Technical Memorandum 6

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C.D. James, S.R. Morton, R.W. Braithwaite and J.C. Wombey

Supervising Scientist for the Alligator Rivers Region

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Australian Government Publishing Service

Canberra 1984

Office of the Supervising Scientist,
P.O. Box 387,
Bondi Junction, N.S.W.,
Australia, 2022

July 1984

ISSN 0810-9532
ISBN 0 644 01263 3

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Printed by Canberra Publishing & Printing Co.

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James, C.D., Morton, S.R., Braithwaite, R.W. and Wombey, J.C. (1984). Dietary pathways through lizards of the Alligator Rivers Region, Northern Territory. Supervising Scientist for the Alligator Rivers Region, Tech. Mem. 6.

A broad survey of the diets of 46 species of terrestrial and arboreal lizards from the families Gekkonidae, Pygopodidae, Agamidae and Scincidae was carried out in the Alligator Rivers Region, and the diets of three of the species were examined in detail by monthly sampling near the Ranger uranium mine. Prey were classified as of aquatic or terrestrial origin. The broad survey showed that only two species, *Cryptoblepharus plagiocephalus* and *Carlia gracilis* (both Scincidae), ate significant quantities of prey of aquatic origin (8% to 13% by volume, respectively). The detailed dietary analyses for the three species *Cryptoblepharus plagiocephalus* and *Ctenotus essingtonii* (Scincidae) and *Lophognathus gilberti* (Agamidae) showed that the diet of *Cryptoblepharus* contained 13% by volume prey of aquatic origin, whereas those of the other two species contained virtually none. Most of the insects of aquatic origin eaten by lizards were chironomids (midges) and culicids (mosquitoes), which mature from aquatic larvae and disperse into terrestrial habitats.

The study shows that, in the event of contamination of the waterbodies, only two species of lizards face any risk of contamination through their food, but more work is necessary on the degree to which midges and mosquitoes may carry contaminants accumulated in their larval stages.

1 INTRODUCTION

There are two principal pathways by which substances contained in living organisms may leave aquatic systems in the Alligator Rivers Region. First, terrestrial or semi-aquatic animals may remove material directly from waterbodies during feeding. Second, animals such as frogs or insects with aquatic juvenile forms disperse on maturation to terrestrial habitats where they may be consumed by terrestrial carnivores. In either case, any contaminants originating from uranium mining and milling will leave the aquatic system, be it artificial ponds at a mine-site or waterbodies downstream of a mine.

This report is part of a study of the movement of insects from waterbodies in the vicinity of the Ranger mine near Jabiru. Information on the degree to which terrestrial and arboreal insectivorous lizards depend on invertebrate animals of aquatic origin is relevant to any future estimation of the significance of the biological dispersion of mine contaminants. Quantitative dietary studies of these inconspicuous animals may be of particular importance for those species whose food intake is dominantly of aquatic origin. For this reason, the study is aimed at providing a quantitative description of the composition of diet.

A major difficulty in choosing species to study is the very diversity of the lizards. Over 50 species occur in the Region, many of them in a wide variety of habitats (Cogger 1973; Sadlier 1981; Braithwaite and Wombey unpubl. data). In order to avoid bias in the results as a consequence of selecting species on the basis of their apparent habitat preferences, relatively small samples from a large number of species were taken. Many samples of species well suited to this objective were available from collections made during the Kakadu fauna survey conducted by the Division of Wildlife and Rangelands Research, CSIRO. It was still necessary, however, to obtain samples throughout the entire seasonal cycle for a small number of species known to occur commonly along creeks in the vicinity of the Ranger mine. Information is given on representative species of all families of lizards in the Region, except the Varanidae (goannas). Varanids are excluded because they are the subject of an associated study by Dr R. Shine of the University of Sydney.

2 MATERIALS AND METHODS

2.1 Collection of Animals

Lizards were collected from 30 sites throughout the Alligator Rivers Region during the late dry season of 1980 (September to December) and the wet season of 1981 (February to April). They were captured either by hand, by shooting or by trapping, in woodland, open forest, monsoon forest and escarpment habitats (Braithwaite 1983). Precise sites of capture of specimens used in this study may be obtained from R.W. Braithwaite. Specimens were fixed in 10% formalin and stored in 70% alcohol until analysis. All local lizard families except the Varanidae were represented.

