminary stomach content analyses, and for inclusion in a study of the incidence of skeletal abnormalities in the Magela Creek system by other workers (Tyler and Crook, 1980, Tyler *et al*., 1981).

4.1.4; FIELD STUDIES (AUGUST 1981).

A week-long visit to the study area in August 1981 was intended to establish the existence of any activity by frogs in the dry season.

Efforts were made to locate individuals of any species. At night, tracks through woodland and the margins of major natural and artificial water bodies were searched on foot with the aid of a powerful torch. During the day sandy creek beds and deep crevices in clay pans were excavated with pick and shovel in attempts to locate frogs sheltering within. Logs, debris and other potential sheltering sites adjacent to water bodies also were examined.

Two pit-trap grids in the Gulungul Creek area were opened for several nights to capture any frogs foraging there. Each grid consisted of six lines of six pits each approximately four metres apart. The pits were steel pails of 20 L capacity buried with their lips flush with the ground surface. Water was placed in each pit to prevent desiccation of captives.

The times, dates and locations of sampling attempts are shown in Table (4.2).

TABLE (4.2)

COLLECTING ACTIVITIES - AUGUST 1981

Date	Time	Sampling Location
24 Aug.	1300	Blacksoil plains, Jabiluka
24 Aug.	2220	Retention Pond No. 1
25 Aug.	1945	Retention Pond No. 1
25 Aug.	2400	Retention Pond No. 1
26 Aug.	0410	Retention Pond No. 1
26 Aug.	2100	Tailings Dam; Gulungul Pit grids opened
26 Aug.	2330	Georgetown Billabong
26 Aug.	2430	Retention Pond No. 2
27 Aug.	1200	Georgetown Billabong
27 Aug.	2200	Jabiluka Billabong
28 Aug.	1400	Magela Creek
28 Aug.	2300	Gulungul Creek; Gulungul Pit grids closed

4.1.5; FIELD STUDIES (OCTOBER 1981 - MAY 1982).

The concurrent aims of the final field component were three-fold.

Firstly, there was a perceived need to collect frogs in such a manner as to minimise the inherent bias associated with the procedures employed in the previous wet season. To present stomach content lists which best represent the diet of different species it was most desirable to catch specimens while they were in the process of foraging in their respective foraging areas.

Secondly, to predict which specimens would be most likely to encounter potential prey of aquatic origin, it was necessary to determine which species forage in or near natural and artificial water-bodies.

A third aim of the field studies involved detailed investigation of variation in feeding habits, distribution and abundance of frogs in relation to spatial, temporal and biological factors.

To fulfill these objectives three main sampling procedures were employed.

4.1.6; PIT TRAPPING

Pit-trap lines and drift fences were used in attempts at qualifying the existence of any habitat partitioning between members of the anuran community in the study area. Their utilisation was planned to provide a means of frog collection not subject to the biases introduced through manual capture of specimens located visually.

Six lines of pit-traps with drift fences were erected in the Magela Creek and Gulungul Creek areas during October 1981. The design of each line is shown in Figure (4.1). In each area, trap lines were set up in paperbark swamp (*Melaleuca* sp.), sedge and grassland, and open woodland assemblages, classified as habitat types 5, 3 and 1 in later surveys (see section 4.1.8). The locations of trap lines in the Magela Creek and Gulungul Creek areas are shown in Figures (4.6) and (4.7) respectively.

At the onset of the wet season, in mid-November 1981,

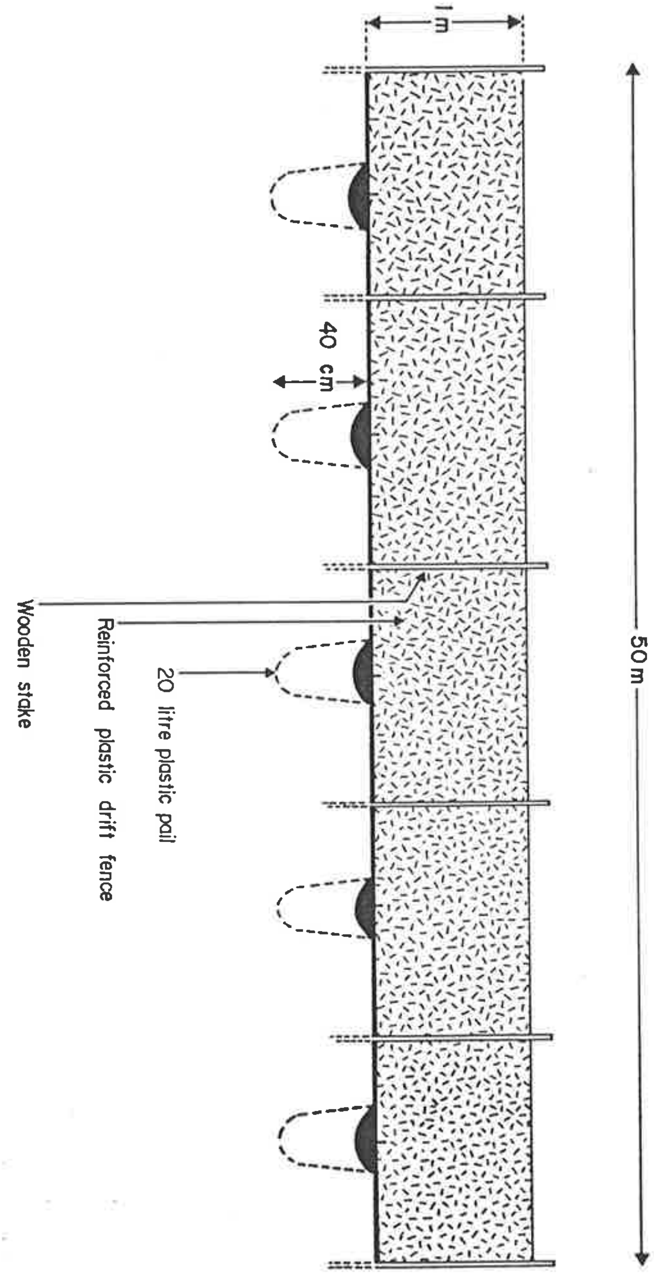


Figure (4.1); The design of pit-trap lines used in the study.

the water table rose at each site and forced the plastic pails used out of the ground. High winds, feral water buffalo and pigs damaged some drift fences. As a result of these problems, the use of pit trap lines was discontinued in early December 1981.

4.1.7; SAMPLING STATIONS

Regular, frequent collections of frogs were made at stations in the Jabiru East townsite, at the Ranger uranium mining site and on the Magela Creek floodplain at Nankeen Billabong. The locations of major sampling stations and associated sampling dates are shown in Figure (4.2) and Table (4.3) respectively.

4.1.7.1; RANGER URANIUM MINING SITE - TAILINGS DAM.

At the Tailings dam, collecting was carried out at night. Both the shoreline vegetation and exposed earthworks of the Tailings dam were searched in regions A and B (see Figure 4.3). The majority of specimens located in the torchbeam used was caught by hand. However, in region B a thick tangle of inundated speargrass (*Sorghum* sp.) necessitated locating the frog with a torchbeam and then angling for it with rod, line and baited hook. A small piece of dyed dragonfly mounted on a small fishhook was jiggled to attract and catch the frog.

Occasional collections of frogs for stomach content analyses also were made at retention ponds (numbers "1" and "4"), and within the uranium mining pit "J" (See Figure 4.2).

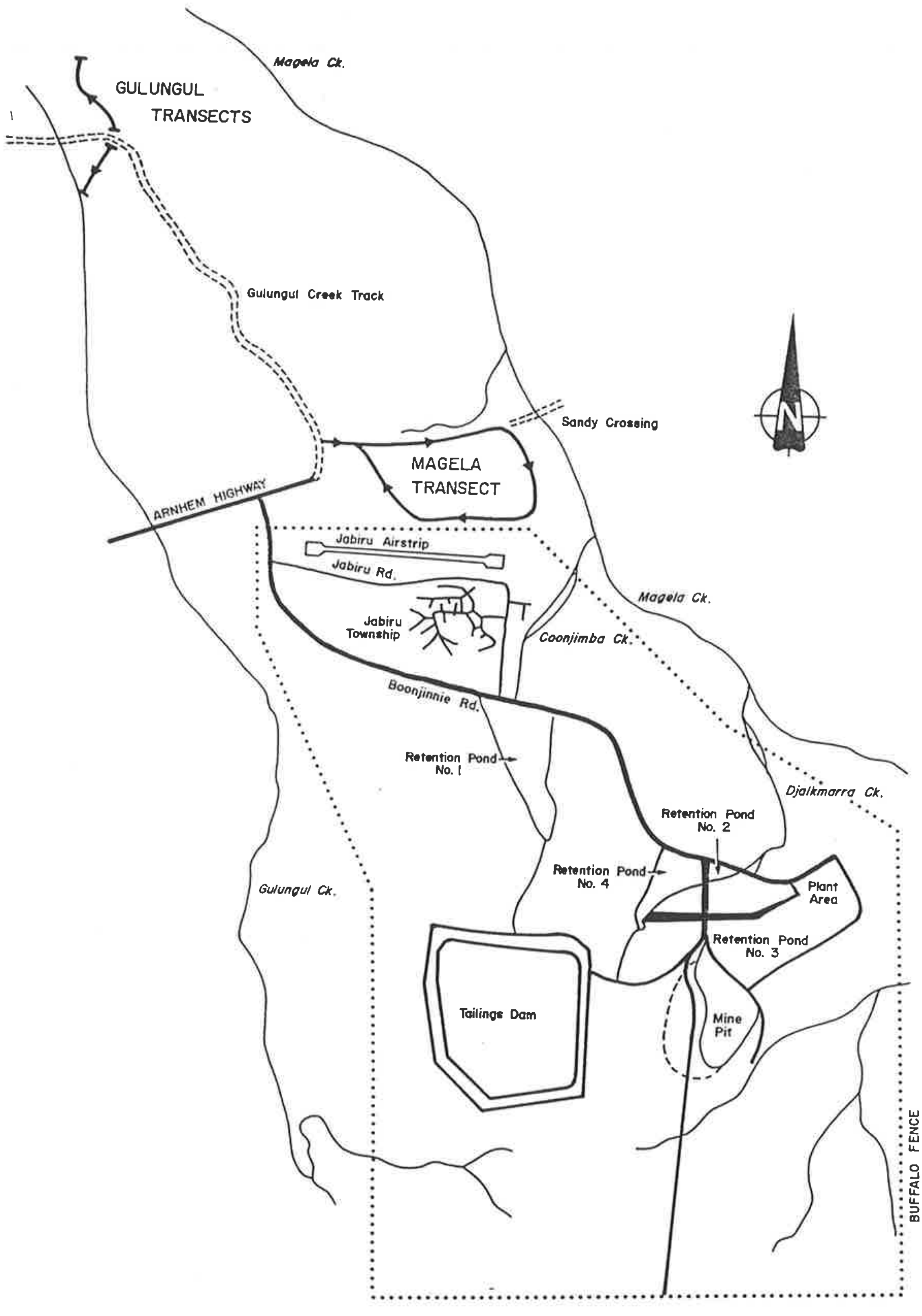


Figure (4.2); Jabiru townsite and minesite with associated sampling locations. **Not To Scale**

TABLE (4.3)

SAMPLING DATES 1981 - 1982 WET SEASON

Month	Dates	Site
Tailings Dam		
November	2, 24	A
December	4, 14, 23	A
January	10, 20, 22	B
February	5, 6, 25	B
March	12, 30	B
April	14	
Townsite Roads (and sewerage treatment works)*		
November	3*, 13*, 20*	
December	3*, 22*	
January	21	
February	15	
March	9	
April	15	
Nankeen Billabong and Floodplain Edge		
November	10, 22, 24, 26	
December	10, 17, 28	
January	10, 12	
February	7, 26	
March	13	
April	8, 16	

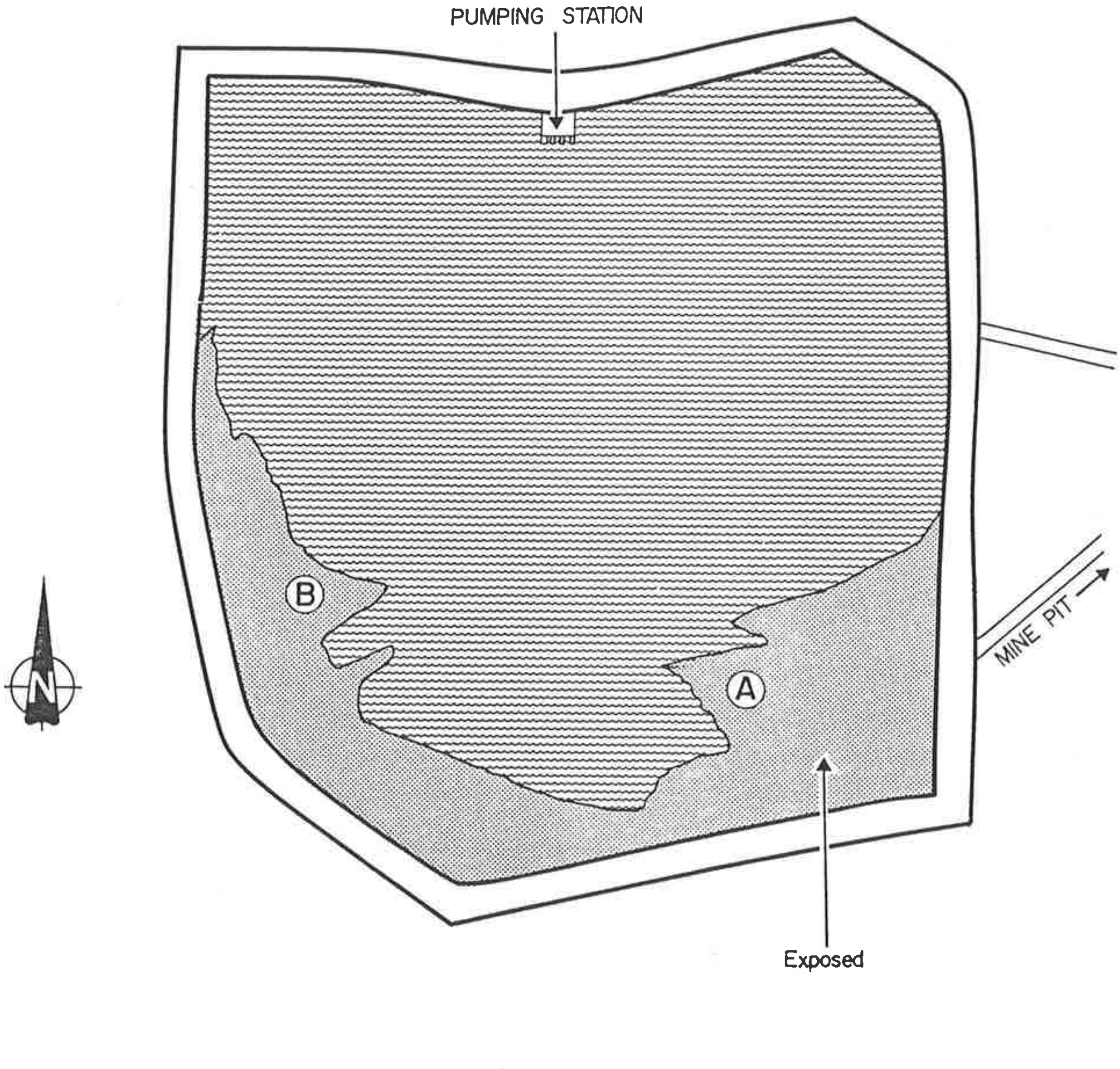


Figure (4.3); Sampling regions (A and B) within the confines of the Tailings dam. **Not To Scale**

4.1.7.2; JABIRU EAST TOWNSITE

Collections of frogs were made at night by traversing, in a slowly moving vehicle, a circuit formed by Boonjinnie road and Jabiru road (see Figure 4.2). Specimens located in the vehicle lights were caught by hand with the aid of a torchbeam.

Frequent visits also were made to the refuse dump and sewerage treatment works at the Jabiru townsite to capture any frogs foraging there (see Figures 4.2, 4.4).

4.1.7.3; MAGELA CREEK FLOODPLAIN - NANKEEN BILLABONG

At the Nankeen Billabong, on the Magela Creek floodplain, sampling was carried out at stations A, B and C (Figure 4.5). The foliage of vegetation fringing the billabong at stations A and B (mainly *Barringtonia acutangula* and *Pandanus aquaticus*) was searched intensively at night for arboreal frogs. This was undertaken from the deck of a floating punt or airboat, and required the use of a powerful torchbeam. Frogs sighted in the torchbeam were caught by hand.

Parts of the western levee bank of Nankeen Billabong, adjacent to station A, were inundated seasonally and exposed depending on the rate of flow of floodwaters. When these areas were exposed they were entered on foot, and any frogs located there in a torchbeam were captured by hand.

On the floodplain margins at station C, a number of

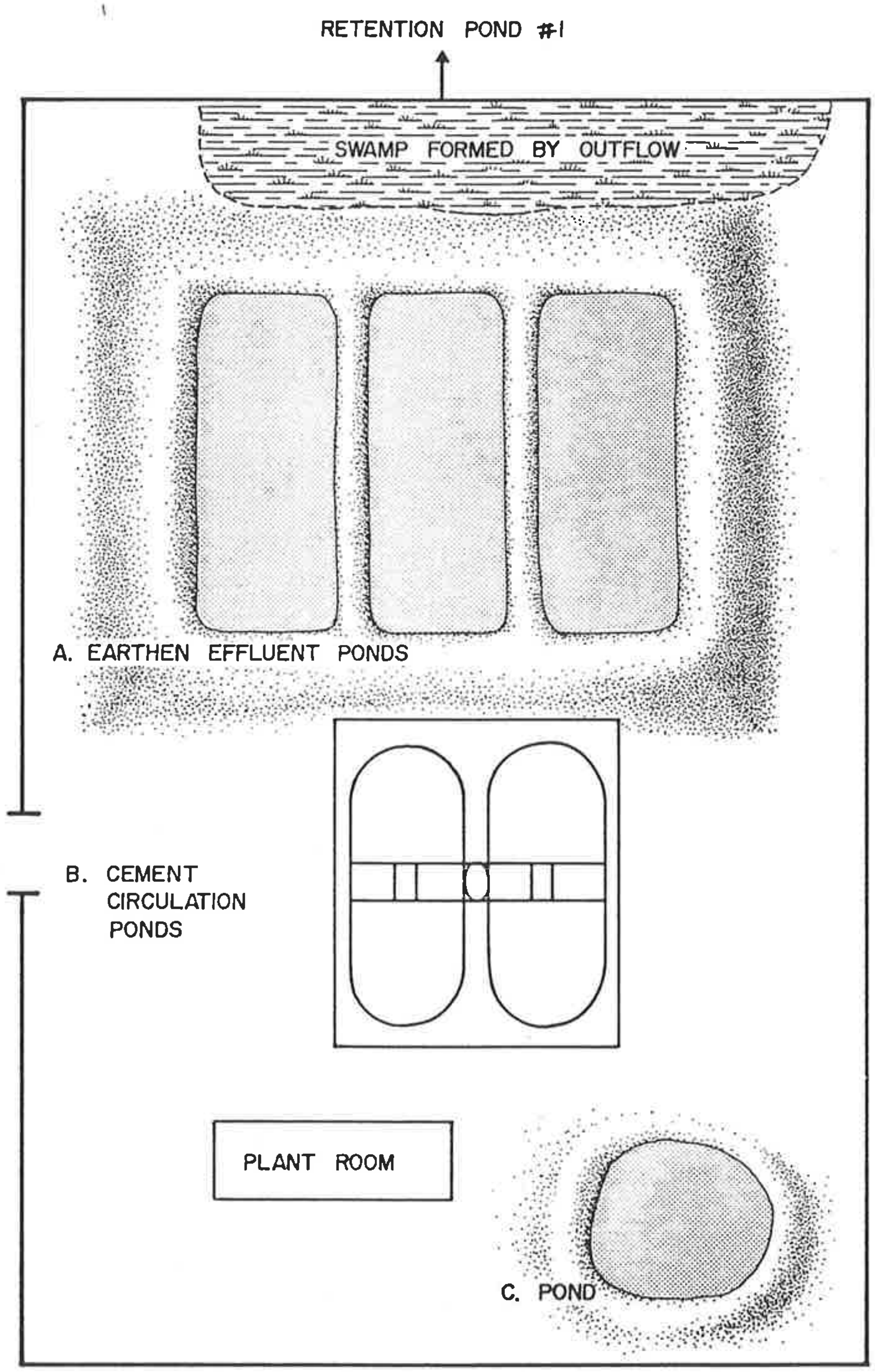
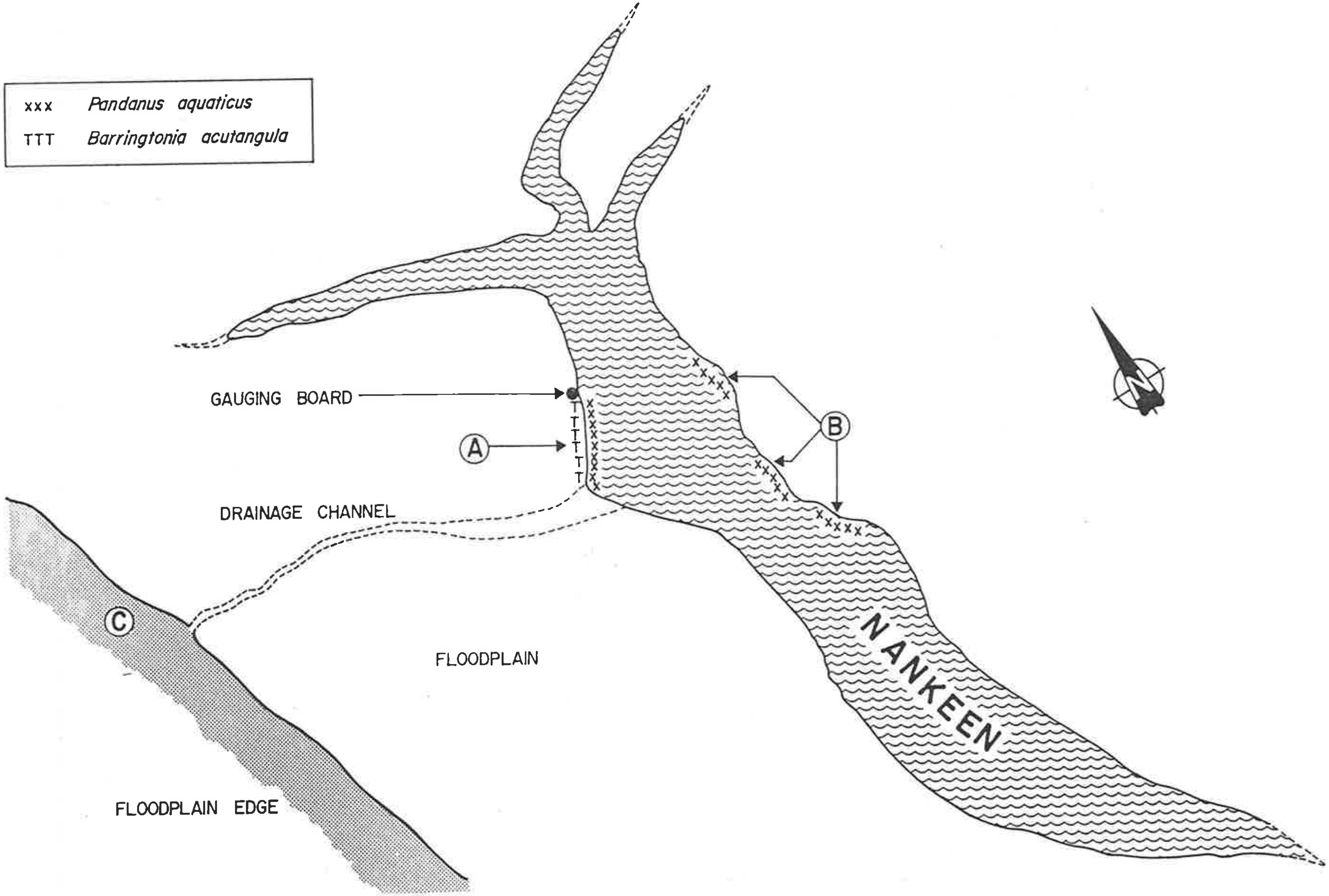


Figure (4.4); Sampling locations at the Jabiru sewerage treatment works. **Not To Scale**

Figure (4.5); Sampling stations (A, B, C) at Nankeen Billabong and on the Magela Creek floodplain.

Not To Scale


xxx *Pandanus aquaticus*
TTT *Barringtonia acutangula*
GAUGING BOARD
A
B
DRAINAGE CHANNEL
C
FLOODPLAIN
NANKEEN
FLOODPLAIN EDGE

methods of capture were used. At night, frogs were located amongst inundated sedges and grasses and shore line vegetation, and captured by hand with the aid of a torchbeam. During the day, frogs were caught by dragging a large dip net through flooded buffalo wallows, and by hauling a 10 m seine net through shallow waters. The seine net used had a "Rachelle" mesh of 2.5 cm (measured diagonally), a drape of 150 cm and a 150 cm pocket or bunt built into the centre. It was used in areas free of extensive macrophyte growth and snags.

Attempts were made to capture frogs which were sitting on emergent macrophytes at station C, and in the billabong waters, with a weighted throw net or by making a rapid sweep with a large dip net.

4.1.8; TRANSECTS

Sampling along foot transects passing through a variety of habitats was undertaken to qualify the existence of any separation between species, in terms of foraging areas, and to collect frogs for stomach content analyses whilst they were foraging there.

Transects were located in the Gulungul Creek and Magela Creek areas because it was possible to recognise in both areas five of the broad habitat types characteristic of the Magela Creek system, and to position these transects to pass through each of those habitat types.

In view of the extreme difficulties experienced in sighting and capturing frogs in the thick undergrowth that is also characteristic of the area, it was decided to site the transects along the paths of vehicle tracks, impassable for most of the wet season.

Sampling was carried out along one transect in the Magela Creek area, and along two transects in the Gulungul Creek area on the dates and at the times shown in Table (4.4). The location of each transect and the route followed are shown in Figures (4.6) and (4.7).

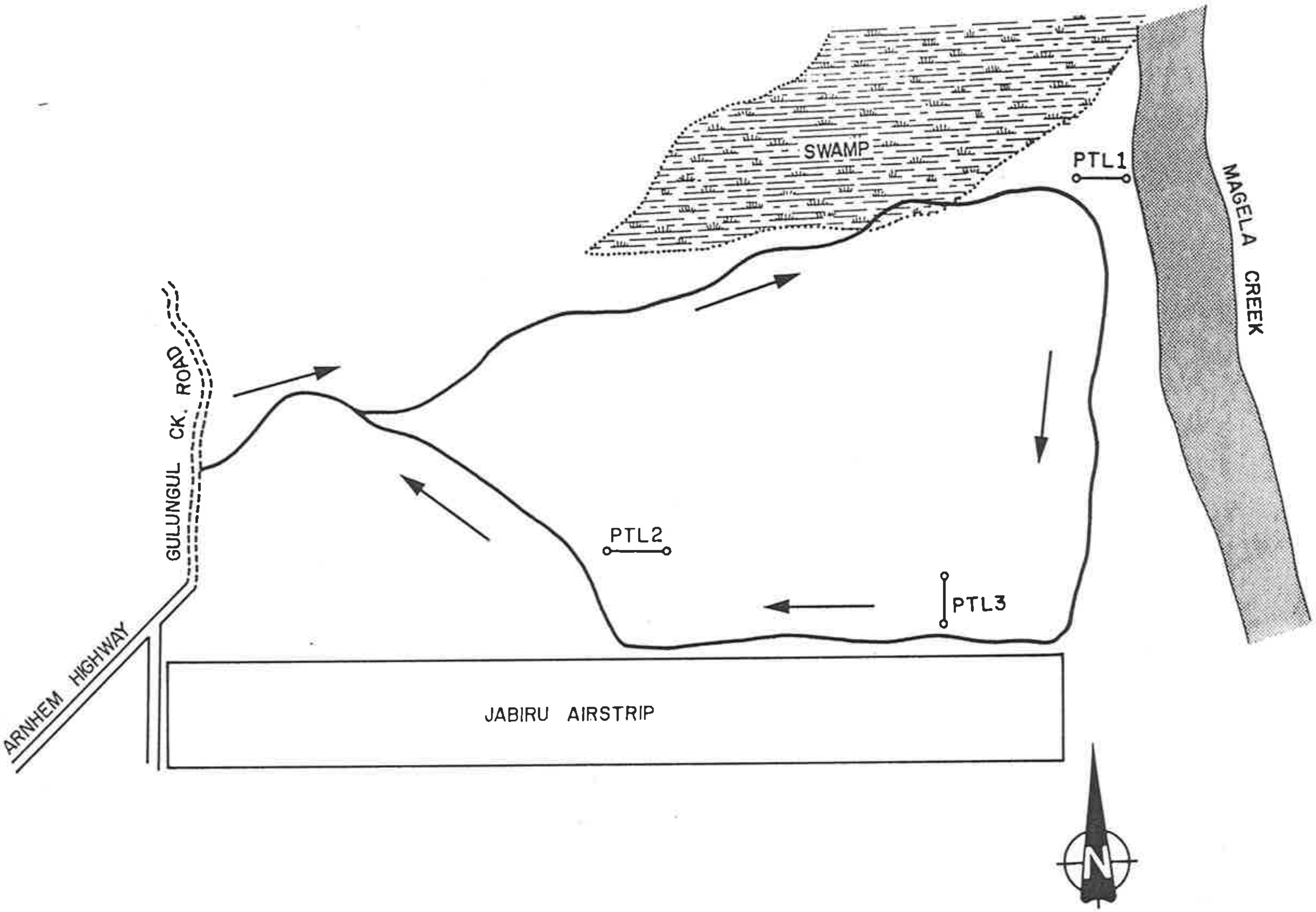
TABLE (4.4)

SAMPLING DATES FOR MAGELA CREEK AND GULUNGUL CREEK TRANSECTS

	Magela	Gulungul
1	6 November 1981	16 November 1981
2	1 December 1981	2 December 1981
3	8 December 1981	9 December 1981
4	15 December 1981	16 December 1981
5	24 December 1981	25 December 1981
6	19 January 1982	25 January 1982
7	4 February 1982	4 February 1982
8	23 February 1982	11 March 1982
9	2 April 1982	1 April 1982
10	16 April 1982	13 April 1982

Figure (4.6); Location of the Magela Creek transect, the route followed during sampling and the location of pit-trap lines (PT1 - PT3).

Not To Scale


SWAMP
PTL1
MAGELA CREEK
GULUNGUL CK. ROAD
PTL2
PTL3
ARNHEM HIGHWAY
JABIRU AIRSTRIP
N

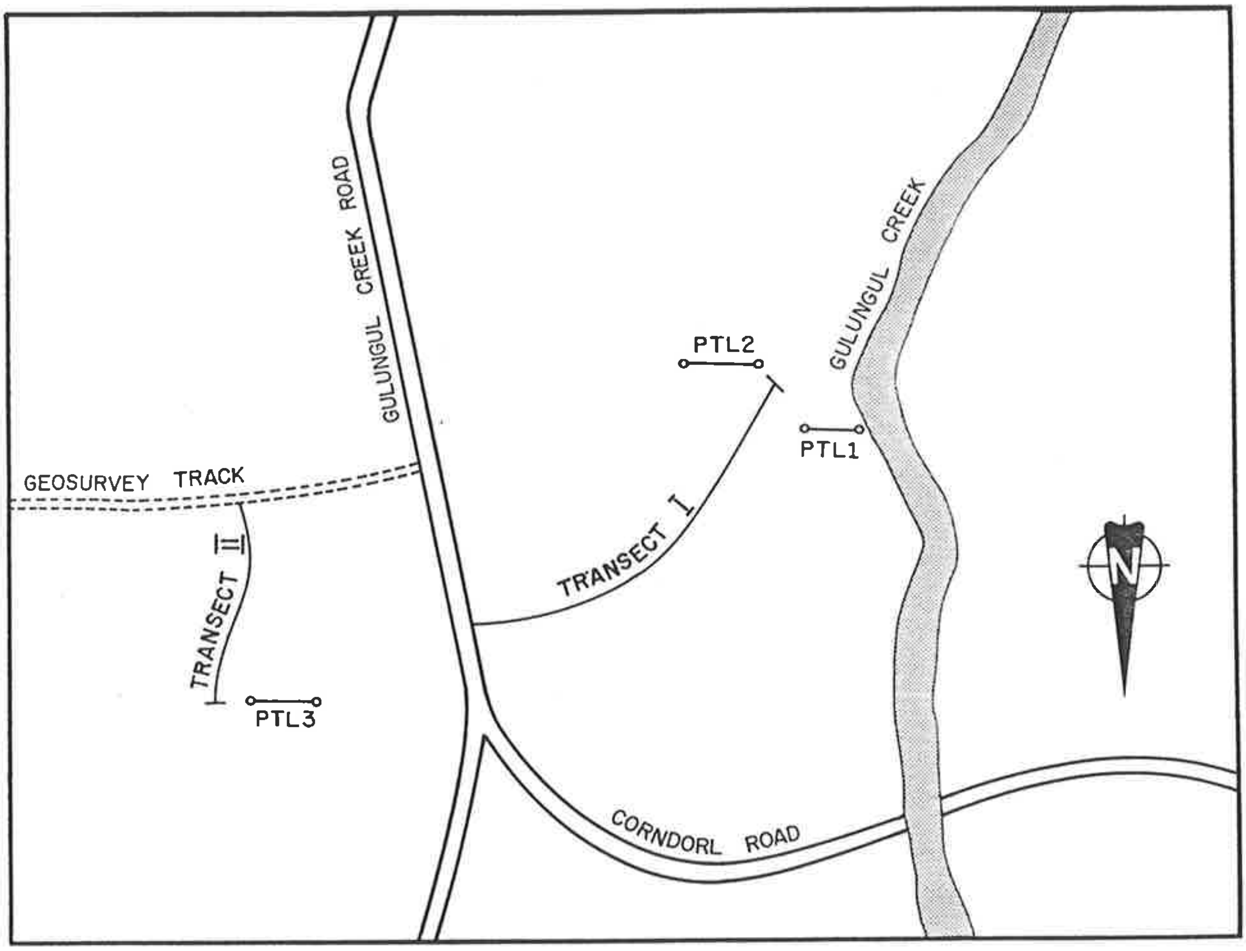


Figure (4.7); The location of the two Gulungul Creek transects and nearby pit-trap lines (PT1 - PT3).

Not To Scale

4.1.8.1; MAGELA CREEK TRANSECT

The Magela Creek transect had a total length of 4,130 metres, and passed through open woodland to follow Magela Creek and low-lying areas of swamp and sedgeland. Whilst walking slowly along the left wheel rut of the track, attempts were made to capture all frogs encountered within the confines of a torchbeam, which was approximately 50 cm wide when aimed approximately two metres in front of me.

A Rotatape terrain wheel was pushed along the transect during sampling, and this enabled the location of each frog sighted to be recorded and determined relative to the total transect length.

4.1.8.2; GULUNGUL CREEK TRANSECTS

Both transects in the Gulungul Creek area (see Figure 4.7) were sited along disused vehicle tracks barely discernible due to overgrowth of vegetation. Transect I passed through open woodland for a short distance into a flat expanse of sedge and grassland with a total length of 300 metres. Transect II passed through open woodland for its entire length of 150 metres.

The sampling methods used along the two transects essentially were similar to those employed for the Magela Creek transect with the following two differences. Firstly, two sampling runs were made at each transect by walking along the left wheel rut to the end of the transect, and sampling along the other rut during the return trip.

Secondly, only those frogs actually captured on sampling dates were recorded in population censusses. Occasionally ground hylids were sighted leaping away from the transect but not captured. Such frogs were not included in counts.

4.1.8.3; CLASSIFICATION OF HABITAT TYPES

During April 1982, the terrain wheel (which displays only Imperial measurements of distance) was used to mark off stations at 500 foot intervals. At each station, soil cores (to a depth of 10 cm) were collected and notes were assembled on the vegetation types, litter cover of the ground and drainage patterns. On the basis of this survey, five broad habitat types were recognised.

4.1.9; DATA RECORDED DURING SAMPLING

Whilst sampling along transects, a Phillips miniature tape recorder was used to record the identity of each frog sighted or captured and the terrain wheel reading at each site. Relevant behavioural observations and notes on the size (juvenile, subadult and adult) and sex of each specimen also were recorded. When sampling along townsite roads, the vehicle odometer reading was recorded for each specimen captured.

On or following each occasion on which frogs were collected, detailed notes were made on:-

Temperature,
Relative humidity (by whirling Hygrometer),
Rainfall (from Bureau of Meteorology, Darwin),
Cloud cover,
Wind velocity,
Phase of moon,
Insect abundance, and
Frog vocal activity.

During sampling activities in the period October 1981 - April 1982, calling males and frogs found in amplexus were separated in collections and labelled accordingly.

4.1.10; KILLING OF FROGS

Immediately after capture, each frog was placed in a labelled killing jar containing a solution of 3% chloral hydrate deposited in an insulated container of ice. The ice immobilised the frog and helped ensure minimal post-collection digestion of stomach contents. The dead frogs were then held in freezer storage pending dissection.

4.2.1; DATA RECORDED DURING FROG DISSECTION

4.2.2; LENGTH AND WEIGHT

Specimens were thawed, measured and dissected within (weeks of capture, with the exception of frogs collected during the August 1981 sampling period, which were preserved in 65% ethanol.

Dial calipers (Mitutoyo) were used to measure the snout to vent length and mouth gape of each frog to the nearest 0.1 mm (see Figure 4.8). The "wet" weight of each frog was measured on a Mettler top loading balance to the nearest 0.001 gm.

4.2.3; CATEGORISATION OF EACH SPECIMEN

An incision was made in the ventral body wall of the frog from the cloaca to the lower jaw and the internal organs exposed. Notes on the activity of the frog immediately prior to capture were referred to at the time of the examination of gonads, if visible, to place the specimen in one of the developmental categories defined in Table (4.5).

4.2.4; STOMACH DISTENTION AND STOMACH WEIGHT

The degree of stomach distention was quantified on an arbitary scale of 0 to 6 as defined in Table (4.6). The stomach was then detached from the remainder of the alimentary tract. Each stomach was weighed to the nearest 0.001 g and preserved in a labelled vial of 65% ethanol.

4.2.5; ESTIMATION OF STOMACH VOLUME

The volume of each preserved stomach included in stomach content analyses was estimated by using two methods.

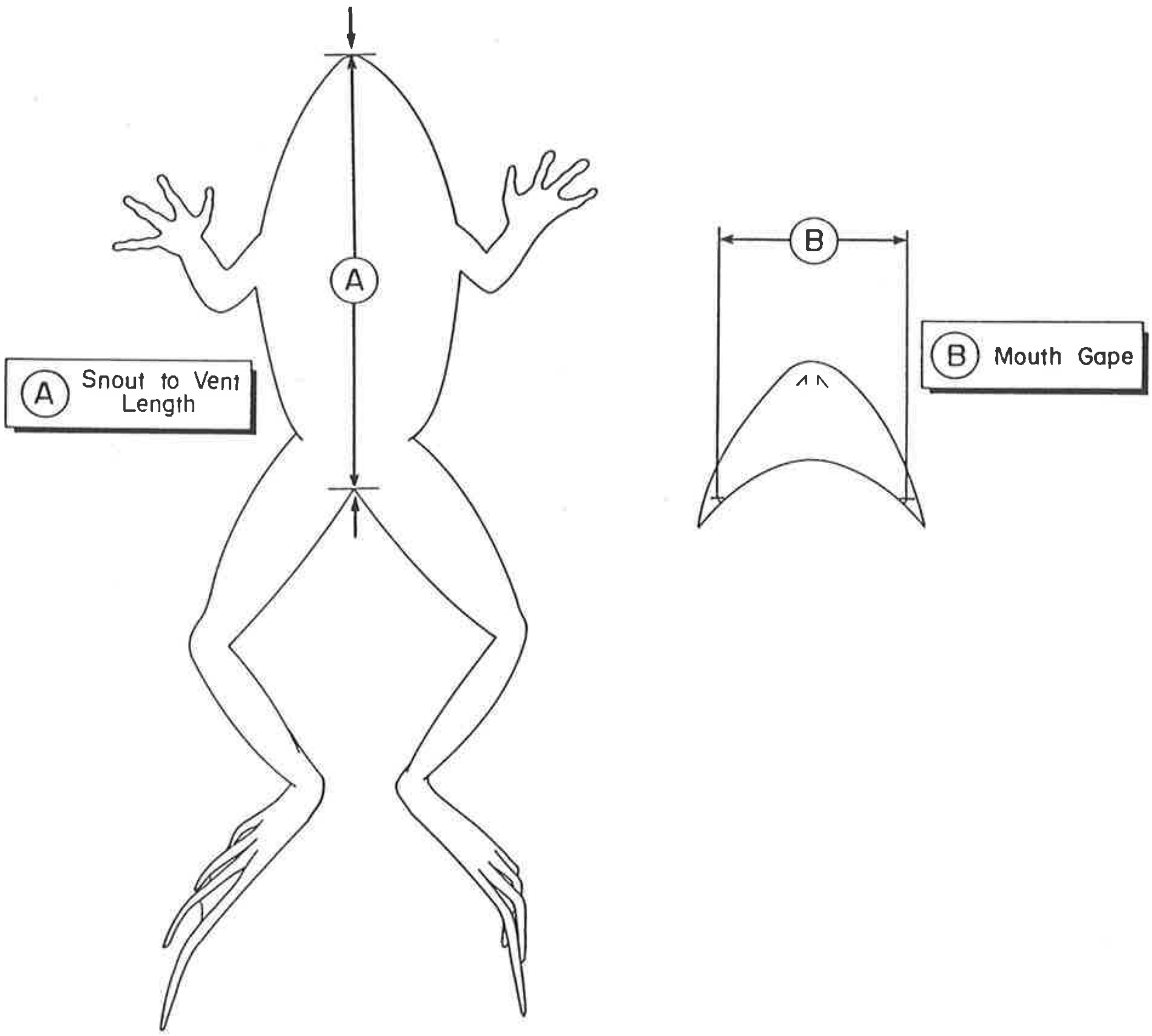


Figure (4.8); Measurement of snout to vent length (A) and mouth gape (B).

Table (4.5); Categorisation of frogs by size, sex and activity immediately prior to capture.

CATEGORY	DEFINITION
UNKNOWN	Frogs of unknown maturity and undetermined sex.
STAGE 42 *	Newly metamorphosed frogs still bearing an unresorbed portion of the larval tail.
JUVENILE (J)	Clearly immature frogs of undetermined sex.
MALE (M)	Male frogs.
MALE, CALLING (MC)	Male frogs found calling and/or in amplexus immediately prior to capture.
FEMALE (F)	Female frogs.
FEMALE, GRAVID (FG)	Gravid female frogs.
FEMALE, GRAVID, in AMPLEXUS (FGA)	Gravid female frogs found in amplexus immediately prior to capture.

* after Gosner (1960)

Firstly, the stomach was placed in a petri dish of 65% ethanol upon a paper grid marked off in $10mm^2$ squares. By using a dissecting microscope the number of squares covered by the stomach was counted. The stomach was then rotated through 90^o and the maximum diameter in cross section measured to the nearest 1.0 mm using the grid, as shown in Figure (4.9). Using this method, stomach volume (STOMVOL I) was estimated as cover (mm^2) multiplied with maximum diameter (mm).

The stomach was then blotted dry and submerged in a known volume of absolute ethanol contained in a measuring cylinder with 0.1 ml graduations. For large stomachs, a cylinder with 0.2 ml graduations was used. The resulting displacement of ethanol was recorded and taken as the second estimate of stomach volume (STOMVOL II).

Table (4.6); Arbitrary scale for quantification of degree of stomach distention.

INDEX OF FULLNESS	DEFINITION
VOMIT	Stomach contents regurgitated and stomach everted into buccal cavity.
0	Stomach empty.
1	Stomach contents visible through wall; occupying less than one-half of lumen of stomach.
2	Stomach contents visibly occupying approximately one-half of lumen of stomach; no distention of stomach wall.
3	Stomach contents visibly occupying more than one-half of lumen of stomach; no distention of stomach wall.
4	Stomach contents visibly occupying entire lumen of stomach.
5	Stomach distended; stomach wall stretched sufficiently to render detail of contents visible through wall.
6	Stomach greatly distended; stomach contents extending into oesophagus and buccal cavity.

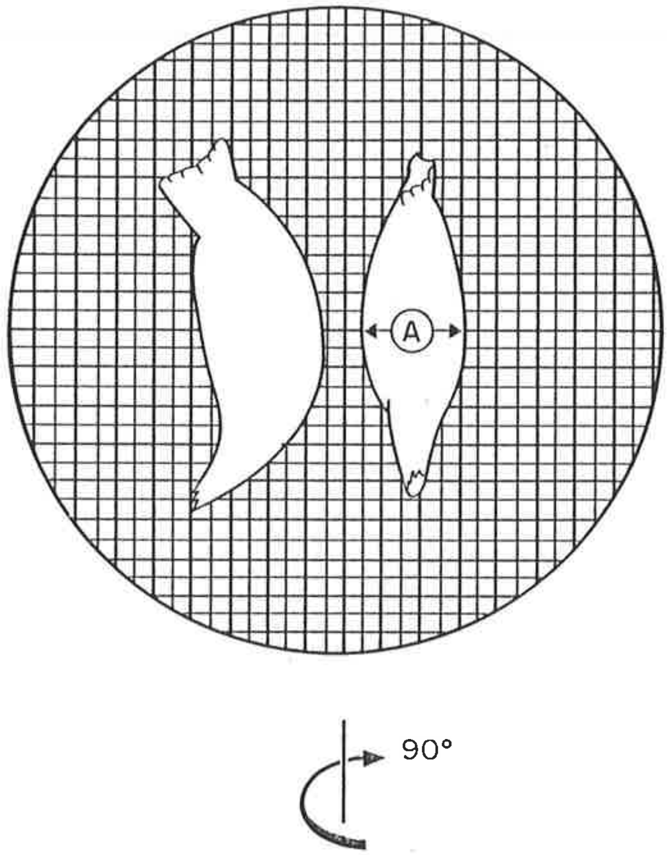
The displacement of ethanol by small stomachs often was not detectable due to the effect of surface tension of the ethanol and the separation of the graduations used. Conversely, the volume of large distended stomachs was underestimated by using STOMVOL I.