Three species of lizards were selected for detailed dietary analysis. These were species that were known to occur relatively commonly along creek channels, and that might therefore be more likely to eat prey of aquatic origin. A further objective was to examine species differing in foraging strategy, so that the work would cover at least some of the range of dietary habits evident within lizards of the Region. Using these criteria, and Sadlier's (1981) information on the abundance of lizards near Jabiru, the arboreal *Cryptoblepharus plagiocephalus* (Scincidae), the terrestrial *Ctenotus essingtonii* (Scincidae), and the larger, semi-arboreal *Lophognathus gilberti* (Agamidae) were selected for study.

Cryptoblepharus plagiocephalus were collected from *Melaleuca viridiflora* along the creek channels and fringing forests near Georgetown and Djalkmara Billabongs, which are within 1 km of the Ranger mine. Except in the latter period of the study, the animals were commonly found and were collected by hand from the tree-trunks. *Ctenotus essingtonii* were captured in pit-traps along Gulungul Creek, 3 km north-west of the Ranger mine. The pit-traps were set both in sandy rises within the bed of the creek and at the margin between the creek and the surrounding woodland. *Lophognathus gilberti* were captured by noosing along Magela and Gulungul Creeks within 5 km of the mine, and especially in the vegetation fringing Georgetown and Djalkmara Billabongs. During the wet season *L. gilberti* appear to leave the creek channels to some extent, and at this time some individuals were captured in open woodland and forest. *Cryptoblepharus plagiocephalus* and *Ct. essingtonii* were killed and frozen until analysis, but the stomachs of most *L. gilberti* were flushed out with water (Legler and Sullivan 1979), the stomach contents retained, and the animals released. Attempts were made to obtain ten individuals of each species per month from March 1982 until February 1983, but this was not always possible.

2.2 Dietary Analysis

Stomach volume was estimated to within 0.1 mL by volumetric displacement of water in a small graduated cylinder. After the contents had been removed, the volume of the empty stomach was similarly determined, and an estimate of the volume of food present obtained from the difference. Individual items of prey were identified and counted, and the approximate volume of each estimated visually to the nearest 0.01 mL by observing the proportion of the total volume of food taken up by that item. The volume of the stomach contents of *L. gilberti* was determined in a similar way. In some cases, however, *L. gilberti* had chewed large prey to a considerable extent, and it was necessary to estimate the original volume of such prey. These volumetric measures provided an estimate of the importance, in terms of biomass, of different types of prey. Where possible, intestinal contents were removed from the lizards, and the remains of prey within them were identified and counted. It was impossible to estimate volumes of prey in intestinal contents because they were considerably digested; hence, numerical estimates only were attempted.

3 RESULTS

3.1 Regional Analysis

Of the 46 species for which analyses are available, only eleven had eaten prey of aquatic origin (Table 1). For *Carlia amax, C. foliorum, C. gracilis, C. triacantha* and *Cryptoblepharus plagiocephalus*, in which the number of samples per season were nine or more, there were no substantial differences between the wet and the dry seasons in the proportions of prey of aquatic origin. All such prey were insects, and these predominantly adults of species that are aquatic in their immature stages (Table 2). Adults of insects that are mainly aquatic when mature were uncommon. In the former group, Diptera (mosquitoes, midges, etc.) were by far the most commonly represented, and other taxa such as Odonata (dragonflies) and Trichoptera (caddis-flies) occurred infrequently. Within the Diptera, the most abundant families found were the Chironomidae (midges) and Culicidae (mosquitoes).

The proportions of prey of aquatic origin were almost always larger by number than by volume, indicating that these prey were on average individually smaller than prey of non-aquatic origin. Analysis of intestinal contents thus provided a biased view, primarily because by this technique it was difficult to estimate volumes or biomasses of different prey types. Similar patterns in intestinal contents and in comparisons between number and volume emerged from the local analysis (Table 3).

3.2 Local Analysis

Neither *Ct. essingtonii* nor *L. gilberti* ate significant quantities of prey of aquatic origin at any stage of the year (Table 3), a result consistent with the regional analysis (Table 1). In contrast, the diet of *C. plagiocephalus* contained an average of 13% by volume of such prey. Again, this result is in broad agreement with Table 1, although slightly greater volumes of prey of aquatic origin were found in *C. plagiocephalus* collected locally than in those from the Region as a whole. On average, between the dry season and wet season there was a slight reduction in the proportion of prey of aquatic origin, but it is difficult to determine how general this result is, because rainfall during the months November 1982 to February 1983 was substantially below average. Lizards were very difficult to obtain at this time and appeared to be uncommon, and those that were captured included a high proportion with empty stomachs. It seems likely that the unusual nature of the 1982-83 wet season affected the dietary results.

As in the regional analysis, the most frequent prey of aquatic origin were adult midges and mosquitoes (Table 4). The majority were insects, but *L. gilberti* also took some mussels *Velesunio angasi* and some frogs of unidentifiable species.

4 DISCUSSION

Analysis shows that the diet of very few species of terrestrial or arboreal lizards in the Alligator Rivers Region contains more than 5% food of aquatic origin. However, it must be stressed that only small numbers of individuals of most species were examined. Nevertheless, general agreement was evident between the results obtained from small numbers of *C. plagiocephalus*, *Ct. essingtonii* and *L. gilberti* in the regional survey and from large numbers of the same species in the local survey. Such consistency suggests that the results in Table 1 are representative, and that the interpretation presented above is reasonable.

A second possible cause of bias in results is that, in the regional survey, most specimens were collected away from creeks and drainage systems and these lizards may consequently have had less access to prey of aquatic origin than their conspecifics living closer to waterbodies. Again, however, results from the local, detailed study do not strongly support the contention. The diets of both *Ct. essingtonii* and *L. gilberti* were found to be virtually devoid of prey of aquatic origin in the broad, regional survey as well as in the local study (Tables 1 and 3). Thus, for these two species, occupation of a riparian environment did not result in an increase in intake of prey of aquatic origin. On the other hand, the proportions of prey of aquatic origin eaten by *C. plagiocephalus* were slightly higher in the local samples collected along creeks near the Ranger mine than in regional samples. On balance, then, the detailed, local studies broadly support the general conclusions derived from the regional dietary survey, although they do suggest that in some cases the proportions of prey of aquatic origin may be slightly underestimated.

It can be concluded that terrestrial and arboreal lizards are not major consumers of food of aquatic origin. Even among the six species sampled that prefer riparian habitats (see Table 1), only two, *Cryptoblepharus plagiocephalus* and *Carlia gracilis*, showed evidence of a relatively high consumption of insects of aquatic origin. *Lophognathus gilberti*, which is often reported as inhabiting principally riparian forests (e.g. Cogger 1979), appears to prefer these habitats, not because it seeks aquatic prey, but because of some other feature of the environment. This study shows that, from the viewpoint of the monitoring and the modelling of potential contamination in the waterbodies of the Region, only *Cryptoblepharus plagiocephalus* and *Carlia gracilis* would warrant detailed attention.

Identification of prey of aquatic origin showed that the insects most frequently represented were Diptera, particularly midges and mosquitoes. Near Jabiru, midges are the most abundant and diverse insects to emerge from waterbodies (A. Sharley and M. Malipatil, personal communication), and so their dominance in that portion of the lizards' diets of aquatic origin does not necessarily mean that they are selected in preference to other taxonomic groups that are also of aquatic origin. However, this involvement of just one or two families of insects will make future work on the likely effects of transport of contaminants easier to study. Although chironomid larvae accumulate heavy metals (Salanki et al. 1982), the amount transported by the adults is unknown at present. Studies of the insects that are currently being carried out by M. Malipatil and A. Sharley will help in the interpretation of the pathways involved.

5 ACKNOWLEDGMENTS

Martin Armstrong, Kym Brennan, Sue Price, Peter Dostine and Sandra Leighton helped collect lizards near Jabiru, George Dudzinski, David Edwards, John Estbergs, Billie Gill and Terry Piper assisted with collections during the regional survey, and Mali Malipatil assisted with identification of insects. R.W. Braithwaite and J.C. Wombey gratefully acknowledge the financial support of the Australian National Parks and Wildlife Service through consultancy agreements for the Kakadu Fauna Survey. Constructive comments on the manuscript were provided by V.M. Brown and R. Shine.