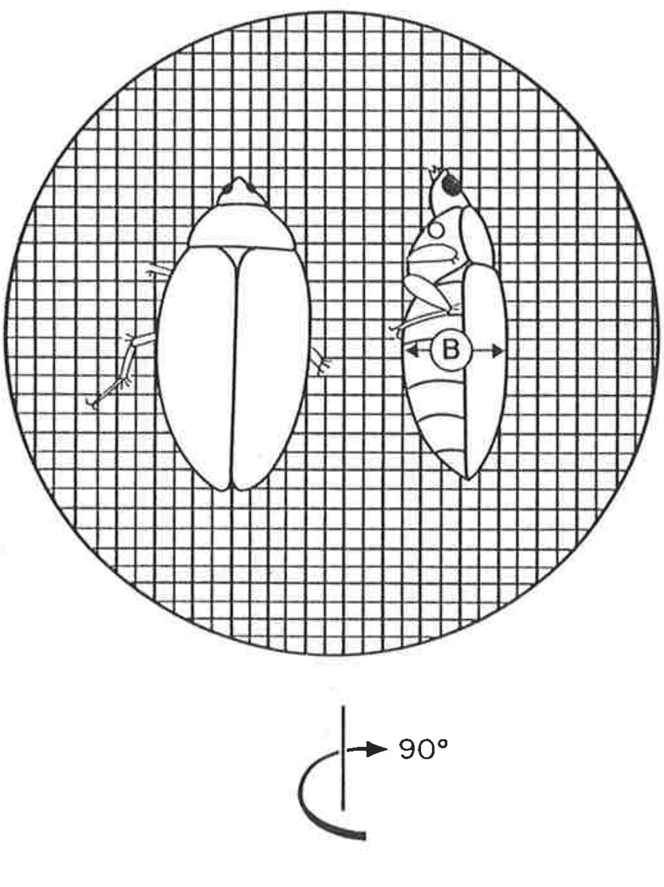
Hence, an average of the two estimates was taken to give a final estimate of stomach volume.

4.3.1; STOMACH CONTENT ANALYSES

4.3.2; SORTING OF STOMACH CONTENTS

Small stomachs were teased open with fine jewellers forceps, and large stomachs were opened with surgical


A
90°


B
90°

scissors, taking care not to damage the food mass within. The contents were then washed out of the stomach and separated by irrigation with 65% ethanol. In the first instance stomach contents were sorted according to the scheme summarised in Figure (4.10).

The food bolus initially was separated into different piles comprising inorganic material, vegetable material, relatively intact animals and disarticulated animal remains. The two piles of intact animals and animal remains were then subdivided into taxonomic groups at the level of Order. Finally each taxonomic group was separated into adult and larval categories of that particular Order.

4.3.3; IDENTIFICATION OF PREY ITEMS

The major objective of the stomach content analyses carried out in this study was to qualify and quantify the presence of prey items of aquatic origin in the stomachs of the species studied. Therefore prey items were identified only as far as was necessary to determine the nature of their origin.

Identification to the level of taxonomic Order proved sufficient for the majority of prey items. However, within several arthropod orders (such as the Coleoptera) there exist some taxa with aquatic life histories and others with wholly terrestrial habits. Hence arthropods in these orders were retained for further classification and analysis at the level of Family to identify prey items of aquatic origin.

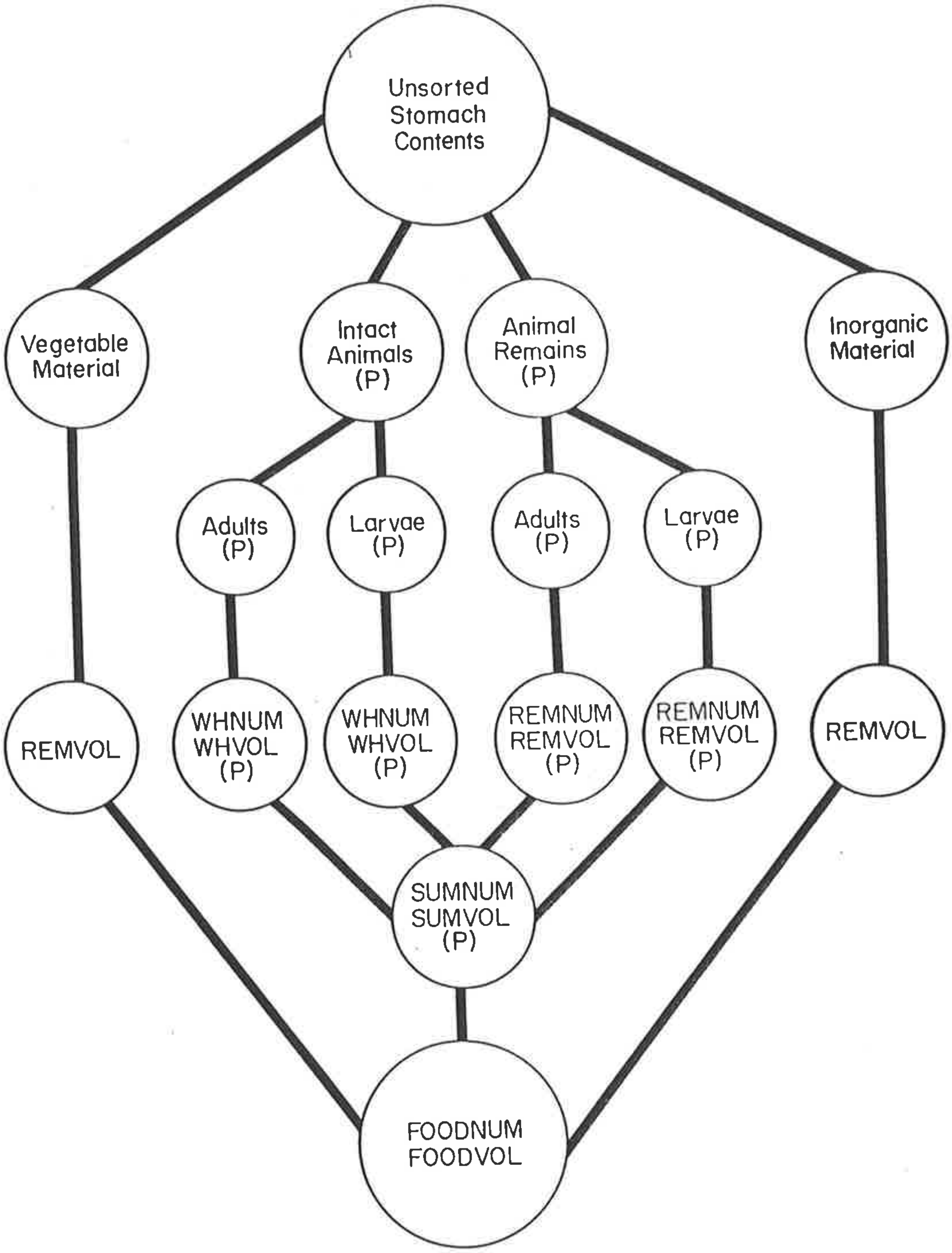


Figure (4.10); Schematic diagram of procedure followed in sorting stomach contents and deriving variables for a prey type **(P)** included in stomach content analyses.

4.3.4; STOMACH CONTENT ANALYSIS AT THE LEVEL OF TAXONOMIC ORDER

4.3.4.1; QUANTIFICATION OF NUMBER AND VOLUME OF PREY GROUPS

The contribution of each prey Order identified to the total suite of contents of each stomach examined was quantified in terms of both number and volume of items. Total volume only was used to quantify the presence of inorganic material and vegetable material. The variables used to describe these contributions are shown in Figure (4.10) and defined in Table (4.7).

4.3.4.2; NUMBER OF ITEMS

The number of intact individuals in each prey Order (WHNUM) was counted with little difficulty. In the case of disarticulated arthropod remains, head capsules, elytra, wings or (as in the case of large Orthopterans) limbs were counted to estimate the number of individuals in this category (REMNUM).

4.3.4.3; VOLUME OF ITEMS

The volume of items in each prey Order was estimated using either one of three methods, two of which have been described previously, for estimation of the volume of large and small stomachs respectively.

The ethanol displacement method was used for estimating the total volume of a number of large individuals

Table (4.7); Data obtained from analysis of the contents of a single stomach at the level of taxonomic Order.

VARIABLE	DEFINITION
WHNUM	Number of intact individuals of prey category (P).
REMNUM	Number of disarticulated individuals of prey category (P).
WHVOL	Total volume of intact individuals of prey category (P).
REMVOL	Total volume of inorganic material, vegetable material or remains of disarticulated individuals of prey category (P).

(WHVOL), or their remains (REMVOL), for prey orders such as the Anura, Araneae and Orthoptera found in the stomachs of large frogs.

For small intact items, the volume of each individual was estimated by using cover (mm^2) and maximum diameter in crosssection (mm) found using grid paper (see Figure 4.9). Finally, a variation of this method was used to estimate the total volume of groups of small animals of the same type, animal remains, vegetable material and inorganic material such as sand grains.

A plastic petri dish with grid paper (marked off into 1 mm^2 squares) underlying the base and taped around the outside of the walls was used under a low-power binocular microscope. The group of items or material was aggregated in the dish forming a roughly rectangular shape. This aggregation was then gently tamped downwards to an approximately uniform height. The surface cover (mm^2) and height (mm) of the aggregation could be read off the horizontal and vertical scales supplied by the grid paper. Multiplied together, these terms gave an estimate of volume.

4.3.5; STOMACH CONTENT ANALYSIS AT THE LEVEL OF TAXONOMIC FAMILY:-

Families with aquatic life histories within the Hemiptera and Coleoptera can be recognised on the basis of morphological adaptations to their aquatic environment such as reduced, clublike antennae, paddle-like limbs bordered with setae and, in the case of some members of the Hemiptera, breathing tubes.

Differences between taxa of aquatic and terrestrial origin within the Diptera and Araneae are subtle and can only be seen in complete specimens. These discerning features, such as antennae in the Diptera and setae patterns in the Araneae, are dissolved rapidly by digestive juices,and only rarely were found on specimens from anuran stomach contents. Therefore , in this study, only the Coleoptera and Hemiptera were included in the stomach content analyses at the level of Family.

4.3.5.1; FURTHER IDENTIFICATION OF PREY ORDERS

Individual coleopterans and hemipterans retained from the previous stomach content analyses were examined microscopically for morphological features characterising the nature of their origin. Specimens were classified as terrestrial or aquatic and treated separately in further analyses. Aquatic individuals were identified to the level of Family. The lengths of all specimens examined were measured with an eyepiece micrometer to the nearest 0.1 mm.

4.3.5.2; QUANTIFICATION OF NUMBER AND VOLUME OF PREY GROUPS

The contribution of each aquatic prey Family to the total group of intact arthropods retained from each stomach was quantified in terms of both number and volume of individuals present. Number of individuals was used only to quantify the contribution of arthropods classified as terrestrial.

The volume of individuals of aquatic prey families was estimated by using methods described previously for large and small intact items.

4.3.6; COMPUTATION OF RESULTS OF STOMACH CONTENT ANALYSES

All data obtained during dissection of frogs and analyses of stomach contents were stored in extensive data files created and edited on a CYBER 173 computer at the University of Adelaide and outlined in Appendices (4.1), (4.2) and (4.3). Computer programs (BMDP (3D) software from the Control Data Corporation) were used to derive the following information for individual stomachs (Table 4.9) and individual prey categories (Table 4.8) included in stomach content analyses at the level of taxonomic Order.

The codes used to identify location of frog capture, frog species, prey categories at the level of taxonomic Order, and prey families are defined in Appendices (4.4), (4.5), (4.6) and (4.7).

Table (4.8); Data derived for each prey category (P) present in the contents of an individual stomach.

VARIABLE	DEFINITION
SUMNUM	Total number of intact and disarticulated individuals of prey category (P) (= WHNUM + REMNUM).
SUMVOL	Total volume occupied by intact and disarticulated individuals of prey category (P) (= WHVOL + REMVOL).
DIGESTATE	An index of the degree of digestion of individuals in prey category (P) $\left\{ = \frac{REMNUM}{SUMNUM} \times 100 \right\}$.
PROPNUM	Contribution of prey category (P) to the total number of intact and disarticulated individuals of all prey categories found. $\left\{ = \frac{SUMNUM}{FOODNUM^*} \times 100 \right\}$.
PROPVOL	Contribution of prey category (P) to the total volume of contents found in the stomach. $\left\{ = \frac{SUMVOL}{FOODVOL^*} \times 100 \right\}$.

* See Table (4.9)

Table (4.9); Data derived from analysis of the contents of an individual stomach.

VARIABLE	DEFINITION
FOODNUM*	Total number of intact and disarticulated individuals of all prey categories present. (= SUMNUM)
FOODVOL*	Total volume occupied by inorganic material, vegetable material and intact disarticulated individuals of all prey categories present. (= SUMVOL)
DIGESTNUM	Total number of disarticulated individuals of all prey categories present. (= REMNUM)
DIGESTVOL	Volume occupied by inorganic material, vegetable material and disarticulated individuals of all prey categories present. (= REMVOL)
%DIGESTNUM	$\left\{ = \frac{\text{DIGESTNUM}}{\text{FOODNUM}} \times 100 \right\}$.
%DIGESTVOL	$\left\{ = \frac{\text{DIGESTVOL}}{\text{FOODVOL}} \times 100 \right\}$.

* See Table (4.8)

5.1.1; RESULTS (1); SPATIAL AND TEMPORAL DISTRIBUTION OF FROGS IN THE STUDY AREA

5.1.2; SAMPLING STATIONS

The number of frogs captured during the study period, and the categorisation of these frogs according to size, sex and activity immediately prior to capture are shown in Table (5.1).

Although 3009 frogs were collected, the number of specimens captured of each species ranged from 13 for *Litoria wotjulumensis* to 645 for *L. dahlii*. Together, *L. dahlii* and *Cyclorana australis* comprised over 30% of the total sample. Similarly, there was a marked variation in the number of size and sexual categories represented in collections of each species. Although a full spectrum of post-metamorphic life stages is represented in the entire sample, adult frogs predominated in collections of all species, particularly males—which comprised 50% of all frogs captured.

The data in Table (5.1) do not represent interspecific difference in abundance or intraspecific differences in size and sex ratios. Rather, they reflect sampling biases outlined previously in Chapter 4.1.3 and differences in sampling effort.

However, it is possible to state that the calling male category has been underestimated in categorisation of captured frogs. When sampling was carried out in breeding

Table (5.1); Categorisation of all frogs captured according to size, sex and activity immediately prior to capture.

	CATEGORY								
SPECIES CODE	UNKNOWN	STAGE 42	JUVENILE	MALE	MALE, CALLING	FEMALE	FEMALE, GRAVID	FEMALE, GRAVID, in AMPLEXUS	TOTAL
L. dahl.	120	7	149	146	30	143	35	15	645
L. roth.	20		50	49	23	35	34	2	213
L. bico.	54		17	131	20	23	52	5	302
L. rube.			34	153	14	1	13	4	219
L. pall.	8		19	146	29	26	15	5	248
L. iner.	3		7	90	3	10	11	2	126
L. nasu.	3	4	24	31	45	18	10	13	148
L. torn.	1			118	9	4	10	1	143
L. wotj.			1	1	9	2			13
C. aust.		40	168	69	71	39	30	13	430
C. long.	3		26	25	4	14	2	3	77
L. orna.	17		40	26	1	12	7		103
L. conv.			3	6	15	4	3	2	33
N. mela.	5		1	75	8	4	15		108
U. inun.	5			64	28	15	12	1	125
R. bili.	13	1		10	38	6	7	1	76
	252	52	539	140	347	356	256	67	3009

aggregations calling males often ceased their activity upon the approach of the collector. These frogs were then included in the male category upon capture.

All sampling locations were classified broadly as being either "waterbodies", "ephemeral waterbodies" or "terrestrial" according to the presence of surface water during the study period. The results of this classification and the numbers of all species collected at each location are shown in Appendices (5.1) and (5.2).

The numbers of frogs captured within these classifications, by species and by faunal groupings, are shown in Tables (5.2) and (5.3).

Although the numbers of frogs, of all species pooled, captured within each classification were very similar (33.5%, 33.4% and 32.9% respectively) the distributions of captures of individual species were skewed.

Captures of aquatic frogs (*Litoria dahlii*), arboreal frogs (*L. rothii*, *L. bicolor* and *L. rubella*) and froglets (*Ranidella bilingua*) were made predominately at locations closely associated with perennial or ephemeral waterbodies. Notably, *Litoria dahlii*, *L. rothii* and *L. bicolor* seldom were captured elsewhere.

The greatest numbers of ground hylids, narrow mouthed and wide mouthed burrowing frogs, and toadlets were captured at terrestrial locations; but significant collections of these groups also were made in close proximity to waterbodies.

Table (5.2); The number of frogs captured[1] within each broad classification of sampling locations.

SPECIES	CLASSIFICATION OF SAMPLING LOCATIONS		
	WATERBODIES	EPHEMERAL WATERBODIES	TERRESTRIAL
Litoria dahlii	137	488	20
L. rothii	168	42	3
L. bicolor	180	112	10
L. rubella	63	126	30
L. pallida	78	87	83
L. inermis	18	42	66
L. nasuta	50	26	72
L. tornieri	19	-	124
L. wotjulumensis	1	-	12
Cyclorana australis	172	1	257
C. longipes	24	11	42
Limnodynastes ornatus	19	7	77
L. convexiusculus	1	8	24
Notaden melanoscaphus	32	25	51
Uperoleia inundata	10	24	91
Ranidella bilingua	39	8	29
SPECIES POOLED	1,001	1,007	991

Table (5.3); Number of frogs in each of seven faunal groupings captured at sampling locations broadly classified according to the presence of water.

	CLASSIFICATION OF SAMPLING LOCATIONS			
FAUNAL GROUP	WATERBODIES	EPHEMERAL WATERBODIES	TERRESTRIAL	TOTAL
Aquatic Frogs	137 (21.2)*	488 (75.6)	20 (3.1)	645
Arboreal Frogs	411 (56.0)	280 (38.1)	43 (5.8)	734
Ground Hylids	166 (24.4)	155 (22.8)	357 (52.6)	678
Wide-mouthed, Burrowing Frogs	216 (33.5)	27 (4.1)	400 (62.2)	643
Narrow-mouthed, Burrowing Frogs	32 (29.6)	25 (23.1)	51 (47.2)	108
Toadlets	10 (8.0)	24 (19.2)	91 (72.8)	125
Froglets	39 (51.3)	8 (10.5)	29 (38.1)	76
Pooled Groups	1,011 (33.5)	1,007 (33.4)	991 (32.9)	3,009

* = data expressed as percentages of totals within groups

This result does not reflect the importance of waterbodies as foraging habitats for these groups. The data in Table (5.4) show that the greater component of collections of the four groups comprised adult frogs in reproductive condition and, in the case of Cyclorana australis, juveniles. These frogs aggregate near waterbodies to breed, or to disperse from the larval habitat respectively.

The results presented so far show that all of the 16 species studied were associated with waterbodies during the wet seasons for feeding and/or breeding purposes. Investigation of patterns of spatial and temporal distribution, and abundance of frogs at sampling locations, is necessary to predict which species forage in or near waterbodies.

5.1.3; THE MAGELA CREEK FLOODPLAIN AND NANKEEN BILLABONG.

The numbers of each species caught at all sampling stations on the Magela Creek floodplain on specific dates are shown in Table (5.5). Changes in patterns of distribution and abundance of frogs in the vicinity of Nankeen Billabong were determined, to a large extent, by great changes in water levels during the sampling period.

Gauge - board readings of water levels at nearby Jabiluka Billabong are shown in Figure (5.1) for the entire study period. The first flush of floodwaters filled Nankeen Billabong and overflowed onto the surrounding floodplain in late December 1981. Water levels continued to rise, slowly at first, then rapidly during the period 26/2/82 - 12/3/82 when an increment of 60 cm was recorded

Table (5.4); Categorisation of all frogs captured, in faunal groupings, according to size, sex and activity immediately prior to capture.

	CATEGORY								
FAUNAL GROUP	UNKNOWN	STAGE 42	J	M	MC	F	FG	FGA	TOTAL
Aquatic Frogs	120 (18.6)*	7 (1.0)	149 (23.1)	146 (22.6)	30 (4.6)	143 (22.1)	35 (5.4)	15 (2.3)	645
Arboreal Frogs	74 (10.0)		101 (13.7)	333 (45.3)	57 (7.7)	59 (8.0)	99 (13.5)	11 (1.5)	734
Ground Hylids	15 (2.2)	4 (0.6)	51 (7.5)	386 (56.9)	95 (14.0)	60 (8.8)	46 (6.7)	21 (3.0)	678
Wide-mouthed Burrowing Frogs	20 (3.1)	40 (6.2)	237 (36.8)	126 (19.6)	91 (14.1)	69 (10.7)	42 (6.5)	18 (2.8)	643
Narrow-mouthed Burrowing Frogs	5 (4.6)		1 (0.9)	75 (69.4)	8 (7.4)	4 (3.7)	15 (13.8)		108
Toadlets	5 (4.0)			64 (51.2)	28 (22.4)	15 (12.0)	12 (9.6)	1 (0.8)	125
Froglets	13 (17.1)	1 (1.3)		10 (13.1)	38 (50.0)	6 (7.9)	7 (9.2)	1 (1.3)	76
Pooled Groups	252 (8.3)	52 (1.7)	539 (17.9)	1140 (37.8)	347 (11.5)	356 (11.8)	256 (8.5)	67 (2.2)	3009

* = data expressed as percentages of totals within groups.

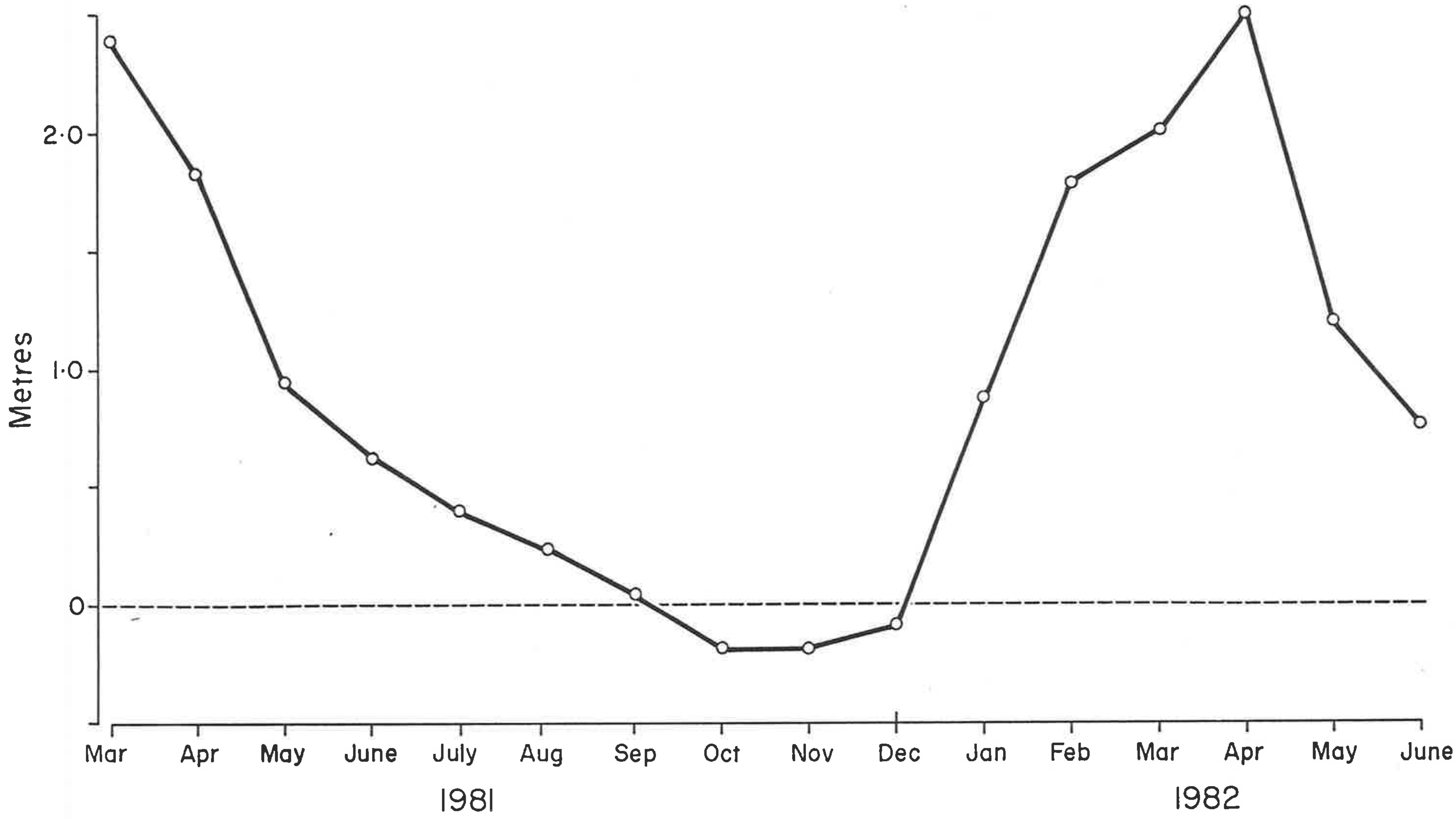
for Nankeen Billabong. During this period, station A on the western levee bank of the billabong was inundated, and was not fully exposed again until 16/4/82.

These changes in water level were accompanied initially by an intense bloom in the biomass of macrophytes and emergent sedges and grasses on the floodplain. As water levels receded towards the end of the wet season, much of the vegetation began to senesce, forming floating mats of decaying material. Within Nankeen Billabong, the superficial effects of changes in water level were not so apparent, with water lilies (Nymphaea spp.) increasing in abundance along the margins.

Table (5.5); Numbers of frogs captured at all sampling sites on the Magela Creek floodplain during the study period.

SPECIES	27/3	20/4	10/11	22/11	24/11	26/11	10/12	17/12	28/12	10/1	12/1	13/1	22/1	7/2	8/2	26/2	27/2	12/3	13/3	9/4	16/4	TOTAL
	1981									1982												
L. dahl	63	87		15	22	52		5	31	19	50		22	40		25	20	2	41	6	22	522
L. roth			1	2	14	17		14	29		1			12	14	12	11	16		15	10	168
L. bico			22		19		25	18	51					13	11	11	8	20		16	14	224
L. rube					1	2	2		1					6	28	1				1		42
L. pall						1									2							3
L. iner						4										3						7
L. nasu			1	1	1	12		8	2			1			6	3					3	38
L. torn																						
L. wotj																						
C. aust															1							1
C. long				1	6	3		1														11
L. orna																						
L. conv						8																8
N. mela																						
U. inun																						
R. bili															5	12	1					18
TOTAL	63	83	24	19	59	99	27	46	114	19	51	1	22	71	68	67	40	38	41	38	49	1055

Figure (5.1); Gauge-board readings of water level at Jabiluka Billabong on the Magela Creek floodplain during the study period.


2·0
1·0
0
Metres
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
1981
1982

Patterns of distribution and abundance of the frog fauna varied with the changing physical environment. The aquatic frog, *Litoria dahlii*, was not sighted on the floodplain until late November 1981, when heavy rains brought them to the surface from their aestivation sites in deep cracks in the floodplain surface (pers. obs.). As seasonal rains further moistened the plains, *L. dahlii* appeared to disperse overland towards Nankeen Billabong and to flooded buffalo wallows. These wallows, buffalo pug marks and natural depressions were utilised as spawning sites by ground hylids, *Cyclorana longipes* and *Limnodynastes convexiusculus* adjacent to the floodplain margin.

Litoria dahlii, *L. rothii*, *L. rubella*, *L. pallida*, *L. nasuta* and *Ranidella bilingua* were captured at similar sites further out onto the floodplains on the banks of Nankeen Billabong. Until late February 1982, sections of these levee banks acted as refuges from rising flood waters for large numbers of adults of *R. bilingua* and *L. nasuta* and juveniles of *L. nasuta* and *L. pallida*.

After more than one month of inundation, portions of the levee were exposed at Station A, and several specimens of *L. nasuta* were captured. It seems most probable that while the banks were submerged these frogs remained in flooded vegetation.

The arboreal species *L. rothii*, *L. bicolor* and *L. rubella*, were often found foraging on the exposed banks of Station A, and were visibly common in the foliage of *Pandanus aquaticus* and *Barringtonia acutangula* growing on the margins of Nankeen Billabong. It appears that L. rothii and L. bicolor were most common on B. acutangula and P. aquaticus respectively. L. rubella was encountered rarely: the greater part of the sample consisting of 34 juveniles obtained from a single small (P. aquaticus) palm.

The abundance of arboreal frogs in vegetation over-hanging the waters of Nankeen Billabong was demonstrated by the defoliation of several P. aquaticus rosettes to reveal the frogs sheltering within. Counts ranged from 5 to 13 individuals of L. bicolor per rosette; many clumps of P. aquaticus on the billabong margins contained more than 50 rosettes.

During the sampling period there was evidence of dispersal of L. bicolor upon the floodplain. This species was only encountered in foliage along the billabong margins until late February, when males were found calling on exposed stems of emergent grasses and sedges away from the billabong. By April, specimens were encountered regularly on emergent vegetation adjacent to the receding flood water margins.

Juveniles of L. dahlii appeared at Station C in early January 1982 amongst flooded vegetation. In contrast to the adults, the juveniles were observed readily during the day swimming amongst or floating on partially submerged vegetation. For the remainder of the wet season, large numbers of L. dahlii were encountered on the floodplain and billabong margins, and up to 2.5 km offshore amongst emergent vegetation. In open waters, specimens were sighted floating upon (Nymphaea spp.) lilies and sheltering on floating mats of decaying vegetation. Adjacent to the floodwater margins, the frogs sheltered amongst emergent vegetation until dusk, when a movement to shoreline vegetation was evident. This species seldom was sighted more than a few metres from water.

The various species captured in different microhabitats at Nankeen Billabong, and upon the adjacent floodplain, are shown in Figure (5.2).

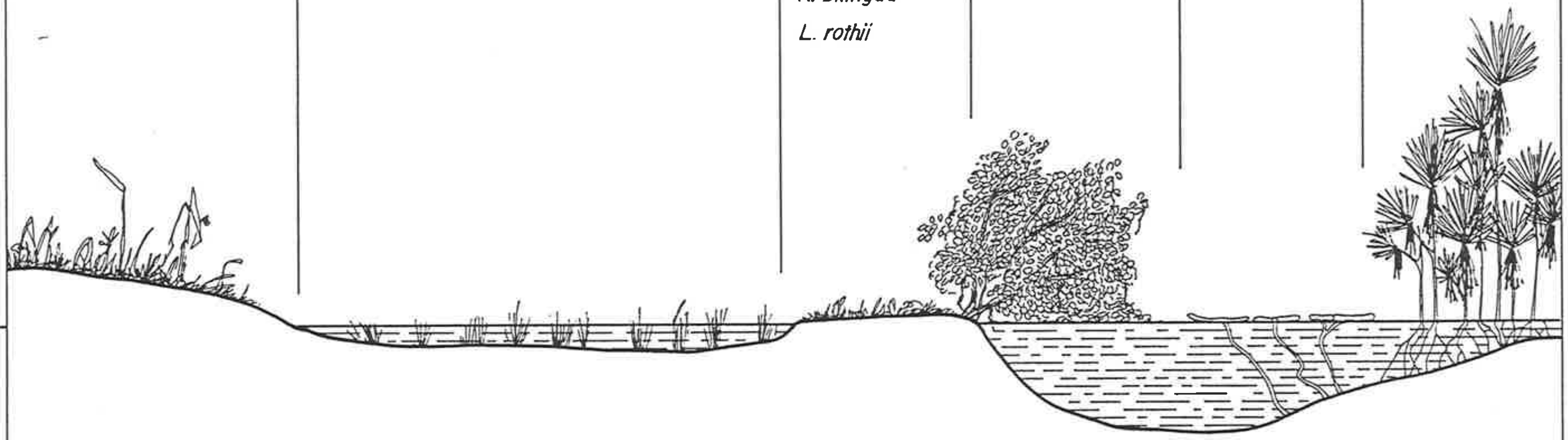
5.1.4; THE TAILINGS DAM

The waste water level in the Tailings dam rose during the 1981 - 1982 sampling period, as a result of rainfall and input of water from the Ranger uranium mine processing plant. Consequently, large areas previously inhabitated by frogs became inundated. Data on numbers and species of frogs caught at this sampling location during the study period are shown in Table (5.6).

In January 1981, water covered approximately 25% of the area within the confines of the Tailings dam walls. Speargrass (Sorghum spp.), sedges, small saplings and shrubs had revegetated much of the remaining area. During this time, 14 species were either captured or heard calling inside the dam walls. Breeding aggregations of arboreal species (L. rothii, L. bicolor, L. rubella), ground hylids (L. pallida, L. nasuta, L. inermis, L. tornieri), toadlets (Uperoleia inundata), froglets (Ranidella bilingua), widemouthed burrowers (Cyclorana australis, C. longipes, Limno-

Figure (5.2); Diagrammatic representation of species captured in different microhabitats at Nankeen Billabong and upon the Magela Creek floodplain.

	FLOODPLAIN MARGIN	FLOODED PLAIN	EXPOSED BANK	*BARRINGTONIA*	*NYMPHAEA*	*PANDANUS*
ON VEGETATION		*L. bicolor*		*L. rothii* *L. bicolor* *L. rubella*		*L. bicolor* *L. rothii* *L. rubella*
ON GROUND OR WATER LEVEL	*L. dahlii* *L. nasuta* *R. bilingua*	*L. dahlii*	*L. dahlii* *L. bicolor* *L. nasuta* *R. bilingua* *L. rothii*		*L. dahlii* *L. bicolor*	
	FLOODPLAIN AND MARGINS		NANKEEN — BILLABONG			



dynastes convexiusculus, *L. ornatus*) and narrow-mouthed burrowers (*Notaden melanoscaphus*) were encountered at puddles derived from rain or in the main body of waste water. Despite a careful search, *L. dahlii* was not found in the Tailings dam during the 1981 sampling period. However, many specimens were obtained several hundred metres away in Retention pond # 1.

During the 1981 - 1982 wet season, there was a shift in the diversity, abundance and population structure of frog samples taken in the Tailings dam. The water level rose to such an extent that at the conclusion of the study more than 70% of the area within the dam walls was inundated. Vegetation cover in the remaining area was sparse.

Notaden melanoscaphus, *U. inundata*, *L. ornatus* and *C. longipes* were found at station A until this area became inundated in late December. Habitat destruction presumably contributed to the absence of these terrestrial species from subsequent samples. *Cyclorana australis* was not encountered in collections made after 5/2/82, and numbers of ground hylids taken in samples also declined.

On several occasions, individuals of *C. australis*, ground hylids and *U. inundata* were observed crossing the dam walls, inferring dispersal to outlying areas. Also, in early January 1982, several dead sub-adults of *C. australis* and *C. longipes* were found floating in a newly inundated area of the dam. It is probable that the rising water levels either drowned fossorial or terrestrial species, or else caused them to vacate the Tailings dam. *Litoria dahlii* was first sighted

Table (5.6); Number of frogs of 16 species captured at the Tailings Dam during the study period.

	1981									1982									
SPECIES	10/1	20/1	22/1	22/2	2/11	24/11	4/12	14/12	23/12	10/1	20/1	22/1	6/2	25/2	12/3	30/3	31/3	14/4	TOTAL
L. dahl									12	8	11		13	15		7	16	14	96
L. roth									1	1					1	1	1		5
L. bico										1			7						8
L. rube	1	1						2											4
L. pall		7	16				7		3	5	4	1	1						44
L. iner						2					2								4
L. nasu			5		1	2	5	6	1	3						1	1	1	26
L. torn		2	4										7						13
L. wotj																			
C. aust			1			1	4	1		3	5	5	1						21
C. long		1							1										2
L. orna					1						1								2
L. conv												1							1
N. mela				27			1												28
U. inun						2	2		1										5
R. bili		12								5	1		4						22
SPECIES POOLED	1	23	26	27	2	7	19	9	19	26	24	7	33	15	1	9	18	15	281

in early December 1981 in large numbers. This species probably colonised the dam by moving upstream from Retention pond # 1. Subsequently it became the most dominant species (in numbers and biomass) in collections made at all stations. *Litoria dahlii* spawned in the waters of the Tailings dam in early December, and large numbers of new recruits to the population were noted from February, 1982 until termination of sampling in April 1982.

The Tailings dam appeared to offer an ideal habitat for *L. dahlii* during the sampling period. Prey in the form of aquatic Odonata, Hemiptera and Coleoptera were abundant in the waterbody. The absence of predatory fish, and the rarity of other vertebrates at this site, would also be advantageous for the growth and reproduction of *L. dahlii*.

Towards the end of the sampling period, the suite of species encountered in the Tailings dam was similar to that found in billabong habitats. The arboreal species, *L. rothii*, *L. bicolor* and *L. rubella*, were found in small numbers on inundated and littoral vegetation such as speargrass and small saplings. *Litoria dahlii* was found in large groups amongst inundated vegetation, and on the margins of the water body. On the shores of the water body, *Ranidella bilingua*, *Litoria nasuta* and *L. pallida* were encountered with *Limnodynastes convexiusculus*. No frogs were found on the large expanses of bare earthworks or rock walls of the Tailings dam in that period.

5.1.5; JABIRU EAST TOWNSITE AND ROADS.

During both the 1980 - 1981 and 1981 - 1982 wet seasons, collections of frogs were made along the roads, and also in the sewerage treatment works at the Jabiru East townsite. The numbers and identifications of the frogs captured at these locations are shown in Tables (5.7) and (5.8).

Frogs were captured crossing roads from the beginning of the wet season until the termination of the sampling period in early April. The largest collections were made adjacent to ephemeral or perennial water bodies. A proportion of these frogs presumably were adults migrating for spawning purposes and juveniles dispersing from larval habitats in the water bodies. The greatest numbers of frogs were captured during or immediately following heavy rain, especially in the first few hours of darkness. Whether similar patterns of movement occur in natural habitats is unknown, but highly probable. Of particular note was the fact that both adult and juveniles of *Litoria dahlii* were captured crossing roads only adjacent to the sewerage treatment works and Coonjimba Swamp.

Cyclorana australis, *Limnodynastes ornatus* and *C. longipes* were the frogs most frequently encountered on roadways. Numbers of ground hylids also were collected regularly. Collections of *L. rubella*, *Uperoleia inundata* and *Notaden melanoscaphus* were infrequent and few in number. *Ranidella bilingua* was not collected or observed on roadways during the study period.

Table (5.7); Numbers and species of frogs captured on Townsite roads during two wet seasons.

SPECIES	1981									1982				
	23/1	26/1	31/1	2/2	3/11	13/11	20/11	3/12	22/12	21/1	15/2	11/3	15/4	TOTAL
<u>Litoria dahlii</u>								1	2	4				7
<u>L. rothii</u>														
<u>L. bicolor</u>														
<u>L. rubella</u>					1			1	2					4
<u>L. pallida</u>		1			3			2	1		4		2	13
<u>L. inermis</u>		1		2	2			1		1	1	1	1	10
<u>L. nasuta</u>			2		3			2	2	1	3			13
<u>L. tornieri</u>								1						1
<u>L. wotjulumensis</u>					1								1	2
<u>Cyclorana australis</u>	15	6	18	5	7	3	3	9	6	22	8	4	6	112
<u>C. longipes</u>	3	2	2	1	4				2	1	1			16
<u>Limnodynastes ornatus</u>	4	1	8	2	6	1		1		5	1	1		30
<u>L. convexiusculus</u>											1		1	2
<u>Notaden melanoscaphus</u>					1			1	1					3
<u>Uperoleia inundata</u>		1	3						3	1				8
<u>Ranidella bilingua</u>														
SPECIES-POOLED	22	12	33	10	28	4	3	19	19	35	19	6	11	221

Table (5.8); The numbers and species of frogs captured at the Jabiru sewerage treatment works during the study period.

	1981						
SPECIES	JAN 29	NOV 3	NOV 20	DEC 3	DEC 9	DEC 22	TOTAL
Litoria dahlii		2			2		4
L. rothii	10	1					11
L. bicolor							
L. rubella	2		1	2			5
L. pallida							
L. inermis							
L. nasuta							
L. tornieri							
L. wotjulumensis							
Cyclorana australis	56	19	2		12	3	92
C. longipes		6		7			13
Limnodynastes ornatus		1		1			2
L. convexiusculus							
Notaden melanoscaphus							
Uperoleia inundata						1	1
Ranidella bilingua							
SPECIES POOLED	68	29	3	10	12	6	128

Cyclorana australis, C. longipes, Limnodynastes ornatus, Litoria pallida, L. inermis and L. rubella commonly were found foraging in or on the edge of the area illuminated by street lights along roadways. These frogs often were observed feeding on alate isopterans, lepidopterans, coleopterans and other arthropods attracted to the light. Some individuals were so distended with food that partially ingested insects protruded from their mouths. Large numbers of frogs also were captured in the grounds of the Jabiru sewerage treatment works (Figure 4.4).

However, most species including, C. australis, C. longipes and several ground hylids, were utilising the works only for spawning. During the 1981 - 1982 wet season, small populations of L. dahlii, L. rothii and L. rubella were resident in and around ponds A, B and C at the works. Recently-metamorphosed juveniles of these three species were observed emerging from the ponds in January 1982. An outflow of effluent from the treatment works into Retention pond # 1 (see Figure 4.4) formed a large expanse of inundated grassland linking the two sites. Large numbers of L. nasuta, L. pallida and L. inermis were captured in this area, together with L. dahlii and L. rubella. Many individuals of L. dahlii also were sighted along the margins of the retention pond adjacent to the effluent overflow.

It is probable that L. dahlii colonised the Tailings dam and sewerage treatment works via the temporary corridors linking these water bodies to Retention pond # 1 and Coonjimba Swamp. The proximity of these water bodies to Magela Creek is illustrated in Figure (4.2).

5.1.6; DRY SEASON ACTIVITY.

A brief visit was made to Jabiru in August, 1981 to investigate the existence of any frog activity. Several species were active in the area. Those captured, and locations sampled, are shown in Table (5.9).

Captures and sightings of frogs were confined to the immediate vicinity of natural and artificial water bodies in the area. No frogs were found in woodland and grassland areas despite intensive searching and use of pit-fall traps.

Large numbers of *Litoria nasuta*, *L. inermis*, *L. pallida*, *L. wotjulumensis* and *L. tornieri* were sighted along the sparsely vegetated margins of Retention ponds # 1 and # 2, the Tailings dam and Georgetown Billabong. Just before dawn many of these frogs were observed sitting in shallow water prior to returning to daytime refuges. At the billabongs, frogs sheltered in deep cracks in dried mud or in hollows beneath logs and leaf litter. In Retention pond # 1, however, the frogs sheltered in crevices in the rock walls around the water body.

No arboreal species were sighted during the sampling period, and fossorial species were rare. Single specimens of *L. ornatus* and *U. inundata* were sighted on the margins of the Tailings dam, and one individual of *C. longipes* was uncovered from a shallow burrow in the sandy bed of Magela Creek. Several specimens of *R. bilingua* also were dug from moist sand in the undercut banks of Magela Creek, and from the margins of

Table (5.9); Numbers of different species captured during a dry season sampling period.

Date	Time (hrs)	Location	Species captured	No. captured
24/8/81	2200	Retention pond No. 1	*L. nasuta* *L. inermis* *L. pallida*	6 5 1
25/8	1945	Retention pond No. 1	*L. inermis*	14
26/8	0100	Retention pond No. 1	*L. inermis* *L. pallida* *L. nasuta*	13 8 1
26/8	0410	Retention pond No. 1	*L. nasuta* *L. inermis* *L. pallida*	8 7 12
26/8	2100	Tailings Dam	*L. wotjulumensis* *L. inermis* *U. inundata* *L. pallida*	4 13 1 14
26/8	2330	Georgetown Billabong	*L. inermis* *L. pallida* *L. tornieri* *L. nasuta*	3 3 1 1
27/8	0100	Retention pond No. 2	*L. inermis* *L. pallida*	2 1
27/8	1400	Georgetown Billabong	*C. longipes*	1
28/8	1300	Ja Ja Billabong	*L. inermis*	2
28/8	1600	Magela Creek	*R. bilingua*	5

ponds in the creek bed. Individuals of this species also were heard calling from amongst grass tussocks in the Tailings dam. *Litoria dahlii* also was active, although comparatively few were sighted, and not one was captured. They were observed on the shore and marginal shallows of Jabiluka Billabong at night. One was found in Retention pond #2.

It is clear that the presence of perennial water-bodies in the area permits dry-season activity of anurans. Therefore, artificial water bodies such as the Tailings dam have great potential as dry season habitats and may attract frogs to the immediate area for shelter and foraging.

5.2.1; THE MAGELA CREEK AND GULUNGUL CREEK TRANSECTS.

5.2.2; CLASSIFICATION OF HABITAT TYPES ALONG TRANSECTS.

The vehicle tracks selected for use as transects were routed for engineering convenience rather than reflecting natural boundaries between local floral assemblages and drainage systems. Delineation of habitat types along the transects was further complicated by the spatial and temporal patchiness of the floral assemblages and water regime in the area. For example, speargrass cover (*Sorghum* spp.) along the transects varied from being sparse to dense in a period of several months. Low-lying sections of the transects became inundated for long periods, whilst others showed no signs of surface water for the entire study period.

Notes on soil and floral assemblages produced for stations along the Magela and Gulungul Creek transects, together with the resultant classification into habitat types, are shown in Tables (5.10) and (5.11). The five habitat types recognised are as follows:

5.2.2.1; Habitat Type # 1 - OPEN WOODLANDS, GRAVELLY LATERITIC SOIL.

Well-drained areas of open woodland with stony or gravelly lateritic soil were placed in this category. Ground litter was generally sparse, dry and comprised mainly of leaves. The tussock grasses, *Sorghum* sp. (Speargrass), *Heteropogon triticeus* (Queensland speargrass) and *Panicum* sp., were the most notable feature of the understorey. The upper storey consisted predominantly of *Eucalyptus tetrodonta* and *E. miniata* interspersed with plants such as *Planchonia* sp., *Petalostigma pubescens* and *Livistona humilis*, which are indicative of drier habitats.

5.2.2.2; Habitat Type # 2 - OPEN WOODLAND, SANDY SOIL.

Areas placed in this category were characterised by an open woodland assemblage with orange or yellow sandy soil. Speargrass tussocks were the most notable feature of the understorey, with a wide variety of sedges, grasses and herbs also present. These included: *Rhynchospora longiseta* (grass), *Fimbristylis* sp. (sedge), *Sowerbaea alliacea* (lily) and the perennial herbs, *Xyris complanata*, *Scleria* sp. *Planchonia* sp., *Pandanus* sp., *Grevillea* sp., *Acacia* sp. and *Banksia dentata* were present amongst taller *Melaleuca nervosa* and *Eucalyptus* species comprising an upper storey.

Table (5.10); Classification of habitat types at stations along the Magela Creek Transect.