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TABLE 1 PERCENTAGES OF PREY OF AQUATIC ORIGIN IN STOMACH AND HINDGUT OF LIZARDS.

N = number of lizards sampled; Num% = percentage by number; Vol% = percentage by volume.

Family Species	Preferred Habitats*	Wet Season					Dry Season				
		Stomach			Hindgut		Stomach			Hindgut	
		N	Num%	Vol%	N	Num%	N	Num%	Vol%	N	Num%
GEKKONIDAE											
Diplodactylus ciliaris	W	0	-	-	0	-	1	0	0	0	-
D. stenodactylus	W	1	0	0	1	33	0	-	-	0	-
Gehyra australis	WO	1	0	0	1	0	4	0	0	0	-
G. nana	E	1	40	14	1	0	3	0	0	0	-
G. pamela	E	1	0	0	1	0	0	-	-	0	-
Hemidactylus frenatus	U	0	-	-	0	-	1	0	0	1	0
Heteronotia binoei	WOM	2	0	0	2	0	5	0	0	3	0
H. spelea	E	1	0	0	0	-	0	-	-	0	-
Nephrurus asper	E	0	-	-	1	0	0	-	-	0	-
Oedura gemmata	E	0	-	-	0	-	1	0	0	0	-
O. marmorata	OW	1	0	0	1	0	0	-	-	0	-
O. rhombifer	WOM	0	-	-	0	-	1	0	0	0	-
Pseudothecadactylus lindneri	E	0	-	-	1	0	0	-	-	0	-
PYGOPODIDAE											
Delma borea	OEW	1	0	0	0	-	1	0	0	1	0
Lialis burtonis	OWE	0	-	-	0	-	0	-	-	1	0
AGAMIDAE											
Chelosania brunnea	OW	0	-	-	0	-	2	0	0	2	0
Chlamydosaurus kingii	WOM	0	-	-	0	-	1	0	0	2	0
Diporiphora bilineata	WOE	0	-	-	0	-	5	0	0	3	0
D. magna	W	0	-	-	0	-	4	0	0	2	0
Lophognathus gilberti	WOR	1	0	0	1	0	1	0	0	1	0
L. temporalis	M	1	0	0	1	0	1	0	0	1	0

*W = woodland; O = open forest; R = riparian forest; M = monsoon forest; E = sandstone escarpment.

TABLE 1 (ctd)

N = number of lizards sampled; Num% = percentage by number; Vol% = percentage by volume.

Family Species	Preferred Habitats*	Wet Season					Dry Season				
		Stomach			Hindgut		Stomach			Hindgut	
		N	Num%	Vol%	N	Num%	N	Num%	Vol%	N	Num%
SCINCIDAE											
Carlia amax	OE	29	10	1	21	32	43	22	4	34	13
C. foliorum	WOM	41	17	2	15	0	22	0	0	13	0
C. gracilis	WMR	30	24	13	21	7	24	39	13	11	32
C. triacantha	WO	13	3	1	7	30	9	0	0	2	33
Cryptoblepharus plagiocephalus	WOMR	9	5	11	11	15	9	3	5	8	0
Ctenotus arnhemensis	WO	3	0	0	2	0	0	-	-	1	0
C. essingtonii	OWR	4	0	0	3	20	8	0	0	7	0
C. hilli	W	0	-	-	0	-	1	0	0	1	50
C. robustus	WO	2	0	0	2	0	2	0	0	1	0
C. saxatilis	E	0	-	-	0	-	2	0	0	1	0
C. sp. A.	WO	4	0	0	2	0	2	0	0	1	0
C. sp. B.	E	3	0	0	2	0	1	0	0	0	-
C. storri	O	0	-	-	1	0	5	0	0	3	0
C. vertebralis	E	1	22	10	1	0	0	-	-	0	-
Lerista karlschmidti	OM	1	0	0	0	-	4	0	0	2	0
Menetia alanae	WO	1	0	0	0	-	3	0	0	3	0
M. greyii	WO	0	-	-	0	-	5	0	0	4	0
Morethia ruficauda	E	1	0	0	1	0	4	0	0	1	0
M. storri	WO	2	0	0	0	-	7	0	0	1	0
Notoscincus ornatus	E	1	0	0	1	0	2	0	0	1	0
Proablepharus tenuis	O	0	-	-	0	-	2	0	0	2	0
Sphenomorphus crassicaudus	OMW	3	0	0	1	0	4	0	0	1	0
S. douglasi	MOR	4	5	0.1	1	0	3	0	0	3	0
S. isolepis	OWR	10	0	0	5	0	6	0	0	2	0
Tiliqua scincoides	MOW	0	-	-	0	-	0	-	-	1	0