Stn.	Soil	Ground Litter	Upper storey	Under storey	Classfn.
1	Orange-yellow Sand	Monocot	Eucalyptus	Grasses, sedges	2
2	Gravel, sand	Leaves	Eucalyptus	Sorghum	2
3	Sand	Leaves, Monocot	Eucalyptus	Sedges	2
4	Dark sand	Monocot	Eucalyptus	Grasses, sedges	2
5	Dark sand	Monocot	Pandanus, Grevillea	Sedges, grasses	4
6	Dark sand	Monocot	Pandanus, Grevillea	Sedges, grasses	4
7	Dark sand	Monocot	Pandanus, Grevillea	Sedges	4
8	Dark sand	Monocot	Grevillea	Sedges, grasses	4
9	Dark sand	Leaves	Pandanus	Sedges, grasses	3
10	Dark sand	Algal mat	Pandanus	Sedges, grasses	3
11	Orange-Yellow sand	Leaves, Monocot	Eucalyptus	Petalostigma, Sorghum	2
12	Dark sand	Algal mat	-	Sedges, grasses, herbs	4
13	Gravel	Leaves	Eucalyptus	Petalostigma, Sorghum	1
14	Gravel	Leaves	Eucalyptus	Petalostigma,	1
15	Stony gravel	Leaves, Monocot	Eucalyptus, Livistona	Petalostigma, Sorghum	1
16	Sand	Leaves, Monocot	Eucalyptus, Livistona	Sorghum, sedges	2
17	Stone, sand	Monocot, leaves	Eucalyptus, Grevillea	Sorghum	2
18	Gravel	Leaves	Eucalyptus	Sorghum	1
19	Gravel	Leaves	Eucalyptus	Petalostigma, Sorghum	1
20	Sand, gravel	Leaves	Eucalyptus	Petalostigma, Sorghum	1
21	Sand, gravel	Leaves	Eucalyptus	Petalostigma, Sorghum	1
22	Gravel	Leaves	Eucalyptus	Petalostigma, sedges	1
23	Dark sand	Monocot	-	Sedges, grasses	4
24	Sand	Monocot	Grevillea, Pandanus	Planchonia, grasses	
25	Dark sand	Monocot	Eucalyptus, Acacia	Sedges, grasses	2

Classifications:
1 Open Woodland, Gravelly Lateritic soil
2 Open Woodland, Sandy soil.
3 Sedge/grassland, Sandy soil.
4 Swamp sedge/grassland, Black soil.

Table (5.11); Classification of habitat types along the Gulungul Creek Transects.

Stn.	Soil	Ground Litter	Upper storey	Under storey	Classfn.
	TRANSECT I				
1	Yellow sand	Monocot	*Eucalyptus*, *Melaleuca*	*Sorghum*, sedges	2
2	Dark sand	Monocot	*Pandanus*, *Grevillea*	Sedges, grasses	3
3	Dark sand	Monocot	*Pandanus*, *Grevillea*	Sedges, grasses	3
	TRANSECT II				
1	Lateritic gravel	Leaves, Monocot	*Eucalyptus* woodland	*Petalostigma*, *Sorghum*	1
2	Lateritic gravel	Leaves, Monocot	*Eucalyptus* woodland	*Planchonia*, *Sorghum*	1

Ground litter generally was abundant and consisted of both monocot remnants and leaves. Areas in habitat type # 2 were considered to be well drained.

5.2.2.3; Habitat Type # 3 - SEDGE/GRASSLAND, SANDY SOIL

This category comprised habitats dominated by expanses of low sedge and grass tussocks in low lying, poorly drained areas. Soils in these areas were moist, sandy and generally dark in colour.

Larger plants, such as *Pandanus* sp., *Grevillea* sp., *Melaleuca nervosa* and *Banksia dentata*, were present but relatively scarce in comparison with other habitat types.

The densely packed tussocks of vegetation in habitats of this type included *Fimbristylis littoralis*, *F. punctata* and *Leptocarpus shultzii* (sedges), *Rhynchospora longiseta* and *Eriachne* sp. (grasses) and *Eriocaulon spectable* (herb). Ground litter comprised a moist mat of monocot remnants and, in wetter areas, algae.

Areas in this category often were inundated to depths of up to several centimetres for long intervals during the wet seasons.

5.2.2.4; Habitat Type # 4 - SWAMP SEDGE/GRASSLAND, BLACK SOIL.

Swamp margins with black sandy soil were placed in this category. *Melaleuca leucadendron* and *Pandanus* sp., which are able to withstand partial inundation for long periods, were present in small stands in such areas.

Speargrass was absent and the ground was covered by densely packed tussocks of Fimbristylis spp. and Leptocarpus schultzii (sedges), Eriocaulon spectable, Xyris paludosum and Borreria australiana (herbs) and grasses such as Rhynchospora longiseta. The insectivorous plant, Drosera peltata, also occurred in exposed areas.

Ground litter consisted of a moist mat of monocot remnants overgrown with algae. Areas in habitats type # 4 were inundated to various degrees for most of the wet seasons.

5.2.2.5; Habitat Type # 5 - PAPERBARK SWAMP.

Stands of closed Melaleuca leucadendron forest on the low lying margins of creeks were included in this category. During the wet seasons, paperbark swamps are inundated directly by floodwaters or indirectly through back flow from creek channels. Emergent macrophytes, such as the grass Pseudoraphis spinescens, and aquatic macrophytes form floating mats beneath the paperbark canopy.

The soils in these swamps are dark alluvial clays which, during the dry seasons, are covered with a litter of Melaleuca bark and leaves.

5.2.3; CALCULATION OF THE AREA EXAMINED IN EACH HABITAT TYPE.

To determine the relative abundances of different species in the habitats examined, it was necessary to calculate the area examined in each habitat type.

Assuming a torch beam width of 50 cm, the area examined in each habitat type during all traverses of the transect was estimated as being:-

(0.5 m X number of traverses X transect length in each habitat type).

Partitioning of the Magela Creek and Gulungul Creek transects by habitat type and the area examined in each habitat type are shown in Tables (5.12) and (5.13).

5.2.4; THE MAGELA CREEK TRANSECT.

The numbers of frogs of 16 species captured along the Magela Creek transect during each of 10 traverses are shown in Table (5.14). When population censusses were carried out along this transect, all frogs sighted were included in counts. These sightings are recorded in Table (5.15). Data have been pooled for all nine censusses. Estimates of relative abundance for different species in each habitat type were based on these censusses, and are shown in Table (5.16).

Sightings of frogs were not uniformly distributed within and between habitat types along the Magela Creek transect.

Table (5.12); Total area examined in each habitat type recognised along the Magela Creek transect during 9 traverses.

Habitat Type	Transect Length m	Transect Area (one traverse) m^2	Total area examined (all traverses) m^2
1	900	450	4,050
2	1,650	825	7,425
3	300	150	1,350
4	1,200	600	5,400

Table (5.13); Total area examined in each habitat type recognised along the Gulungul Creek transects during 10 traverses. (Transects I and II pooled.)

Habitat Type	Transect Length m	Transect Area (one traverse) m^2	Total area examined (all traverses) m^2
1	300	150	1,500
2	45	22.5	225
3	555	277.5	2,775

		1981					1982					
CODE	SPECIES	6/11	1/12	8/12	15/12	24/12	19/1	4/2	23/2	2/4	16/4	TOTAL
S1	*Litoria dahlii*	1										1
S2	*L. rothii*											
S3	*L. bicolor*									2		2
S4	*L. rubella*											
S5	*L. pallida*		1		2	1		2	1	9	6	22
S6	*L. inermis*	1	1				1		2		3	8
S7	*L. nasuta*	3	1			3	10		1	4	2	24
S8	*L. tornieri*											
S9	*L. wotjulumensis*											
S10	*Cyclorana australis*	5	7	10	4	9	6	5	4		1	51
S11	*C. longipes*	1	2	3	1	1	1	1				10
S12	*Limnodynastes ornatus*	3	6	5	1	2	4		5	3	2	31
S13	*L. convexiusculus*			1						1	4	6
S14	*Notaden melanoscaphus*		1	2	1	1	1	3			2	11
S15	*Uperoleia inundata*				1	5	5	4		1	1	17
S16	*Ranidella bilingua*					1	3					4
	SPECIES POOLED	14	19	21	10	23	31	15	13	20	21	187

Table (5.14); Numbers of frogs of 16 species captured along the Magela Creek transect during each of 10 traverses.

Table (5.15); Numbers of frogs sighted in each of four habitat types recognised along the Magela Creek transect. (data pooled for 9 sampling nights.)

		HABITAT TYPE				
CODE	SPECIES	1	2	3	4	Habitats Pooled
S1	*Litoria dahlii*				2	2
S2	*L. rothii*				1	1
S3	*L. bicolor*				2	2
S4	*L. rubella*			5		5
S5	*L. pallida*		10	12	1	23
S6	*L. inermis*		12	5	1	18
S7	*L. nasuta*	1	6	7	5	19
S8	*L. tornieri*		1			1
S9	*L. wotjulumensis*			1		1
S10	*Cyclorana australis*		35	4	7	46
S11	*C. longipes*	2	4	3		9
S12	*Limnodynastes ornatus*	4	13	5	4	26
S13	*L. convexiusculus*		3	2	2	7
S14	*Notaden melanoscaphus*	2	6	1		9
S15	*Uperoleia inundata*		4	10		14
S16	*Ranidella bilingua*				1	1
	SPECIES POOLED	9	94	55	26	184

Table (5.16); Estimates of number of frogs sighted per square metre examined (x 1000)in each of four habitat types recognised along the Magela Creek transect. (data pooled for 9 sampling nights.)

CODE	SPECIES	HABITAT TYPE 1	2	3	4	Habitats Pooled
S1	*Litoria dahlii*				1.5	0.1
S2	*L. rothii*				0.7	0.1
S3	*L. bicolor*				1.5	0.1
S4	*L. rubella*			0.9		0.3
S5	*L. pallida*		1.3	2.2	0.7	1.2
S6	*L. inermis*		1.6	0.9	0.7	1.0
S7	*L. nasuta*	0.2	0.8	1.3	3.7	1.0
S8	*L. tornieri*		0.1			0.1
S9	*L. wotjulumensis*			0.2		0.1
S10	*Cyclorana australis*		4.7	0.7	5.2	2.5
S11	*C. longipes*	0.5	0.5	0.6		0.5
S12	*Limnodynastes ornatus*	1.0	1.8	0.9	3.0	1.4
S13	*L. convexiusculus*		0.4	0.4	1.5	0.4
S14	*Notaden melanoscaphus*	0.5	0.8	0.2		0.5
S15	*Uperoleia inundata*		0.5	1.9		0.8
S16	*Ranidella bilingua*				0.7	0.1
	SPECIES POOLED	2.2	12.7	10.2	19.3	9.9

Poorly-drained areas with sandy soils produced the greatest number and highest diversity of sightings of different species. Frogs were sighted only rarely in areas of open woodland with well-drained, gravelly soils (habitat type # 1). In such areas, burrowing species such as *Limnodynastes ornatus* and *Notaden melanoscaphus* were sighted most commonly. It should also be noted here that the toadlet, *Uperoleia inundata*, occasionally was heard calling in habitat type # 1 during periods of heavy rainfall, although this species was not sighted on the transect in this habitat.

As a group, ground hylids were the most commonly sighted frogs, being found in relatively large numbers in poorly drained areas with sandy soils (habitat types # 2, # 3 and # 4). A single specimen of the highly mobile species, *Litoria nasuta*, was sighted in habitat type # 1.

Few aquatic frogs, arboreal frogs and froglets were sighted along the transect, occurring only amongst flooded sedges and grasses in swampland (habitat type # 4).

Cyclorana australis was the most commonly sighted species along the transect, with adults being encountered only in the well-drained areas of habitat type # 2, but juveniles also being found in areas of sedge and grassland prone to inundation.

Sightings of other wide-mouthed, burrowing frogs also were widespread throughout the habitat types along the transect, particularly of *Limnodynastes ornatus* which was found commonly in all four habitats.

The species sighted in each habitat type recognised along the Magela Creek transect are shown in order of abundance in Figure (5.3).

5.2.5; THE GULUNGUL CREEK TRANSECT

The numbers of frogs captured along, and in the vicinity of, transects # I and # II during the study period are shown in Table (5.17). Data have been pooled for both transects. During population censusses along the two transects, only those individuals actually captured were included in counts. The captures made during censusses have been pooled for transects # I and # II, and are shown in Table (5.18). Estimates of relative abundance for different species, in each of three habitat types recognised along the transects, are presented in Table (5.19).

The main features of these results are similar to those outlined for the Magela Creek transect, with one major exception. Counts of frogs, per square metre examined, were greater for the Gulungul Creek transects despite the fact that only those frogs actually captured were included in censusses.

The numbers of frogs captured in areas of open woodland with well-drained, gravelly soils (habitat type # 1) were very low, consisting of single specimens of Cyclorana longipes, Notaden melanoscaphus and Uperoleia inundata and four individuals of Cyclorana australis.

The greatest density of frogs occurred at the small

Figure (5.3); Species of frogs sighted in each of four habitat types recognised along the Magela Creek transect.

SPECIES SIGHTED : IN ORDER OF ABUNDANCE				
C. australis (juv.) *L. nasuta* *L. ornatus* *L. convexiusculus* *L. dahlii* *L. bicolor* *L. pallida* *L. inermis* *L. rothii* *R. bilingua*	*L. pallida* *U. inundata* *L. nasuta* *L. ornatus* *L. inermis* *L. rubella* *C. australis* *C. longipes* *L. convexiusculus* *N. melanoscaphus* *L. wotjulumensis*	*C. australis* *L. ornatus* *L. inermis* *L. pallida* *L. nasuta* *N. melanoscaphus* *C. longipes* *U. inundata* *L. convexiusculus* *L. tornieri*		*L. ornatus* *N. melanoscaphus* *C. longipes* *L. nasuta* *U. inundata*
Swamp Inundated Sedges	Sedge / Grassland	Open Woodland Sandy Soil	Sedge / Grassland	Open Woodland Gravelly Lateritic Soil
HABITAT TYPE : 4	3	2	3	1

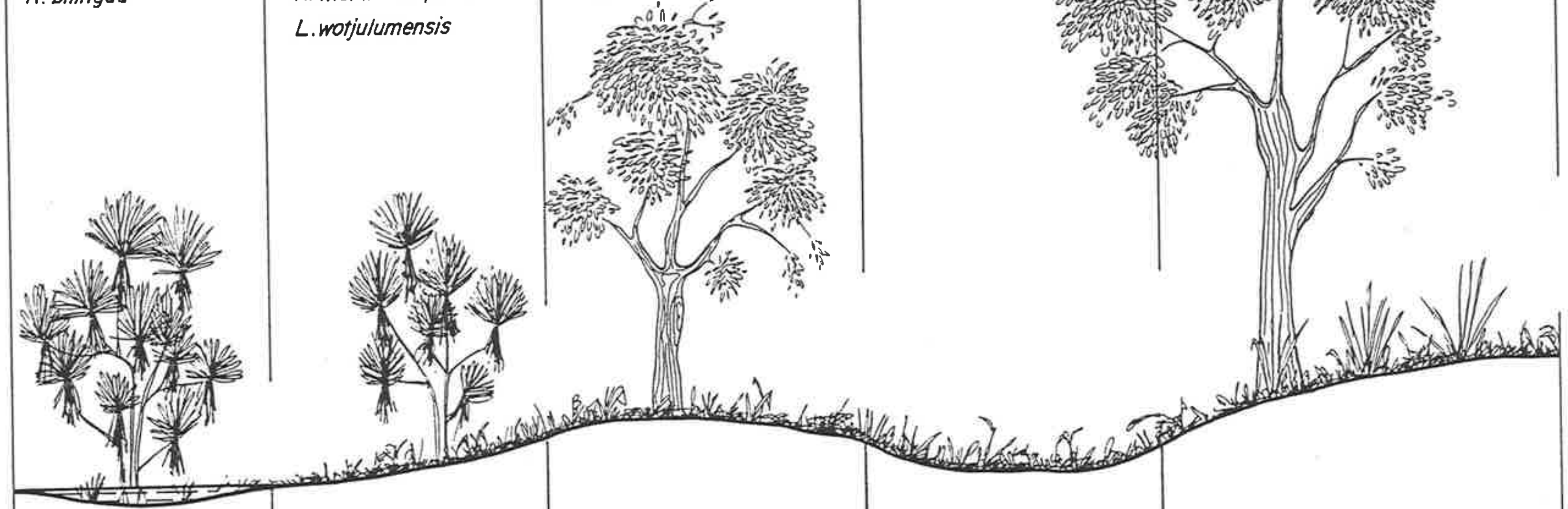


Table (5.17); Numbers of frogs of 16 species captured along and around the Gulungul Creek transects (I and II) during the study period.

CODE	SPECIES	1981						1982								
		5/11	12/11	2/12	9/12	16/12	25/12	22/1	25/1	30/1	4/2	24/2	11/3	1/4	13/4	TOTAL
S1	*Litoria dahlii*							1	4		9					14
S2	*L. rothii*															
S3	*L. bicolor*				8											8
S4	*L. rubella*	1														1
S5	*L. pallida*			1	1	1					3	3	2	7	2	20
S6	*L. inermis*	1							1							2
S7	*L. nasuta*				4		1		10	1	5		3	2		26
S8	*L. tornieri*															
S9	*L. wotjulumensis*															
S10	*Cyclorana australis*	3		1	7	3	4			4	1			1	1	25
S11	*C. longipes*	1			1		1									3
S12	*Limnodynastes ornatus*			1	2										1	4
S13	*L. convexiusculus*			12	1	1	1						1			16
S14	*Notaden melanoscaphus*			2	1				5		1	1				10
S15	*Uperoleia inundata*			1	1	14			11	14	2		2	1		46
S16	*Ranidella bilingua*				1	3					1		7			12
	SPECIES POOLED	6		18	27	22	7	1	31	19	22	4	15	11	4	187

Table (5.18); Numbers of frogs captured in each of three habitat types recognised along the Gulungul Creek transects (data pooled for 10 sampling nights at both transects I and II.)

CODE	SPECIES	HABITAT TYPE 1	2	3	Habitats Pooled
S1	*Litoria dahlii*			5	5
S2	*L. rothii*				
S3	*L. bicolor*				
S4	*L. rubella*		1		1
S5	*L. pallida*		4	15	19
S6	*L. inermis*		2	2	4
S7	*L. nasuta*		8	6	14
S8	*L. tornieri*				
S9	*L. wotjulumensis*				
S10	*Cyclorana australis*	4	7	7	18
S11	*C. longipes*	1		1	2
S12	*Limnodynastes ornatus*		2	4	6
S13	*L. convexiusculus*		1	4	5
S14	*Notaden melanoscaphus*	1		9	10
S15	*Uperoleia inundata*	1		23	24
S16	*Ranidella bilingua*			10	10
	SPECIES POOLED	7	25	86	118

Table (5.19); Estimates of number of frogs captured per square metre examined (x 1000) in each of three habitat types recognised along the Gulungul Creek transects (data pooled for 10 sampling nights at both transects I and I .)

		HABITAT TYPE			
CODE	SPECIES	1	2	3	Habitats Pooled
S1	*Litoria dahlii*			1.8	1.1
S2	*L. rothii*				
S3	*L. bicolor*				
S4	*L. rubella*		4.4		0.2
S5	*L. pallida*		17.0	5.4	4.2
S6	*L. inermis*		8.9	0.7	0.9
S7	*L. nasuta*		35.0	22.0	3.1
S8	*L. tornieri*				
S9	*L. wotjulumensis*				
S10	*Cyclorana australis*	2.7	31.1	2.5	4.0
S11	*C. longipes*	0.7		0.4	0.4
S12	*Limnodynastes ornatus*		8.9	1.4	1.3
S13	*L. convexiusculus*		4.4	1.4	1.1
S14	*Notaden melanoscaphus*	0.7		3.2	2.2
S15	*Uperoleia inundata*	0.7		8.3	5.3
S16	*Ranidella bilingua*			3.6	2.2
	SPECIES POOLED	4.7	111.1	31.0	26.2

portion of transect # 1 passing through an area of open woodland with well drained, sandy soil (habitat type # 2). Here, the number of frogs captured was estimated at 11/m^2 examined, predominantly adults of _C. australis_ and the ground hylid, _L. nasuta_. These high numbers may be correlated in some way with the proximity of this part of the transect to the sandy Gulungul Creek road (see Figure 4.6).

A wide range of species was captured in areas of sedge and grassland subject to annual inundation (habitat type # 3) along transect I.

Temporal changes in patterns of distribution and abundance were discernible with changes in the local water regime. Six of the seven specimens of _Cyclorana australis_ captured in habitat type # 3 were newly metamorphosed juveniles, collected with five juveniles of _Litoria dahlii_ when transect # 1 was inundated to the fullest extent in late January, 1982. No individuals of _L. dahlii_ were captured or sighted along the transect at any other times, although nine specimens were captured on 4/2/82 at a nearby pond when water levels had receded.

Numbers of froglets, toadlets, ground hylids and burrowing frogs also were captured foraging on moist terrain at the edges of the floodwaters on the transect. However, the high numbers of _Notaden melanoscaphus_ and _Uperoleia inundata_ captured in habitat type # 3 came mainly from breeding aggregations of these species in flooded portions of the transect.

Only a single arboreal frog, Litoria rubella, was captured during population censusses along the Gulungul Creek transects; although numbers of L. bicolor were collected from a breeding aggregation in inundated sedge and grassland nearby.

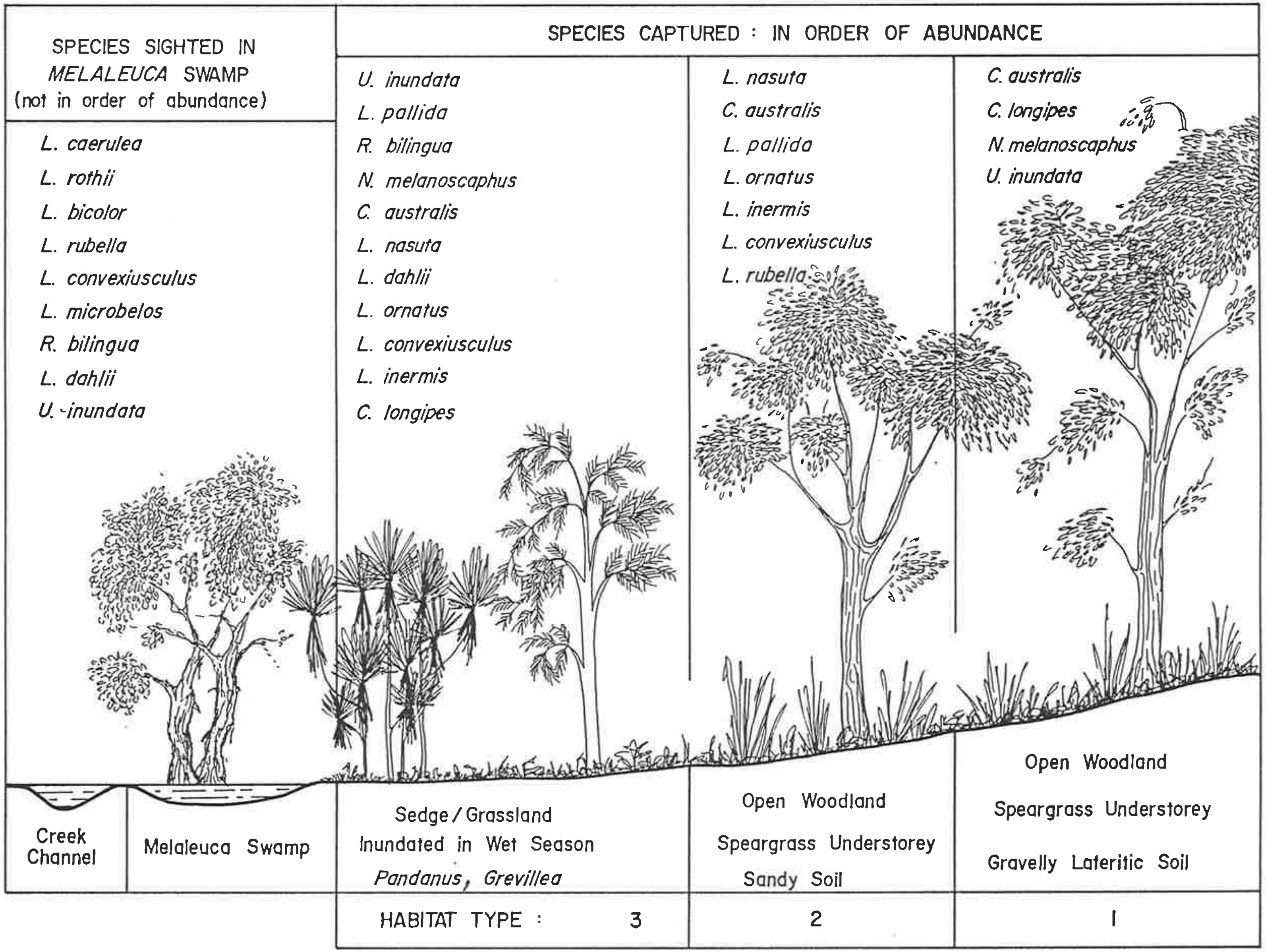
The western end of transect # 1 abutted a paperbark swamp (habitat type # 5), where many specimens were collected for stomach content analyses. Population censusses were not possible here due to flooding and overgrowth of tall grasses and emergent macrophytes. The species sighted in the paperbark swamp, and the species captured in each of three habitat types along the Gulungul Creek transects, are shown in Figure (5.4).

5.2.6; THE MAGELA AND GULUNGUL CREEK TRANSECTS; TRENDS IN PATTERNS OF DISTRIBUTION AND PROBLEMS IN INTERPRETATION OF RESULTS.

There are a number of sources of error in the construction of estimates of relative abundance expressed here. Observer behaviour and frog behaviour both introduced bias into data collection; while the data, in the form of frogs counted, was relatively sparse. These problems are compounded further when extrapolating estimations of patterns of abundance to areas adjacent to the transects and, indeed, to the Magela Creek System as a whole.

The temporal heterogeneity in rainfall and growth of vegetation led to difficulties in sighting and capturing frogs along the transects. At times, flooding and erosion

Figure (5.4); Species of frogs sighted in paperbark swamp and species captured in each of three habitat types recognised along the Gulungul Creek transect.


SPECIES SIGHTED IN *MELALEUCA* SWAMP (not in order of abundance)
L. caerulea
L. rothii
L. bicolor
L. rubella
L. convexiusculus
L. microbelos
R. bilingua
L. dahlii
U. inundata
SPECIES CAPTURED : IN ORDER OF ABUNDANCE
U. inundata
L. pallida
R. bilingua
N. melanoscaphus
C. australis
L. nasuta
L. dahlii
L. ornatus
L. convexiusculus
L. inermis
C. longipes
L. nasuta
C. australis
L. pallida
L. ornatus
L. inermis
L. convexiusculus
L. rubella
C. australis
C. longipes
N. melanoscaphus
U. inundata
Creek Channel
Melaleuca Swamp
Sedge / Grassland
Inundated in Wet Season
Pandanus, Grevillea
Open Woodland
Speargrass Understorey
Sandy Soil
Open Woodland
Speargrass Understorey
Gravelly Lateritic Soil
HABITAT TYPE : 3
2
1

along the Magela Creek track made censusses impossible, and probably prevented frog movement in the immediate vicinity.

The cryptic habits of species such as *Ranidella bilingua* and *Uperoleia inundata* (which often shelter beneath leaf litter), and the rapid departure of others when approached, such as *Litoria wotjulumensis*, made the skill of the observer in sighting and capturing frogs a major source of bias. Frogs counted were those sighted or captured on the terrain surface, so tending to introduce an under-estimation of numbers for cryptic species and arboreal frogs.

Frogs may have been attracted to, or deterred from, the open nature of the transects. Terrestrial prey presumably would be easier to locate and capture on the flat, open tracks than in adjacent undergrowth, and there is evidence that frogs were attracted to portions of the transects for breeding purposes.

During the study period, flooded wheel ruts offered breeding sites previously unavailable in the open woodland habitats; while inundation of the grassland and swampland portions of the transect refilled customary spawning sites.

Inclusion of congregations of calling males in population censusses would lead to over-estimation of local frog densities. Therefore, the high numbers of *U. inundata*, *L.nasuta* and *N. melanoscaphus* estimated for the Gulungul Creek transect 1, and the numbers of *L. nasuta* and *U. inundata* estimated for portions of the Magela Creek transects, must be considered over-estimates.

Flooded portions of the transects also offered ideal larval habitats. Hence, the high numbers of *Cyclorana australis* estimated for areas of swampland and grassland along the Magela Creek and Gulungul Creek transects are attributed to the inclusion of a number of newly metamorphosed juveniles emerging from the larval habitat.

6.1.1; RESULTS (2); STOMACH CONTENT ANALYSES.

The nature and quantity of stomach contents were examined to permit interpretation of the time devoted to foraging for food as opposed to other activities such as breeding. Particular emphasis was placed on distinguishing which species ingest prey of aquatic origin.

6.2.1; INDEX OF STOMACH DISTENTION.

To compare the amount of food present in the stomachs of different developmental stages of post-larval anurans, an index of stomach distention was assigned to each frog examined.

The categorisation of all frogs collected according to developmental stage and employment of an index of stomach distention is presented in Appendix (6.1) and as percentages of raw data in Table (6.1).

Significant differences in the degree of stomach distention were observed in frogs in each of the eight categories recognised on the basis of developmental stage.

Recently-metamorphosed juveniles (stage 42), calling males and gravid females in amplexus were determined as having the least amount of stomach contents on the basis of index of stomach distention. For these frog categories, over 84%, 24% and 14% of specimens respectively had empty stomachs (an index of 0). These categories also included

INDEX OF STOMACH DISTENTION	DEVELOPMENTAL STAGE *								
	Unknown Stage	Stage 42	Juvenile	Male	Male, Calling	Female	Female, Gravid	Female, Gravid, in Amplexus	TOTAL
VOMIT	6.35	3.85	1.11	2.98	0.29	2.81	2.73	0.00	2.53
0	6.75	84.62	9.09	12.02	24.50	6.74	8.20	14.93	12.86
1	15.87	9.62	23.38	27.98	29.11	25.00	19.14	32.84	24.96
2	18.25	1.92	21.52	20.61	20.46	22.75	19.14	19.40	20.34
3	17.86	0.00	16.33	17.28	14.12	13.20	20.31	8.96	16.09
4	18.10	0.00	12.24	9.30	6.63	9.83	11.33	11.94	9.97
5	15.48	0.00	10.20	7.37	4.32	11.80	10.16	8.96	8.87
6	6.35	0.00	6.,12	2.46	0.58	7.87	8.98	2.99	4.39

Table 6.1; Categorisation of all frogs collected according to developmental stage and index of stomach distention expressed as percentages of totals within frog categories.

* Variables defined in Chapter 4.2.3 and 4.2.4

the greatest numbers of frogs with a mass of food in the stomach occupying less than one half of the stomach lumen (over 94%, 53% and 50% respectively).

The male category probably comprises many calling male frogs which ceased calling upon the approach of the collector (Chapter 4.1.3). This factor may act to reduce the percentage of stomachs, of "male" category frogs, scored as having distention indices in the range 2 - 6, and increasing the percentages for indices of less than 2 for these frogs.

Frogs of unknown sex and maturity, gravid females, females and juveniles had the greatest amount of stomach contents on the basis of the index of stomach distention. For these frog categories, over 34%, 30%, 28% and 28% respectively of specimens had a mass of food at least filling the stomach and, at the most, causing marked distention of the stomach.

In Table (6.2), frog categories have been combined into BREEDING and NON-BREEDING classifications. Indices of stomach distention have been pooled to form EMPTY, MEDIUM and FULL classifications. A row by column test of independence of these data, using the G-statistic of Sokal & Rohlf (1973), demonstrated that the index of stomach distention is significantly dependent upon breeding activity at the level of $P < 0.005$. Calling male frogs and gravid females in amplexus have significantly less material in the stomach than do the other frog categories when pooled.

POOLED INDEX OF STOMACH DISTENTION	INDEX	DEVELOPMENTAL STAGE: BREEDING -Male, Calling -Female, Gravid in Amplexus	DEVELOPMENTAL STAGE: NON-BREEDING -Unknown stage -Stage 42 -Juvenile -Male -Female -Female, Gravid	TOTAL
EMPTY	0	95	292	387
MEDIUM	1,2,3	262	1,585	1,847
FULL	4,5,6	56	643	699
	TOTAL	413	2,520	2,933

G-test statistic = 54.37
significant at P < 0.005 (d.f = 3)

Table 6.2; Categorisation of frogs pooled according to frog category and index of stomach distention.

6.3.1; STOMACH CONTENT ANALYSES - STATISTICAL CONSIDERATIONS.

Detailed analyses of the number and volume of prey categories in the stomach contents of 15 species yielded an extensive data base. In line with original research objectives, I chose to quantify the contribution of a prey Order (Pi) to the total range of contents in a stomach in terms of occurrence (presence or absence), number of items of Pi and volume of items of Pi.

The standard method of summarising such a set of data is to calculate the arithmetic mean and the variance from this mean. These two statistics can be shown to contain as much information as the original data, provided that the frequency distribution of food item "scores" (in terms of number or volume) is normal (Sibert and Obrebski, 1981).

Scores were calculated for the percentage contribution of items of a prey Order Pi, in a single stomach, to the total pool of items from all stomachs examined. These scores were expressed as a variable, PROPNUM, where, for a single stomach of species Sj, and a single prey Order Pi;

$$\mathrm{PROPNUM} = \left(\frac{\mathrm{SUMNUM}}{\mathrm{TOTNUM}} \times 100 \right)$$

and

SUMNUM = Number of items of prey orders Pi,

TOTNUM = Total number of items of <u>all</u> prey orders found in <u>all</u> stomachs of species Sj examined.

In Table (6.3.1), results are presented for the most frequently occurring (in terms of presence or absence) prey orders identified in samples of the 15 study species. Scores for PROPNUM for each stomach have been ranked from zero (recorded when Pi does not occur in that stomach) to the maximum recorded value. Rankings for samples of each species were divided into 10 percentiles in Table (6.3.1).

In general, frequency distributions of food item scores within stomachs of study species are not normal but skewed, with a relatively high proportion of zero scores

Table 6.3.1 Frequency distributions of "PROPNUM" scores for most commonly occurring prey orders in stomachs of study species. Scores are divided into ten percentiles.

PREY ORDER SPECIES	PROPNUM SCORE BY 10 PERCENTILE										
	0	10	20	30	40	50	60	70	80	90	100
COLEOPTERA, <u>Litoria dahlii</u>	0	0	0	0	0	0	0.035	0.070	0.106	0.211	2.114
DIPTERA, <u>L. rothii</u>	0	0	0	0	0	0	0	0.129	0.259	0.776	12.716
DIPTERA, <u>L. bicolor</u>	0	0	0	0	0	0.077	0.077	0.154	0.247	0.463	2.008
HYMENOPTERA - non-alate, <u>L. rubella</u>	0	0	0	0.056	0.093	0.185	0.278	0.556	0.649	1.242	5.468
COLEOPTERA, <u>L. pallida</u>	0	0	0	0	0	0	0.095	0.095	0.095	0.284	0.569
COLEOPTERA, <u>L. inermis</u>	0	0	0	0	0	0	0.258	0.258	0.258	0.465	9.819
COLEOPTERA, <u>L. nasuta</u>	0	0	0	0	0	0	0.203	0.203	0.406	0.609	4.057
ORTHOPTERA, <u>L. tornieri</u>	0	0	0	0	0	0	0.433	0.433	0.433	0.433	1.299
ORTHOPTERA, <u>Cyclorana australis</u>	0	0	0	0	0	0	0	0.201	0.201	0.402	0.803
COLEOPTERA, <u>C. longipes</u>	0	0	0	0	0	0.098	0.098	0.098	0.293	0.608	6.354
HYMENOPTERA - non-alate, <u>Limnodynastes ornatus</u>	0	0.082	0.124	0.247	0.330	0.495	0.660	0.825	0.990	1.443	7.588
COLEOPTERA, <u>L. convexiusculus</u>	0	0	0	0	0	0	0.500	2.500	4.000	5.000	7.500
HYMENOPTERA - non-alate, <u>Notaden melanoscaphus</u>	0	0.039	0.094	0.156	0.234	0.449	0.868	1.540	1.938	2.962	8.363
HYMENOPTERA - non-alate <u>Uperoleia inundata</u>	0	0	0.078	0.117	0.171	0.330	0.552	0.739	0.972	1.820	10.575
COLLEMBOLA, <u>Ranidella bilingua</u>	0	0	0	0	0.219	0.365	0.487	0.731	1.096	2.631	9.135

and a long tail containing a few very high scores. This trend is clearly evident from Table (6.3.1), despite the fact that it includes only results for the most frequently occurring prey Order. For example, at least 60% of Litoria rothii stomachs do not contain dipterans, 40% have scores of 0 to 12.716, and very high scores are restricted to less than 10% of the stomachs examined. Within the sample of Notaden melanoscaphus stomachs, less than 10% lack nonalate hymenopterans, but less than 10% of stomachs have high scores of 2.962 to 8.363.

It is considered, therefore, that the use of means and associated variances as summarising statistics for data from stomach content analyses are not justified in the present study. Consequently, my analyses of data will be restricted to simple comparisons of results, rather than to analyses of variance and other parametric tests based on means and variances from the mean.

6.4.1; STOMACH CONTENT ANALYSES AT THE LEVEL OF PREY ORDER.

Stomach content analyses were performed on 1665 frogs representing 15 species. The length-frequency distributions, site of collection and categorisation of specimens examined according to size, sex and activity prior to capture, are presented in Appendices (6.4.1), (6.4.2) and (6.4.3).

Information on total length and categorisation of frogs examined is lacking for 22 specimens included in analyses. It comprises data for 2 Litoria rubella, 6 L.

pallida, 1 L. inermis, 1 L. nasuta, 4 L. tornieri, 3 Limnodynastes ornatus, 3 Uperoleia inundata and 2 Ranidella bilingua.

Insufficient numbers of Litoria wotjulumensis were collected for inclusion in stomach content analyses.

The frequency of occurrence, numbers and volumes of 43 prey orders for each of the 15 study species are presented in Appendices (6.4.4), (6.4.5) and (6.4.6). These quantities are expressed as percentages of totals in the lists of stomach contents to follow for each species.

Each of 41 prey orders identified has been classified as aquatic, terrestrial or terrestrial/aquatic in Table (6.4.1) according to the life histories of the families included. Aquatic orders, including the Anura and Odonata, are families which have a partially or fully aquatic life history. Others such as the Isoptera and Hymenoptera, comprise families which are classified in this study as fully terrestrial.

Orders classified as terrestrial/aquatic contain families of fully terrestrial origin and others with partially or fully aquatic life histories. For example, the Dytiscidae and Cicindellidae are coleopterans which complete their life histories in aquatic habitats and terrestrial habitats respectively.

For the purpose of intraspecific and interspecific comparison, prey orders are grouped according to these

Table 6.4.1; Classification of prey orders according to the life history pattern and habitat of member families.

PREY ORDER	PREY CODE	CLASSIFICATION OF ORIGIN	CODE OF ORIGIN
ANURA ADULT	29	AQUATIC	A
ANURA LARVA	37	"	A
EPHEMEROPTERA	28	"	A
ODONATA ADULT	20	"	A
ODONATA NYMPH	36	"	A
OSTRACODA	39	"	A
PLECOPTERA	34	"	A
TRICHOPTERA ADULT	18	"	A
TRICHOPTERA NYMPH	26	"	A
ZYGOPTERA ADULT	25	"	A
ZYGOPTERA NYMPH	40	"	A
ARANEAE	5	TERRESTRIAL/AQUATIC	TA
COLEOPTERA ADULT	2	" "	TA
COLEOPTERA LARVA	23	" "	TA
DIPTERA	3	" "	TA
GASTROPODA	35	" "	TA
HEMIPTERA	4	" "	TA
OTHER, VERTEBRATE	42	" "	TA
OTHER, INVERTEBRATE	43	" "	TA
UNDETERMINED, ADULT	9	" "	TA
UNDETERMINED, LARVA	19	" "	TA
ACARINA	16	TERRESTRIAL	T
BLATTODEA	15	"	T
CHILOPODA	17	"	T
COLLEMBOLA	11	"	T
DERMAPTERA	24	"	T
DIPLOPODA	38	"	T
HYMENOPTERA ALATE	12	"	T
HYMENOPTERA NON-ALATE	1	"	T
ISOPTERA ALATE	14	"	T
ISOPTERA NON-ALATE	21	"	T
ISOPODA	27	"	T
LEPIDOPTERA ADULT	10	"	T
LEPIDOPTERA LARVA	13	"	T
MANTODEA	33	"	T
OLIGOCHAETA	30	"	T
ORTHOPTERA	6	"	T
PHALANGIDA	22	"	T
PHASMIDA	31	"	T
SCORPIONIDA	41	"	T
THYSANOPTERA	32	"	T

classifications in lists of stomach contents presented for each species.

6.5; AQUATIC FROGS.

The sample of 207 specimens of *Litoria dahlii* included the complete range of post-metamorphic developmental stages recognised in the current study. These frogs were collected mainly at the Magela Creek floodplain near Nankeen Billabong, and at the Tailings dam.

Results of stomach content analyses of the sample are presented as Table (6.5.1), and summarised in terms of the six most frequently occurring prey orders in Figure (6.5.1). The incidence of aquatic, terrestrial and terrestrial/aquatic prey orders is quantified by frequency of occurrence, numbers and volume of items identified in Figure (6.5.2).

6.5.1; OCCURRENCE OF AQUATIC PREY ORDERS.

Orders of aquatic origin were identified in over 46% of stomachs, comprising both adults and nymphs of the Odonata, Zygoptera, Trichoptera and Ephemeroptera, Anura and the wholly aquatic Ostracoda. Aquatic prey orders constituted the greatest volumes of prey items identified, and occurred at a frequency similar to those of terrestrial orders,

Predominant prey orders, in terms of frequency of occurrence and numbers identified, were the terrestrial/

Table (6.5.1); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 207 specimens of Litoria dahlii.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
ANURA ADULT	29	4.83	0.42	18.71	A
EPHEMEROPTERA	28	5.80	13.00	0.64	A
ODONATA ADULT	20	7.73	0.60	2.26	A
ODONATA NYMPH	36	23.19	4.02	29.67	A
OSTRACODA	39	2.90	0.21	0.01	A
TRICHOPTERA ADULT	18	4.35	1.06	0.10	A
TRICHOPTERA NYMPH	26	2.90	0.28	0.36	A
ZYGOPTERA ADULT	25	3.38	0.35	0.34	A
TOTAL		46.37	19.94	52.08	AQUATIC
ARANEAE	5	31.88	3.63	4.59	TA
COLEOPTERA ADULT	2	46.86	22.80	9.59	TA
COLEOPTERA LARVA	23	2.90	0.49	0.19	TA
DIPTERA	3	37.68	22.23	0.82	TA
HEMIPTERA	4	35.75	5.64	2.01	TA
OTHER, INVERTEBRATE	43	0.48	0.04	0.09	TA
UNDETERMINED, ADULT	9	1.93	0.07	0.15	TA
UNDETERMINED, LARVA	19	15.94	2.68	0.90	TA
TOTAL		85.02	57.58	18.35	TERRESTRIAL and AQUATIC
ACARINA	16	0.48	0.04	0.00	T
BLATTODEA	15	4.35	0.32	1.00	T
CHILOPODA	17	3.38	0.42	1.80	T
COLLEMBOLA	11	12.08	12.12	0.06	T
DERMAPTERA	24	0.48	0.04	0.26	T
HYMENOPTERA ALATE	12	5.80	0.63	0.49	T
HYMENOPTERA NON-ALATE	1	22.71	3.81	1.48	T
ISOPTERA NON-ALATE	21	1.45	1.20	0.53	T
LEPIDOPTERA ADULT	10	6.76	0.53	2.90	T
LEPIDOPTERA LARVA	13	4.35	0.42	0.31	T
OLIGOCHAETA	30	0.48	0.04	0.02	T
ORTHOPTERA	6	25.12	2.89	16.37	T
THYSANOPTERA	32	0.48	0.04	0.00	T
TOTAL		61.83	22.48	25.23	TERRESTRIAL
INORGANIC MATERIAL	7		0.00	1.06	
VEGETABLE MATERIAL	8		0.00	3.28	

Figure 6.5.1; Percentage frequency of occurrence of principal prey orders in stomach contents of <u>Litoria dahlii</u>.

Ny - Nymphs Ad - Adults

Litoria dahlii

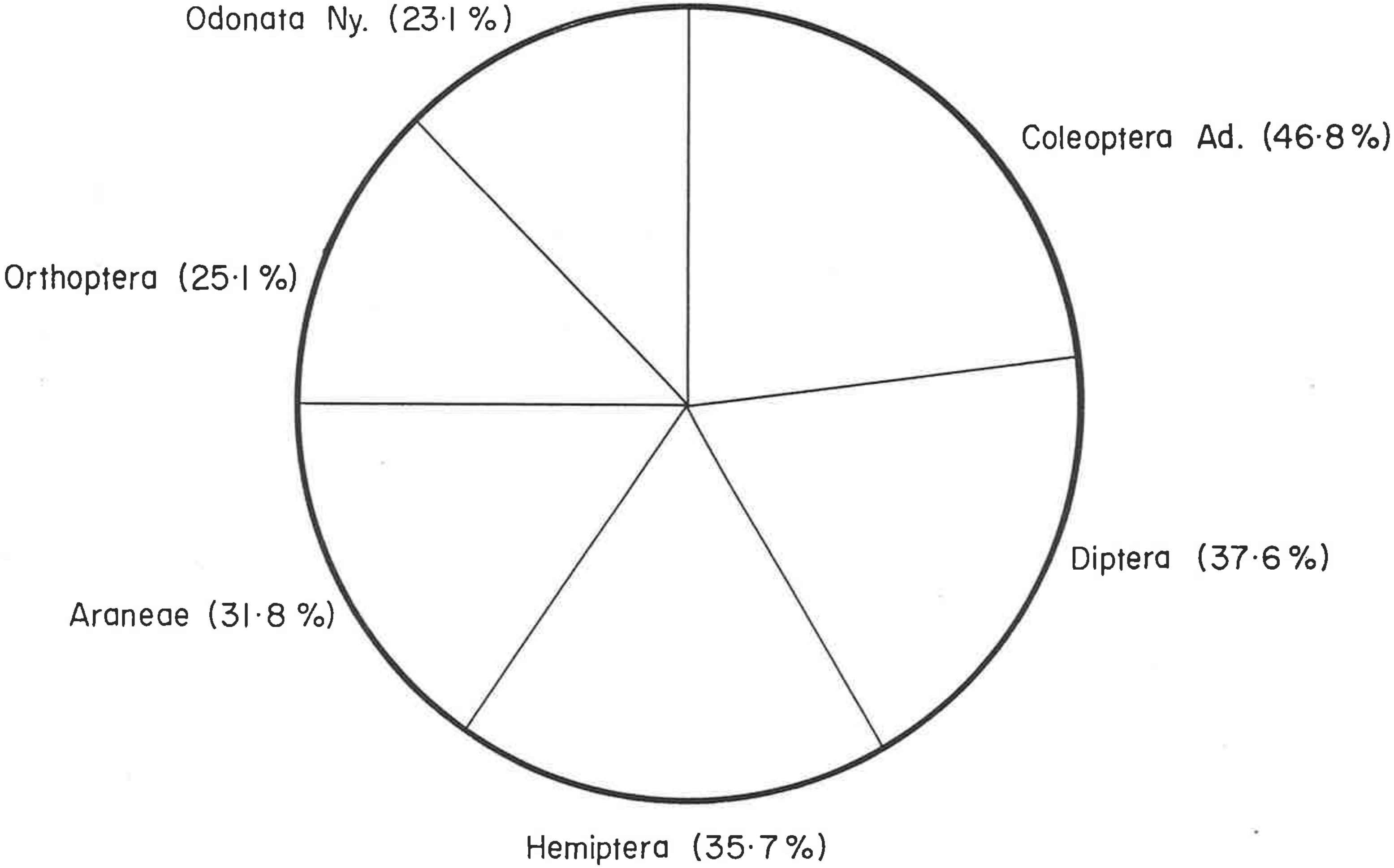
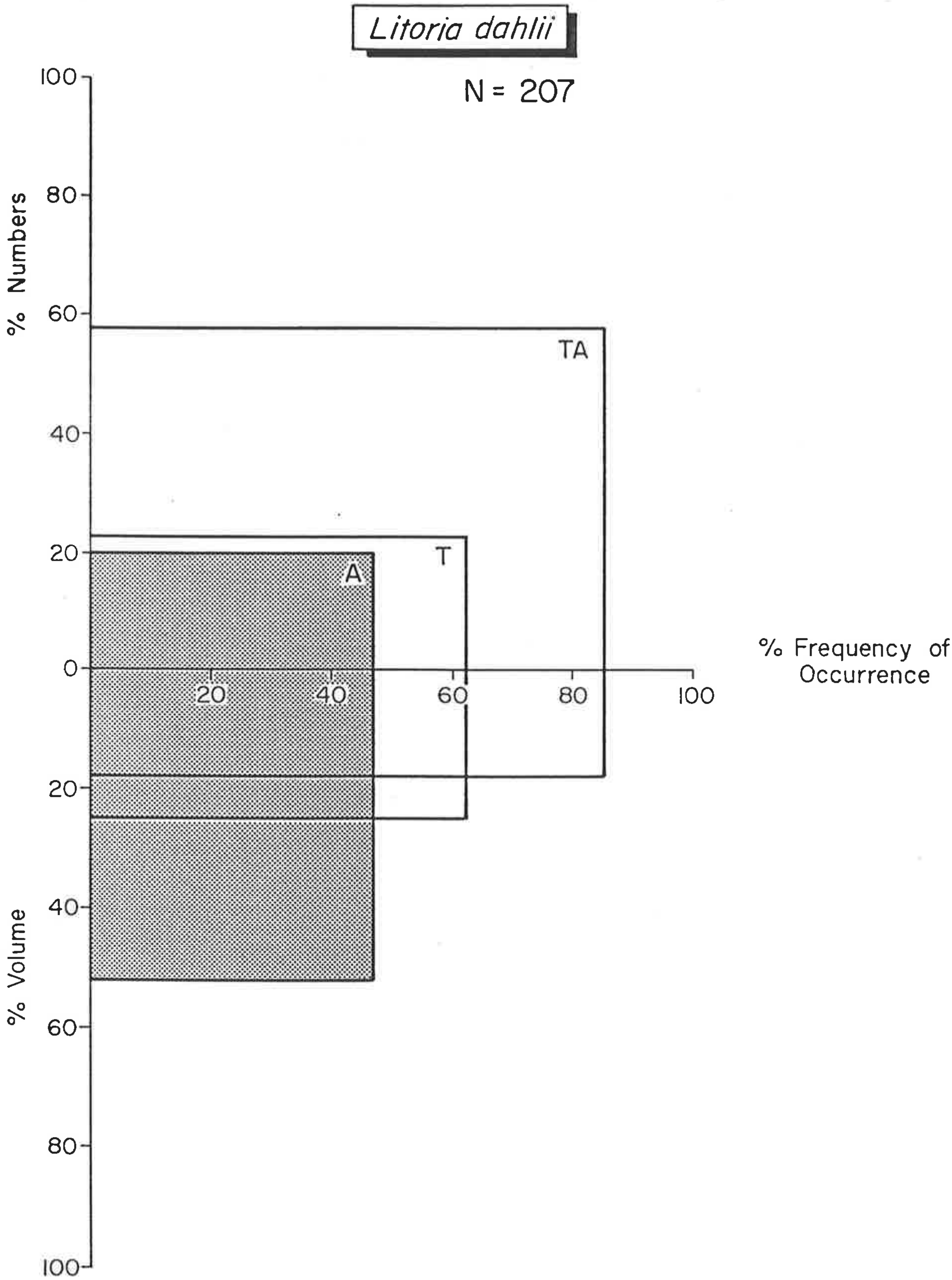


Figure (6.5.2); Contribution of aquatic, terrestrial and terrestrial/aquatic prey orders to the sample of stomach contents of *Litoria dahlii* quantified in terms of prey occurrence, numbers and volume.

T = Terrestrial orders

TA = Terrestrial/aquatic orders

A = Aquatic orders


Litoria dahlii
N = 207
% Numbers
% Volume
% Frequency of Occurrence
TA
T
A
100
80
60
40
20
0
20
40
60
80
100

aquatic orders (Coleoptera, Diptera, Hemiptera and Araneae), the terrestrial orders (mainly Orthoptera, Hymenoptera and Collembola) and the aquatic nymphs of the Odonata.

6.6; ARBOREAL FROGS.

The majority of the 142 specimens of *Litoria rothii* and the 249 specimens of *L. bicolor* whose stomach contents were analysed, were collected on the foliage of *Barringtonia acutangula* and *Pandanus aquaticus* overhanging the waters of Nankeen Billabong. Specimens of *L. rubella* were obtained from a breeding congregation in a roadside gravel scrape (37%), from a group of juveniles in a *P. aquaticus* palm at Nankeen Billabong (23%), and from the area of the Ranger mining lease.

Lists of stomach contents for each species are presented in Tables (6.6.1), (6.6.2) and (6.6.3). The six predominant prey orders, in terms of frequency of occurrence, are shown for each of the arboreal species in Figure (6.6.1).

The incidence of aquatic prey orders is quantified in Figure (6.6.2).

6.6.1; OCCURRENCE OF ORDERS OF AQUATIC PREY.

Orders of aquatic prey occurred frequently in the samples of *Litoria rothii* (27.4%) and *L. bicolor* (16.4%) (predominantly Trichoptera), but were identified only rarely

Table (6.6.1); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 142 specimens of <u>Litoria rothii</u>.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
ANURA ADULT	29	1.41	0.09	5.77	A
ODONATA ADULT	20	5.63	0.34	6.03	A
PLECOPTERA	34	0.70	0.04	0.03	A
TRICHOPTERA ADULT	18	19.01	2.07	1.56	A
ZYGOPTERA ADULT	25	0.70	0.04	0.33	A
TOTAL		27.46	2.59	13.71	AQUATIC
ARANEAE	5	27.46	3.49	15.06	TA
COLEOPTERA ADULT	2	23.24	2.54	11.49	TA
DIPTERA	3	39.44	82.92	16.32	TA
HEMIPTERA	4	14.79	1.34	4.23	TA
UNDETERMINED, ADULT	9	3.52	0.13	1.01	TA
UNDETERMINED, LARVA	19	2.11	0.13	0.08	TA
TOTAL		72.53	90.56	48.19	TERRESTRIAL and AQUATIC
ACARINA	16	0.70	0.04	0.03	T
BLATTODEA	15	11.27	0.86	7.47	T
CHILOPODA	17	0.70	0.09	0.09	T
DERMAPTERA	24	4.23	0.26	2.17	T
HYMENOPTERA ALATE	12	8.45	1.34	8.27	T
HYMENOPTERA NON-ALATE	1	11.27	1.03	0.62	T
ISOPTERA ALATE	14	1.41	0.09	0.05	T
LEPIDOPTERA ADULT	10	6.34	0.60	2.08	T
LEPIDOPTERA LARVA	13	11.27	1.81	8.00	T
MANTODEA	33	0.70	0.04	0.66	T
ORTHOPTERA	6	11.27	0.69	8.36	T
TOTAL		54.22	6.86	37.80	TERRESTRIAL
INORGANIC MATERIAL	7	0.70	0.00	0.03	
VEGETABLE MATERIAL	8	2.11	0.00	0.28	

Table (6.6.2); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 249 specimens of Litoria bicolor.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
EPHEMEROPTERA	28	1.20	2.63	0.20	A
ODONATA ADULT	20	2.41	0.46	7.22	A
TRICHOPTERA ADULT	18	8.03	8.11	1.56	A
ZYGOPTERA ADULT	25	5.62	1.08	10.34	A
TOTAL		16.46	12.28	19.31	AQUATIC
ARANEAE	5	17.27	4.17	8.26	TA
COLEOPTERA ADULT	2	20.88	7.80	9.57	TA
COLEOPTERA LARVA	23	0.80	0.23	0.20	TA
DIPTERA	3	51.41	39.92	11.06	TA
HEMIPTERA	4	24.90	8.03	11.82	TA
UNDETERMINED, ADULT	9	22.09	0.15	5.51	TA
UNDETERMINED, LARVA	19	2.41	0.46	0.35	TA
TOTAL		89.55	60.77	46.76	TERRESTRIAL and AQUATIC
ACARINA	16	0.80	0.39	0.08	T
BLATTODEA	15	5.62	1.08	12.06	T
COLLEMBOLA	11	2.01	1.16	0.13	T
DERMAPTERA	24	0.40	0.08	0.34	T
HYMENOPTERA ALATE	12	6.43	2.39	3.13	T
HYMENOPTERA NON-ALATE	1	33.73	16.37	9.52	T
ISOPODA	27	0.40	0.08	0.03	T
LEPIDOPTERA ADULT	10	9.64	3.17	2.72	T
LEPIDOPTERA LARVA	13	4.42	1.39	2.89	T
ORTHOPTERA	6	2.01	0.39	0.83	T
THYSANOPTERA	32	0.80	0.31	0.03	T
TOTAL		50.60	26.80	31.77	TERRESTRIAL
INORGANIC MATERIAL	7	0.00	0.00	0.00	
VEGETABLE MATERIAL	8	4.02	0.15	2.15	

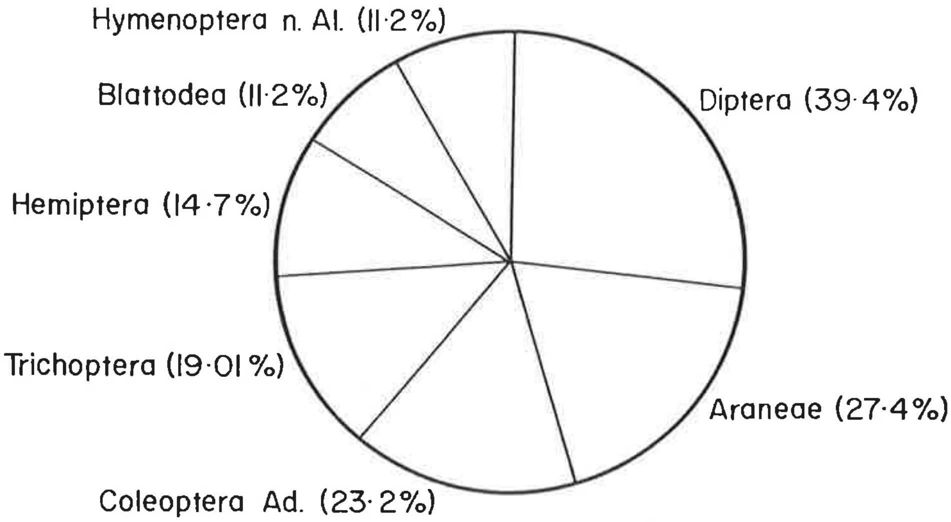
Table (6.6.3); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 122 specimens of Litoria rubella.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
TRICHOPTERA ADULT	18	4.92	2.41	0.71	A
TOTAL		4.92	2.41	0.71	AQUATIC
ARANEAE	5	9.02	1.20	3.42	TA
COLEOPTERA ADULT	2	28.69	3.89	7.50	TA
DIPTERA	3	27.05	9.55	2.19	TA
HEMIPTERA	4	14.75	2.04	3.23	TA
UNDETERMINED, ADULT	9	0.82	0.00	0.12	TA
UNDETERMINED, LARVA	19	3.28	0.46	0.21	TA
TOTAL		56.55	17.15	16.68	TERRESTRIAL and AQUATIC
ACARINA	16	4.92	0.74	0.02	T
BLATTODEA	15	5.74	0.65	2.62	T
CHILOPODA	17	2.46	0.28	0.96	T
COLLEMBOLA	11	9.84	2.69	0.23	T
DERMAPTERA	24	0.82	0.09	0.21	T
DIPLOPODA	38	0.82	0.09	0.17	T
HYMENOPTERA ALATE	12	4.92	6.02	4.60	T
HYMENOPTERA NON-ALATE	1	70.49	60.89	35.96	T
ISOPTERA ALATE	14	7.38	6.86	23.09	T
ISOPTERA NON-ALATE	21	3.28	0.37	0.78	T
LEPIDOPTERA ADULT	10	3.28	0.65	1.06	T
LEPIDOPTERA LARVA	13	4.92	0.65	7.39	T
ORTHOPTERA	6	3.28	0.46	3.00	T
TOTAL		86.88	80.44	80.10	TERRESTRIAL
INORGANIC MATERIAL	7	13.11	0.00	1.42	
VEGETABLE MATERIAL	8	4.10	0.00	1.10	

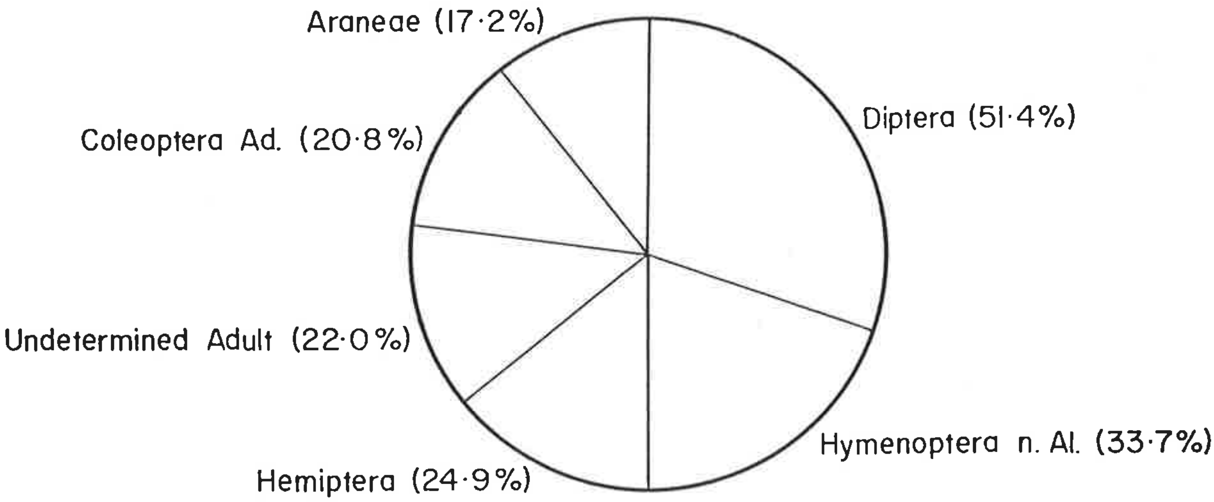
Figure 6.6.1; Percentage frequency of occurrence of principal prey orders in stomach contents of arboreal frogs.

n.Al. - non Alate   Ad - Adults

Litoria rothii



Litoria bicolor



Litoria rubella

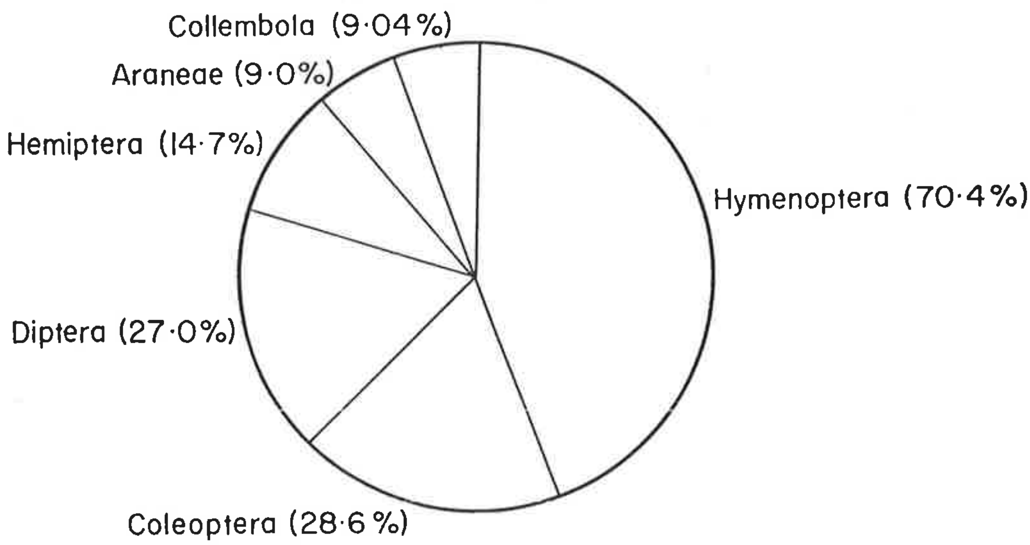
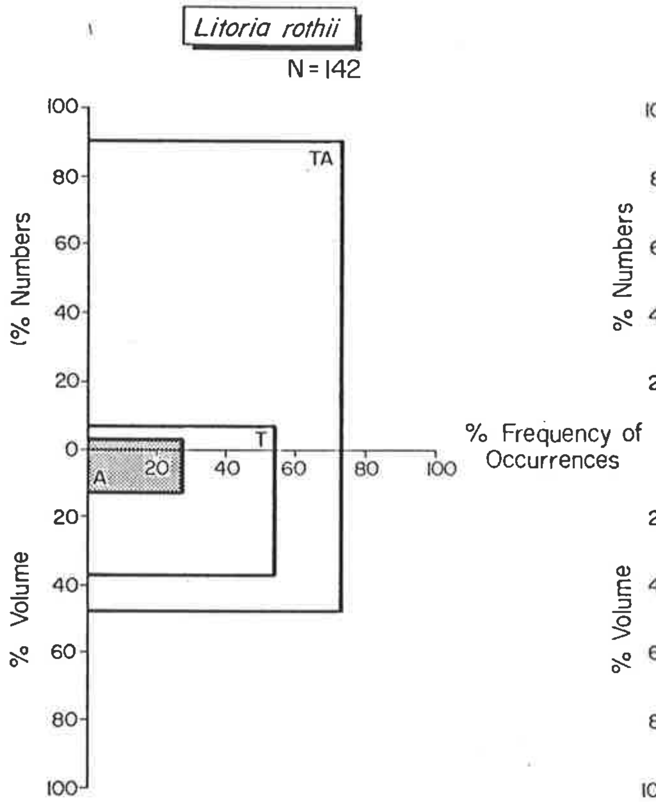
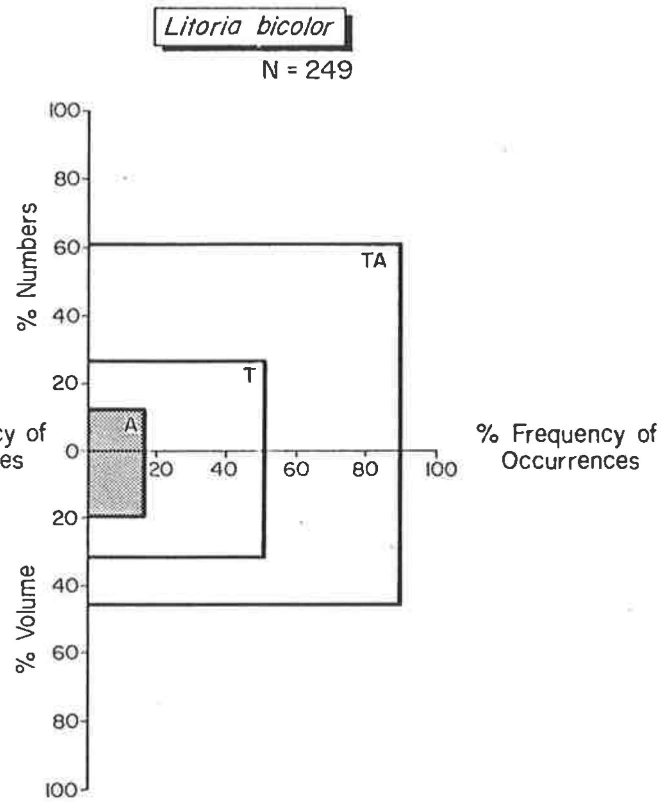
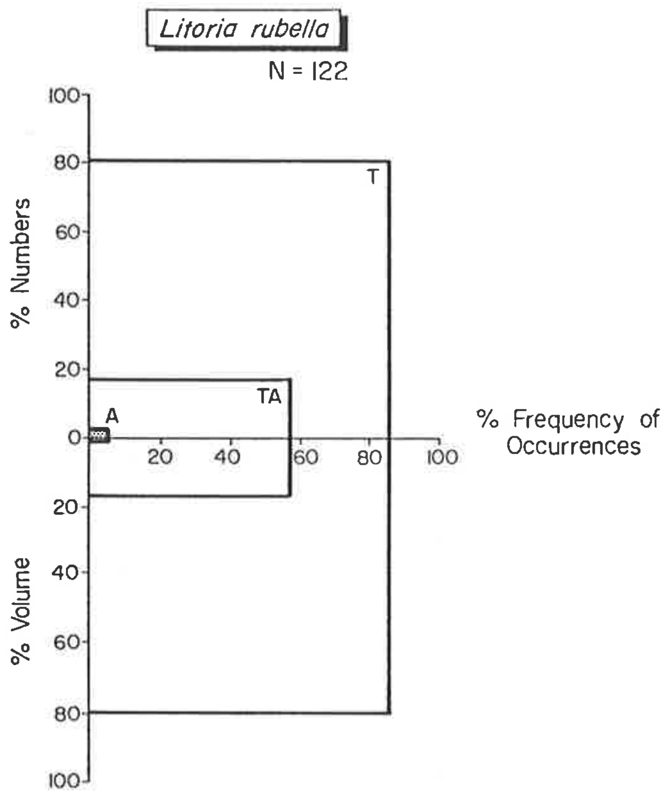


Figure 6.6.2; Contribution of aquatic, terrestrial and terrestrial/aquatic prey orders to the sample of stomach contents of arboreal frogs quantified in terms of prey occurrence, numbers and volume.


Litoria rothii
N = 142
% Numbers
% Volume
% Frequency of Occurrences
TA
T
A
0
20
40
60
80
100


Litoria bicolor
N = 249
% Numbers
% Volume
% Frequency of Occurrences
TA
T
A
0
20
40
60
80
100


Litoria rubella
N = 122
% Numbers
% Volume
% Frequency of Occurrences
T
TA
A
0
20
40
60
80
100

in stomachs of *L. rubella* (4.9%). These aquatic orders were represented by the alate, adult stages of arthropods and a single anuran from a single individuals of *L. rothii*.

For each species aquatic orders were of lesser importance, in terms of all quantifications used, than both terrestrial and terrestrial/aquatic classifications.

Alate prey were predominant, both in terms of frequency of occurrence and of numbers present, in samples of *L. rothii* and *L. bicolor*, with dipterans being the most common group for both species.

These terrestrial/aquatic prey (including also the Coleoptera, Araneae and Hemiptera) occurred frequently in samples of all three species, and were predominant for *L. rothii* and *L. bicolor*.

Terrestrial prey orders, mainly non-alate hymenopterans, were the dominant items in stomachs of *L. rubella* in terms of frequency of occurrence (86.8%), number of items (60.8%) and volume (35.9%).

6.7; GROUND HYLIDS.

Four species of ground hylids were included as subjects in stomach content analyses. The majority of specimens were males collected in the vicinity of waterbodies , and were taken amongst breeding congregations throughout the study area.

Lists of stomach contents of Litoria pallida, L. inermis, L. nasuta and L. tornieri are presented as Tables (6.7.1), (6.7.2), (6.7.3) and (6.7.4). The six predominant prey orders, in terms of frequency of occurrence, are presented in Figure (6.7.1). The incidence of aquatic, terrestrial and terrestrial/aquatic prey orders is quantified in terms of frequency of occurrence, numbers and volume for each species in Figure (6.7.2).

6.7.1; OCCURRENCE OF AQUATIC PREY ORDERS.

Aquatic orders occurred in stomachs of Litoria pallida (8.3%), L. inermis (11.1%) and L. nasuta (2.7%) but were absent from the sample of L. tornieri. The predominate aquatic prey comprised alate, adult forms of the Odonata, Zygoptera, Trichoptera and Ephemeroptera.

When present,aquatic orders were only of minor significance in terms of numbers and volume in comparison with terrestrial and terrestrial/aquatic orders, as shown in Figure (6.7.2).

The prey orders occurring most commonly were similar for each of the four ground hylids, and comprised the terrestrial/aquatic orders Coleoptera, Araneae, Hemiptera and Diptera ,and the terrestrial orders Hymenoptera and Lepidoptera.

6.8; WIDE-MOUTHED, BURROWING FROGS.

Cyclorana australis, C. longipes, Limnodynastes orna-

Table (6.7.1); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 180 specimens of Litoria pallida.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
EPHEMEROPTERA	28	0.56	0.09	0.01	A
ODONATA ADULT	20	4.44	0.76	5.64	A
ODONATA NYMPH	36	0.56	0.09	0.30	A
TRICHOPTERA ADULT	18	1.67	0.47	0.37	A
ZYGOPTERA ADULT	25	1.11	0.19	0.30	A
TOTAL		8.33	1.61	6.61	AQUATIC
ARANEAE	5	32.22	7.68	5.73	TA
COLEOPTERA ADULT	2	46.11	14.69	13.15	TA
COLEOPTERA LARVA	23	3.33	0.57	1.82	TA
DIPTERA	3	16.67	29.38	5.05	TA
HEMIPTERA	4	35.00	13.08	7.82	TA
OTHER, INVERTEBRATE	43	0.56	0.09	0.10	TA
UNDETERMINED, ADULT	9	18.89	0.00	4.28	TA
UNDETERMINED, LARVA	19	1.67	0.38	0.02	TA
TOTAL		88.33	65.88	37.97	TERRESTRIAL and AQUATIC
ACARINA	16	1.67	0.28	0.08	T
BLATTODEA	15	2.78	0.47	0.66	T
CHILOPODA	17	3.33	0.57	1.99	T
COLLEMBOLA	11	3.33	0.57	0.04	T
DERMAPTERA	24	1.67	0.28	0.90	T
DIPLOPODA	38	0.56	0.09	0.05	T
HYMENOPTERA ALATE	12	11.67	3.03	2.42	T
HYMENOPTERA NON-ALATE	1	26.11	7.49	1.82	T
ISOPTERA ALATE	14	5.56	5.50	4.51	T
ISOPTERA NON-ALATE	21	0.56	0.09	0.02	T
LEPIDOPTERA ADULT	10	7.22	1.52	4.26	T
LEPIDOPTERA LARVA	13	10.00	2.27	6.86	T
OLIGOCHAETA	30	2.78	0.47	4.72	T
ORTHOPTERA	6	40.00	9.48	21.87	T
PHALANGIDA	22	0.56	0.09	0.06	T
THYSANOPTERA	32	1.11	0.28	0.08	T
TOTAL		74.44	32.51	50.35	TERRESTRIAL
INORGANIC MATERIAL	7	17.78	0.00	4.02	
VEGETABLE MATERIAL	8	5.56	0.00	1.04	

Table (6.7.2); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 72 specimens of Litoria inermis.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
ODONATA ADULT	20	6.94	1.29	4.73	A
TRICHOPTERA ADULT	18	2.78	0.78	0.32	A
ZYGOPTERA ADULT	25	1.39	0.26	0.14	A
TOTAL		11.11	2.33	5.18	AQUATIC
ARANEAE	5	27.78	6.20	1.50	TA
COLEOPTERA ADULT	2	43.06	21.71	12.44	TA
DIPTERA	3	20.83	14.21	2.39	TA
GASTROPODA	35	1.39	0.26	0.36	TA
HEMIPTERA	4	26.39	12.14	5.63	TA
UNDETERMINED, ADULT	9	9.72	0.00	1.33	TA
UNDETERMINED, LARVA	19	5.56	1.55	0.68	TA
TOTAL		77.77	56.07	24.34	TERRESTRIAL and AQUATIC
ACARINA	16	2.78	0.52	0.01	T
BLATTODEA	15	4.17	0.78	3.18	T
CHILOPODA	17	4.17	0.78	2.31	T
COLLEMBOLA	11	4.17	0.78	0.01	T
DERMAPTERA	24	2.78	0.52	1.62	T
DIPLOPODA	38	1.39	0.26	0.09	T
HYMENOPTERA ALATE	12	8.33	1.55	0.71	T
HYMENOPTERA NON-ALATE	1	37.50	12.92	3.29	T
ISOPTERA ALATE	14	2.78	3.62	3.71	T
ISOPTERA NON-ALATE	21	8.33	5.17	3.12	T
ISOPODA	27	1.39	0.26	0.29	T
LEPIDOPTERA ADULT	10	8.33	2.58	9.15	T
LEPIDOPTERA LARVA	13	11.11	2.84	14.48	T
MANTODEA	33	1.39	0.26	0.09	T
ORTHOPTERA	6	33.33	8.53	24.01	T
PHALANGIDA	22	1.39	0.26	0.14	T
TOTAL		83.33	41.60	66.22	TERRESTRIAL
INORGANIC MATERIAL	7	19.44	0.00	2.25	
VEGETABLE MATERIAL	8	13.89	0.00	2.01	

Table (6.7.3); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 108 specimens of Litoria nasuta.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
ODONATA ADULT	20	0.93	0.20	1.35	A
ODONATA NYMPH	36	0.93	0.61	8.98	A
TRICHOPTERA ADULT	18	0.93	0.20	0.01	A
ZYGOPTERA ADULT	25	0.93	0.20	0.27	A
TOTAL		2.77	1.22	10.61	AQUATIC
ARANEAE	5	32.41	9.94	17.10	TA
COLEOPTERA ADULT	2	42.59	23.73	11.15	TA
COLEOPTERA LARVA	23	0.93	0.20	0.02	TA
DIPTERA	3	24.07	24.14	1.43	TA
HEMIPTERA	4	20.37	5.88	3.14	TA
UNDETERMINED, ADULT	9	14.81	0.20	2.41	TA
UNDETERMINED, LARVA	19	0.93	0.20	0.22	TA
TOTAL		83.33	64.30	35.48	TERRESTRIAL and AQUATIC
ACARINA	16	0.93	0.20	0.00	T
BLATTODEA	15	4.63	1.01	0.54	T
CHILOPODA	17	5.56	1.42	0.62	T
COLLEMBOLA	11	0.93	0.41	0.01	T
DERMAPTERA	24	2.78	0.61	1.00	T
DIPLOPODA	38	0.93	0.20	0.09	T
HYMENOPTERA ALATE	12	8.33	4.26	0.85	T
HYMENOPTERA NON-ALATE	1	24.07	9.74	1.39	T
LEPIDOPTERA ADULT	10	3.70	1.01	0.48	T
LEPIDOPTERA LARVA	13	12.96	3.04	6.41	T
MANTODEA	33	0.93	0.20	2.24	T
ORTHOPTERA	6	39.81	11.76	36.08	T
PHASMIDA	31	1.85	0.41	1.54	T
TOTAL		70.37	34.28	51.26	TERRESTRIAL
INORGANIC MATERIAL	7	3.70	0.00	0.67	
VEGETABLE MATERIAL	8	11.11	0.20	1.98	

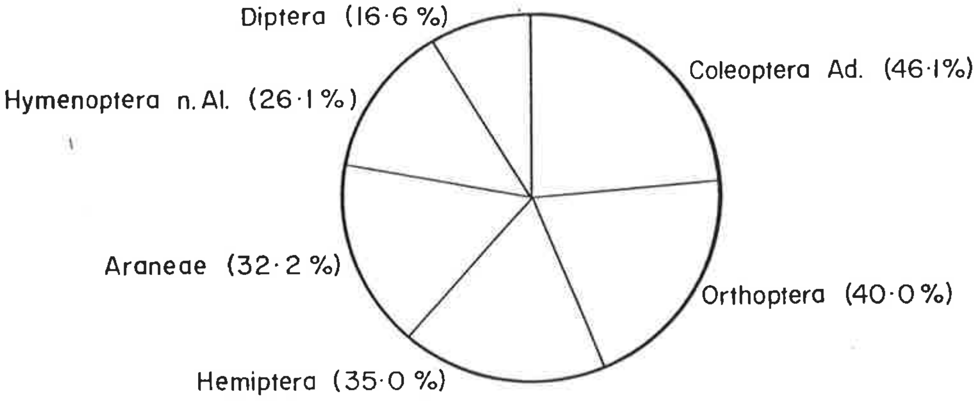
Table (6.7.4); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 89 specimens of Litoria tornieri.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
TOTAL		0.00	0.00	0.00	AQUATIC
ARANEAE	5	20.22	9.52	8.76	TA
COLEOPTERA ADULT	2	35.96	18.61	8.33	TA
COLEOPTERA LARVA	23	3.37	1.30	3.45	TA
DIPTERA	3	8.99	5.63	0.59	TA
HEMIPTERA	4	32.58	18.61	7.88	TA
UNDETERMINED, ADULT	9	12.36	0.00	1.69	TA
UNDETERMINED, LARVA	19	1.12	0.43	0.00	TA
TOTAL		74.15	54.11	30.71	TERRESTRIAL and AQUATIC
ACARINA	16	1.12	0.43	0.05	T
COLLEMBOLA	11	2.25	1.30	0.01	T
HYMENOPTERA ALATE	12	8.99	3.90	2.63	T
HYMENOPTERA NON-ALATE	1	14.61	5.63	1.08	T
ISOPTERA ALATE	14	5.62	6.93	5.75	T
ISOPTERA NON-ALATE	21	1.12	0.43	0.05	T
LEPIDOPTERA ADULT	10	10.11	3.90	6.05	T
LEPIDOPTERA LARVA	13	6.74	3.03	4.36	T
ORTHOPTERA	6	43.82	20.35	46.08	T
TOTAL		69.66	45.89	66.06	TERRESTRIAL
INORGANIC MATERIAL	7	11.24	0.00	1.70	
VEGETABLE MATERIAL	8	6.74	0.00	1.53	

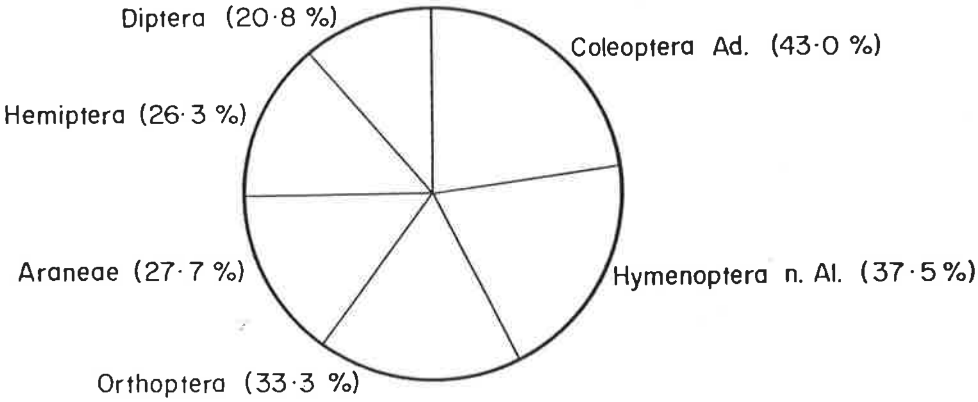
Figure 6.7.1; Percentage frequency of occurrence of principal prey orders in stomach contents of ground hylids.

Ad - Adults n.Al. - non Alate

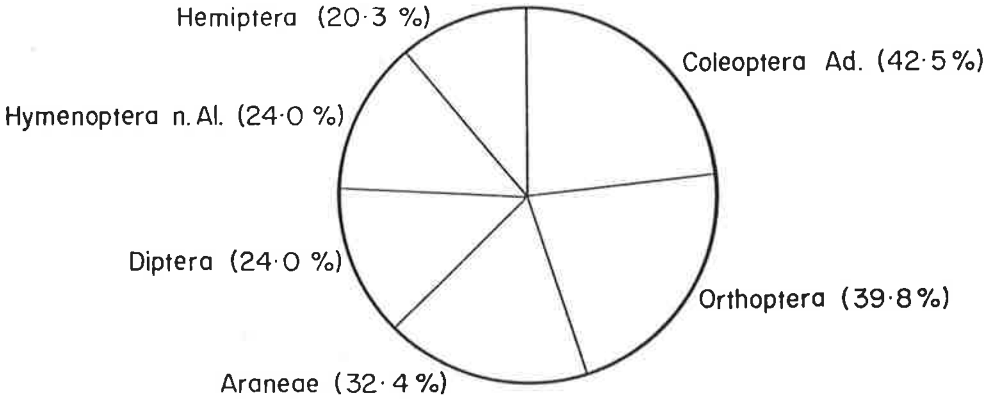
Litoria pallida



Litoria inermis



Litoria nasuta



Litoria tornieri

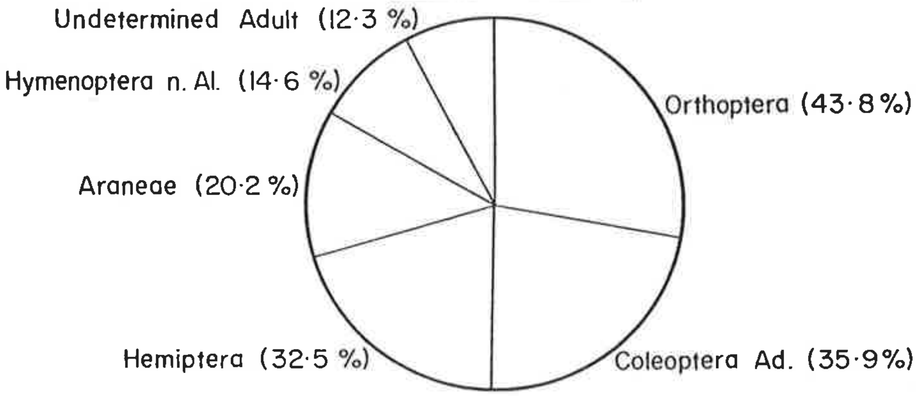
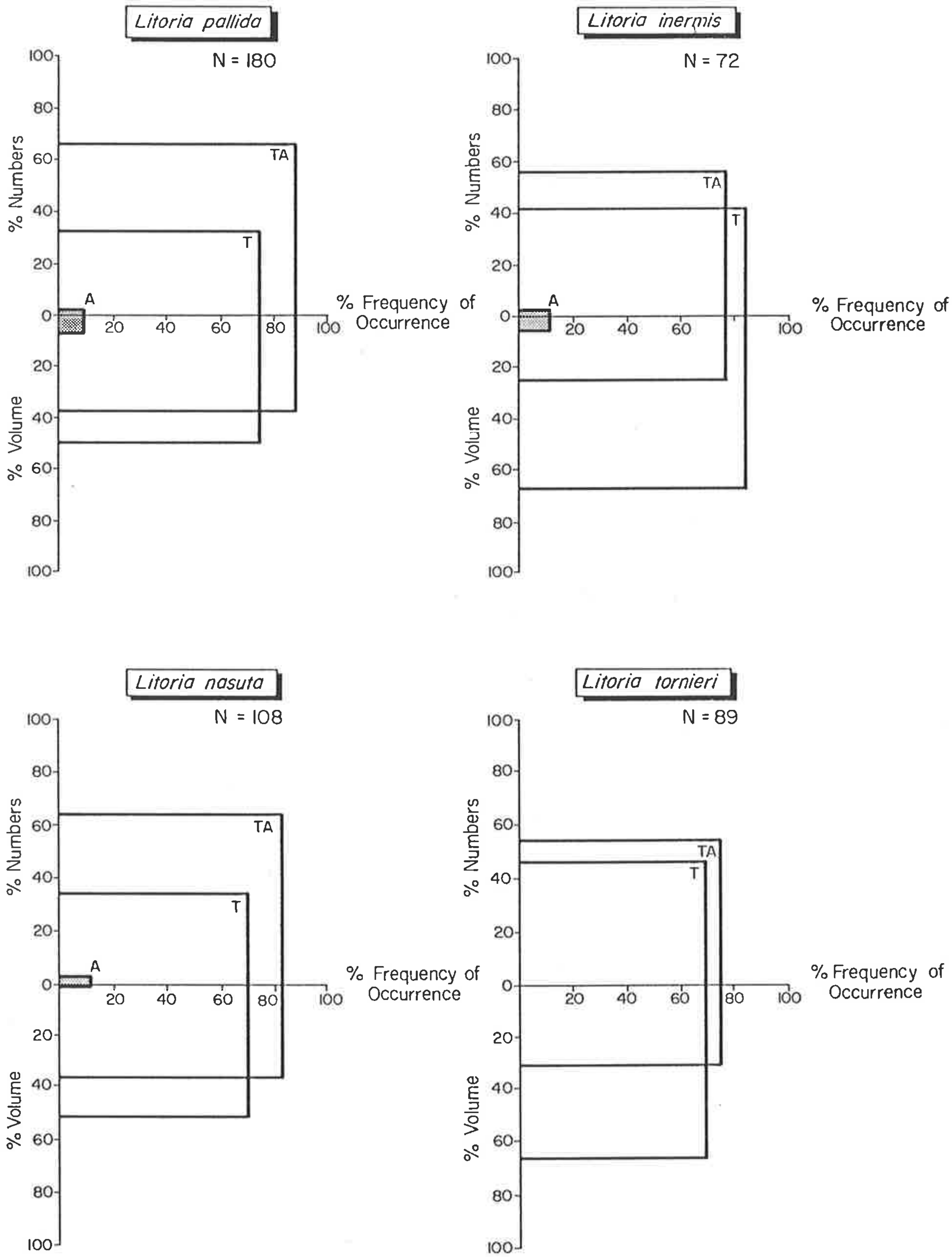


Figure 6.7.2; Contribution of aquatic, terrestrial and terrestrial/aquatic prey order to the samples of stomach contents of ground hylids quantified in terms of prey occurrence, numbers and volume.



Litoria pallida
N = 180
TA
T
A
% Numbers
% Volume
% Frequency of Occurrence
Litoria inermis
N = 72
TA
T
A
% Numbers
% Volume
% Frequency of Occurrence
Litoria nasuta
N = 108
TA
T
A
% Numbers
% Volume
% Frequency of Occurrence
Litoria tornieri
N = 89
TA
T
% Numbers
% Volume
% Frequency of Occurrence

tus and L. convexiusculus were classified as wide-mouthed, burrowing species. The samples of C. australis, C. longipes and L. ornatus were collected predominantly on roads in the Jabiru townsite along the Magela Creek transect and from breeding congregations at the Jabiru sewerage treatment works. Specimens of Limnodynastes convexiusculus were collected on the Magela Creek flood-plain, along the Magela Creek and Gulungul Creek transects, and on townsite roads.

Lists of stomach contents and the number of stomachs examined for each species are presented as Tables (6.8.1), (6.8.2), (6.8.3) and (6.8.4). The six predominant prey orders for each species, in terms of frequency of occurrence, are presented in Figure (6.8.1). The contribution of aquatic, terrestrial and terrestrial/aquatic prey orders is quantified in terms of frequency of occurrence, numbers and volume for these species in Figure (6.8.2).

6.8.1; OCCURRENCE OF AQUATIC PREY ORDERS.

Aquatic orders occurred infrequently in stomachs of Cyclorana australis (Anura 3.8%) and C. longipes (Trichoptera and Odonata 6.0%) but were absent from samples of Limnodynastes ornatus and L. convexiusculus.