TABLE 2 NUMBERS OF PREY OF AQUATIC ORIGIN (BY TAXON) FOUND IN STOMACH AND HINDGUT OF LIZARDS.

Numbers of lizards sampled as in Table 1. Stom. = stomach; HG = hindgut.

Lizard Species	Prey Order Family	Wet Season		Dry Season	
		Stom.	HG	Stom.	HG
Diplodactylus stenodactylus					
	Hemiptera				
	Saldidae	-	1	-	-
Gehyra nana					
	Diptera				
	Culicidae + Chironomidae	2	1	-	-
Carlia amax					
	Diptera				
	Culicidae + Chironomidae	10	13	13	6
	Tabanidae	-	-	1	-
	Tipulidae	-	-	-	1
	Coleoptera				
	Dytiscidae*	-	-	-	1
Carlia foliorum					
	Diptera				
	Culicidae + Chironomidae	24	4	-	-
Carlia gracilis					
	Diptera				
	Culicidae + Chironomidae	39	2	49	14
	Ephydridae	2	-	-	-
	Sciomyzidae	1	-	-	-
	Tipulidae	2	-	-	-
	Unidentified	5	-	5	-
	Coleoptera				
	Dytiscidae*	1	-	-	-
Carlia triacantha					
	Diptera				
	Culicidae + Chironomidae	-	1	-	1
	Ceratopogonidae	-	1	-	-
	Unidentified	1	-	-	-
	Odonata	-	1	-	-
Cryptoblepharus plagiocephalus					
	Diptera				
	Culicidae + Chironomidae	3	2	2	-

Table 2 (ctd)

Lizard Species	Prey Order Family	Wet Season Stom.	Wet Season HG	Dry Season Stom.	Dry Season HG
	Hemiptera				
	Ochteridae*	1	-	1	-
Ctenotus essingtonii					
	Hemiptera				
	Ochteridae*	-	1	-	-
Ctenotus hilli					
	Coleoptera				
	Dytiscidae*	-	1	-	-
Ctenotus vertebralis					
	Diptera				
	Ceratopogonidae	1	-	-	-
	Coleoptera				
	Limnichidae*	1	-	-	-
Sphenomorphus douglasi					
	Diptera				
	Culicidae + Chironomidae	2	-	-	-

* Purely aquatic insects

TABLE 3 PERCENTAGES OF PREY OF AQUATIC ORIGIN IN STOMACH AND HINDGUT OF THREE LIZARD SPP. FOUND NEAR RANGER MINE.

N = no. of lizards sampled; Num% = percentage by no.; Vol% = percentage by volume. Averages are weighted means.