Terrestrial orders occurred most frequently in samples of C. australis and L. ornatus and equalled terrestrial/aquatic orders in frequency of occurrence within samples of C. longipes and L. convexiusculus. Terrestrial orders were most important in terms of numbers and volume in the

Table (6.8.1); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 78 specimens of Cyclorana australis.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
ANURA ADULT	29	3.85	0.60	1.52	A
TOTAL		3.85	0.60	1.52	AQUATIC
ARANEAE	5	23.08	4.02	2.83	TA
COLEOPTERA ADULT	2	35.90	7.43	9.63	TA
COLEOPTERA LARVA	23	1.28	0.20	0.01	TA
DIPTERA	3	5.13	1.00	0.01	TA
HEMIPTERA	4	10.26	3.01	0.41	TA
OTHER, VERTEBRATE	42	1.28	0.20	0.63	TA
UNDETERMINED, ADULT	9	5.13	0.40	1.15	TA
UNDETERMINED, LARVA	19	2.56	0.40	0.24	TA
TOTAL		51.82	16.67	14.91	TERRESTRIAL and AQUATIC
BLATTODEA	15	7.69	1.20	4.46	T
CHILOPODA	17	14.10	2.41	12.08	T
COLLEMBOLA	11	1.28	1.41	0.00	T
DERMAPTERA	24	2.56	0.40	0.26	T
DIPLOPODA	38	6.41	1.00	0.30	T
HYMENOPTERA ALATE	12	5.13	1.00	0.08	T
HYMENOPTERA NON-ALATE	1	20.51	15.06	0.52	T
ISOPTERA ALATE	14	19.23	34.74	12.07	T
ISOPTERA NON-ALATE	21	5.13	11.85	1.07	T
LEPIDOPTERA ADULT	10	5.13	1.00	0.22	T
LEPIDOPTERA LARVA	13	12.82	2.61	2.16	T
ORTHOPTERA	6	35.90	8.84	41.84	T
PHASMIDA	31	1.28	0.20	1.22	T
TOTAL		78.20	81.73	76.28	TERRESTRIAL
INORGANIC MATERIAL	7	41.03	0.60	4.87	
VEGETABLE MATERIAL	8	30.77	0.40	2.42	

Table (6.8.2); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 66 specimens of <u>Cyclorana longipes</u>.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
ODONATA ADULT	20	3.03	0.20	0.22	A
TRICHOPTERA ADULT	18	3.03	0.78	0.27	A
TOTAL		6.06	0.98	0.50	AQUATIC
ARANEAE	5	36.36	3.91	3.02	TA
COLEOPTERA ADULT	2	57.58	21.41	7.79	TA
DIPTERA	3	30.30	6.26	1.15	TA
HEMIPTERA	4	36.36	4.59	5.32	TA
UNDETERMINED, ADULT	9	1.52	0.00	0.32	TA
UNDETERMINED, LARVA	19	4.55	0.20	0.10	TA
TOTAL		83.33	36.36	17.70	TERRESTRIAL and AQUATIC
BLATTODEA	15	7.58	0.49	0.36	T
CHILOPODA	17	6.06	0.49	0.39	T
COLLEMBOLA	11	6.06	0.78	0.01	T
HYMENOPTERA ALATE	12	7.58	1.37	0.32	T
HYMENOPTERA NON-ALATE	1	37.88	14.76	2.83	T
ISOPTERA ALATE	14	18.18	11.44	13.66	T
ISOPTERA NON-ALATE	21	4.55	20.92	2.09	T
LEPIDOPTERA ADULT	10	13.64	1.37	3.06	T
LEPIDOPTERA LARVA	13	19.70	4.20	17.78	T
MANTODEA	33	1.52	0.10	0.05	T
ORTHOPTERA	6	46.97	6.55	36.03	T
PHALANGIDA	22	1.52	0.10	0.02	T
PHASMIDA	31	1.52	0.10	3.21	T
TOTAL		83.33	62.66	79.81	TERRESTRIAL
INORGANIC MATERIAL	7	13.64	0.00	0.63	
VEGETABLE MATERIAL	8	24.24	0.00	1.36	

Table (6.8.3); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 100 specimens of Limnodynastes ornatus.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
TOTAL		0.00	0.00	0.00	AQUATIC
ARANEAE	5	18.00	0.99	0.65	TA
COLEOPTERA ADULT	2	72.00	7.71	19.59	TA
COLEOPTERA LARVA	23	5.00	0.29	0.23	TA
DIPTERA	3	10.00	0.66	0.08	TA
GASTROPODA	35	2.00	0.08	0.08	TA
HEMIPTERA	4	17.00	1.07	1.86	TA
UNDETERMINED, ADULT	9	6.00	0.08	1.16	TA
UNDETERMINED, LARVA	19	1.00	0.04	0.00	TA
TOTAL		89.00	10.93	23.66	TERRESTRIAL and AQUATIC
ACARINA	16	6.00	0.25	0.05	T
BLATTODEA	15	6.00	0.37	0.45	T
CHILOPODA	17	5.00	0.21	0.35	T
COLLEMBOLA	11	5.00	0.33	0.02	T
DERMAPTERA	24	1.00	0.04	0.02	T
DIPLOPODA	38	8.00	0.54	1.34	T
HYMENOPTERA ALATE	12	11.00	3.92	3.50	T
HYMENOPTERA NON-ALATE	1	96.00	75.75	40.39	T
ISOPTERA ALATE	14	15.00	5.32	21.50	T
ISOPTERA NON-ALATE	21	3.00	0.74	0.83	T
ISOPODA	27	3.00	0.21	0.50	T
LEPIDOPTERA ADULT	10	4.00	0.37	0.26	T
LEPIDOPTERA LARVA	13	5.00	0.21	0.26	T
ORTHOPTERA	6	10.00	0.49	3.37	T
PHALANGIDA	22	7.00	0.33	0.33	T
TOTAL		98.00	89.07	73.19	TERRESTRIAL
INORGANIC MATERIAL	7	34.00	0.00	2.18	
VEGETABLE MATERIAL	8	6.00	0.00	0.97	

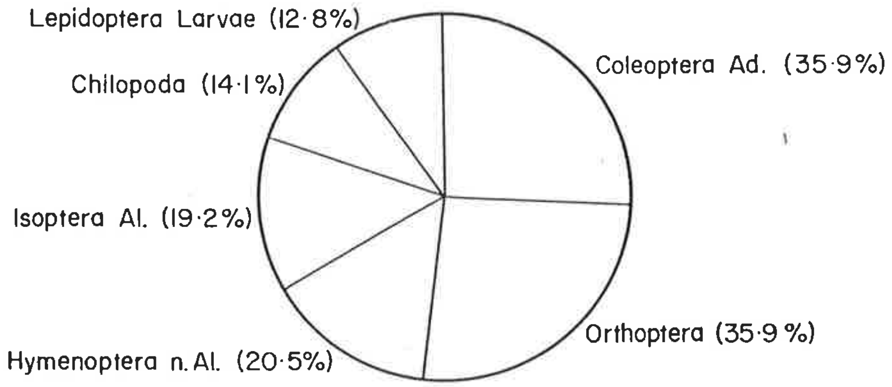
Table (6.8.4); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 22 specimens of Limnodynastes convexiusculus.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
TOTAL		0.00	0.00	0.00	AQUATIC
ARANEAE	5	9.09	5.00	10.25	TA
COLEOPTERA ADULT	2	40.91	40.00	13.66	TA
HEMIPTERA	4	9.09	7.50	1.09	TA
TOTAL		59.09	52.50	25.00	TERRESTRIAL and AQUATIC
BLATTODEA	15	4.55	2.50	25.95	T
CHILOPODA	17	4.55	2.50	1.17	T
DERMAPTERA	24	9.09	5.00	3.50	T
HYMENOPTERA NON-ALATE	1	13.64	7.50	0.14	T
LEPIDOPTERA LARVA	13	4.55	2.50	0.05	T
OLIGOCHAETA	30	4.55	2.50	0.10	T
ORTHOPTERA	6	27.27	15.00	42.16	T
PHALANGIDA	22	9.09	10.00	1.04	T
TOTAL		59.09	47.50	74.11	TERRESTRIAL
INORGANIC MATERIAL	7	13.64	0.00	0.46	
VEGETABLE MATERIAL	8	9.09	0.00	0.43	

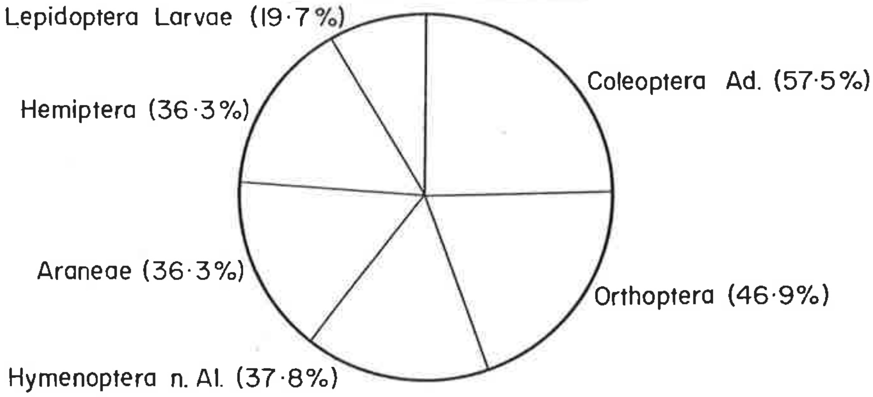
Figure 6.8.1; Percentage frequency of occurrence of principal prey orders in stomach contents of wide-mouthed, burrowing frogs.

Al - Alate   n.Al. - non Alate

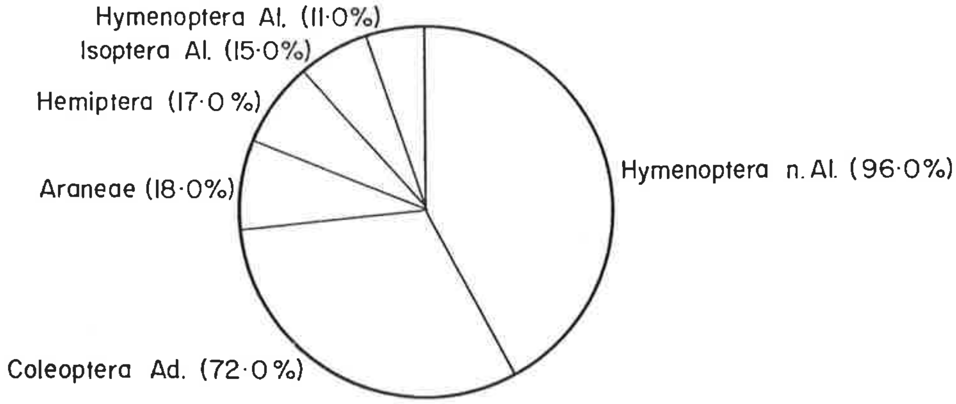
Cyclorana australis



Cyclorana longipes



Limnodynastes ornatus



Limnodynastes convexiusculus

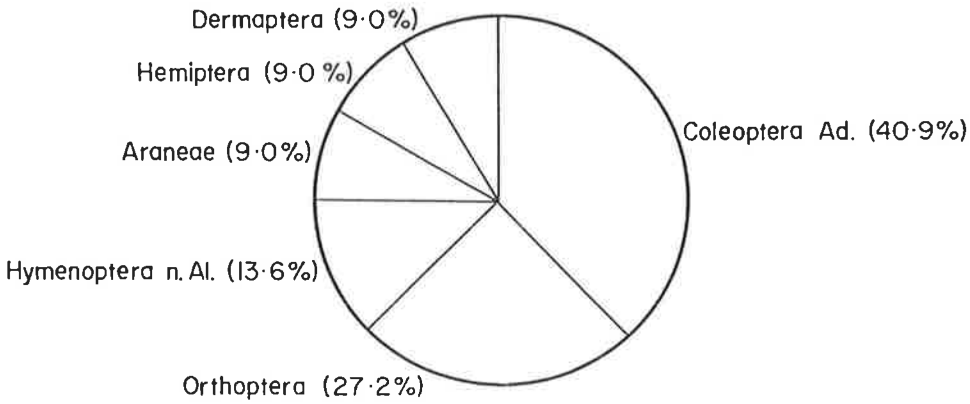
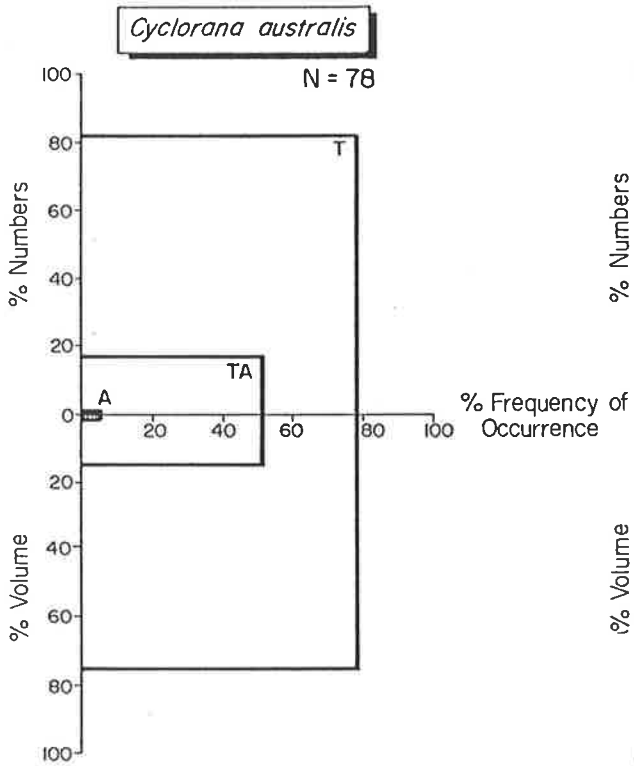
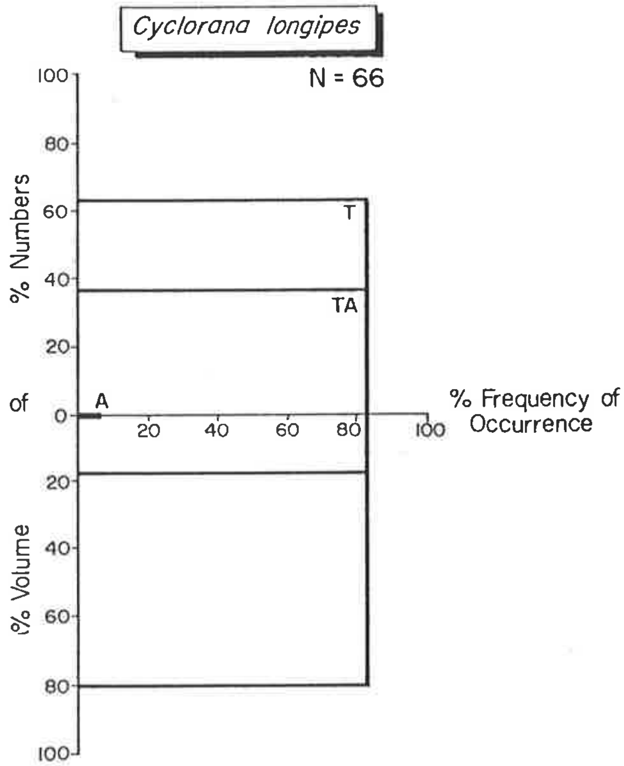
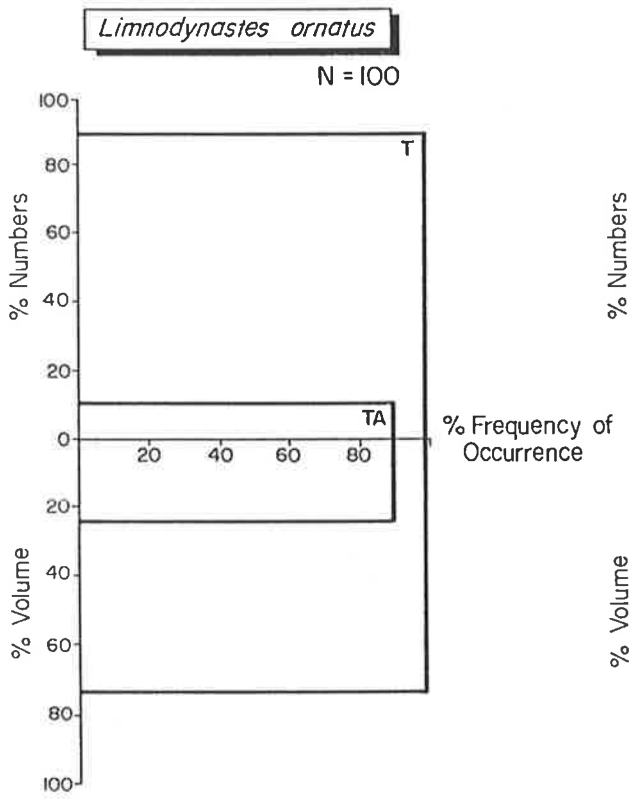
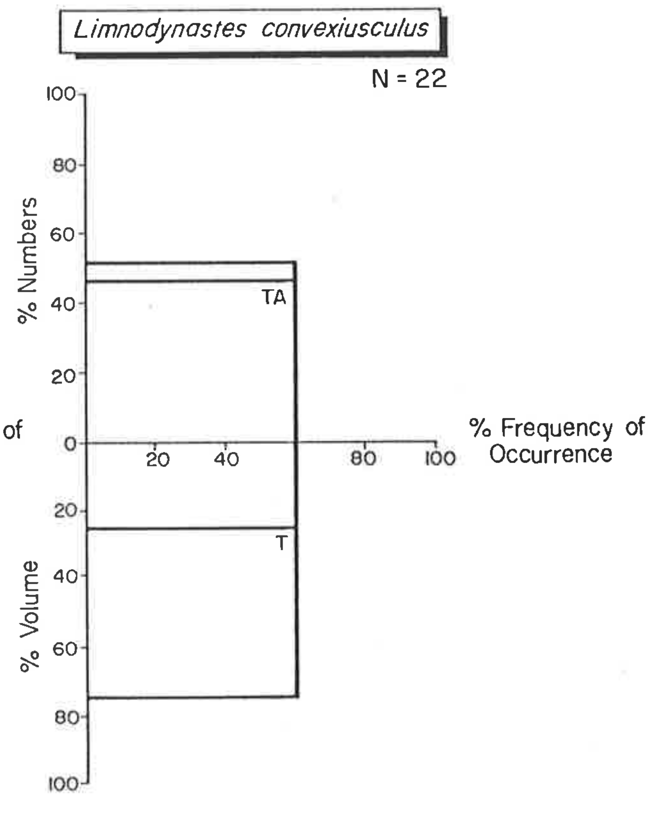


Figure 6.8.2; Contribution of aquatic, terrestrial and terrestrial/aquatic prey orders to the sample of stomach contents of wide-mouthed, burrowing frogs quantified in terms of prey occurrence, numbers and volume.


Cyclorana australis
N = 78
% Numbers
% Volume
% Frequency of Occurrence
T
TA
A
0
20
40
60
80
100


Cyclorana longipes
N = 66
% Numbers
% Volume
% Frequency of Occurrence
T
TA
A
0
20
40
60
80
100


Limnodynastes ornatus
N = 100
% Numbers
% Volume
% Frequency of Occurrence
T
TA
0
20
40
60
80
100


Limnodynastes convexiusculus
N = 22
% Numbers
% Volume
% Frequency of Occurrence
TA
T
0
20
40
60
80
100

samples of all four species.

The Coleoptera, Orthoptera, Hymenoptera and Araneae were the four most commonly occurring prey orders for Cyclorana australis, C. longipes and Limnodynastes convexiusculus. Non-alate Hymenoptera occurred in 96% of the L. ornatus stomachs examined and predominated in terms of numbers and volumes of items for this species.

Alate isopterans, lepidopteran larvae and hemipterans also were predominant prey orders in the stomach contents of the wide-mouthed, burrowing species.

6.9; NARROW-MOUTHED, BURROWING FROGS.

Most of the specimens of Notaden melanoscaphus examined were males collected from breeding congregations at the Jabiru East airstrip, the Tailings dam, Gulungul Swamp and along the Gulungul Creek and Magela Creek transects.

Results of analyses of stomach contents of this species are presented in full as Table (6.9.1), and in terms of the six predominant prey orders as Figure (6.9.1). The contribution of all orders classified as aquatic, terrestrial and terrestrial/aquatic is quantified in Figure (6.9.2).

6.9.1; OCCURRENCE OF AQUATIC PREY ORDERS.

No aquatic prey orders were identified in the stomachs of N. melanoscaphus. Non-alate Hymenoptera dominated in

Table (6.9.1); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 77 specimens of Notaden melanoscaphus.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
TOTAL		0.00	0.00	0.00	AQUATIC
ARANEAE	5	2.60	0.08	0.02	TA
COLEOPTERA ADULT	2	46.75	2.62	5.21	TA
HEMIPTERA	4	3.90	0.12	1.01	TA
UNDETERMINED, ADULT	9	1.30	0.04	0.02	TA
TOTAL		48.05	2.85	6.26	TERRESTRIAL and AQUATIC
ACARINA	16	1.30	0.04	0.01	T
CHILOPODA	17	3.90	0.16	0.24	T
HYMENOPTERA ALATE	12	1.30	0.12	0.24	T
HYMENOPTERA NON-ALATE	1	92.21	95.12	78.95	T
ISOPTERA ALATE	14	3.90	1.02	0.61	T
ISOPTERA NON-ALATE	21	3.90	0.55	0.37	T
ORTHOPTERA	6	1.30	0.04	0.03	T
PHALANGIDA	22	2.60	0.08	0.10	T
TOTAL		92.20	97.11	80.55	TERRESTRIAL
INORGANIC MATERIAL	7	58.44	0.00	11.63	
VEGETABLE MATERIAL	8	16.88	0.04	1.56	

Figure 6.9.1; Percentage frequency of occurrence of principal prey orders in stomach contents of narrow-mouthed, burrowing frogs.

Notaden melanoscaphus

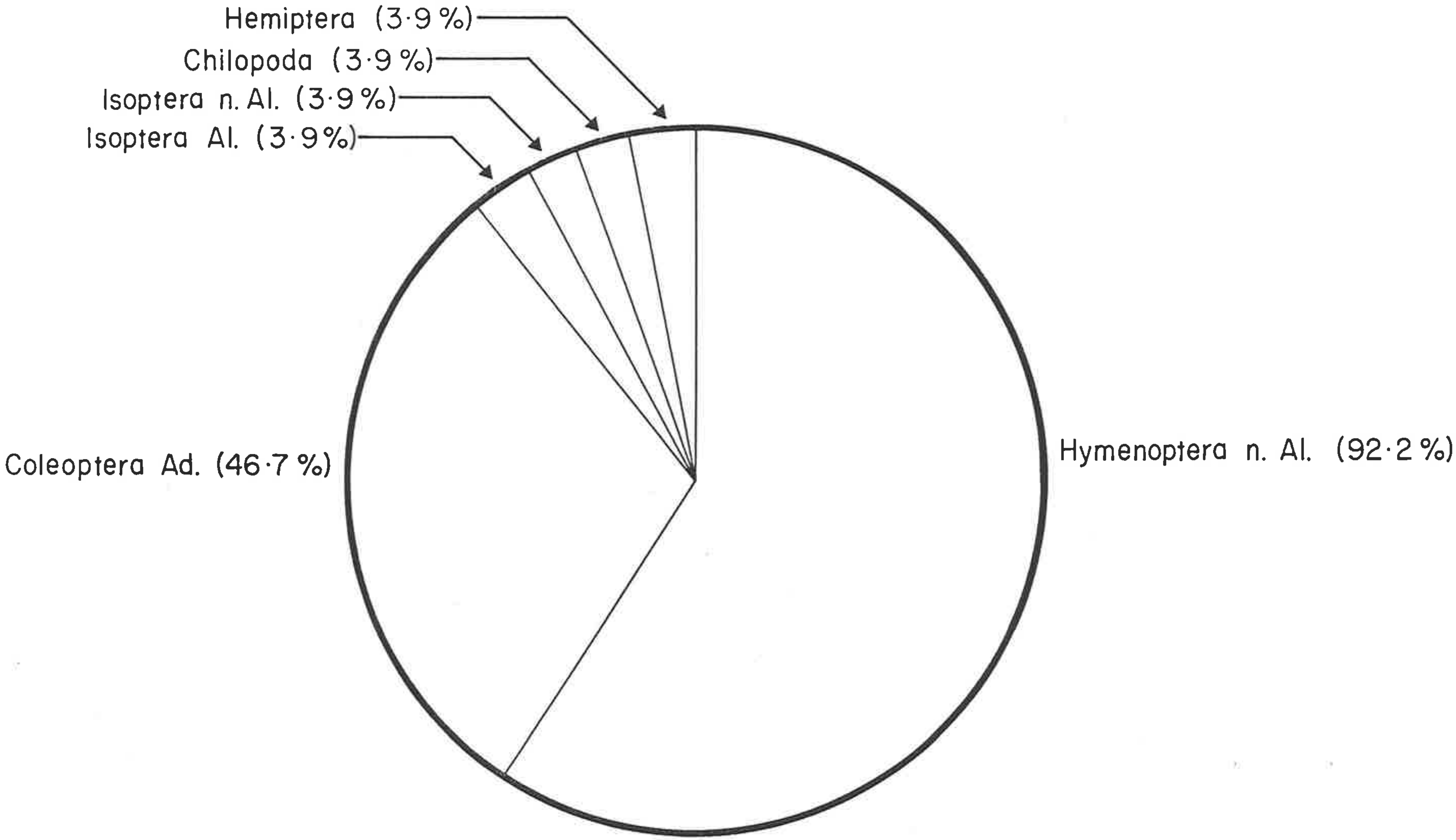
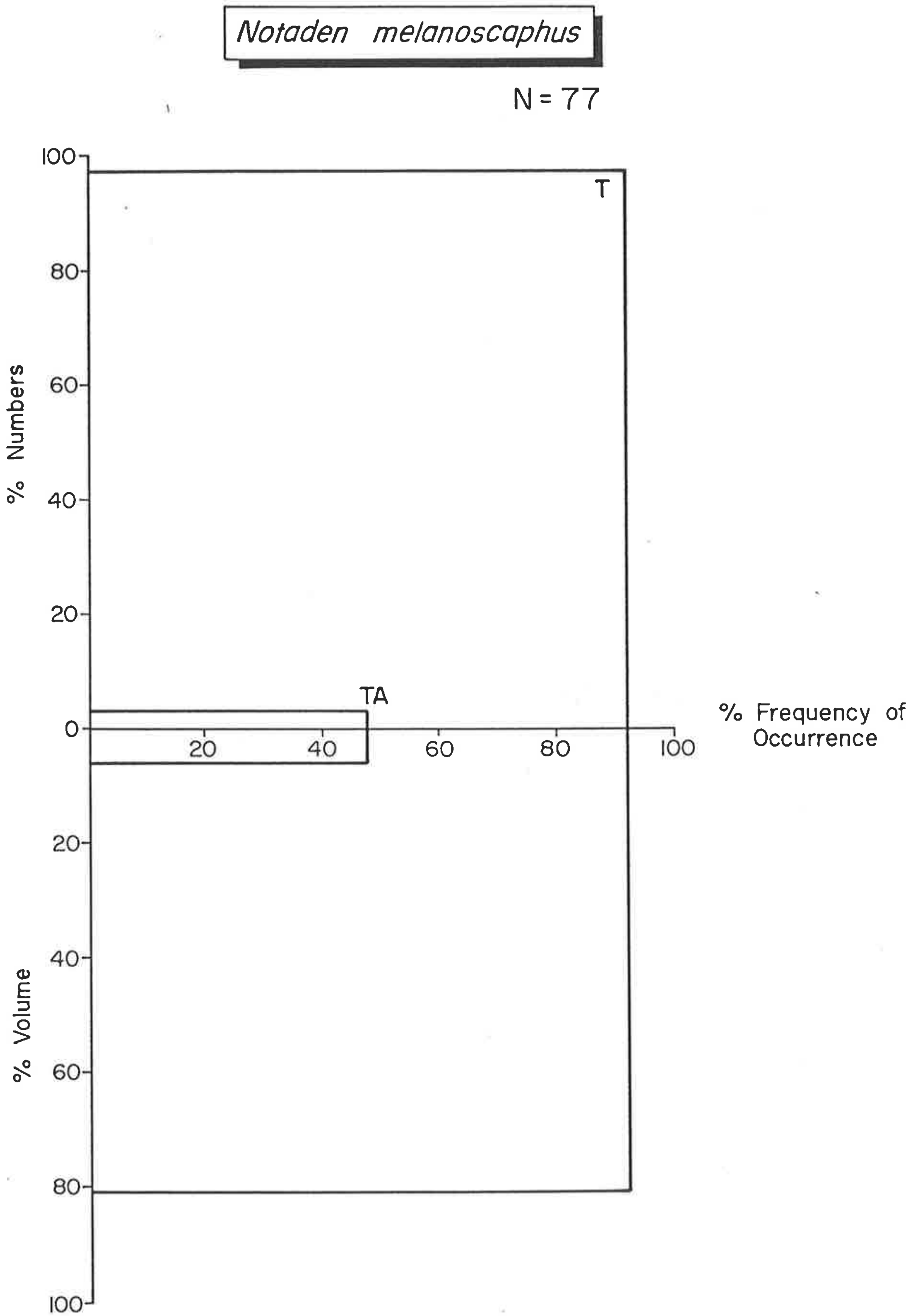


Figure 6.9.2; Contribution of aquatic, terrestrial and terrestrial/aquatic prey orders to the samples of stomach contents of narrow-mouthed, burrowing frogs quantified in terms of prey occurrence, numbers and volume.



Notaden melanoscaphus
N = 77
100
80
60
40
20
0
% Numbers
T
TA
20
40
60
80
100
% Frequency of Occurrence
20
40
60
80
100
% Volume

terms of frequency of occurrence (92.2%), number of items (95.1%) and volume of items identified (78.9%). Orders classified as terrestrial/aquatic occurred less frequently, consisting almost entirely of adult Coleoptera. All other orders occurred in less than 4% of stomachs examined.

6.10; TOADLETS.

The stomach contents of 91 specimens of *Uperoleia inundata* were examined. Most of these toadlets were collected within or adjacent to breeding congregations along the Magela Creek and Gulungul Creek transects and in Gulungul Swamp.

Results of stomach content analyses for *U. inundata* are presented as Table (6.10.1) and summarised in terms of the six predominantly occurring prey orders, as Figure (6.10.1). The contribution of all orders classified as aquatic, terrestrial and terrestrial/aquatic is quantified in Figure (6.10.2).

6.10.1; OCCURRENCE OF AQUATIC PREY ORDERS.

Aquatic prey orders were not identified in stomachs of *Uperoleia inundata*. Non-alate Hymenoptera were predominant in terms of frequency of occurrence (86.8%) and number of items identified (65.9%). Non-alate Isoptera occupied the greatest volume within the items identified (46.4%). Very small prey animals (Collembola and Acarina) were significant in terms of frequency of occurrence.

Orders classified as terrestrial/aquatic were of

Table (6.10.1); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 91 specimens of Uperoleia inundata.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
TOTAL		0.00	0.00	0.00	AQUATIC
ARANEAE	5	9.89	0.47	0.23	TA
COLEOPTERA ADULT	2	29.67	1.75	2.93	TA
COLEOPTERA LARVA	23	1.10	0.04	0.29	TA
DIPTERA	3	4.40	0.23	0.08	TA
HEMIPTERA	4	4.40	0.16	0.21	TA
UNDETERMINED, ADULT	9	13.19	0.04	1.13	TA
TOTAL		47.25	2.68	4.87	TERRESTRIAL and AQUATIC
ACARINA	16	17.58	1.32	0.40	T
BLATTODEA	15	1.10	0.04	0.09	T
CHILOPODA	17	2.20	0.08	0.27	T
COLLEMBOLA	11	30.77	4.00	0.57	T
DIPLOPODA	38	1.10	0.04	0.09	T
HYMENOPTERA ALATE	12	4.40	0.43	0.38	T
HYMENOPTERA NON-ALATE	1	86.81	65.94	32.04	T
ISOPTERA ALATE	14	3.30	1.91	5.38	T
ISOPTERA NON-ALATE	21	15.38	22.98	46.40	T
ISOPODA	27	2.20	0.08	0.63	T
LEPIDOPTERA LARVA	13	1.10	0.04	0.12	T
ORTHOPTERA	6	8.79	0.35	0.47	T
SCORPIONIDA	41	1.10	0.04	0.01	T
THYSANOPTERA	32	1.10	0.04	0.01	T
TOTAL		96.70	97.28	86.87	TERRESTRIAL
INORGANIC MATERIAL	7	21.98	0.00	3.74	
VEGETABLE MATERIAL	8	16.48	0.04	4.52	

Figure 6.10.1; Percentage frequency of occurrence of principal prey orders in stomach contents of toadlets.

Uperoleia inundata

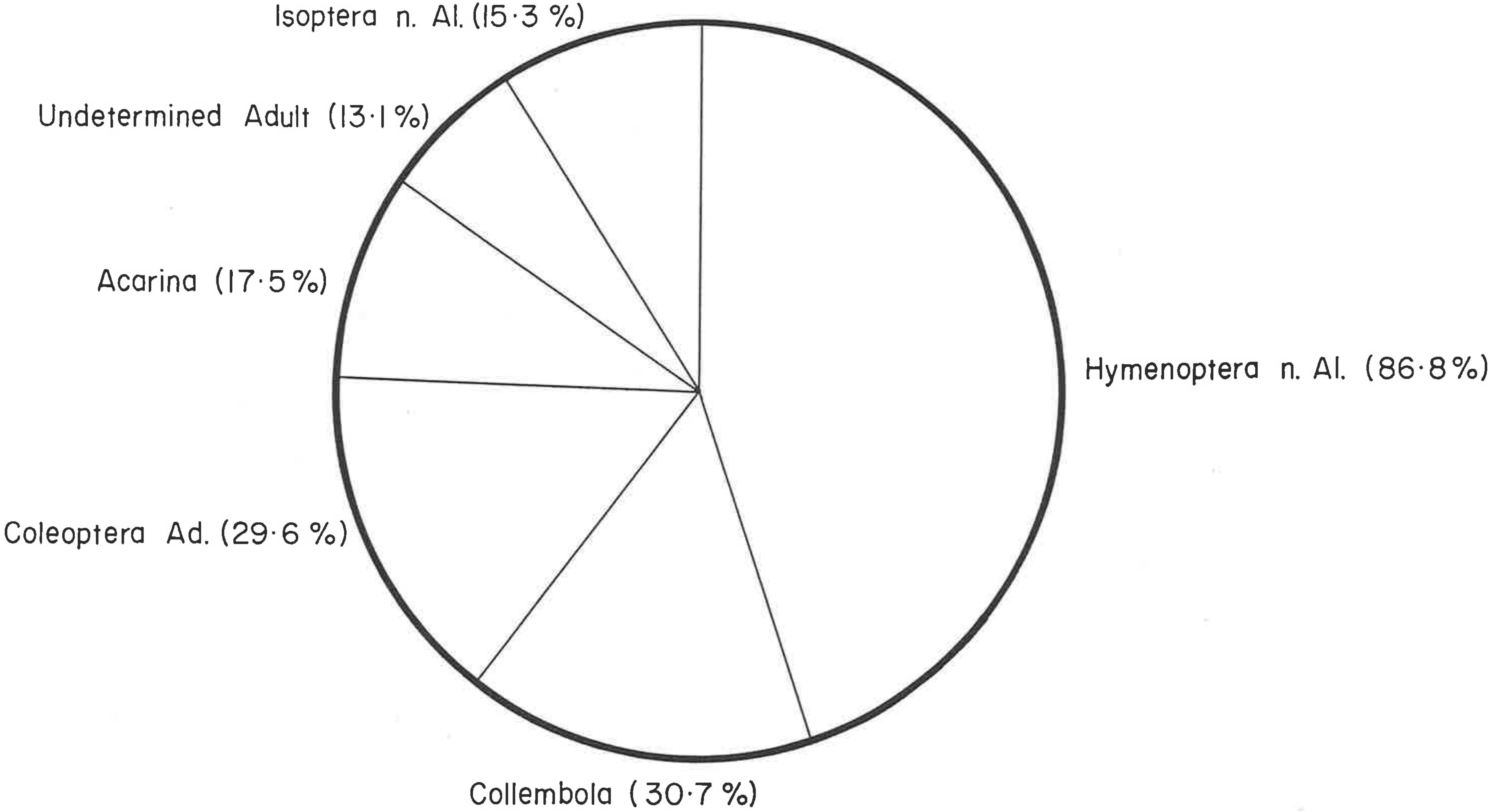
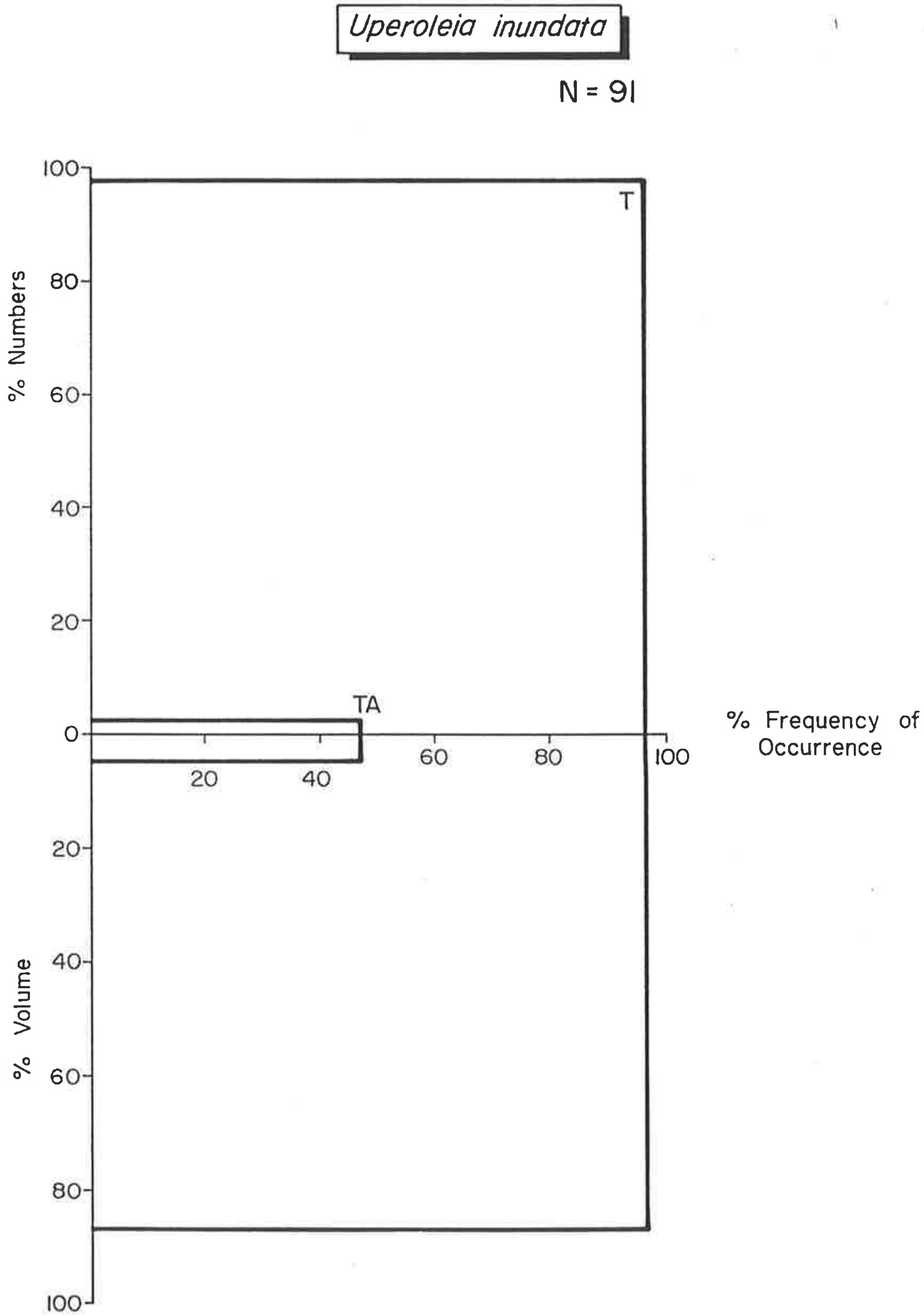


Figure 6.10.2 Contribution of aquatic, terrestrial and terrestrial/aquatic prey orders to the sample of stomach contents of toadlets quantified in terms of prey occurrence, numbers and volume.


Uperoleia inundata
N = 91
100
80
60
40
20
0
20
40
60
80
100
% Numbers
% Volume
T
TA
20
40
60
80
100
% Frequency of Occurrence

secondary significance, comprised mainly of adult Coleoptera and unidentified adult arthropods.

6.11; FROGLETS.

The sample of 62 specimens of Ranidella bilingua comprised mainly calling males collected at the Tailings dam, Nankeen Billabong and the along Gulungul Creek transects.

Lists of stomach contents are presented in Table (6.11.1) and summarised in terms of the six predominantly occurring prey orders as Figure (6.11.1). The contribution of all orders classified as aquatic, terrestrial and terrestrial/aquatic is quantified in Figure (6.11.2).

6.11.1; OCCURRENCE OF AQUATIC PREY ORDERS.

A single aquatic prey Order, the Ephemeroptera, occurred in less than 2% of the stomachs examined. Aquatic prey were of minor significance in comparison with terrestrial and terrestrial/aquatic orders. The small terrestrial Collembola, Hymenoptera and Acarina occurred most frequently and in greatest numbers. The Coleoptera, Hemiptera and Diptera were the most frequently occurring orders classified as terrestrial/aquatic in origin and occupied the greater volume of items identified in stomach content analyses.

7.1; STOMACH CONTENT ANALYSES AT THE LEVEL OF PREY FAMILY.

Coleoptera, Hemiptera, Diptera and Araneae were the

Table (6.11.1); Percentage Frequency of Occurrence, Numbers and Volume of prey Orders identified during stomach content analyses of N = 91 specimens of Ranidella bilingua.

PREY ORDER	PREY CODE	% FREQUENCY OF OCCURRENCE (% F.O.)	% NUMBERS (% SUMNUM)	% VOLUME (% SUMVOL)	PREY ORIGIN
EPHEMEROPTERA	28	1.61	0.12	0.67	A
TOTAL		1.61	0.12	0.67	AQUATIC
ARANEAE	5	29.03	2.44	7.49	TA
COLEOPTERA ADULT	2	50.00	6.94	19.86	TA
COLEOPTERA LARVA	23	1.61	0.12	0.01	TA
DIPTERA	3	33.87	6.21	9.42	TA
HEMIPTERA	4	54.84	7.80	18.78	TA
UNDETERMINED, ADULT	9	3.23	0.00	0.94	TA
UNDETERMINED, LARVA	19	14.52	1.83	1.48	TA
TOTAL		90.32	25.33	57.99	TERRESTRIAL and AQUATIC
ACARINA	16	41.94	4.99	2.26	T
COLLEMBOLA	11	69.35	54.45	10.77	T
HYMENOPTERA ALATE	12	1.61	0.12	0.01	T
HYMENOPTERA NON-ALATE	1	59.68	12.79	15.70	T
LEPIDOPTERA ADULT	10	4.84	0.37	1.48	T
LEPIDOPTERA LARVA	13	1.61	0.12	0.20	T
ORTHOPTERA	6	16.13	1.58	8.76	T
PHALANGIDA	22	1.61	0.12	0.07	T
TOTAL		93.54	74.54	39.25	TERRESTRIAL
INORGANIC MATERIAL	7	8.06	0.00	1.95	
VEGETABLE MATERIAL	8	1.61	0.00	0.13	

Figure 6.11.1; Percentage frequency of occurrence of principal prey orders in stomach contents of froglets.

Ranidella bilingua

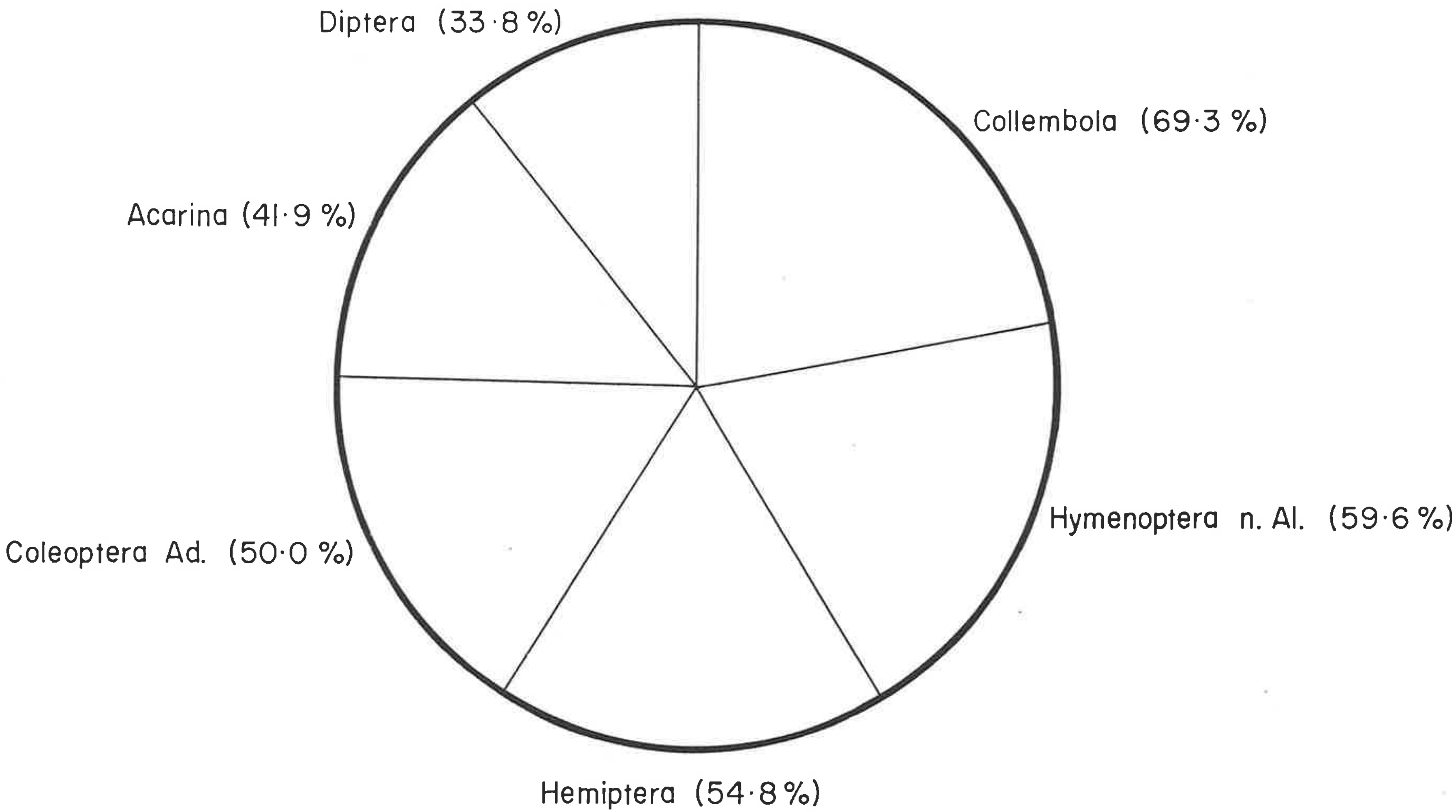
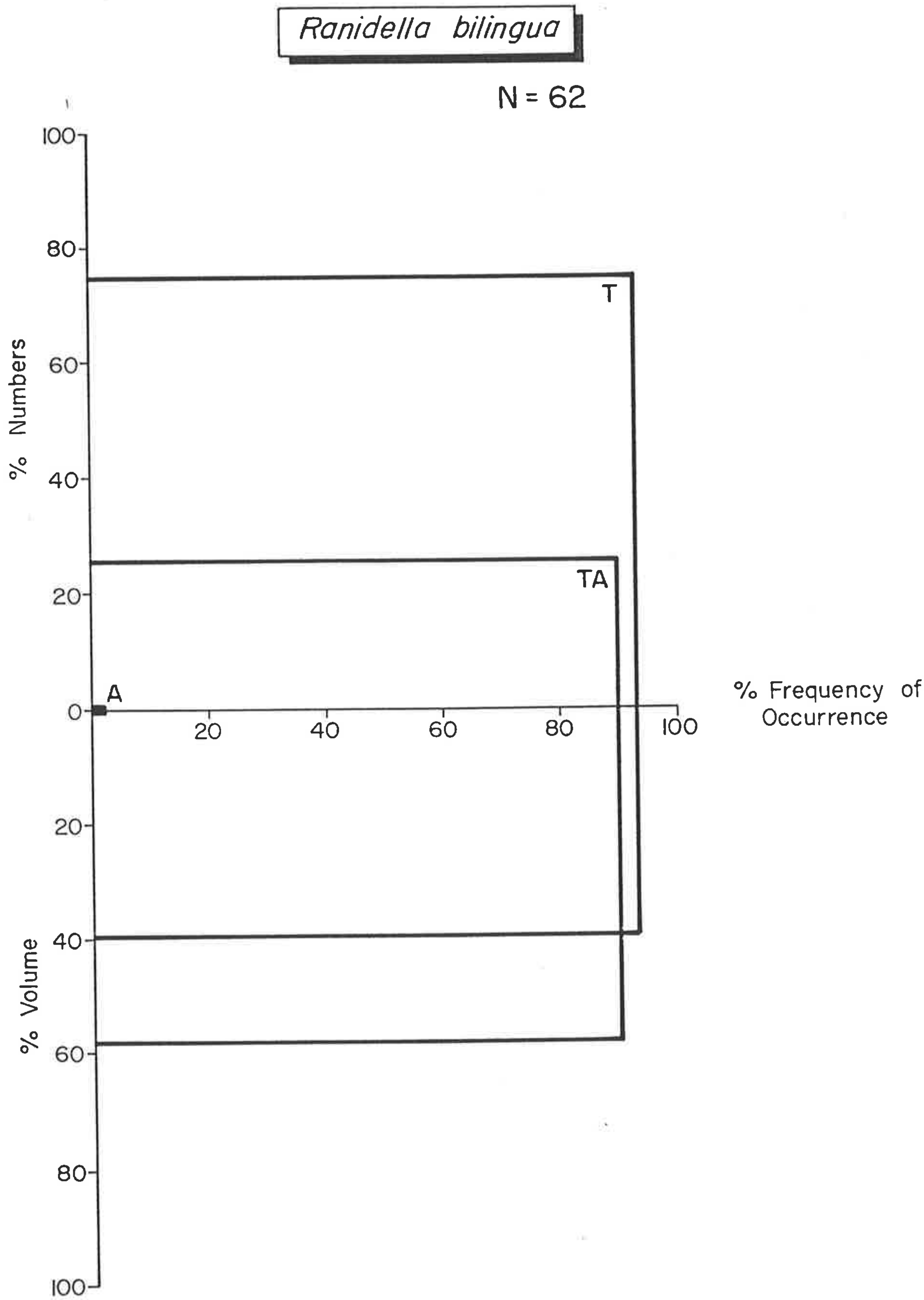


Figure 6.11.2; Contribution of aquatic, terrestrial and terrestrial/aquatic prey orders to the sample of stomach contents of **Froglets** *Ranidella bilingua* quantified in terms of prey occurrence, numbers and volume.


Ranidella bilingua
N = 62
100
80
60
% Numbers
40
20
0
A
T
TA
20
40
60
80
100
% Frequency of Occurrence
20
40
% Volume
60
80
100

most important prey orders classified as terrestrial/ aquatic in origin. To determine the proportion of the Coleoptera and Hemiptera in stomach contents of each species of aquatic origin, relatively intact specimens were identified to Family level. This analysis resulted in recognition of 13 coleopteran and 7 hemipteran families of aquatic origin.

The frequencies of occurrence of 22 prey families are presented as percentages of total numbers of stomachs examined for each species in Table (7.1.1), and as unprocessed data in Appendix (7.1.1). The numbers of items of each prey Family identified are presented as percentages of total numbers of items identified for each species in Table (7.1.2) and as unprocessed data in Appendix (7.1.2).

The results of these analyses have been summarised further in Table (7.1.3) and Appendix (7.1.3) by presenting the pooled contribution of both terrestrial and aquatic prey families of both the Coleoptera and Hemiptera to the total number of prey items identified. These pooled data for each species are presented in Figures (7.2.1) to (7.8.1).

7.2; AQUATIC FROGS.

Aquatic prey families of the Coleoptera (7) and Hemiptera (7) were identified in 31.9% and 21.2% respectively, of stomachs of *Litoria dahlii*. These families comprised 26.9% of the total number of items identified for this species.

Table (7.1.1) Frequency of occurrence of 22 prey families identified in stomach content analyses; expressed as pércentages of total number of stomachs examined for each of 15 species.

PREY FAMILY	FAMILY CODE	SPECIES															
		L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.	TOTAL
1. COLEOPTERA																	
TERRESTRIAL	20	61.7	66.7	41.2	64.0	71.4	53.6	82.3	70.4	88.5	74.3	93.5	83.3	81.2	80.0	36.7	67.4
DYTISCIDAE	21	7.4	0.0	2.0	0.0	4.1	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	2.3
GYRINIDAE	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.2
HALIPLIDAE	24	0.0	0.0	0.0	0.0	4.1	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
HELODIDAE	220	0.0	20.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
HISTERIDAE	26	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
HYDRAENIDAE	27	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	3.3	1.0
HYDROCHIDAE	28	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
HYDROPHILIDAE	29	19.1	0.0	3.9	4.0	0.0	0.0	0.0	0.0	3.8	0.0	4.3	16.6	12.5	0.0	6.7	5.7
HYGROBIIDAE	210	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
LIMNICHIDAE	211	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.8
PSEPHENIDAE	216	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	16.7	1.8
SPERCHEIDAE	217	0.0	0.0	0.0	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
SPHAERIIDAE	218	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
POOLED AQUATIC		31.9	20.0	13.7	4.0	8.2	17.8	0.0	0.0	3.8	2.9	6.5	16.7	12.5	26.7	33.3	14.6
2. HEMIPTERA																	
TERRESTRIAL	40	29.8	30.0	53.0	32.0	34.7	42.9	26.5	48.1	23.1	42.9	13.0	0.0	6.2	13.3	63.3	33.6
GERRIDAE	42	2.1	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
HEBRIDAE	45	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.4
MESOVELIIDAE	412	5.3	0.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
NAUCORIDAE	413	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	1.6
OCHTERIDAE	414	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
PLEIDAE	415	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
VELIIDAE	419	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
POOLED AQUATIC		21.3	0.0	4.0	0.0	2.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	6.7	0.0	4.9
NUMBER OF STOMACHS EXAMINED		94	30	51	25	49	28	34	27	26	35	46	6	16	15	30	512

Table 7.1.2; Number of items of 22 prey families identified in stomach content analyses; expressed as percentages of total number of prey items identified for each of 15 species.

PREY FAMILY	FAMILY CODE	SPECIES L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.	TOTAL
1. COLEOPTERA																	
TERRESTRIAL	20	55.9	49.1	37.0	65.4	58.4	44.4	81.1	62.5	71.0	71.2	79.2	88.9	80.0	68.2	32.7	59.4
DYTISCIDAE	21	2.4	0.0	1.4	0.0	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	1.2
GYRINIDAE	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.1
HALIPLIDAE	24	0.0	0.0	0.0	0.0	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
HELODIDAE	220	0.0	19.3	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
HISTERIDAE	26	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
HYDRAENIDAE	27	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	1.8	0.5
HYDROCHIDAE	28	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
HYDROPHILIDAE	29	10.1	0.0	2.7	3.8	0.0	0.0	0.0	0.0	2.6	0.0	3.1	11.1	15.0	0.0	5.4	4.4
HYGROBIIDAE	210	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
LIMNICHIDAE	211	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5345	0.4
PSEPHENIDAE	216	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	10.9	1.0
SPERCHEIDAE	217	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
SPHAERIIDAE	218	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
TOTAL		72.4	68.4	49.3	69.2	62.9	55.6	81.1	62.5	73.7	72.7	83.3	100.0	95.0	86.4	56.4	70.0
2. HEMIPTERA																	
TERRESTRIAL	40	17.1	31.6	43.8	30.8	36.0	44.4	18.9	37.5	21.0	17.3	16.7	0.0	5.0	9.1	43.6	25.9
GERRIDAE	42	0.7	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
HEBRIDAE	45	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.2
MESOVELIIDAE	412	4.2	0.0	4.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
NAUCORIDAE	413	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	1.0
OCHTERIDAE	414	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
PLEIDAE	415	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
VELIIDAE	419	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
TOTAL		27.6	31.6	50.7	30.8	37.1	44.4	18.9	37.5	23.7	27.3	16.7	0.0	5.0	13.6	43.6	29.8
PREY ITEMS IDENTIFIED		286	57	73	26	89	45	53	40	38	66	96	9	20	22	55	975
NUMBER OF STOMACHS EXAMINED		94	30	51	25	49	28	34	27	26	35	46	6	16	15	30	512

Table 7.1.3; Number of aquatic and terrestrial items of two prey orders identified to the level of Family in stomach content analyses of 15 study species; expressed as percentages of total numbers identified.

PREY ORDER	SPECIES														
	L. dahl.	*L. roth.*	*L. bico.*	*L. rube.*	*L. pall.*	*L. iner.*	*L. nasu.*	*L. torn.*	*C. aust.*	*C. long.*	*L. orna.*	*L. conv.*	*N. mela.*	*U. inun.*	*R. bili.*	TOTAL
TERRESTRIAL COLEOPTERA	55.9	49.1	37.0	65.4	58.4	44.4	81.1	62.5	71.0	71.2	79.1	88.9	80.0	68.2	32.7	59.4
AQUATIC COLEOPTERA	16.4	19.3	12.3	3.8	4.5	11.1	0.0	0.0	2.6	1.5	4.2	11.1	15.0	18318	23.6	10.7
TOTAL COLEOPTERA	72.4	68.4	49.3	69.2	62.9	55.6	81.1	62.5	73.7	72.7	83.3	100.0	95.0	86.4	56.4	70.0
TERRESTRIAL HEMIPTERA	17.1	31.6	43.8	30.8	36.0	44.4	18.9	37.5	21.0	27.3	16.7	0.0	5.0	9.1	43.6	25.9
AQUATIC HEMIPTERA	10.5	0.0	6.8	0.0	1.1	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	4.5	0.0	3.9
TOTAL HEMIPTERA	27.6	31.6	50.7	30.8	37.1	44.4	18.9	37.5	23.7	27.3	16.7	0.0	5.0	13.6	43.6	29.8
TOTAL TERRESTRIAL	73.1	80.7	80.8	96.1	94.4	88.9	100.0	100.0	92.1	98.5	95.8	88.9	85.0	77.3	76.4	85.3
TOTAL AQUATIC	26.9	19.3	19.2	3.8	5.6	11.1	0.0	0.0	5.3	1.5	4.2	11.1	15.0	22.7	23.7	14.6
TOTAL IDENTIFIED	286	57	73	26	89	45	53	40	38	66	96	9	20	22	55	975

Figure 7.2.1; Incidence of aquatic and terrestrial families of two prey orders, quantified in terms of frequency of occurrence and number of items present in stomachs of *Litoria dahlii*.

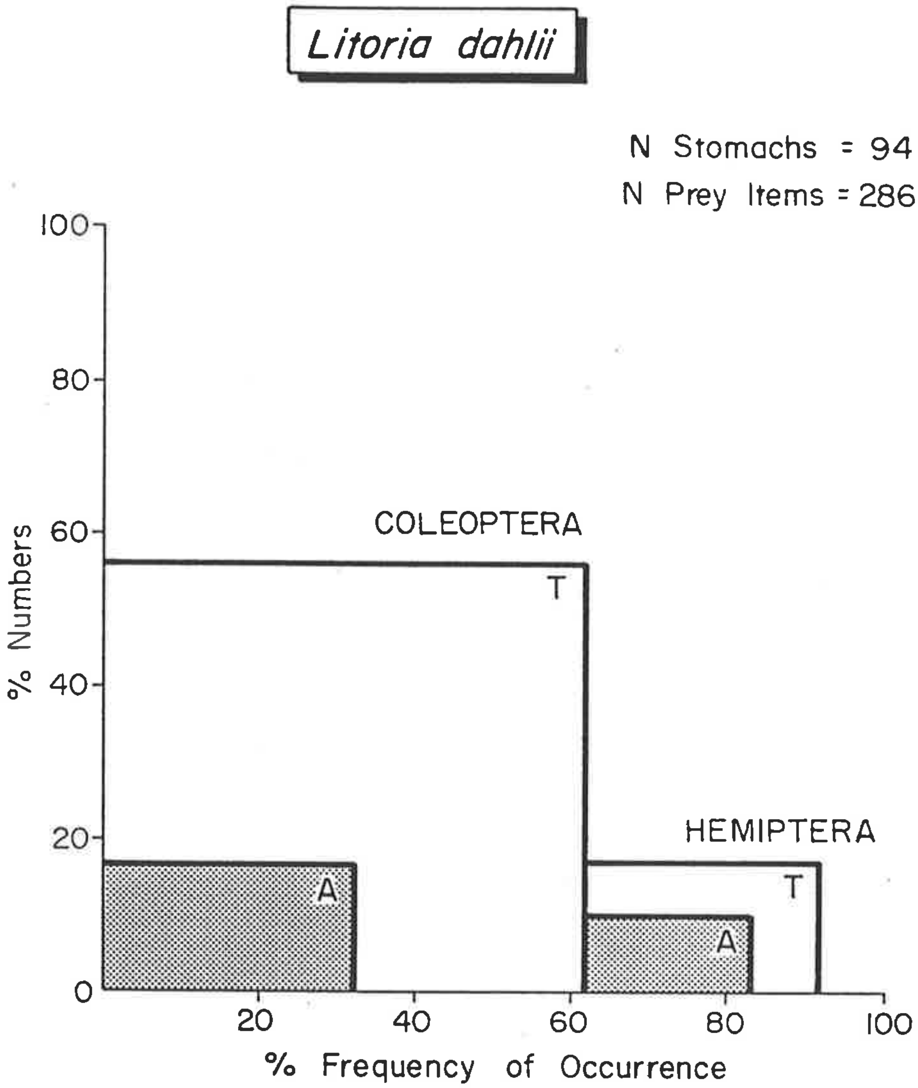
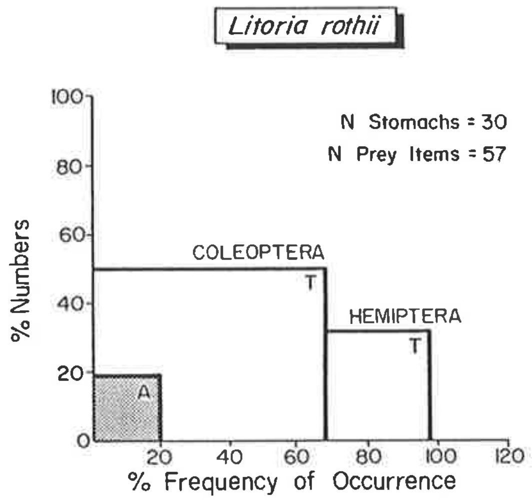
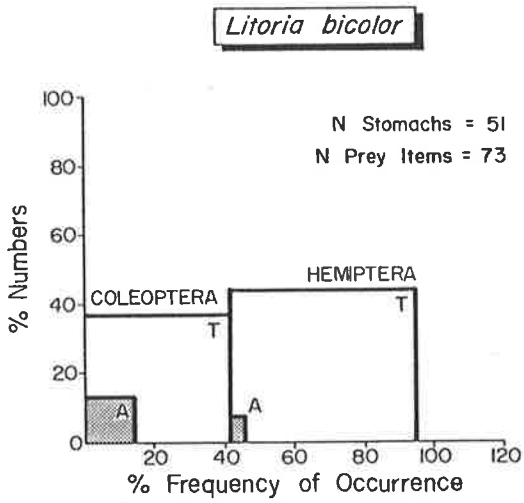

Litoria dahlii
N Stomachs = 94
N Prey Items = 286
COLEOPTERA
HEMIPTERA
T
A
T
A
% Numbers
0
20
40
60
80
100
20
40
60
80
100
% Frequency of Occurrence

Figure 7.3.1; Incidence of aquatic and terrestrial families of two prey orders, quantified in terms of frequency of occurrence and number of items present in stomachs of arboreal frogs.


Litoria rothii
N Stomachs = 30
N Prey Items = 57
COLEOPTERA
HEMIPTERA
T
T
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100
120


Litoria bicolor
N Stomachs = 51
N Prey Items = 73
COLEOPTERA
HEMIPTERA
T
T
A
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100
120

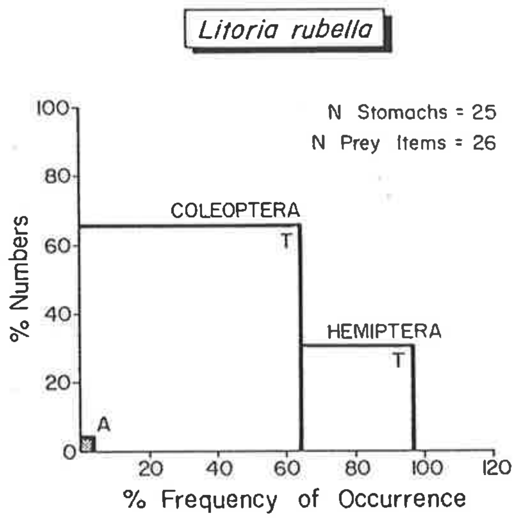
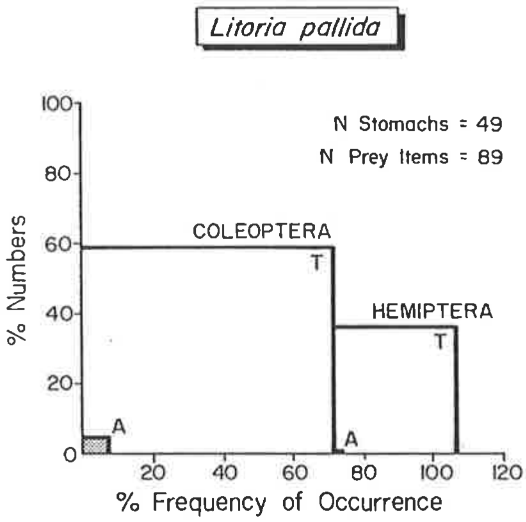
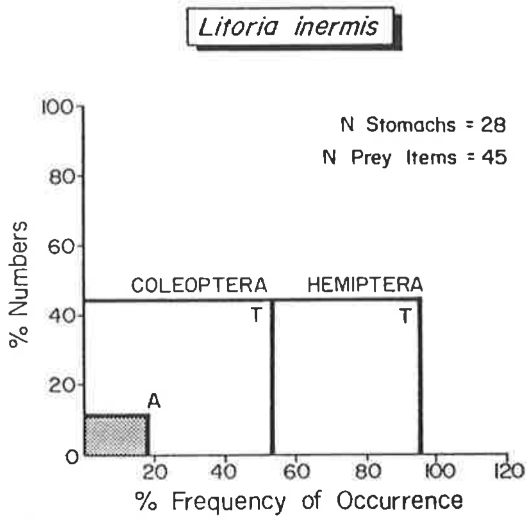
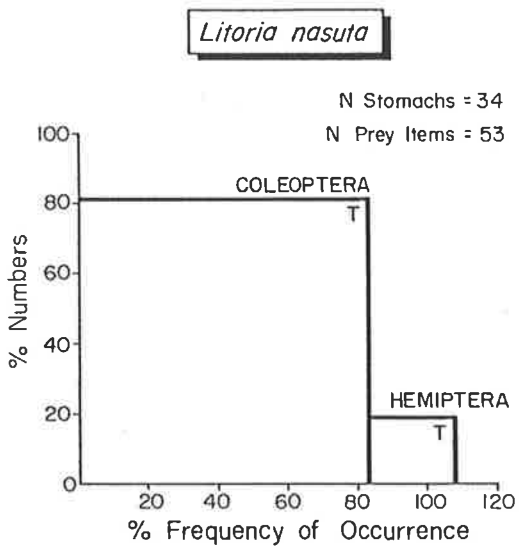

Litoria rubella
N Stomachs = 25
N Prey Items = 26
COLEOPTERA
HEMIPTERA
T
T
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100
120

Figure 7.4.1; Incidence of aquatic and terrestrial families of two prey orders, quantified in terms of frequency of occurrence and number of items present in stomachs of ground hylids.


Litoria pallida
N Stomachs = 49
N Prey Items = 89
100
80
60
40
20
0
% Numbers
COLEOPTERA
T
HEMIPTERA
T
A
A
20
40
60
80
100
120
% Frequency of Occurrence


Litoria inermis
N Stomachs = 28
N Prey Items = 45
100
80
60
40
20
0
% Numbers
COLEOPTERA
HEMIPTERA
T
T
A
20
40
60
80
100
120
% Frequency of Occurrence


Litoria nasuta
N Stomachs = 34
N Prey Items = 53
100
80
60
40
20
0
% Numbers
COLEOPTERA
T
HEMIPTERA
T
20
40
60
80
100
120
% Frequency of Occurrence

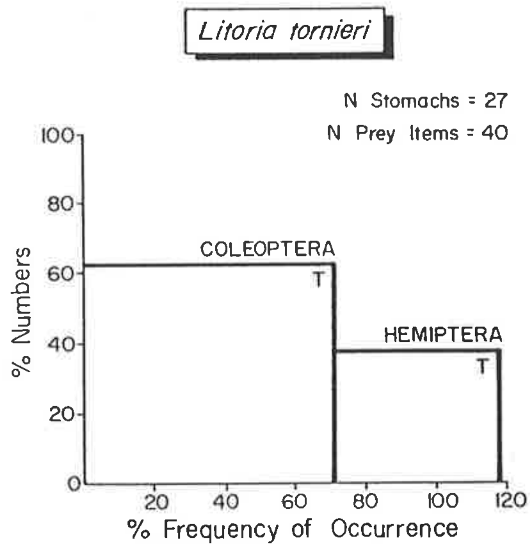
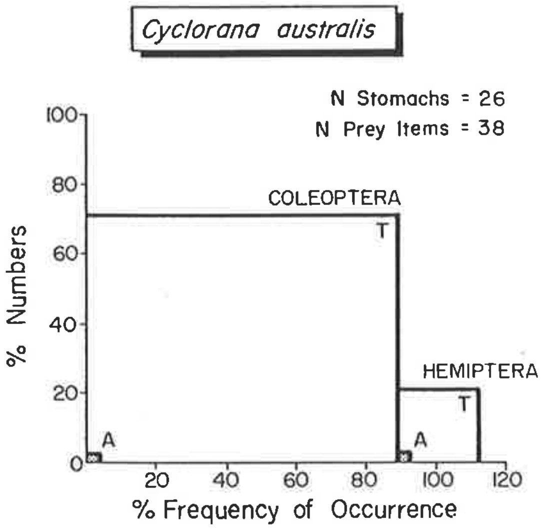
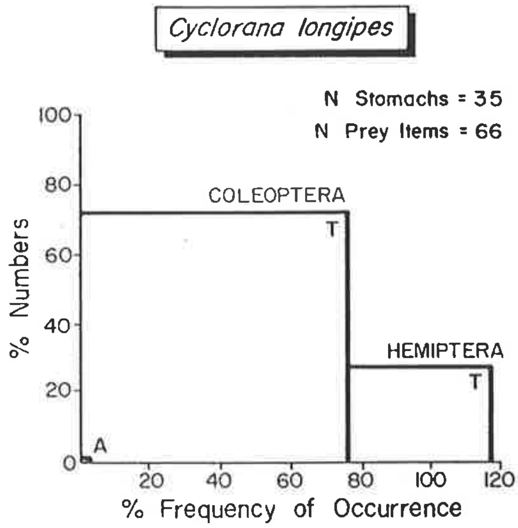
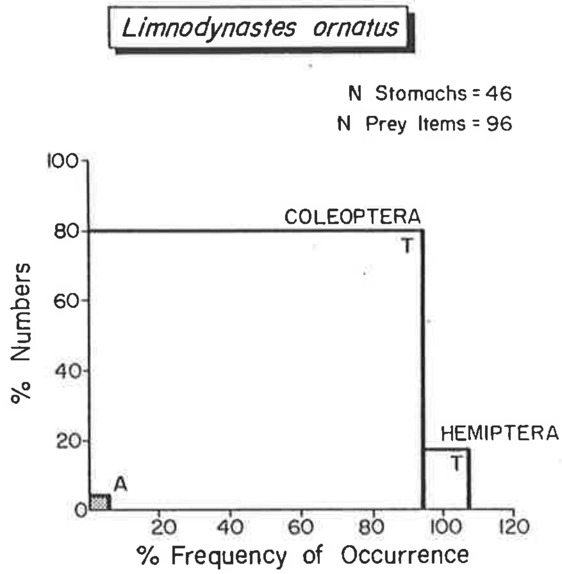

Litoria tornieri
N Stomachs = 27
N Prey Items = 40
100
80
60
40
20
0
% Numbers
COLEOPTERA
T
HEMIPTERA
T
20
40
60
80
100
120
% Frequency of Occurrence

Figure 7.5.1; Incidence of aquatic and terrestrial families of two prey orders, quantified in terms of frequency of occurrence and number of items present in stomachs of wide-mouthed, burrowing frogs.


Cyclorana australis
N Stomachs = 26
N Prey Items = 38
COLEOPTERA
HEMIPTERA
T
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100
120


Cyclorana longipes
N Stomachs = 35
N Prey Items = 66
COLEOPTERA
HEMIPTERA
T
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100
120


Limnodynastes ornatus
N Stomachs = 46
N Prey Items = 96
COLEOPTERA
HEMIPTERA
T
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100
120

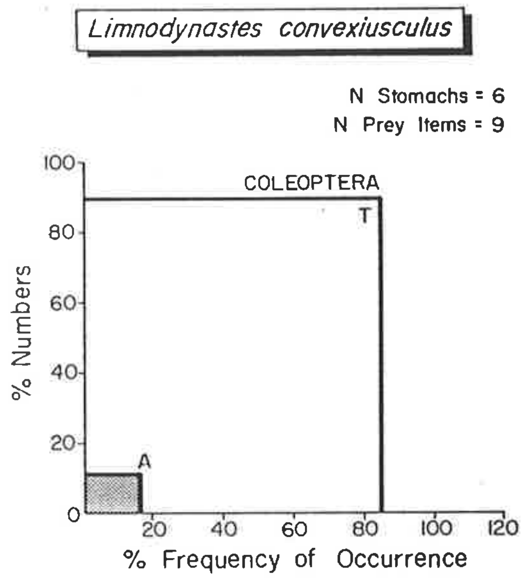

Limnodynastes convexiusculus
N Stomachs = 6
N Prey Items = 9
COLEOPTERA
T
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100
120

Figure 7.6.1; Incidence of aquatic and terrestrial families of two prey orders, quantified in terms of frequency of occurrence and number of items present in stomachs of *Notaden melanoscaphus*.

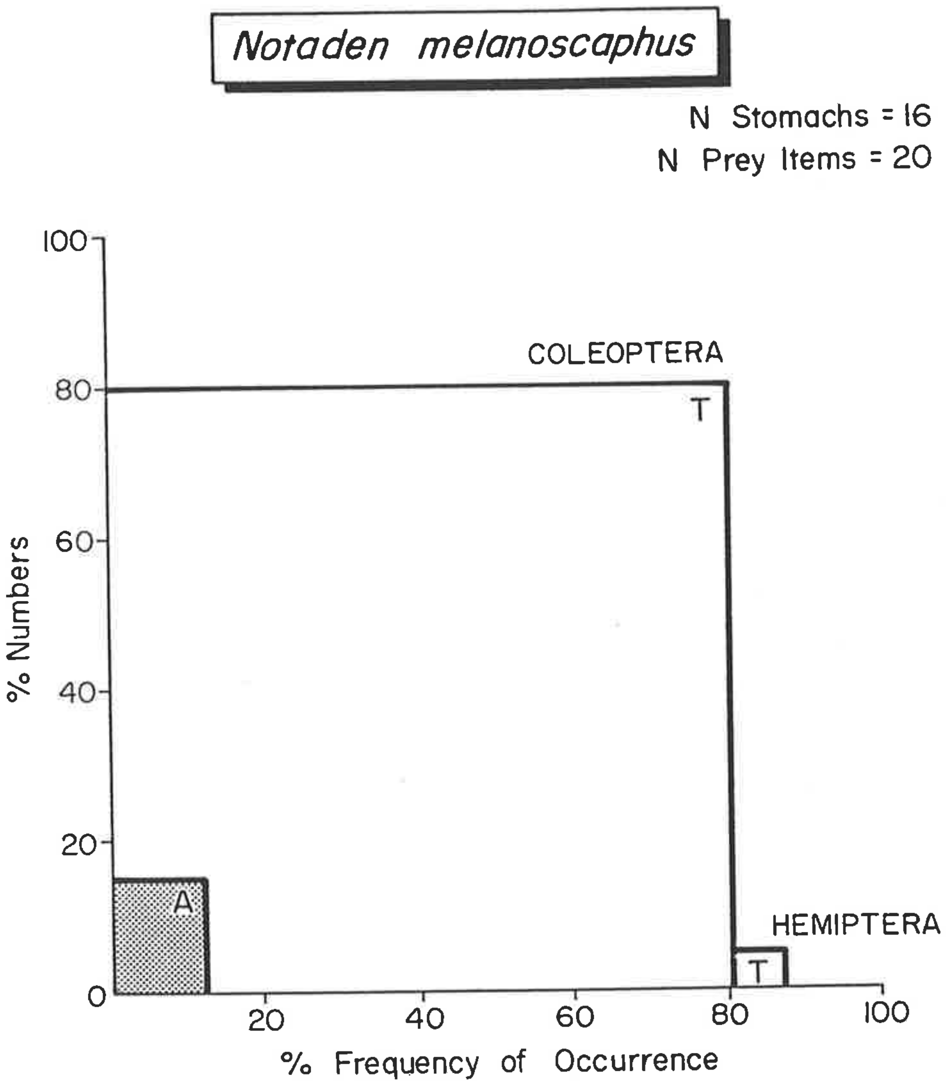

Notaden melanoscaphus
N Stomachs = 16
N Prey Items = 20
COLEOPTERA
T
HEMIPTERA
T
A
% Numbers
% Frequency of Occurrence
0
20
40
60
80
100

Figure 7.7.1; Incidence of aquatic and terrestrial families of two prey orders, quantified in terms of frequency of occurrence and number of items present in stomachs of *Uperoleia inundata*.

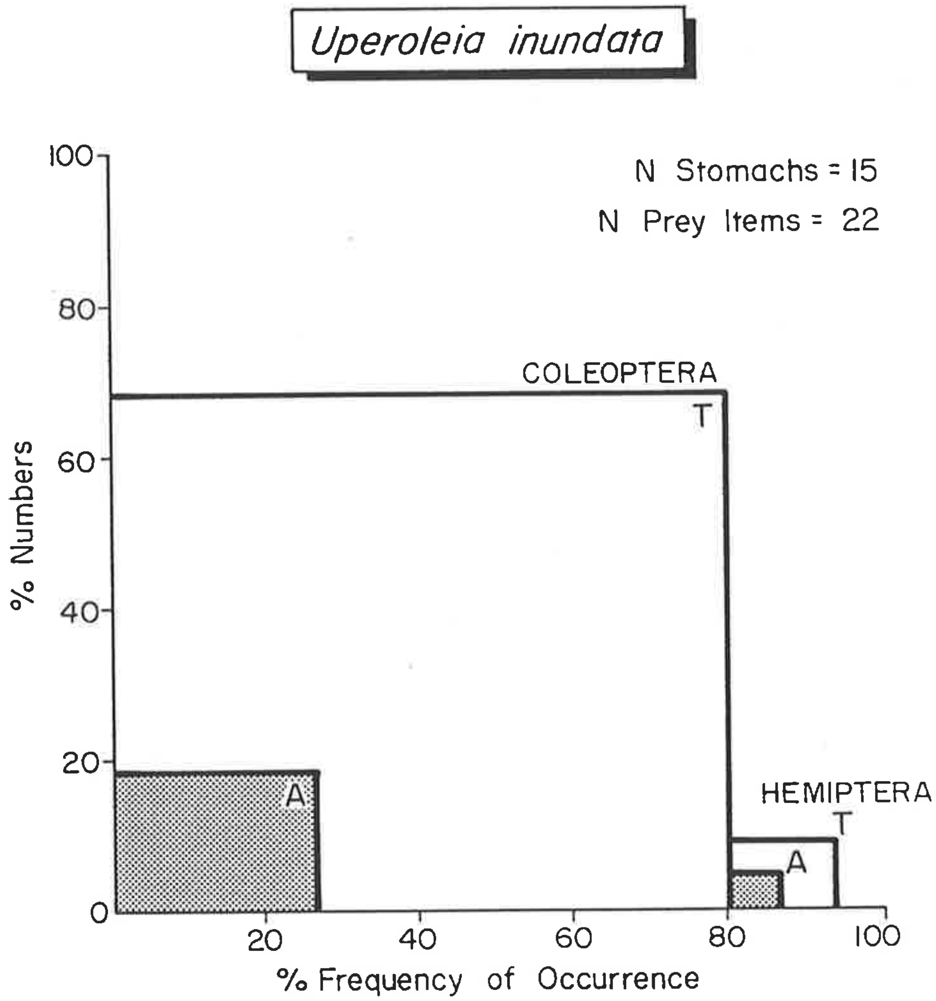
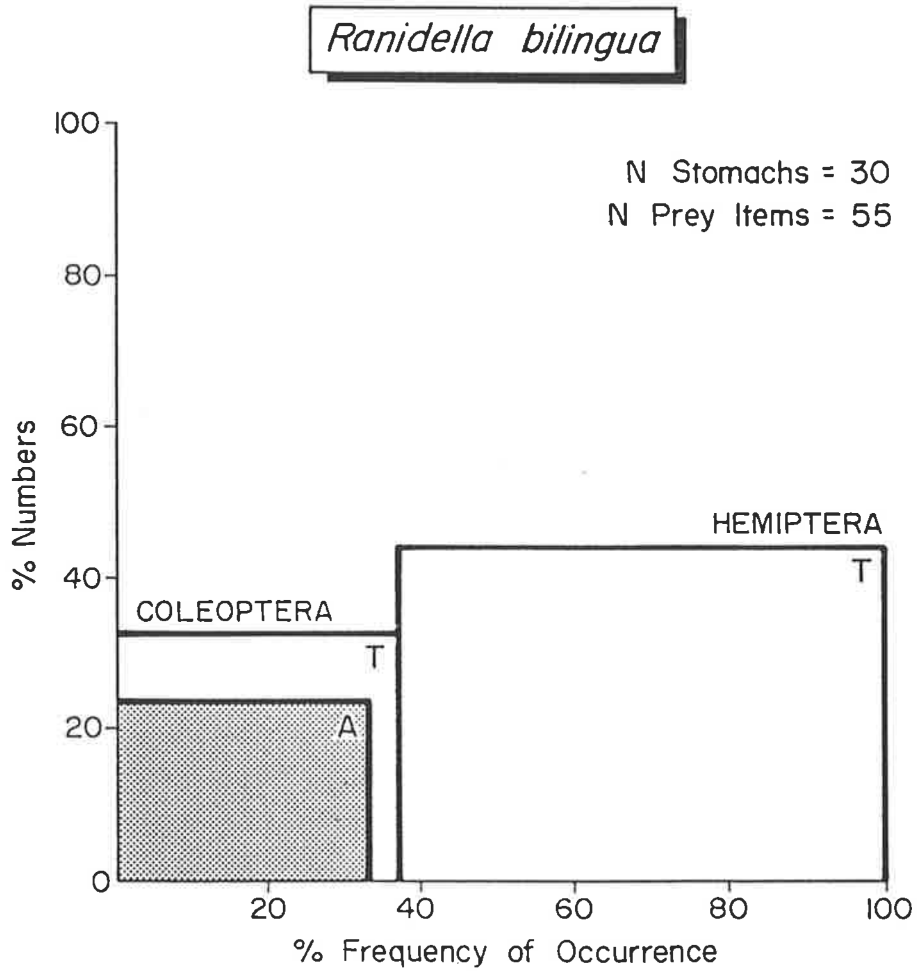

Uperoleia inundata
N Stomachs = 15
N Prey Items = 22
COLEOPTERA
T
A
HEMIPTERA
T
A
% Numbers
100
80
60
40
20
0
20
40
60
80
100
% Frequency of Occurrence

Figure 7.8.1; Incidence of aquatic and terrestrial families of two prey orders, quantified in terms of frequency of occurrence and number of items present in stomachs of *Ranidella bilingua*.


Ranidella bilingua
N Stomachs = 30
N Prey Items = 55
HEMIPTERA
COLEOPTERA
T
T
A
% Numbers
0
20
40
60
80
100
20
40
60
80
100
% Frequency of Occurrence

7.3; ARBOREAL FROGS.

The occurrence and numbers of aquatic families varied in samples of the three species of arboreal frogs. Aquatic Hemiptera were not identified in stomachs of *Litoria rothii* and *L. rubella*, and samples of both species contained only single aquatic families of the Coleoptera. The Helodidae occurred frequently in stomachs of *L. rothii* and comprised over 19% of the total number of items identified. The Hydrophilidae occurred rarely in *L. rubella*.

Two families of aquatic Hemiptera and four aquatic families of the Coleoptera occurred in the sample of *L. bicolor*: comprising over 19% of the items identified.

7.4; GROUND HYLIDS.

Aquatic families of both orders examined (Coleoptera, Hemiptera) were absent from the samples of *Litoria nasuta* and *L. tornieri*. The largest numbers of aquatic prey occurred in the sample of *L. inermis*; four families of aquatic Coleoptera comprising 11.1% of the prey items identified. Aquatic families of the Coleoptera and Hemiptera occurred only in the sample of *L. pallida*, but represented less than 6% of all items identified.

7.5; WIDE-MOUTHED, BURROWING FROGS.

Within the samples of *Cyclorana australis*, *C. longipes*, and *Limnodynastes ornatus*, aquatic prey families occurred in less than 7% of the stomachs examined and comprised less than 6% of the items identified. Only nine prey items were identified for L. convexiusculus, and one of these was an aquatic coleopteran (11.1%).

7.6; NARROW-MOUTHED, BURROWING FROGS.

Twenty prey items were identified in a sample of 16 Notaden melanoscaphus stomachs, and only three hydrophilid beetles comprised 15% of the items identified. Aquatic Hemiptera were not included in this small sample.

7.7; TOADLETS.

Only 22 prey items were identified from 15 stomachs of the toadlet, Uperoleia inundata. Both aquatic Coleoptera and Hemiptera were identified in this small sample and comprised 22.7% of the items examined.

7.8; FROGLETS.

Over 33% of stomachs examined in the sample of Ranidella bilingua contained aquatic Coleoptera. These prey, from four families, represented over 23% of the prey identified. Aquatic Hemiptera were absent from the sample.

8.1; VARIATION IN STOMACH CONTENTS.

To examine temporal and spatial variation in stomach contents, samples of Litoria dahlii, varying in times and locations of collection, have been analysed.

8.1.1; TEMPORAL VARIATION IN STOMACH CONTENTS.

The percentage frequencies of occurrence of prey orders identified in seven samples of Litoria dahlii collected at the Magela Creek floodplain are presented in Table (8.1.1), together with the number and average length of the frogs examined. The seven samples were collected during months approaching the end of a dry season, the mid-period of a wet season, and the wet/dry transitional stage of two wet seasons. Stages were recognised on the basis of water levels in billabongs and rainfall (Chapter (5.1.3)). These results are summarised in Figures (8.1.1), (8.1.2) and (8.1.3), where the percentage frequencies of occurrence of seven predominant prey orders are presented for each sampling date.

The occurrence of principal prey orders and aquatic orders varied widely between samples of Litoria dahlii collected at different times from the same locations. The occurrence of aquatic prey in samples coincided with rising water levels in the Magela Creek system, as documented in Chapter (5.1.3).

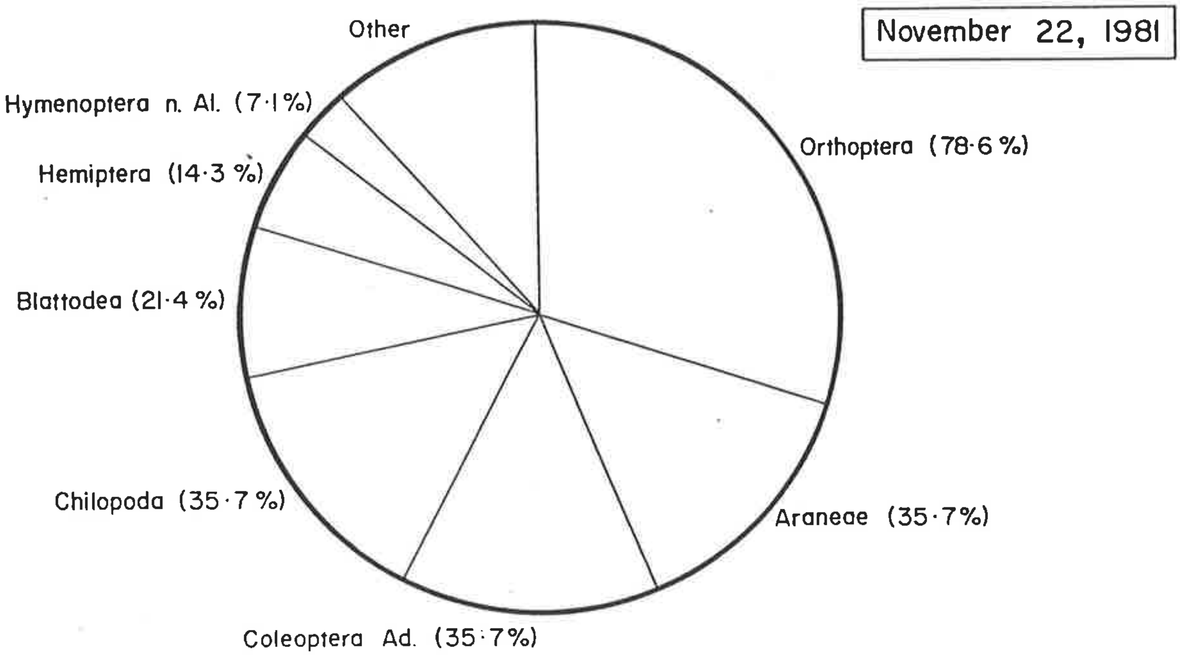
Aquatic prey orders were not identified in stomachs collected during the late dry season in 1981. Terrestrial

PREY ORDER	PREY CODE	PREY ORIGIN	SAMPLING DATE 20 APR '81	22 NOV '81	26 NOV '81	7 FEB '82	13 MAR '82	9 APR '82	16 APR '82
ANURA ADULT	29	A	0.0	0.0	0.0	0.0	42.9	0.0	0.0
ANURA LARVA	37	A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EPHEMEROPTERA	28	A	0.0	0.0	0.0	22.2	0.0	100.0	0.0
ODONATA ADULT	20	A	6.3	0.0	0.0	0.0	0.0	0.0	4.5
ODONATA NYMPH	36	A	43.8	0.0	0.0	0.0	0.0	0.0	27.3
OSTRACODA	39	A	0.0	0.0	0.0	11.1	0.0	0.0	9.1
PLECOPTERA	34	A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRICHOPTERA ADULT	18	A	12.5	0.0	0.0	22.2	0.0	0.0	0.0
TRICHOPTERA NYMPH	26	A	18.8	0.0	0.0	0.0	0.0	0.0	13.6
ZYGOPTERA ADULT	25	A	12.5	0.0	0.0	3.7	0.0	0.0	13.6
ZYGOPTERA NYMPH	40	A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARANEAE	5	TA	12.5	35.7	30.0	18.5	7.1	16.7	50.0
COLEOPTERA ADULT	2	TA	93.8	35.7	80.0	33.3	64.3	0.0	86.4
COLEOPTERA LARVA	23	TA	6.3	0.0	0.0	0.0	0.0	0.0	0.0
DIPTERA	3	TA	56.3	0.0	25.0	70.4	14.3	66.7	27.3
GASTROPODA	35	TA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HEMIPTERA	4	TA	68.8	14.3	30.0	44.4	21.3	83.3	72.7
OTHER, VERTEBRATE	42	TA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OTHER, INVERTEBRATE	43	TA	0.0	0.0	5.0	0.0	0.0	0.0	0.0
UNDETERMINED, ADULT	9	TA	0.0	0.0	5.0	0.0	0.0	0.0	0.0
UNDETERMINED, LARVA	19	TA	25.0	7.1	0.0	48.1	7.1	0.0	40.9
ACARINA	16	T	0.0	0.0	0.0	3.7	0.0	0.0	0.0
BLATTODEA	15	T	0.0	21.4	5.0	0.0	7.1	0.0	0.0
CHILOPODA	17	T	0.0	35.7	10.0	0.0	0.0	0.0	0.0
COLLEMBOLA	11	T	68.8	0.0	0.0	33.3	0.0	0.0	22.7
DERMAPTERA	24	T	0.0	7.1	0.0	0.0	0.0	0.0	0.0
DIPLOPODA	38	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYMENOPTERA ALATE	12	T	12.5	0.0	0.0	7.4	0.0	0.0	18.2
HYMENOPTERA NON-ALATE	1	T	37.5	7.1	15.0	22.2	50.0	0.0	22.7
ISOPTERA ALATE	14	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ISOPTERA NON-ALATE	21	T	0.0	7.1	0.0	0.0	0.0	0.0	0.0
ISOPODA	27	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEPIDOPTERA ADULT	10	T	31.3	7.1	0.0	0.0	0.0	50.0	18.2
LEPIDOPTERA LARVA	13	T	0.0	0.0	5.0	0.0	14.3	0.0	0.0
MANTODEA	33	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OLIGOCHAETA	30	T	0.0	0.0	0.0	3.7	0.0	0.0	0.0
ORTHOPTERA	6	T	25.0	78.6	55.0	3.7	21.4	0.0	31.8
PHALANGIDA	22	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHASMIDA	31	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCORPIONIDA	41	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0
THYSANOPTERA	32	T	0.0	0.0	0.0	3.7	0.0	0.0	0.0
N frogs examined			16	14	20	27	14	6	22
Average snout to vent length (mm)			42.2	52.4	54.3	36.6	50.5	34.2	46.0
+/- Standard Deviation (mm)			0.9	0.8	1.2	1.6	2.1	0.9	1.2

Table 8.1.1; Percent frequency of occurrence of prey orders identified in seven samples of *Litoria dahlii* collected on the Magela floodplain.

Figure 8.1.1; Percentage frequency of occurrence of principal prey orders in stomach contents of *Litoria dahlii* collected at the Magela Creek floodplain during the late dry season, 1981.

Late Dry Season
L. dahlii



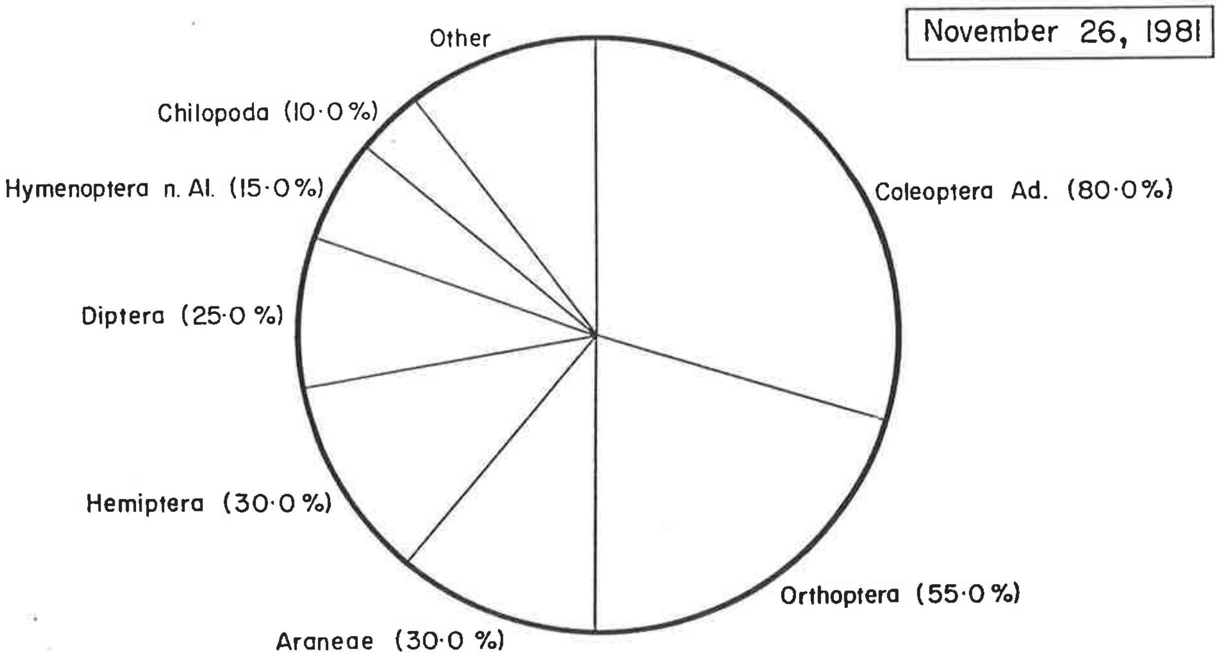
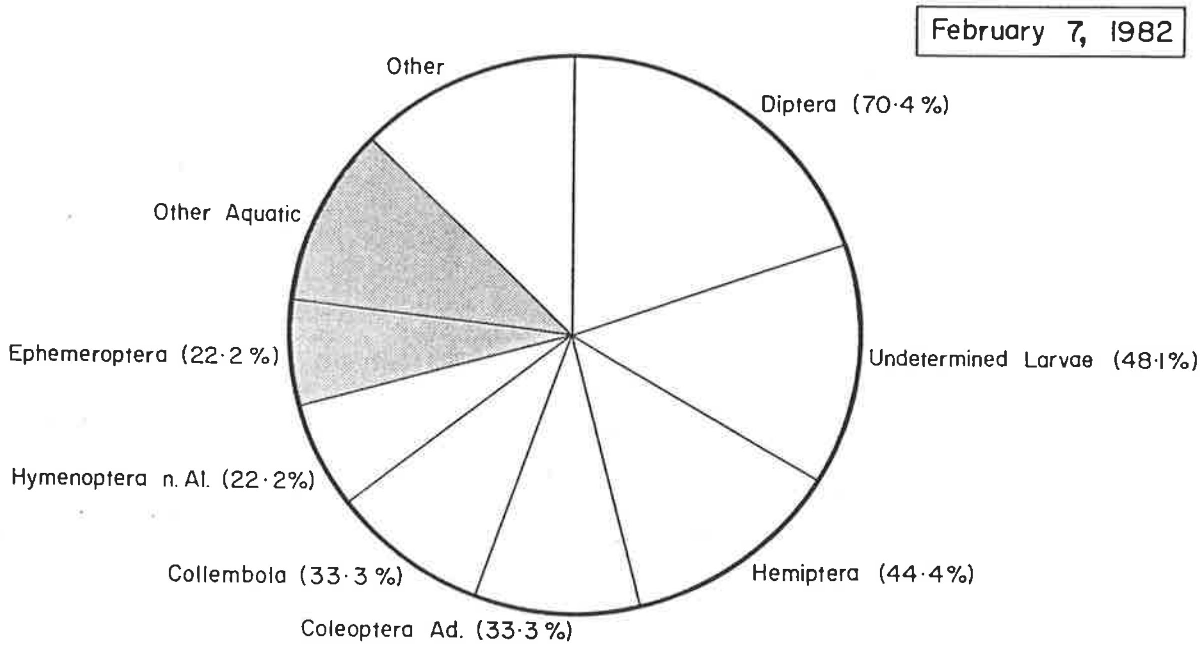


Figure 8.1.2; Percentage frequency of occurrence of principal prey orders in stomach contents of *Litoria dahlii* collected at the Magela Creek floodplain during the mid wet season, 1982.