Period of Sample	*Cryptoblepharus plagiocephalus*					*Ctenotus essingtonii*					*Lophognathus gilberti*				
	Stomach			Hindgut		Stomach			Hindgut		Stomach			Hindgut	
	N	Num%	Vol%	N	Num%	N	Num%	Vol%	N	Num%	N	Num%	Vol%	N	Num%
Dry Season (1982)															
May	10	51	27	4	59	10	0	0	7	0	7	0	0	4	0
June	10	27	6	5	0	10	0	0	4	0	9	0	0	3	0
July	10	72	27	6	82	10	0	0	5	0	9	0	0	1	0
Aug.	9	38	22	8	52	9	0	0	4	0	11	0	0	6	0
Sept.	9	5	1	6	4	10	0	0	3	0	10	2	11	0	-
Oct.	11	30	13	4	0	6	0	0	2	0	11	2	34	1	0
Total:	**59**			**33**		**55**			**25**		**57**			**15**	
Wet Season (1982-83)															
Nov.	2	0	0	2	100	3	0	0	1	0	8	2	1	0	-
Dec.	8	0	0	8	82	3	0	0	1	0	3	0	0	1	0
Jan.	4	0	0	0	-	2	0	0	2	0	1	0	0	1	0
Feb.	2	0	0	5	36	1	0	0	2	0	10	0	0	3	0
March	10	60	21	6	46	8	0	0	9	0	6	0	0	4	0
April	10	37	10	4	50	9	14	10	9	18	7	1	2	4	0
Total:	**36**			**25**		**26**			**24**		**35**			**13**	
Average (Dry Season)		38	16		35		0	0		0		1	8		0
Average (Wet Season)		27	9		60		5	3		7		1	1		0
Average (whole year)		34	13		46		2	1		3		1	5		0
Total:	**95**			**58**		**81**			**49**		**92**			**28**	

TABLE 4 NUMBER OF PREY OF AQUATIC ORIGIN (BY TAXON) FOUND IN STOMACH AND HINDGUT OF THREE LIZARD SPP. CAPTURED NEAR RANGER MINE.

Numbers of lizards sampled as in Table 3.

Lizard Species	Prey Order Family	Wet Season		Dry Season	
		Stom.	HG	Stom.	HG
Cryptoblepharus plagiocephalus					
	Diptera				
	Culicidae + Chironomidae	42	12	111	62
	Ephydridae	1	0	0	0
	Unidentified	8	0	9	2
	Ephemeroptera	0	0	1	1
	Hemiptera				
	Ochteridae*	0	1	0	0
Ctenotus essingtonii					
	Diptera				
	Tabanidae	2	0	0	0
	Hemiptera				
	Ochteridae*	1	1	0	0
	Coleoptera				
	Carabid larvae	1	0	0	0
	Odonata	0	1	0	0
Lophognathus gilberti					
	Diptera	2	0	4	0
	Hemiptera				
	Saldidae	1	1	0	0
	Gelastocoridae*	1	0	6	0
	Odonata	0	0	2	0
	Mollusca	0	0	5	0
	Amphibia	0	0	1	0

*Purely aquatic animals

SUPERVISING SCIENTIST FOR THE ALLIGATOR RIVERS REGION

RESEARCH PUBLICATIONS

Research Reports (RR) and Technical Memoranda (TM)

TM 1	Transport of trace metals in the Magela Creek system, Northern Territory. I. Concentrations and loads of iron, manganese, cadmium, copper, lead and zinc during flood periods in the 1978-1979 wet season. December 1981 (pb - 26 pp)	Hart, B.T., Davies, S.H.R., Thomas, P.A.
TM 2	Transport of trace metals in the Magela Creek system, Northern Territory. II. Trace Metals in the Magela Creek billabongs at the end of the 1978 dry season. December 1981 (pb - 23 pp)	Davies, S.H.R., Hart, B.T.
TM 3	Transport of trace metals in the Magela Creek system, Northern Territory. III. Billabong sediments. December 1981 (pb - 23 pp)	Thomas, P.A., Davies, S.H.R., Hart, B.T.
TM 4	The foraging behaviour of herons and egrets on the Magela Creek flood plain, Northern Territory. March 1982 (pb, mf - 20 pp)	Recher, H.F. Holmes, R.T.
TM 5	Flocculation of retention pond water. May 1982 (pb, mf - 10 pp)	Hart, B.T. McGregor, R.J.
RR 1	The macroinvertebrates of Magela Creek, Northern Territory. April 1982 (pb, mf - 46 pp)	Marchant, R.
RR 2	Water quality characteristics of eight billabongs in the Magela Creek catchment. December 1982 (pb, mf - 60 pp)	Hart, B.T. McGregor, R.J.
RR 3	A limnological survey of the Alligator Rivers Region, Northern Territory. I. Diatoms (Bacillariophycaea) of the Region. August 1983 (pb, mf - 140 pp)	Thomas, D.P.

pb = available as paperback; mf = available as microfiche