The presence of aquatic prey orders is represented by shading.

Mid Wet Season
L. dahlii



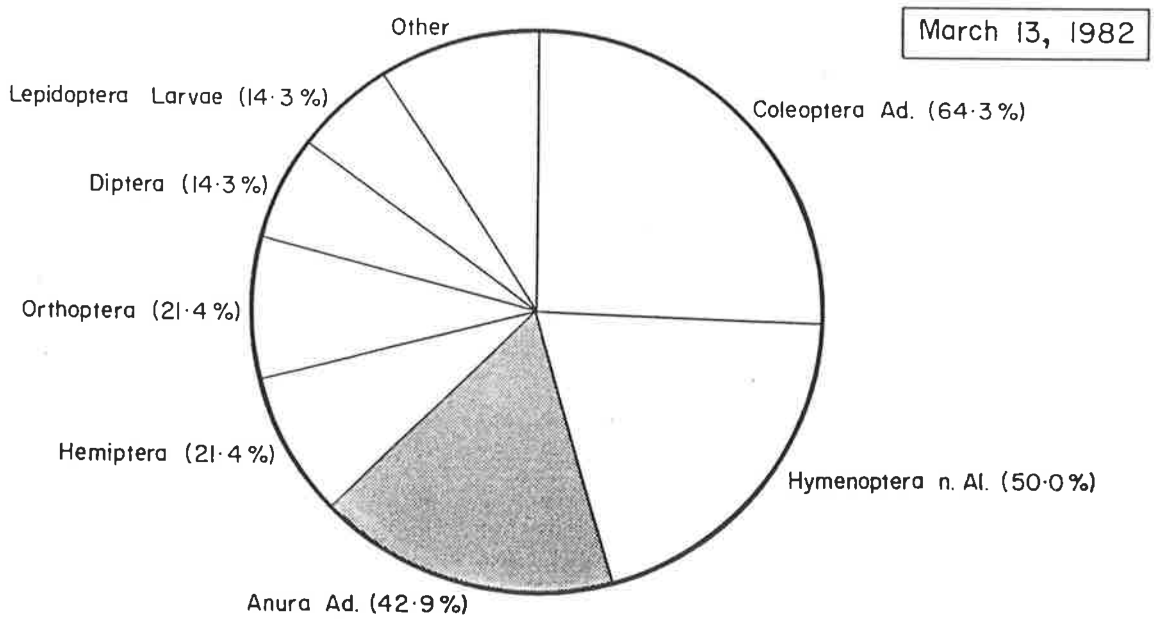
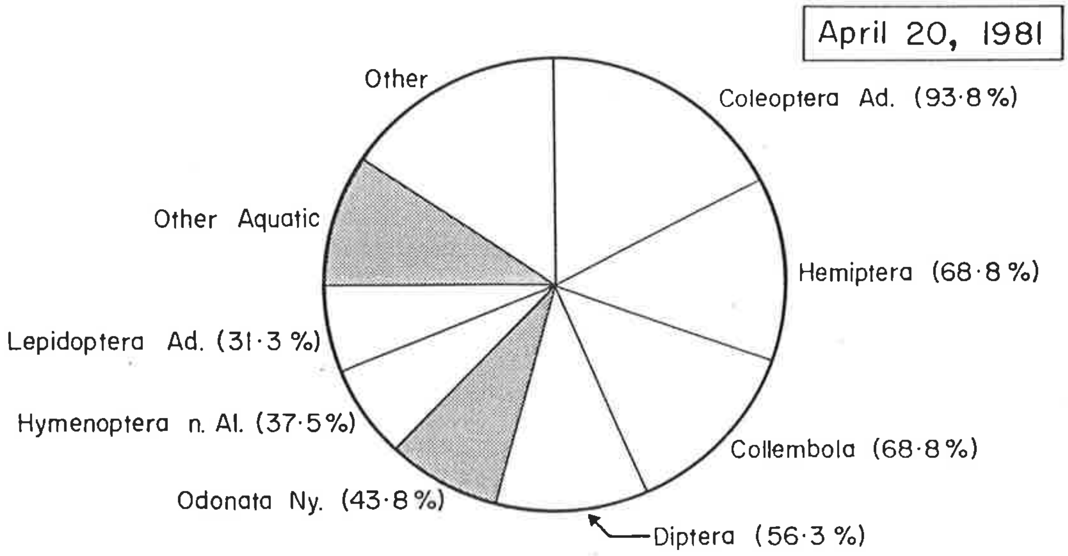
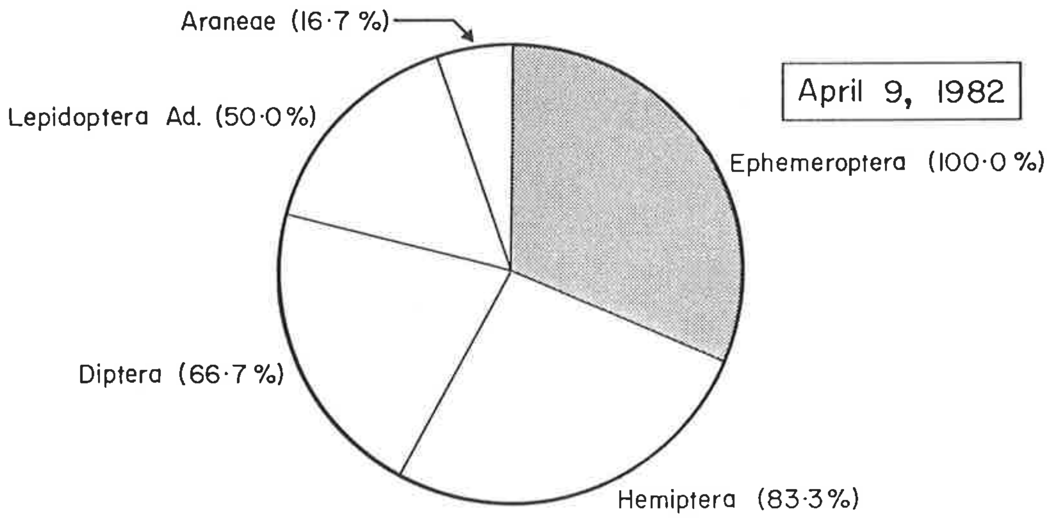


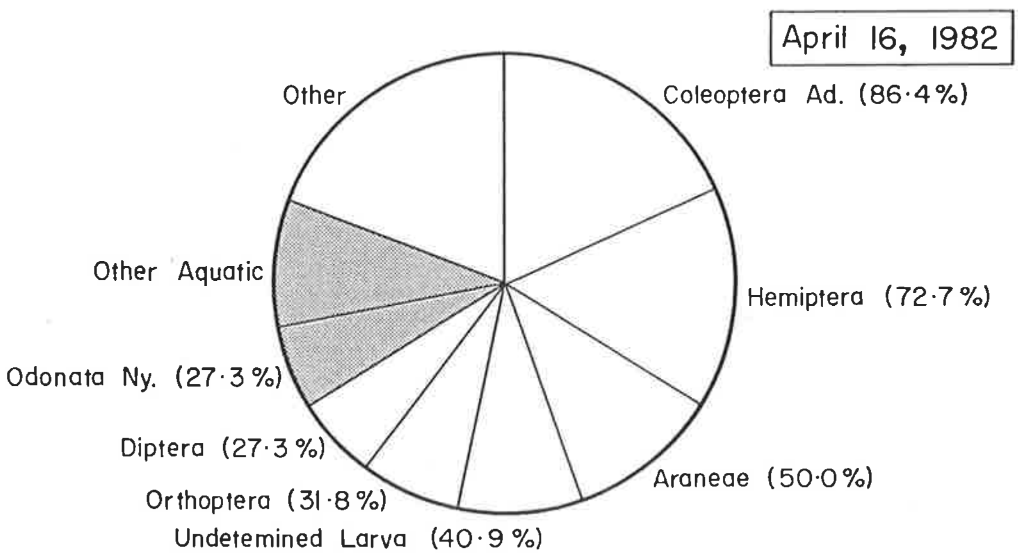
Figure 8.1.3; Percentage frequency of occurrence of principal prey orders in stomach contents of Litoria dahlii collected at the Magela Creek floodplain during the late wet season, 1981 and 1982.

The presence of aquatic orders is represented by shading.

Late Wet Season
L. dahlii







prey, including the Orthoptera and Chilopoda, predominated in these samples. Following light falls of rain, the surface of the floodplain was moistened only slightly and many terrestrial arthropods were sighted on the cracked alluvial soil.

Aquatic orders were identified in each of five samples collected during two wet seasons but the occurrence of these orders varied between the samples. The number of aquatic orders present ranged from five for samples collected on 20/4/81 and 16/4/82 to one for stomachs obtained on 13/3/82 and 19/4/82. Prey orders such as the Ephemeroptera and Coleoptera predominated in some samples, but were absent from others collected at the same location only days later.

Large numbers of flying Ephemeroptera, Coleoptera and Hemiptera were observed at the sampling locations on the occasions when these orders occurred most frequently in stomachs (9/4/82 and 16/4/82).

8.2; SPATIAL VARIATION IN STOMACH CONTENTS.

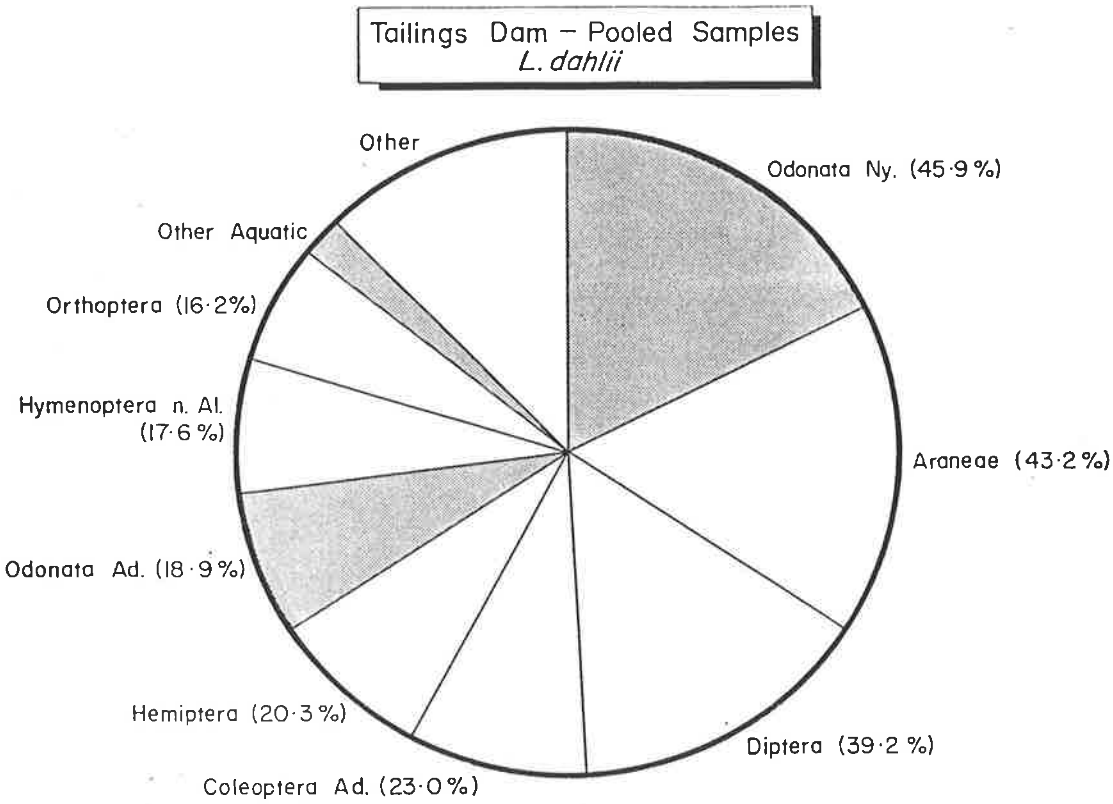
The results of stomach content analyses for samples of *Litoria dahlii* collected at the Tailings dam and Magela Creek floodplain during the 1981-82 wet season have been pooled, and are presented in Table (8.2.1). Results are summarised in Figure (8.2.1) in terms of percentage frequency of occurrence of those prey orders present in at least 10% of stomachs examined.

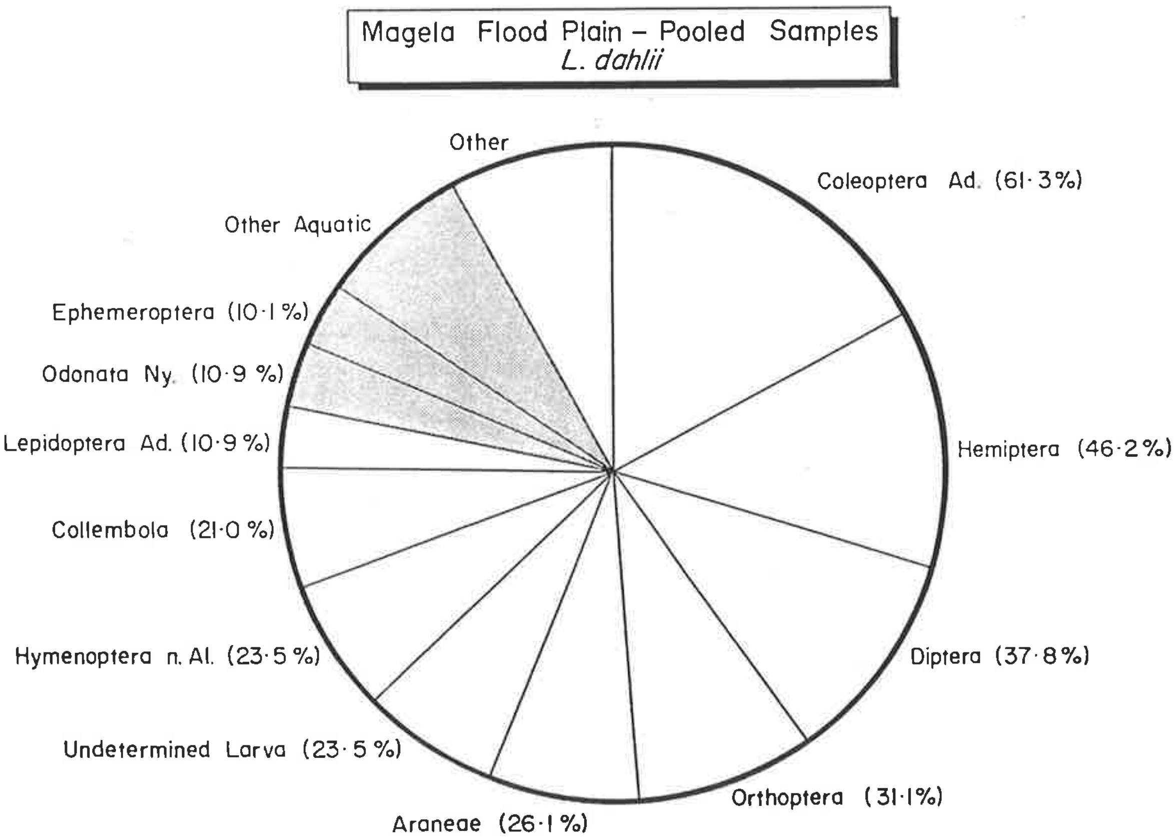
Table 8.2.1; Percent frequency of occurrence of prey orders identified in all samples of *Litoria dahlii* collected at the Tailings dam and the Magela Creek floodplain.

PREY ORDER	PREY CODE	PREY ORIGIN	TAILINGS DAM	MAGELA FLOODPLAIN
ANURA ADULT	29	A	4.10	5.00
ANURA LARVA	37	A	0.00	0.00
EPHEMEROPTERA	28	A	0.00	10.10
ODONATA ADULT	20	A	18.90	1.70
ODONATA NYMPH	36	A	45.90	10.90
OSTRACODA	39	A	0.00	4.20
PLECOPTERA	34	A	0.00	0.00
TRICHOPTERA ADULT	18	A	1.40	6.70
TRICHOPTERA NYMPH	26	A	0.00	5.00
ZYGOPTERA ADULT	25	A	0.00	5.00
ZYGOPTERA NYMPH	40	A	0.00	0.00
ARANEAE	5	TA	43.20	26.10
COLEOPTERA ADULT	2	TA	23.00	61.30
COLEOPTERA LARVA	23	TA	6.80	0.80
DIPTERA	3	TA	39.20	37.80
GASTROPODA	35	TA	0.00	0.00
HEMIPTERA	4	TA	20.30	46.20
OTHER, VERTEBRATE	42	TA	0.00	0.00
OTHER, INVERTEBRATE	43	TA	0.00	0.80
UNDETERMINED, ADULT	9	TA	2.70	0.80
UNDETERMINED, LARVA	19	TA	1.40	23.50
ACARINA	16	T	0.00	0.80
BLATTODEA	15	T	5.40	4.20
CHILOPODA	17	T	0.00	5.90
COLLEMBOLA	11	T	0.00	21.00
DERMAPTERA	24	T	0.00	0.80
DIPLOPODA	38	T	0.00	0.00
HYMENOPTERA ALATE	12	T	1.40	6.70
HYMENOPTERA NON-ALATE	1	T	17.60	23.50
ISOPTERA ALATE	14	T	0.00	0.00
ISOPTERA NON-ALATE	21	T	0.00	0.80
ISOPODA	27	T	0.00	0.00
LEPIDOPTERA ADULT	10	T	1.40	10.90
LEPIDOPTERA LARVA	13	T	6.80	2.50
MANTODEA	33	T	0.00	0.00
OLIGOCHAETA	30	T	0.00	0.80
ORTHOPTERA	6	T	16.20	31.10
PHALANGIDA	22	T	0.00	0.00
PHASMIDA	31	T	0.00	0.00
SCORPIONIDA	41	T	0.00	0.00
THYSANOPTERA	32	T	0.00	0.80
Number of stomachs examined			74	119
Average snout to vent length (mm)			49.50	45.44
+/- Standard Deviation (mm)			1.73	0.83

Figure 8.2.1; Percentage frequency of occurrence of principal prey orders in stomach contents of Litoria dahlii collected at the Magela Creek floodplain and Tailings dam.

The presence of aquatic prey orders is represented by shading.


Tailings Dam – Pooled Samples
L. dahlii
Other
Odonata Ny. (45·9 %)
Other Aquatic
Orthoptera (16·2%)
Hymenoptera n. Al. (17·6 %)
Araneae (43·2 %)
Odonata Ad. (18·9 %)
Hemiptera (20·3 %)
Diptera (39·2 %)
Coleoptera Ad. (23·0 %)


Magela Flood Plain – Pooled Samples
L. dahlii
Other
Coleoptera Ad. (61·3%)
Other Aquatic
Ephemeroptera (10·1 %)
Odonata Ny. (10·9 %)
Lepidoptera Ad. (10·9 %)
Hemiptera (46·2%)
Collembola (21·0 %)
Hymenoptera n. Al. (23·5 %)
Diptera (37·8%)
Undetermined Larva (23·5 %)
Orthoptera (31·1%)
Araneae (26·1 %)

The principal prey orders and diversity of prey orders identified varied between the pooled samples. In stomachs collected from the Magela Creek floodplain, 20 orders were identified, including eight aquatic orders. Coleoptera, Hemiptera and Diptera predominated, each occurring in over 35% of these stomachs.

The diversity of prey in samples from the Tailings dam was lower (17 orders) than at the floodplain and the principal prey orders identified were Odonata (nymphs and adults), Araneae and Diptera. Coleoptera and Hemiptera also were significant but occurred less frequently in frogs from the Tailings dam than in frogs from the Magela Creek floodplain.

9.1 DISCUSSION

I studied the distributions and diets of the Magela Creek frog fauna to answer a specific question: which species are most significant in the ingestion of prey of aquatic origin? Clear results were obtained, despite the fact that the study was undertaken in an area of environmental heterogeneity characterised by wide and rapid variation in patterns of inundation and primary production.

9.2 FORAGING MACROHABITATS

The spatial and temporal patterns of distribution of 16 species were investigated to determine which species forage in or near waterbodies. Regular collections made at major waterbodies and along transects through different types of habitat showed that species comprising different faunal groups forage in different macrohabitats.

Sightings of aquatic frogs (*Litoria dahlii*), two arboreal species (*L. rothii*, *L. bicolor*) and froglets (*Ranidella bilingua*) were restricted to the immediate vicinity of water during the sampling period; and it is concluded that these species spend the greatest portions of their foraging time in close proximity to aquatic macrohabitats. The ground hylids (*L. pallida*, *L. inermis*, *L. nasuta*, *L. tornieri* and *L. wotjulumensis*), which lack fossorial adaptations and which are presumed to have limited ability to store water (pers. obs.), were most frequently encountered along transects in moist areas with sandy soil, and at the edges of waterbodies. It is considered that macrohabitats in close vicinity to waterbodies are important foraging areas for these highly mobile species. Toadlets (*Uperoleia inundata*) were recorded in all macrohabitat types recognised, including those associated with waterbodies. Along the transects, poorly drained areas with sandy soils (Habitat types # 2, # 3 and # 4) support a more diverse and abundant anuran fauna than do well drained areas with hard gravelly soils (Habitat type # 1). Muscular, fossorial species with the ability to store large amounts of water in the bladder (pers. obs.), such as *Notaden melanoscaphus* and *Limnodynastes ornatus* were the most common frogs found in Habitat type # 1. However, sightings of these species were not restricted to such areas. Adults and sub-adults of the wide-mouthed burrowers, *Cyclorana australis*, were most common along transects in areas of open woodland with sandy soil (Habitat type # 2), and were seldom sighted elsewhere. Consequently, I propose that aquatic macrohabitats are of minor significance as foraging areas for wide-mouthed and narrow-mouthed burrowing frogs (*Cyclorana australis*, *C. longipes*, *Limnodynastes ornatus* and *Notaden melanoscaphus*).

The spatial distribution of the frog fauna varies temporally with rising water levels at waterbodies, inundation of grassland and woodland and the onset of breeding activities. All species studied are active in aquatic macrohabitats as newly metamorphosed juveniles departing the larval habitat, and as breeding adults. Therefore, it is concluded that all species could encounter prey of aquatic origin during at least two stages of their post-larval life histories.

My results show that an index of food consumption (stomach distention) is significantly influenced by breeding activity. Calling males and gravid females in amplexus both had significantly less food in the stomach than did other categories of frogs. Frogs of undetermined developmental stage, gravid females, females and juveniles had the most food in the stomach. Such findings have been reported by Johnson and Christiansen (1976) and Durant and Dole (1974), and are outlined in my literature review. I propose that foraging activities are placed at a lower premium than breeding activities whilst frogs are aggregated at water-bodies for breeding purposes.

In accordance with this proposal, I consider that, with the exception of aquatic frogs, food items identified in stomachs of calling males and gravid females at waterbodies are consumed elsewhere in foraging habitats. In the case of *L. dahlii*, breeding sites coincide with the foraging habitat. The Magela Creek fauna comprises opportunistic breeders and, because of the widespread inundation of the region in the wet seasons, breeding sites can be found in close proximity to terrestrial foraging habitats. During roadway surveys on nights of heavy rain, *Cyclorana australis*, considered to be a terrestrial forager, was observed often to move across to breeding aggregations at waterbodies and then back to drier areas before dawn. Species which normally forage in more terrestrial habitats may encounter prey of aquatic origin during breeding activities, but I assume that the level of ingestion of this type of prey by such species is not significant.

To test this prediction adequately, it would be necessary to compare the stomach contents of both breeding and foraging frogs collected simultaneously, in such a manner as to standardise all other factors governing feeding habits such as site and time of collection, prey availability and level of satiation. Such research was beyond the scope of the present study, but supporting evidence is available from stomach content analyses. By necessity, the majority of specimens of *Notaden melanoscaphus*, *Uperoleia inundata*, *Ranidella bilingua*, the four ground hylids and *Litoria rubella* included in stomach content analyses were collected from breeding aggregations at waterbodies. Despite the proximity of these breeding frogs to water, aquatic prey orders were absent from stomachs of *N. melanoscaphus* and *U. inundata*, and were present in less than 12% of the stomachs of the other species.

There is a lack of data on the ingestion of prey of aquatic origin by juvenile frogs departing the larval habitat. Over 84% of all recently metamorphosed juveniles still possessing a portion of the larval tail had empty stomachs. Newly metamorphosed juveniles of all species, with the exception of *Litoria dahlii*, were not collected in large numbers adjacent to waterbodies containing great numbers of larval conspecifics. Presumably juveniles depart the littoral zones of waterbodies rapidly as they are vulnerable in these areas to a range of fish, birds, reptiles and mammals known to prey on anurans in the Magela Creek system (Tyler and Crook, 1980, Tyler and Cappo, 1982).

Elsewhere it has been found that garter snakes (_Thamnophis_) converge on anuran larval habitats to prey on metamorphosing anurans, which are considered to be intrinsically vulnerable, specifically because they are inept at locomotion (Arnold and Wassersug, 1978). These authors proposed that transformation is an ecological hurdle, overcome in some cases by satiation of predators, through synchronisation of metamorphosis in time and space, and by formation of selfish herds (Hamilton, 1971) in which individuals gain protection by association with more vulnerable conspecifics. Bragg (1950) reported the complete dispersal overnight of many thousands of synchronously metamorphosing individuals of _Scaphiopus holbrooki_ away from their larval habitat. I found no evidence of such mass movements in the study area, but _Cyclorana australis_, _Litoria dahlii_ and _Limnodynastes convexiusculus_ are known to form dense pre-metamorphic schools containing thousands of individuals (Tyler and Crook, 1980, Tyler and Cappo, 1982).

9.3 CONSUMPTION OF PREY OF AQUATIC ORIGIN

Lists of stomach contents produce a stationary picture of frog diets which are known to be dynamic, varying with developmental stage, motivational state and prey availability. To overcome this bias in stomach content analyses of each species, I pooled samples of a range of developmental stages collected over two wet seasons at different locations. I am confident that this spread of sampling effort, often enforced by sampling baises outlined earlier, gives an accurate reflection of the relative levels of ingestion of prey of aquatic origin by 15 * species.

At the level of prey Order, there were marked differences in the frequency of occurrence of aquatic prey in stomach contents of each species. This occurrence is summarised in Table (9.1). From these results I conclude that only *Litoria dahlii* and two arboreal species, *L. rothii* and *L. bicolor*, consume significant amounts of prey of aquatic origin. Aquatic prey orders were completely lacking from stomachs of *Litoria tornieri*, *Limnodynastes ornatus*, *L. convexiusculus*, *Notaden melanoscaphus* and *Uperoleia inundata*, despite the fact that the collections of these species comprised individuals found in close association with waterbodies. Other ground hylids, *Litoria rubella* and *Cyclorana longipes*, consumed alate stages of the Odonata, Zygoptera, Trichoptera and Ephemeroptera; but in all cases, the frequency of occurrence of such aquatic prey was less than 12%. The Anura constituted the only aquatic Order identified in the sample of *Cyclorana australis*, a species notorious for consuming other frogs in captive situations (pers. comm. G. Crook, pers. obs.). Predation on conspecifics, or other frogs, was observed regularly only for *C. australis* and *Litoria dahlii*.

Orders comprising both terrestrial and aquatic prey families were of major importance in stomach content analyses of aquatic frogs, arboreal frogs, ground hylids

* *Litoria wotjulumensis* was not included in stomach content analyses.

Table (9.1); Frequency of occurrence of aquatic prey orders and aquatic prey families in stomach content analyses of the 15 study species.

SPECIES	AQUATIC PREY - ANALYSES AT THE LEVEL OF PREY ORDER % FREQUENCY OF OCCURRENCE	AQUATIC PREY - ANALYSES AT THE LEVEL OF PREY FAMILY % TOTAL NUMBERS IDENTIFIED
AQUATIC FROGS		
Litoria dahlii	46.4	26.9
ARBOREAL FROGS		
L. rothii	27.5	19.3
L. bicolor	16.5	19.2
L. rubella	4.9	3.8
GROUND HYLIDS		
L. pallida	8.3	5.6
L. inermis	11.1	11.1
L. nasuta	2.7	0
L. tornieri	0	0
WIDE-MOUTHED, BURROWING FROGS		
Cyclorana australis	3.8	5.3
C. longipes	6.0	1.5
Limnodynastes ornatus	0	4.2
L. convexiusculus	0	11.1
NARROW-MOUTHED, BURROWING FROGS		
Notaden melanoscaphus	0	15.0
TOADLETS		
Uperoleia inundata	0	22.7
FROGLETS		
Ranidella bilingua	1.6	23.6

and wide-mouthed, burrowing frogs, and were of secondary importance as a contribution to analyses of narrow-mouthed burrowers, toadlets and froglets. It was possible only to identify whole individuals of the Coleoptera and Hemiptera to Family level. The percentage of individuals identified as belonging to an aquatic Family is shown for each species in Table (9.1).

These results largely reflect the frequency of occurrence of aquatic orders, with the exceptions of Notaden melanoscaphus, Uperoleia inundata and Ranidella bilingua. Aquatic coleopterans comprised a significant proportion of the items identified for these three species, although the number of items identified for N. melanoscaphus (20) and U. inundata (22) are low. A large percentage of the hemipterans and coleopterans identified in the stomach contents of L. dahlii, L. rothii and L. bicolor were of aquatic origin, reinforcing earlier predictions concerning their roles as predators of such items. Similarly, L. rubella, the four ground hylids and the wide-mouthed, burrowing species did not have significant proportions of prey from aquatic families in their stomachs.

Dipterans were the most common prey items found in the stomach contents of the arboreal species, L. rothii and L. bicolor, and I consider that the majority of these dipterans originated from the waterbodies at which the arboreal frogs were collected. These prey were small, and superficially resembled chironomids and chaoborinids which occur commonly at these waterbodies (Marchant, 1982); but the rapid digestion of taxonomic features prevented identification. The relative role of these arboreal frogs as predators of prey of aquatic origin was consequently under-estimated in the stomach content analyses.

9.4 INGESTION OF PREY OF AQUATIC ORIGIN - SPATIAL AND TEMPORAL VARIATION

In a survey of the littoral zones of five permanent billabongs along Magela Creek, Marchant (1982) found that in shallow billabongs (similar to Nankeen Billabong in the current study) there were wide temporal fluctuations in the abundance and diversity of the macroinvertebrate fauna. Greatest numbers of taxa and of individuals were caught in the late wet season and early dry season. By the end of the dry season (December), the diversity and abundance of the fauna had declined, respectively, to levels one-third and one-fifth of previous values. These changes were associated with the extensive growth of macrophyte beds (*Nymphaea*, *Nymphoides*, *Utricularia*, *Eleocharis*, *Aponogeton*) which occurs during the wet seasons in all billabongs and on the Magela Creek floodplain.

The diversity and abundance of prey of aquatic origin in samples of *Litoria dahlii* stomach contents varied temporally in a similar manner. This species was not seen on the floodplain near Nankeen Billabong until late in the dry season, when soaking rains caused them to emerge from their aestivation sites in deep cracks in the surface of the floodplain. At this time, only terrestrial arthropods predominated in stomach contents, mainly crickets, centipedes and spiders. The occurrence of aquatic orders was associated with great changes in water levels on the floodplain and the resultant bloom in vegetative growth from buried seeds and corms. The Anura, Ephemeroptera, Odonata, Ostracoda, Trichoptera and Zygoptera were represented in samples of frogs collected during the middle and late wet seasons, but there were marked differences between samples. One of these differences can be attributed directly to microtemporal differences in prey abundance. On April 9, 1982, vast hatches of ephemeropterans occurred from within and around Nankeen Billabong; and all frogs captured there contained large numbers of these insects. Only one week later, no ephemeropterans were observed or found in stomach contents; but, instead, a small coleopteran, observed in great numbers on emergent macrophytes, occurred in 86% of stomachs examined.

Pooled stomach contents of Litoria dahlii collected at the Tailings dam and the Magela Creek floodplain differed markedly in the diversity and abundance of prey taxa. At least some of these differences can be attributed directly to spatial differences in prey abundance. In the pooled samples from the Tailings dam and floodplain there were, respectively, 17 and 29 prey types present. Principal prey, in terms of frequency of occurrence in samples, were representatives of the Odonata and Araneae at the Tailings dam, and of the Coleoptera and Hemiptera at the floodplain. There was no growth of macrophyte beds in the Tailings dam, and the only emergent vegetation present for most of the study was flooded speargrass (Sorghum) and dying eucalypt saplings. Marchant (1982) found little variation between billabongs in the mean composition of the macroinvertebrate fauna; but in the shallows of the Tailings dam, only the nymphs of the Odonata were seen to be abundant in my study. I believe that there was a lower diversity of prey types available to L. dahlii living in the Tailings dam because of the lack of any macrophyte growth in the waters there.

The stomach contents of Litoria dahlii vary with seasonal, microtemporal and spatial factors. The occurrence of prey of aquatic origin in the diets of all species presumably varies also. My objective was to establish the relative levels of consumption of prey of aquatic origin and, despite the probability of absolute variation in diets, the following conclusions can be drawn.

By virtue of their foraging activities at waterbodies, and the nature of their stomach contents, I conclude that the aquatic frog, Litoria dahlii, and two arboreal frogs, L. rothii and L. bicolor, are the species most significant in the ingestion of prey of aquatic origin.

Litoria dahlii, in particular, is morphologically adapted for foraging in waterbodies and may have the ability to feed underwater (pers. obs.). In the laboratory, this species fed on tadpoles but it was not determined whether the frogs captured this prey below the surface or at the air/water interface (pers. obs.). A wide range of aquatic prey was identified in stomach contents, including adults and larvae of hemipterans, dytiscid beetles, trichopterans and odonatans, ostracods and conspecific frogs. This species forages in large numbers amongst flooded grasses and sedges on the floodplain and also on the bare surface of the littoral zone of waterbodies (pers. obs.). Marchant (1982) found that these areas support the greatest diversity and abundance of aquatic insects, associated with macrophyte beds and organic detritus. In habits and morphology, Litoria dahlii resembles the ranid ecotypes of the northern hemisphere which are known also to consume significant amounts of aquatic prey, including other frogs (e.g. Bruggers, 1973).

Although seldom found far from water, L. dahlii demonstrated great ability to disperse along the temporary corridors provided by linkage of waterbodies in heavy rain. At these times, individuals were seen to move upstream from Coonjimba Swamp across roads to large rain puddles, the sewerage treatment works and retention ponds. Within a year of construction, the retention ponds and Tailings dam near the Ranger uranium mine were colonised by large numbers of L. dahlii which presumably had moved up the Magela Creek. Breeding occurred soon after colonisation.

The aboreal species, Litoria rothii and L. bicolor, forage in the foliage of trees, such as Pandanus aquaticus and Barringtonia acutangula, overhanging waterbodies. Litoria bicolor, which is small, slender and green, moves over the floodplain to forage on the stems of emergent macrophytes. It is apparent that the foraging micro-habitats of the two species do not overlap widely on foliage, perhaps because L. rothii preys on L. bicolor. A single specimen of L. bicolor was found in a L. rothii stomach from Nankeen Billabong.

Alate prey predominated in analyses of the stomach contents of both species, especially dipterans and zygopterans, but also trichopterans, ephemeropterans and members of aquatic families of the Hemiptera and Coleoptera. Vast hatches of these insects occur at waterbodies, and many spent individuals were observed to alight on overhanging vegetation, so thickly at times as to form a film. Emerging and spent adults of the Trichoptera, Ephemeroptera and Diptera presumably would afford a continuous source of prey for *L. rothii* and *L. bicolor* foraging in this foliage, as Marchant (1982) found that these insects breed and emerge throughout the year at Magela Creek billabongs. Both species rapidly colonised the Tailings dam, retention ponds, sewerage treatment works and townsite buildings during the study period. Both species may be particularly important in the potential transfer of material away from these waterbodies as they consume many small prey items of aquatic origin. Small aquatic larvae have higher surface area to weight ratios, and hence may absorb more water-borne contaminants prior to emerging as alate adults.

In fulfillment of my original objectives, this thesis has outlined which anuran species are most significant in the ingestion of prey with wholly or partially aquatic life histories. Quantitative data on stomach contents and spatial distributions of 15 species also have been presented. It is anticipated that this information will be utilised to model paths of energy flow from aquatic to terrestrial ecosystems, and to select anurans as points for biological monitoring of environmental contamination in the Magela Creek system.

BIBLIOGRAPHY

Alexander, T.R. (1965).
Observations on the feeding behaviour of *Bufo marinus* (Linn.).
Herpetologica *20* (4),255-59.

Arnold, S.J., and Wassersug, R.J.(1978).
Differential predation on metamorphic anurans by garter snakes (*Thamnophis*): social behaviour as a possible defense.
Ecology *59*(5), 1014-22.

Avila, V.L., and Frye, P.G.(1978).
Feeding behaviour of the African clawed frog *Xenopus laevis*, Amphibia, Anura, Pipidae; effect of prey type.
J. Herpetol. *12*(3), 391-96.

Bailey, P.(1976).
Food of the marine toad *Bufo marinus* and six species of skink in a cacao plantation in New Britain, Papua New Guinea.
Aust. Wildl. Res. *3*(2), 185-88.

Barclay-Rose, A.(1974).
Gut contents of some amphibians and reptiles.
Herpetofauna *7*(1), 4-8.

Berry, P.Y.(1965).
The diet of some Singapore Anura (Amphibia).
Proc. Zool. Soc. London *144*, 163-174.

Berry, P.Y.(1966).
The food and feeding habits of the torrent frog *Amolops larutensis*.
Proc. Zool. Soc. London *149*, 204-14.

Berry, P.Y.(1970).
The food of the giant toad *Bufo asper*.
Zool. J. Linn. Soc. London *49*, 61-68.

Berry, P.Y., and Bullock, J.A.(1962).
The food of the common Malayan toad *Bufo melanostictus* Schneider.
Copeia *1962*, 736-41.

Blackith, R.M., and Speight, M.C.(1974).
Food and feeding habits of the frog *Rana temporaria* in bogland habitats in the west of Ireland.
J. Zool. Proc. Zool. Soc. London *172*(1), 67-79.

Bragg, A.N.(1950).
Mass movement at metamorphosis in the savannah spadefoot, *Scaphiopus hurterii* Strecker.
Proc. Okla. Acad. Sci. *31*, 26-7.

Brown, R.L.(1974).
Diets and habitat preferences of selected anurans in south east Arkansas, U.S.A..
Am. Midl. Nat. 91(2), 468-73.

Brown, L.E.(1978).
Subterranean feeding by the chorus frog *Pseudacris streckeri* (Anura: Hylidae).
Herpetologica 34(2), 212-16.

Bruggers, R.L.(1973).
Food habits of bull frogs in north west Ohio.
Ohio J. Sci. 73(3), 185-88.

Bush, F.M., and Menhinnick, E.F.(1962).
The food of *Bufo woodhousei fowleri*, Hinckley.
Herpetologica 18, 110-14.

Calaby, J.H.(1956).
The food habits of the frog *Myobatrachus gouldi* (Gray).
West Aust. Nat. 5(4), 93-6.

Calaby, J.H.(1960).
A note on the diet of Australian desert frogs.
West Aust. Nat. 7(3), 79-80.

Calaby, J.H., and Main, A.R.(1957).
New records and notes on the biology of frogs from north-western Australia.
West Aust. Nat. 5(8), 216-28.

Christian, C.S., and Aldrick, J.M.(1977).
Alligator Rivers Study - A review report of the Alligator Rivers Region environmental fact finding study.
Australian Government Publishing Service, Canberra.

Christian, K.A.(1982).
Changes in the food niche during post-metamorphic ontogeny of the frog *Pseudacris triseriata*.
Copeia 1982(1), 168-74.

Clarke, R.D.(1974).
Food habits of toads genus *Bufo*, Amphibia, Bufonidae.
Am. Midl. Nat. 91(1), 140-47.

Cohen, N.W., and Howard, W.E.(1958).
Bull frog food and growth at the San Joaquin experimental range, California.
Copeia 1958(3), 223-25.

Corse, W.A., and Metter, D.E.(1980).
Economics, adult feeding and larval growth of Rana catesbeiana on a fish hatchery.
J. Herpetol. 14, 231-38.

Cott, H.B.(1932).
On the ecology of tree frogs in the lower Zambesi Valley with special reference to predatory habits considered in relation to the theory of warning colours and mimicry.
Proc. Zool. Soc. London 1932, 471-541.

Dole, J.W., Rose, B.B., and Tachiki,K.H.(1981).
Western toads Bufo boreas learn odor of prey insects.
Herpetologica 37(1), 63-8.

Drewes, R.C., and Roth, B.(1981).
Snail eating frogs from the Ethiopian Highlands, a new anuran specialisation.
Zool. J. Linn. Soc. 72(3), 267-87.

Durant, P., and Dole, J.W.(1974).
Food of Atelopus oxyrhynchus, Anura, Atelopodidae in a Venezuelan cloud forest.
Herpetologica 30(2), 183-87.

Emerson, S.B.(1976).
Burrowing in frogs.
J. Morphol. 149(4), 437-58.

Elliot, A.B., and Karunakaran, L.(1974).
Diet of Rana cancrivora in fresh water and brackish water environments.
J. Zool. Proc. Zool. Soc. London 174(2), 203-16.

Fite, K.V.(1973).
The visual fields of the frog and toad; a comparative study.
Behav. Biol. 9(6), 707-18.

Freed, A.N.(1980).
Prey selection and feeding behaviour of the green tree frog, Hyla cinerea.
Ecology 61(3), 461-65.

Freed, A.N.(1982).
A tree frog Hyla cinerea menu selection for an evening meal.
Oecologia (Berl.) 53(1), 20-6.

Gosner, K.(1960).
A simplified table for staging anuran embryos and larvae with notes on identification.
Herpetologica 16, 183-90.

Greding, E.J., and Hellebuyck, V.J.(1980).
Ecological separation by prey selection among five species of central American anuran amphibians.
Carib. J. Sci. 16(1), 23-31.

Hamilton, W.D.(1971).
Geometry of the selfish herd.
J. Theoret. Biol. 31, 295-311.

Hamilton, W.J.(1948).
The food and feeding behaviour of the green frog, Rana clamitans, Latrielle, in New York state.
Copeia 1948(3), 203-7.

Hamilton, W.J.(1954).
The economic status of the toad.
Herpetologica 10, 37-40.

Hart, B.T., and McGregor, R.J.(1980).
Limnological survey of eight billabongs in the Magela catchment, Northern Territory.
Aust. J. Mar. Freshwater Res. 31, 611-26.

Heatwole, H., and Heatwole, A.(1968).
Motivational aspects of toad feeding.
Copeia 1968(4),692-8.

Hedeen, S.E.(1972).
Food and feeding behaviour of the mink frog, Rana septentrionalis in Minnesota.
Am. Midl. Nat. 88(2), 291-300.

Hinckley, A.D.(1962).
Diet of the giant toad, Bufo marinus (L.) in Fiji.
Herpetologica 18(4),253-59.

Houston, W.W.(1973).
The food of the common frog Rana temporaria on high moorland in northern England.
J. Zool. Proc. Zool. Soc. London 171(2), 153-65.

Hulse, A.C.(1978).
Food habits of the frog Lepidobatrachus llanensis, Amphibia, Anura, Leptodactylidae in Argentina.
J. Herpetol. 12(2), 258-60.

Humphries, R.B.(1979).
Dynamics of a breeding frog community.
Ph. D. Thesis,
Australian National University, Canberra.

Inger, R.F., and Greenberg, B.(1966).
Ecological and competitive relations among three species of frogs (genus Rana).
Ecology 47, 246-59.

Ingle, D.(1971).
Prey catching behaviour of anurans towards moving and stationary objects.
Vision Res. 3, 447-56.

Ingle, D., and McKinley, D.(1978).
Effects of stimulus configuration on elicited prey catching by the marine toad (Bufo marinus).
Anim. Behav. 26, 885-91.

Ivlev, V.S.(1961).
Experimental ecology of the feeding of fishes.
Yale University Press, New Haven, Connecticut.

Jaeger, R.G.(1976).
A possible prey-call window in anuran auditory perception.
Copeia 1976(4), 833-34.

Jeffree, R.A., and Williams, N.J.(1980).
Mining pollution and the diet of the purple striped gudgeon Mogurnda mogurnda Richardson (Eleotridae) in the Finniss River, Northern Territory, Australia.
Ecol. Monogr. 50, 457-85.

Jenssen, T.A., and Klimstra, W.D.(1966).
Food habits of the green frog, Rana clamitans, in southern Illinois.
Am. Midl. Nat. 76, 169-82.

Johnson, B.K., and Christiansen, J.L.(1976).
The food and food habits of Blanchard's cricket frog, Acris crepitans, Amphibia, Anura, Hylidae in Iowa U.S.A..
J. Herpetol. 10(2), 63-74.

Kirkland, A.H.(1897).
The habits, food and economic value of the American toad, Bufo lentiginosus americanus Le C.
Hatch. Exp. Sta. Mass. Agric. Coll. Bull. 46, 1-30.

Kramek, W.C.(1976).
Feeding behaviour of Rana septentrionalis, Amphibia, Anura, Ranidae.
J. Herpetol. 10(3), 251-52.

Labanick, G.M.(1976).
Prey availability, consumption, and selection in the cricket frog, Acris crepitans.
J. Herpetol. 10, 293-98.

Lee, A.K.(1967).
Studies in Australian Amphibia [2].
Taxonomy, ecology and evolution of the genus Heleioporus Gray (Anura: Leptodactylidae).
Aust. J. Zool. 15, 367-439.

MacNally, R.C.(1983).
Trophic relationships of two sympatric species of Ranidella (Anura).
Herpetologica 39, 130-40.

Main, A.R.(1957).
Studies in Australian Amphibia [1].
The genus Crinia Tschudi in south western Australia and some species from south eastern Australia.
Aust. J. Zool. 5, 30-55.

Martof, B.S.(1953).
Territoriality in the green frog, Rana clamitans.
Ecology 34, 165-74.

Moore, J.A.(1961).
The frogs of eastern New South Wales.
Bull. Am. Mus. Nat. Hist. 121(3), 149-386.

Pengilley, R.K.(1971).
The food of some Australian anurans (Amphibia).
J. Zool. London 163, 93-103.

Perez, M.E.(1951).
The food of Rana catesbeiana, Shaw in Puerto Rico.
Herpetologica 7(1), 102-4.

Regal, R.J., and Gans, C.(1976).
Functional aspects of the evolution of frog tongues.
Evolution 30(4), 713-34.

Robertson, J.G.(1982).
Territoriality and sexual selection in Uperoleia rugosa (Anura: Leptodactylidae).
Ph. D. Thesis,
Australian National University, Canberra.

Root, R.(1967).
The niche exploitation pattern of the blue-gray gnat-catcher.
Ecol. Monogr. 37, 317-50.

Rossi, J.V.(1983).
The use of olfactory cues by Bufo marinus.
J. Herpetol. 17, 72-3.

Shinn, E.A., and Dole, J.W.(1978).
Evidence for a role for olfactory cues in the feeding response of leopard frogs, Rana pipiens.
Herpetologica 34(2), 167-72.

Shinn, E.A., and Dole, J.W.(1979).
Evidence for a role for olfactory cues in the feeding response of western toads, Bufo boreas.
Copeia 1979(1), 163-5.

Sibert, J., and Obrebski, S.(1981)
Frequency distributions of food item counts in individual fish stomachs.
In: Gutshop '81 - Fish food habit studies - Proceedings of the third Pacific workshop.
Caillet, G.M., and Simenstad, C.A.(eds)
Washington Sea Grant publication, University of Washington, Seattle.

Smith, A.K.(1977).
Attraction of bull frogs, Amphibia, Anura, Ranidae to distress calls of immature frogs.
J. Herpetol. 11(2), 234-5.

Smith, G.B.(1981).
Sampling considerations in the analysis of food web relationships.
In: Gutshop '81 - Fish food habit studies - Proceedings of the third Pacific workshop.
Caillet, G.M., and Simenstad, C.A.(eds)
Washington Sea Grant publication, University of Washington, Seattle.

Sokal, R.R., and Rohlf, F.J.(1973).
Introduction to biostatistics.
W.H. Freeman and Company, San Francisco, U.S.A.

Stewart, M.M., and Sandison, P.(1972).
Comparative food habits of sympatric mink frogs, bull frogs and green frogs.
J. Herpetol. 6(3), 241-4.

Taigen, T.L., and Pough, F.H.(1983).
Prey preference, foraging behaviour, and metabolic characteristics of frogs.
Am. Nat. 122(4), 509-20.

Toft, C.A.(1980a).
Feeding ecology of 13 syntopic species of anurans in a seasonal tropical environment.
Oecologia (Berl.) 45(1), 131-41.

Toft, C.A.(1980b).
Seasonal variation in populations of Panamanian litter frogs and their prey - a comparison of wetter and drier sites.
Oecologia (Berl.) *47*, 34-8.

Toft, C.A.(1981).
Feeding ecology of Panamanian litter anurans; patterns in diet and foraging mode.
J. Herpetol. *15*(2), 139-44.

Toft, C.A.(1985).
Resource partitioning in amphibians and reptiles.
Copeia *1985*(1), 1-21.

Turner, F.B.(1959).
An analysis of the feeding habits of *Rana p. pretiosa* in Yellowstone Park, Wyoming.
Am. Midl. Nat. *61*, 403-13.

Tyler, M.J.(1958).
On the diet and feeding habits of the edible frog (*Rana esculenta* L.).
Proc. Zool. Soc. London *131*, 583-95.

Tyler, M.J., and Cappo, M.C.(1983).
Diet and feeding habits of frogs and tadpoles of the Magela Creek system.
Open File Record 10: Final report to the Office of the Supervising Scientist for the Alligator Rivers Region.

Tyler, M.J., and Crook, G.A.(1980).
Frogs of the Magela Creek System, Alligator Rivers Region, N.T., Australia.
Open File Record 1: Final report to the Office of the Supervising Scientist for the Alligator Rivers Region.

Tyler, M.J., Watson, G.F., Davies, M., and Crook, G.C.(1981).
Frogs as environmental monitoring organisms.
Program A: Abnormalities in frogs.
Open File Record 24: Final report to the Office of the Supervising Scientist for the Alligator Rivers Region.

Werner, E.E., and Hall, D.J.(1974).
Optimal foraging and the size selection of prey by bluegill sunfish (*Lepomis macrochirus*).
Ecology *55*, 1042-52.

Williams, A.R.(1979).
Vegetation and stream pattern as indicators of water movement on the Magela Floodplain, Northern Territory.
Aust. J. Ecol. *4*, 239-47.

Wotherspoon, D.(1981).
The great barred frog - mouth breeder ?
Herpetofauna 12(2), 30.

Zug, G.R., Lindgren, E., and Pippet, J.R.(1975).
Distribution and ecology of the marine toad *Bufo marinus* in Papua New Guinea.
Pac. Sci. 29(1), 31-50.

Zug, G.R., and Zug, P.B.(1979).
The marine toad, *Bufo marinus*: a natural history resume' of native populations.
Smithson. Contrib. Zool. 284, 1-58.

ADDENDA TO BIBLIOGRAPHY

Emerson, S.B. (1985).
Skull shape in frogs - correlations with diet.
Herpetologica 41 (2), 177-188.

Marchant, R.(1982).
Seasonal variation in the macro-invertebrate fauna of billabongs along Magela Creek, Northern Territory.
Aust. J. Freshwat. Mar. Res. 33, 329-342.

Schoener, T.W. (1974).
Resource partitioning in ecological communities.
Science 185, 27-39.

Appendix (1.1); Australian studies of frog food and feeding habits.

AUTHOR	SPECIES	Number Examined
Calaby (1956)	Myobatrachus gouldii	26
Calaby (1960)	Limnodynastes spenceri	9
	Cyclorana cultripes	12
Main (1957)	Crinia rosea	?
	C. leai	?
	C. georgiana	?
	C. glauerti	?
	C. insignifera	?
	C. pseudinsignifera	?
Main and Calaby (1957)	Uperoleia russelli	6
	Limnodynastes spenceri	9
	Cyclorana cultripes	12
Barclay-Rose (1974)	Heleioporus australiacus	2
	Limnodynastes peronii	6
	L. ornatus	1
	L. dorsalis	2
	Pseudophryne australis	2
	P. bibronii	1
	Crinia signifera	3
	Litoria caerulea	2
	L. phyllochroa	3
	L. verreauxii	1
	L. freycineti	1
	L. jervisiensis	1
Wotherspoon (1981)	Mixophyes fasciolatus	1
Lee (1967)	Heleioporus albopunctatus	4
	H. eyrei	78
	H. inornatus	11
	H. barycragus	20
	H. psammophilus	12
Pengilley (1971)	Pseudophryne corroboree	322
	P. dendyi	54
	P. bibroni	29
	Crinia signifera	46
	Hyla verreauxii	21
MacNally (1983)	Ranidella signifera	148
	R. parinsignifera	40
Humphries (1979)	Litoria aurea	?
	L. raniformis	?

Appendix (4.1); Data recorded for each specimen on the MORFROGMETRICS computer file.

FROG SPECIES CODE.
FROG IDENTITY NUMBER.
FROG CATEGORY.
SNOUT-VENT LENGTH (mm)
MOUTH GAPE (mm)
TOTAL WEIGHT (g)
INDEX OF STOMACH DISTENTION
STOMACH WEIGHT. (g)
DATE OF CAPTURE.
TIME OF CAPTURE.
LOCATION OF CAPTURE.

Appendix (4.2); Data recorded from stomach content analyses at the level of taxonomic Order on the DISSECT computer file.

FROG SPECIES CODE.
FROG IDENTITY NUMBER.
STOMVOL I (mm^2)
STOMVOL II (cm^2)
AVERAGE STOMVOL (mm^2)
FOODNUM.
FOODVOL (mm^2)
DIGESTNUM
DIGESTVOL (mm^2)
% DIGESTNUM
% DIGESTVOL

For each prey category (P) found in the stomach contents;
PREY CATEGORY CODE,
WHNUM, REMNUM, WHVOL, REMVOL, SUMNUM, SUMVOL,
DIGESTATE, PROPNUM, PROPVOL.

Appendix (4.3); **Data recorded for arthropods included in stomach content analyses at the level of taxonomic Family on the FAMLEV computer file.**

FROG SPECIES CODE.

FROG IDENTITY NUMBER.

NUMBER OF ARTHROPODS MEASURED.

PREY CATEGORY CODE.

PREY FAMILY CODE.

TOTAL LENGTH OF PREY INDIVIDUAL (mm)

VOLUME OF PREY INDIVIDUAL (only >0 if Prey Family Code >0) (mm^3)

Appendix (4.4); Codes used to identify sampling sites.

CODE	LOCATION
SITE 1	MAGELA CREEK TRANSECT
SITE 2	GULUNGUL CREEK TRANSECT # 1
SITE 3	GULUNGUL CREEK TRANSECT # 2
SITE 4	JABIRU EAST ROADS
SITE 5	JABIRU EAST ROADS, ADJACENT TO SWAMPLAND
SITE 6	MINESITE TAILINGS DAM
SITE 7	JABIRU EAST SEWERAGE TREATMENT WORKS
SITE 8	MINESITE RETENTION POND # 1
SITE 9	MINESITE RETENTION POND # 2
SITE 10	MINESITE RETENTION POND # 3
SITE 11	JABIRU TOWNSITE ROADS
SITE 12	JABIRU TOWNSITE ARTIFICIAL LAKE
SITE 13	GOANNA BILLABONG
SITE 14	NANKEEN BILLABONG
SITE 15	NANKEEN BILLABONG LEVEE, STATION A
SITE 16	NANKEEN BILLABONG, *Pandanus aquaticus* foliage STATION B
SITE 17	NANKEEN BILLABONG, *Barringtonia acutangula* foliage
SITE 18	MAGELA CREEK FLOODPLAIN
SITE 19	MAGELA CREEK FLOODPLAIN MARGIN, STATION C
SITE 20	MAGELA CREEK FLOODPLAIN, DRAINAGE CHANNEL
SITE 21	JABIRU EAST AIRSTRIP
SITE 22	ROAD, WESTERN END OF JABIRU EAST AIRSTRIP
SITE 23	ARNHEM HIGHWAY
SITE 24	ARNHEM HIGHWAY, Roadside borrow pits
SITE 25	ARNHEM HIGHWAY, Adjacent to swampland
SITE 26	GULUNGUL CREEK, Sandy creek bed
SITE 27	MINESITE ORE BODY, PIT "J"
SITE 28	JABIRU EAST REFUSE DUMP
SITE 29	GULUNGUL CREEK SWAMP
SITE 30	NANKEEN BILLABONG, Unspecified foliage
SITE 31	ARNHEM HIGHWAY, Grassland 800 metres west of Gulungul Creek
SITE 32	MAGELA CREEK, Sandy creek bed

Appendix (4.5); Codes used to identify frog species

CODE	SPECIES
L. dahl.	*Litoria dahlii*
L. roth.	*Litoria rothii*
L. bico.	*Litoria bicolor*
L. rube.	*Litoria rubella*
L. pall.	*Litoria pallida*
L. iner.	*Litoria inermis*
L. nasu.	*Litoria nasuta*
L. torn.	*Litoria tornieri*
L. wotj.	*Litoria wotjulumensis*
C. aust.	*Cyclorana australis*
C. long.	*Cyclorana longipes*
L. orna.	*Limnodynastes ornatus*
L. conv.	*Limnodynastes convexiusculus*
N. mela.	*Notaden melanoscaphus*
U. inun.	*Uperoleia inundata*
R. bili.	*Ranidella bilingua*

Appendix (4.6); Codes used to identify prey Orders.

CODE	PREY ORDER	VERNACULAR TERM
16	ACARINA	Mites
29	ANURA - ADULT	Frogs
37	ANURA - LARVA	Tadpoles
5	ARANEAE	Spiders
15	BLATTODEA	Cockroaches
17	CHILOPODA	Centipedes
2	COLEOPTERA - ADULT	Beetles
23	COLEOPTERA - LARVA	Beetle grubs
11	COLLEMBOLA	Springtails
24	DERMAPTERA	Earwigs
38	DIPLOPODA	Millipedes
3	DIPTERA	Mosquitoes, gnats and two-winged flies
28	EPHEMEROPTERA	Mayflies
35	GASTROPODA	Snails
4	HEMIPTERA	Bugs
12	HYMENOPTERA - ALATE	Ants, wasps and bees
1	HYMENOPTERA - NON-ALATE	Ants
14	ISOPTERA - ALATE	Termites
21	ISOPTERA - NON-ALATE	Termites
27	ISOPODA	Pill lice
10	LEPIDOPTERA - ADULT	Moths and butterflies
13	LEPIDOPTERA - LARVA	Caterpillars
33	MANTODEA	Mantises
20	ODONATA - ADULT	Dragon flies
36	ODONATA - NYMPH	Mudeyes
30	OLIGOCHAETA	Earthworms
6	ORTHOPTERA	Grasshoppers and crickets
39	OSTRACODA	
22	PHALANGIDA	Harvest spiders
31	PHASMIDA	Stick insects
34	PLECOPTERA	Stone flies
41	SCORPIONIDA	Scorpions
32	THYSANOPTERA	Thrips
18	TRICHOPTERA - ADULT	Caddis flies
26	TRICHOPTERA - NYMPH	Caddis
25	ZYGOPTERA - ADULT	Damsel flies
40	ZYGOPTERA - NYMPH	
42	OTHER, VERTEBRATE	
43	OTHER, INVERTEBRATE	
9	UNDETERMINED ADULT	
19	UNDETERMINED LARVA	
8	VEGETABLE MATERIAL	Grass, twigs
7	INORGANIC MATERIAL	Sand, stones

Appendix (4.7); Codes used to identify prey families.

CODE	PREY FAMILY
0	TERRESTRIAL COLEOPTERA and HEMIPTERA
	AQUATIC COLEOPTERA
1	DYTISCIDAE
3	GYRINIDAE
4	HALIPLIDAE
20	HELODIDAE
6	HISTERIDAE
7	HYDRAENIDAE
8	HYDROCHIDAE
9	HYDROPHILIDAE
10	HYGROBIIDAE
11	LIMNICHIDAE
16	PSEPHENIDAE
17	SPERCHEIDAE
18	SPHAERIIDAE
	AQUATIC HEMIPTERA
2	GERRIDAE
5	HEBRIDAE
12	MESOVELIIDAE
13	NAUCORIDAE
14	OCHTERIDAE
15	PLEIDAE
19	VELIIDAE

Appendix (5.1); Classification of Sampling Locations as Waterbodies (W), Ephemeral Waterbodies (EW) and Terrestrial (T)

SITE	SAMPLING LOCATION	CLASSFN
1	MAGELA CREEK TRANSECT	T
2	GULUNGUL CREEK TRANSECT # 1	T
3	GULUNGUL CREEK TRANSECT # 2	T
4	JABIRU EAST ROADS	T
5	JABIRU EAST ROADS, Adjacent to swampland	T
6	MINESITE TAILINGS DAM	W
7	JABIRU EAST SEWERAGE TREATMENT WORKS	W
8	MINESITE RETENTION POND # 1	T
9	MINESITE RETENTION POND # 2	T
10	MINESITE RETENTION POND # 3	T
11	JABIRU TOWNSITE ROADS	T
12	JABIRU TOWNSITE ARTIFICIAL LAKE	W
13	GOANNA BILLABONG	T
14	NANKEEN BILLABONG	W
15	NANKEEN BILLABONG LEVEE, STATION A	W
16	NANKEEN BILLABONG, *Pandanus aquaticus* foliage STATION B	W
17	NANKEEN BILLABONG, *Barringtonia acutangula* foliage	W
18	MAGELA CREEK FLOODPLAIN	W
19	MAGELA CREEK FLOODPLAIN MARGIN, STATION C	W
20	MAGELA CREEK FLOODPLAIN, Drainage channel	W
21	JABIRU EAST AIRSTRIP	T
22	ROAD, WESTERN END OF JABIRU EAST AIRSTRIP	T
23	ARNHEM HIGHWAY	T
24	ARNHEM HIGHWAY, Roadside borrow pits	EW
25	ARNHEM HIGHWAY, Adjacent to swampland	EW
26	GULUNGUL CREEK, Sandy creek bed	T
27	MINESITE ORE BODY, PIT "J"	T
28	JABIRU EAST REFUSE DUMP	T
29	GULUNGUL CREEK SWAMP	EW
30	NANKEEN BILLABONG, Unspecified foliage	W
31	ARNHEM HIGHWAY, Grassland 800 metres west of Gulungul Creek	EW
32	MAGELA CREEK, Sandy creek bed	T

LOCATION	L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	L. wotj.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.	TOTALS
SITE 1	1	0	2	0	22	8	24	0	0	51	10	31	6	11	17	4	187
SITE 2	14	0	8	0	20	7	27	0	0	15	2	4	16	9	46	13	181
SITE 3	0	0	0	1	0	0	0	0	0	10	1	0	0	2	0	0	14
SITE 4	5	0	0	11	14	9	10	6	1	98	16	9	2	3	4	0	188
SITE 5	0	0	0	0	10	0	5	0	0	0	0	0	0	0	19	0	34
SITE 6	96	5	8	4	44	4	26	13	0	22	2	2	1	28	5	22	282
SITE 7	4	11	0	5	0	0	0	0	0	92	13	2	0	0	1	0	128
SITE 8	3	0	3	8	3	3	10	3	0	13	1	2	0	0	4	0	52
SITE 9	0	9	0	0	18	0	0	3	0	8	2	1	0	0	0	0	41
SITE 10	0	5	0	0	4	0	0	0	0	3	0	0	0	0	0	0	12
SITE 11	0	0	0	0	0	0	0	0	1	15	0	0	0	0	0	0	16
SITE 12	0	0	0	8	7	8	1	0	1	34	6	12	0	4	0	0	81
SITE 13	0	0	0	0	0	1	0	0	0	2	0	2	0	0	0	0	5
SITE 14	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
SITE 15	22	18	14	2	2	3	13	0	0	0	0	0	0	0	0	17	91
SITE 16	2	40	115	36	0	0	0	0	0	0	0	0	0	0	0	0	193
SITE 17	4	63	19	0	0	0	0	0	0	0	0	0	0	0	0	0	86
SITE 18	159	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159
SITE 19	310	30	45	4	1	4	25	0	0	1	11	1	8	0	0	1	441
SITE 20	19	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	28
SITE 21	0	3	0	9	11	35	0	36	3	2	6	4	0	26	1	0	136
SITE 22	0	0	0	8	1	0	2	0	0	47	4	25	0	0	4	0	91
SITE 23	0	0	0	0	0	0	0	77	0	11	3	0	0	0	0	0	91
SITE 24	0	12	0	122	62	38	0	0	0	0	0	6	0	0	0	0	240
SITE 25	0	0	9	0	15	0	1	0	0	0	0	0	0	11	16	7	59
SITE 26	0	0	0	1	5	6	4	5	0	1	0	1	0	0	0	0	23
SITE 27	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
SITE 28	0	0	0	0	0	0	0	0	6	0	0	1	0	0	0	0	7
SITE 29	0	0	49	0	7	0	0	0	0	0	0	0	0	14	8	0	78
SITE 30	0	17	22	0	0	0	0	0	0	0	0	0	0	0	0	0	39
SITE 31	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
SITE 32	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	12	16
TOTALS	645	213	302	219	248	126	148	143	13	430	77	103	33	108	125	76	3009

Appendix (5.2); Number of frogs of 16 species collected from 32 sampling locations during the study period.

INDEX OF STOMACH DISTENTION	DEVELOPMENTAL STAGE								
	Unknown	Stage 42*	Juvenile	Male	Male, Calling	Female	Female, Gravid	Female, Gravid, in Amplexus	TOTAL
VOMIT	16	2	6	34	2	10	7	0	76
0	17	44	49	137	85	24	21	10	387
1	40	5	126	319	101	89	49	22	751
2	46	1	116	235	71	81	49	13	612
3	45	0	88	197	49	47	52	6	484
4	33	0	66	106	23	35	29	8	300
5	39	0	55	84	15	42	26	6	267
6	16	0	33	28	2	28	23	2	132
TOTAL	252	52	539	1140	347	356	256	67	3009

Appendix 6.1; Categorisation of all frogs collected according to developmental stage and index of stomach distention.

* after Gosner (1960)

Appendix 6.4.1; Length frequency distributions of species examined in stomach content analyses.

SNOUT TO VENT LENGTH	SPECIES CODE																
LENGTH CLASS (mm)	L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	L. wotj.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.	TOTAL
0 - 5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1- 10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.1- 15.0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	3	5
15.1- 20.0	0	0	30	25	3	1	8	0	0	0	1	11	0	1	2	48	130
20.1- 25.0	0	0	128	2	10	8	10	0	0	1	4	12	0	0	71	9	255
25.1- 30.0	14	5	87	69	24	25	4	21	0	3	6	19	2	0	15	0	294
30.1--35.0	31	36	3	24	103	30	9	60	0	5	11	32	1	3	0	0	348
35.1- 40.0	16	25	0	0	32	7	33	4	0	12	19	21	3	16	0	0	188
40.1- 45.0	37	28	0	0	2	0	28	0	0	6	15	1	4	40	0	0	161
45.1- 50.0	26	43	0	0	0	0	11	0	0	1	10	0	7	17	0	0	115
50.1- 55.0	37	5	0	0	0	0	4	0	0	0	0	0	3	0	0	0	49
55.1- 60.0	15	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	17
60.1- 65.0	15	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	21
65.1- 70.0	10	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	32
70.1- 75.0	3	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	15
75.1- 80.0	3	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	11
80.1- 85.0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
85.1- 90.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90.1- 95.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95.1-100.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100.1-105.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
105.1-110.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	207	142	249	120	174	71	107	85	0	78	66	97	22	77	88	60	1643

SITE	L. dahl.	L. roth.	L. bico.	L. ruba.	L. pall.	L. iner.	L. torn.	L. nasu.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.	TOTAL
	SPECIES															
SITE 1	0	0	2	0	19	6	18	0	5	10	31	5	10	12	4	122
SITE 2	6	0	8	0	18	6	17	0	0	2	4	8	8	41	11	129
SITE 3	0	0	0	1	0	0	0	0	3	1	0	0	1	0	0	6
SITE 4	0	0	0	6	12	6	9	1	14	13	9	2	2	4	0	78
SITE 5	0	0	0	0	7	0	3	0	0	0	0	0	0	11	0	21
SITE 6	74	4	7	4	35	3	19	9	1	2	2	1	20	5	21	207
SITE 7	0	4	0	4	0	0	0	0	18	11	1	0	0	1	0	39
SITE 8	0	0	1	7	3	3	6	1	5	0	1	0	0	3	0	30
SITE 9	0	0	0	0	12	0	0	2	2	1	1	0	0	0	0	18
SITE 10	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	4
SITE 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SITE 12	0	0	0	4	2	7	1	0	0	5	11	0	4	0	0	34
SITE 13	0	0	0	0	0	1	0	0	2	0	2	0	0	0	0	5
SITE 14	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
SITE 15	22	15	13	2	2	3	11	0	0	0	0	0	0	0	17	85
SITE 16	0	37	97	28	0	0	0	0	0	0	0	0	0	0	0	162
SITE 17	0	52	18	0	0	0	0	0	0	0	0	0	0	0	0	70
SITE 18	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
SITE 19	65	11	37	4	0	3	17	0	0	11	1	6	0	0	1	156
SITE 20	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	9
SITE 21	0	0	0	6	8	16	0	26	0	4	3	0	18	1	0	82
SITE 22	0	0	0	7	1	0	2	0	22	4	24	0	0	2	0	62
SITE 23	0	0	0	0	0	0	0	42	3	2	0	0	0	0	0	47
SITE 24	0	3	0	46	32	12	0	0	0	0	5	0	0	0	0	98
SITE 25	0	0	3	0	10	0	1	0	0	0	0	0	4	6	6	30
SITE 26	0	0	0	1	5	5	3	4	1	0	1	0	0	0	0	20
SITE 27	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
SITE 28	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
SITE 29	0	0	41	0	5	0	0	0	0	0	0	0	10	2	0	58
SITE 30	0	14	13	0	0	0	0	0	0	0	0	0	0	0	0	27
SITE 31	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
SITE 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	207	142	249	120	174	71	107	85	78	66	97	22	77	88	60	1643

Appendix (6.4.2); Site of collection of 15 species of frogs examined in stomach content analyses.

Appendix 6.4.3; Categorisation of frogs examined in stomach content analyses according to size, sex and activity immediately prior to capture.

	DEVELOPMENTAL STAGE									
SPECIES	CODE	UNKNOWN	STAGE 42*	JUVENILE	MALE	MALE, CALLING	FEMALE	FEMALE, GRAVID	FEMALE, GRAVID IN AMPLEXUS	TOTAL
L. dahl.	S 1	78	2	14	42	7	44	10	10	207
L. roth.	S 2	20	0	43	25	3	26	24	1	142
L. bico.	S 3	44	0	12	107	16	23	43	4	249
L. rube.	S 4	0	0	26	69	9	0	12	4	120
L. pall.	S 5	7	0	18	93	21	19	11	5	174
L. iner.	S 6	2	0	7	46	1	4	9	2	71
L. nasu.	S 7	2	1	22	20	34	12	7	9	107
L. torn.	S 8	0	0	0	70	6	2	6	1	85
C. aust.	S10	0	0	28	18	13	2	15	2	78
C. long.	S11	2	0	20	24	2	13	2	3	66
L. orna.	S12	17	0	37	24	1	12	6	0	97
L. conv.	S13	0	0	2	5	7	4	3	1	22
N. mela.	S14	4	0	1	49	8	3	12	0	77
U. inun.	S15	4	0	0	35	24	12	12	1	88
R. bili.	S16	1	0	0	10	35	6	7	1	60
TOTAL		181	3	230	637	187	182	179	44	1643

Appendix (6.4.4); Frequency of Occurrence of 43 prey orders Identified in stomach content analyses of 15 study species.

Prey Order	Prey Code	Code of Origin	L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.
ANURA ADULT	29	A	10	2	0	0	0	0	0	0	3	0	0	0	0	0	0
ANURA LARVA	37	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPHEMEROPTERA	28	A	12	0	3	0	1	0	0	0	0	0	0	0	0	0	1
ODONATA ADULT	20	A	16	8	6	0	8	5	1	0	0	2	0	0	0	0	0
ODONATA NYMPH	36	A	48	0	0	0	1	0	1	0	0	0	0	0	0	0	0
OSTRACODA	39	A	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLECOPTERA	34	A	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TRICHOPTERA ADULT	18	A	9	27	20	6	3	2	1	0	0	2	0	0	0	0	0
TRICHOPTERA NYMPH	26	A	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA ADULT	25	A	7	1	14	0	2	1	1	0	0	0	0	0	0	0	0
ZYGOPTERA NYMPH	40	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POOLED AQUATIC			96	39	41	6	15	8	3	0	3	4	0	0	0	0	1
ARANEAE	5	TA	66	39	43	11	58	20	35	18	18	24	18	2	2	9	18
COLEOPTERA ADULT	2	TA	97	33	52	35	83	31	46	32	28	38	72	9	36	27	31
COLEOPTERA LARVA	23	TA	6	0	2	0	6	0	1	3	1	0	5	0	0	1	1
DIPTERA	3	TA	78	56	128	33	30	15	26	8	4	20	10	0	0	4	21
GASTROPODA	35	TA	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0
HEMIPTERA	4	TA	74	21	62	18	63	19	22	29	8	24	17	2	3	4	34
OTHER, VERTEBRATE	42	TA	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
OTHER, INVERBRATE	43	TA	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
UNDETERMINED ADULT	9	TA	4	5	55	1	34	7	16	11	4	1	6	0	1	12	2
UNDETERMINED LARVA	19	TA	33	3	6	4	3	4	1	1	2	3	1	0	0	0	9
POOLED TERRESTRIAL/ AQUATIC			176	103	223	69	159	59	90	66	40	55	89	13	37	43	56
ACARINA	16	T	1	1	2	6	3	2	1	1	0	0	6	0	1	16	26
BLATTODEA	15	T	9	16	14	7	5	3	5	0	6	5	6	1	0	1	0
CHILOPODA	17	T	7	1	0	3	6	3	6	0	11	4	5	1	3	2	0
COLLEMBOLA	11	T	25	0	5	12	6	3	1	2	1	4	5	0	0	28	43
DERMAPTERA	24	T	1	6	1	1	3	2	3	0	2	0	1	2	0	0	0
DIPLOPODA	38	T	0	0	0	1	1	1	1	0	5	0	8	0	0	1	0
HYMENOPTERA ALATE	12	T	12	12	16	6	21	6	9	8	4	5	11	0	1	4	1
HYMENOPTERA NON-ALATE	1	T	47	16	84	86	47	27	26	13	16	25	96	3	71	79	37
ISOPTERA ALATE	14	T	0	2	0	9	10	2	0	5	15	12	15	0	3	3	0
ISOPTERA NON-ALATE	21	T	3	0	0	4	1	6	0	1	4	3	3	0	3	14	0
ISOPODA	27	T	0	0	1	0	0	1	0	0	0	0	3	0	0	2	0
LEPIDOPTERA ADULT	10	T	14	9	24	4	13	6	4	9	4	9	4	0	0	0	3
LEPIDOPTERA LARVA	13	T	9	16	11	6	18	8	14	6	10	13	5	1	0	1	1
MANTODEA	33	T	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0
OLIGOCHAETA	30	T	1	0	0	0	5	0	0	0	0	0	0	1	0	0	0
ORTHOPTERA	6	T	52	16	5	4	72	24	43	39	28	31	10	6	1	8	10
PHALANGIDA	22	T	0	0	0	0	1	1	0	0	0	1	7	2	2	0	1
PHASMIDA	31	T	0	0	0	0	0	0	3	0	1	1	0	0	0	0	0
SCORPIONIDA	41	T	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
THYSANOPTERA	32	T	1	0	2	0	2	0	0	0	0	0	0	0	0	1	0
POOLED TERRESTRIAL			128	77	126	106	134	60	76	62	61	55	98	13	71	88	58
INORGANIC MATERIAL	7		28	1	0	16	32	14	4	10	32	9	34	3	45	20	5
VEGETABLE MATERIAL	8		59	3	10	5	10	10	12	6	24	16	6	2	13	15	1

Appendix (6.4.5); Number of items (WHNUM) of 43 prey orders identified in stomach content analyses of 15 study species.

Prey Order	Prey Code	Code of Origin	L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.
ANURA ADULT	29	A	12	2	0	0	0	0	0	0	3	0	0	0	0	0	0
ANURA LARVA	37	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPHEMEROPTERA	28	A	369	0	34	0	1	0	0	0	0	0	0	0	0	0	1
ODONATA ADULT	20	A	17	8	6	0	8	5	1	0	0	2	0	0	0	0	0
ODONATA NYMPH	36	A	114	0	0	0	1	0	3	0	0	0	0	0	0	0	0
OSTRACODA	39	A	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLECOPTERA	34	A	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TRICHOPTERA ADULT	18	A	30	48	105	26	6	3	1	0	0	8	0	0	0	0	0
TRICHOPTERA NYMPH	26	A	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA ADULT	25	A	10	1	14	0	2	1	1	0	0	0	0	0	0	0	0
ZYGOPTERA NYMPH	40	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POOLED AQUATIC			566	60	159	26	17	9	6	0	3	10	0	0	0	0	1
ARANEAE	5	TA	103	81	54	13	82	24	49	22	20	40	24	2	2	12	20
COLEOPTERA ADULT	2	TA	647	59	101	42	255	84	117	43	37	219	187	16	67	45	57
COLEOPTERA LARVA	23	TA	14	0	3	0	6	0	1	3	1	0	7	0	0	1	1
DIPTERA	3	TA	631	923	517	103	310	55	119	13	5	64	16	0	0	6	51
GASTROPODA	35	TA	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0
HEMIPTERA	4	TA	160	31	104	22	138	47	29	43	15	47	26	3	3	4	64
OTHER, VERTEBRATE	42	TA	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
OTHER, INVERBRATE	43	TA	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
UNDETERMINED ADULT	9	TA	2	3	2	0	0	0	1	0	2	0	2	0	1	1	0
UNDETERMINED LARVA	19	TA	76	3	6	5	4	6	1	1	2	2	1	0	0	0	15
POOLED TERRESTRIAL/ AQUATIC			634	100	787	185	695	217	317	125	83	372	265	21	73	69	208
ACARINA	16	T	1	1	5	8	3	2	1	1	0	0	6	0	1	34	41
BLATTODEA	15	T	9	20	14	7	5	3	5	0	6	5	9	1	0	1	0
CHILOPODA	17	T	12	2	0	3	6	3	7	0	12	5	5	1	4	2	0
COLLEMBOLA	11	T	344	0	15	29	6	3	2	3	7	8	8	0	0	103	447
DERMAPTERA	24	T	1	6	1	1	3	2	3	0	2	0	1	2	0	0	0
DIPLOPODA	38	T	0	0	0	1	1	1	1	0	5	0	13	0	0	1	0
HYMENOPTERA ALATE	12	T	18	31	31	65	32	6	21	9	5	14	95	0	3	11	1
HYMENOPTERA NON-ALATE	1	T	108	24	212	657	79	50	48	13	75	151	837	3	434	696	105
ISOPTERA ALATE	14	T	0	2	0	74	58	14	0	16	173	117	129	0	26	549	0
ISOPTERA NON-ALATE	21	T	34	0	0	4	1	20	0	1	59	214	18	0	14	591	0
ISOPODA	27	T	0	0	1	0	0	1	0	0	0	0	5	0	0	2	0
LEPIDOPTERA ADULT	10	T	15	14	41	7	16	10	5	9	5	14	9	0	0	0	3
LEPIDOPTERA LARVA	13	T	12	42	18	7	24	11	15	7	13	43	5	1	0	1	1
MANTODEA	33	T	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0
OLIGOCHAETA	30	T	1	0	0	0	5	0	0	0	0	0	0	1	0	0	0
ORTHOPTERA	6	T	82	16	5	5	100	33	58	47	44	67	12	6	1	9	13
PHALANGIDA	22	T	0	0	0	0	1	1	0	0	0	1	8	4	2	0	1
PHASMIDA	31	T	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0
SCORPIONIDA	41	T	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
THYSANOPTERA	32	T	1	0	4	0	3	0	0	0	0	0	0	0	0	1	0
POOLED TERRESTRIAL			638	159	347	868	343	161	169	106	407	641	160	19	485	502	612
INORGANIC MATERIAL	7		0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
VEGETABLE MATERIAL	8		0	0	2	0	0	0	1	0	2	0	0	0	1	1	0
TOTAL			2838	2319	1295	1079	1055	387	493	231	498	1023	2425	40	2559	2572	821

ACARINA	16	T	0.20	4	3.7	1.2	10	0.6	0.2	2	0	0	12.5	0	1.5	27.1	16.8
BLATTODEA	15	T	1000.00	1134	538	126	81	141	60	0	2561	113	110	2000	0	6	0
CHILOPODA	17	T	1795.00	14	0	46	243	102.5	69	0	6931	123	86	90	61	18.5	0
COLLEMBOLA	11	T	64.80	0	5.8	11.1	5.1	0.4	1.5	0.6	0.5	2.7	5.5	0	0	38.5	79.9
DERMAPTERA	24	T	260.00	329	15	10	110	72	111	0	150	0	4	270	0	0	0
DIPLOPODA	38	T	0.00	0	0	8	6	4	10	0	170	0	327	0	0	6	0
HYMENOPTERA ALATE	12	T	484.50	1254	139.5	221	295	31.5	95	115	44	101	853	0	62	25.5	0.1
HYMENOPTERA NON-ALATE	1	T	1471.60	93.6	424.8	1727.3	222.6	146	155.3	47.5	299.5	882.5	9834.5	11	20093	2174	116.5
ISOPTERA ALATE	14	T	0.00	7	0	1109	550	164.5	0	252	6926	4260	5235	0	156	365	0
ISOPTERA NON-ALATE	21	T	526.00	0	0	37.5	2	138.5	0	2	612	652	203	0	93	3148	0
ISOPODA	27	T	0.00	0	1.5	0	0	13	0	0	0	0	122	0	0	43	0
LEPIDOPTERA ADULT	10	T	2892.00	316	121.5	51	520	406	53.5	265	128	956	64	0	0	0	11
LEPIDOPTERA LARVA	13	T	313.00	1214	129	355	837	642.5	714	191	1242	5546	64	4	0	8	1.5
MANTODEA	33	T	0.00	100	0	0	0	4	250	0	0	15	0	0	0	0	0
OLIGOCHAETA	30	T	20.00	0	0	0	576	0	0	0	0	0	0	8	0	0	0
ORTHOPTERA	6	T	16326.50	1269	37	144	2668.5	1065.5	4018.5	2018	24014.5	11240.5	820	3250	8	32	65
PHALANGIDA	22	T	0.00	0	0	0	7	6	0	0	0	5	81	80	26	0	0.5
PHASMIDA	31	T	0.00	0	0	0	0	0	171	0	700	1000	0	0	0	0	0
SCORPIONIDA	41	T	0.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0
THYSANOPTERA	32	T	0.50	0	1.2	0	10	0	0	0	0	0	0	0	0	1	0
POOLED TERRESTRIAL			25154	5734.6	1417	3847.1	6143.2	2938	5709	2893.1	43778.5	24896.7	17821.5	5713	20500.5	5893.6	291.3
INORGANIC MATERIAL	7		1055.50	4	0	68	491	100	75	74.5	2796	197	532	35.5	2961	254	14.5
VEGETABLE MATERIAL	8		3268.50	42	96	53	127	89	220.5	67	1387	423	235	33	396	306.5	1
TOTAL			99705.70	15172.4	4460.3	4803.1	12200	4437	11136.5	4379.3	57391.1	31194.5	24350.5	7708.5	25450	6784.4	742.2

Appendix (6.4.6); Volume of items (WHVOL) of 43 prey orders identified in stomach content analyses of 15 study species.

Prey Order	Prey Code	Code of Origin	L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili
ANURA ADULT	29	A	18650.00	875	0	0	0	0	0	0	872	0	0	0	0	0	0
ANURA LARVA	37	A	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPHEMEROPTERA	28	A	640.00	0	8.7	0	1	0	0	0	0	0	0	0	0	0	5
ODONATA ADULT	20	A	2249.00	915	322	0	688	210	150	0	0	70	0	0	0	0	0
ODONATA NYMPH	36	A	29582.00	0	0	0	36	0	1000	0	0	0	0	0	0	0	0
OSTRACODA	39	A	7.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLECOPTERA	34	A	0.00	4	0	0	0	0	0	0	0	0	0	0	0	0	0
TRICHOPTERA ADULT	18	A	98.00	236	69.8	34	45	14	1.2	0	0	85	0	0	0	0	0
TRICHOPTERA NYMPH	26	A	358.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA ADULT	25	A	343.00	50	461	0	37	6	30	0	0	0	0	0	0	0	0
ZYGOPTERA NYMPH	40	A	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POOLED AQUATIC			51928	2080	861.5	34	807	230	1181.2	0	872	155	0	0	0	0	0
ARANEAE	5	TA	4577.90	2284.8	368.5	164.5	698.5	66.7	1904.7	383.5	1626.5	941.1	157.5	790	4.5	15.3	55.6
COLEOPTERA ADULT	2	TA	9563.40	1743.6	426.8	360.3	1604.8	552	1241.5	365	5526.5	2431.5	4771	1053	1327	198.8	147.4
COLEOPTERA LARVA	23	TA	193.00	0	9	0	221.8	0	2	151	8	0	57	0	0	20	0.1
DIPTERA	3	TA	815.40	2476.8	493.3	105.2	616.4	106	159.6	26	8.6	360	20.5	0	0	5.7	69.9
GASTROPODA	35	TA	0.00	0	0	0	0	16	0	0	0	0	19	0	0	0	0
HEMIPTERA	4	TA	2009.00	641.5	527.1	155	953.5	250	350	345	234	1660	454	84	256	14	139.4
OTHER, VERTEBRATE	42	TA	0.00	0	0	0	0	0	0	0	360	0	0	0	0	0	0
INVERTEBRATE	43	TA	90.00	0	0	0	12	0	0	0	0	0	0	0	0	0	0
UNDETERMINED ADULT	9	TA	153.00	153	245.7	6	522	59	268	74	658	100	282	0	5	76.5	7
UNDETERMINED LARVA	19	TA	898.10	12.1	15.4	10	2.8	30.3	25	0.2	136	30.2	1	0	0	0	11
POOLED TERRESTRIAL /AQUATIC			18300	7311.8	2085.8	801	4631.8	1080	3950.8	1344.7	8557.6	5522.8	5762	1927	1592.5	330.3	430.4

Appendix 7.1.1; Frequency of occurrence of 22 prey families identified in stomach content analyses.

PREY FAMILY	FAMILY CODE	SPECIES L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.	TOTAL
1. COLEOPTERA																	
TERRESTRIAL	20	58	20	21	16	35	15	28	19	23	26	43	5	13	12	11	345
DYTISCIDAE	21	7	0	1	0	2	1	0	0	0	0	0	0	0	1	0	12
GYRINIDAE	23	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
HALIPLIDAE	24	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	3
HELODIDAE	220	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	9
HISTERIDAE	26	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
HYDRAENIDAE	27	3	0	0	0	0	0	0	0	0	1	0	0	0	0	1	5
HYDROCHIDAE	28	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
HYDROPHILIDAE	29	18	0	2	1	0	0	0	0	1	0	2	1	2	0	2	29
HYGROBIIDAE	210	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
LIMNICHIDAE	211	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4
PSEPHENIDAE	216	0	0	0	0	0	1	0	0	0	0	0	0	0	3	5	9
SPERCHEIDAE	217	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
SPHAERIIDAE	218	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
POOLED AQUATIC		30	6	7	1	4	5	0	0	1	1	3	1	2	4	10	75
2. HEMIPTERA																	
TERRESTRIAL	40	28	9	27	8	17	12	9	13	6	15	6	0	1	2	19	172
		2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4
GERRIDAE	42	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
HEBRIDAE	45	5	0	1	0	1	0	0	0	0	0	0	0	0	0	0	7
MESOVELIIDAE	412	7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	8
NAUCORIDAE	413	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
OCHTERIDAE	414	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
PLEIDAE	415	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
VELIIDAE	419																
POOLED AQUATIC		20	0	2	0	1	0	0	0	1	0	0	0	0	1	0	25
NUMBER OF STOMACHS EXAMINED		94	30	51	25	49	28	34	27	26	35	46	6	16	15	30	512

Appendix 7.1.2; Number of items of 22 prey families identified in stomach content analyses of 15 study species.

PREY FAMILY	FAMILY CODE	SPECIES															
		L. dahl.	L. roth.	L. bico.	L. rube.	L. pall.	L. iner.	L. nasu.	L. torn.	C. aust.	C. long.	L. orna.	L. conv.	N. mela.	U. inun.	R. bili.	TOTAL
1. COLEOPTERA																	
TERRESTRIAL	20	160	28	27	17	52	20	43	25	27	47	76	8	16	15	18	579
DYTISCIDAE	21	7	0	1	0	2	1	0	0	0	0	0	0	0	1	0	12
GYRINIDAE	23	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
HALIPLIDAE	24	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	3
HELODIDAE	220	0	11	5	0	0	0	0	0	0	0	0	0	0	0	0	16
HISTERIDAE	26	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
HYDRAENIDAE	27	3	0	0	0	0	0	0	0	0	1	0	0	0	0	1	5
HYDROCHIDAE	28	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
HYDROPHILIDAE	29	0	0	2	1	0	0	0	0	1	0	3	1	3	0	3	43
HYGROBIIDAE	210	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
LIMNICHIDAE	211	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4
PSEPHENIDAE	216	0	0	0	0	0	1	0	0	0	0	0	0	0	3	6	10
SPERCHEIDAE	217	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
SPHAERIIDAE	218	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
TOTAL		207	39	36	18	56	25	43	25	28	48	80	9	19	19	31	683
2. HEMIPTERA																	
TERRESTRIAL	40	49	18	32	8	32	20	10	15	8	18	16	0	1	2	24	253
GERRIDAE	42	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4
HEBRIDAE	45	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
MESOVELIIDAE	412	12	0	3	0	1	0	0	0	0	0	0	0	0	0	0	16
NAUCORIDAE	413	9	0	0	0	0	0	0	0	1	0	0	0	0	0	0	10
OCHTERIDAE	414	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
PLEIDAE	415	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
VELIIDAE	419	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
TOTAL		79	18	37	8	33	20	10	15	9	18	16	0	1	3	24	291
PREY ITEMS IDENTIFIED		286	57	73	26	89	45	53	40	38	66	96	9	20	22	55	975
NUMBER OF STOMACHS EXAMINED		94	30	51	25	49	28	34	27	26	35	46	6	16	15	30	512

Appendix 7.1.3; Number of aquatic and terrestrial items of two prey orders identified to the level of family in stomach content analyses of 15 species.

	SPECIES															
PREY ORDER	*L. dahl.*	*L. roth.*	*L. bico.*	*L. rube.*	*L. pall.*	*L. iner.*	*L. nasu.*	*L. torn.*	*C. aust.*	*C. long.*	*L. orna.*	*L. conv.*	*N. mela.*	*U. inun.*	*R. bili.*	TOTAL
TERRESTRIAL COLEOPTERA	160	28	27	17	52	20	43	25	27	47	76	8	16	15	18	579
AQUATIC COLEOPTERA	47	11	9	1	4	5	0	0	1	1	4	1	3	4	13	104
TOTAL COLEOPTERA	207	39	36	18	56	25	43	25	28	48	80	9	19	19	31	683
TERRESTRIAL HEMIPTERA	49	18	32	8	32	20	10	15	8	18	16	0	1	2	24	253
AQUATIC HEMIPTERA	30	0	5	0	1	0	0	0	1	0	0	0	0	1	0	38
TOTAL HEMIPTERA	79	18	37	8	33	20	10	15	9	18	16	0	1	3	24	291
TOTAL TERRESTRIAL	209	46	59	25	84	40	53	40	35	65	92	8	17	17	42	832
TOTAL AQUATIC	77	11	14	1	5	5	0	0	2	1	4	1	3	5	13	142
TOTAL IDENTIFIED	286	57	73	26	89	45	53	40	38	66	96	9	20	22	55	975