The status of herpetofauna and herpetology in the Northern Territory

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ABSTRACT

The Northern Territory occupies about one-sixth of Australia and contains slightly more than one-third of its herpetofauna species. Herpetological interest (and funding) in the Northern Territory has long been focused upon the two crocodile species present. In this paper I largely ignore these more obtrusive elements of the herpetofauna, and attempt instead to assemble and consider the diverse strands of research dealing with the less conspicuous majority of species.

The composition and diversity of the Northern Territory herpetofauna is strongly linked to a pronounced rainfall gradient from the Wet-Dry tropics to arid central Australia. Within regions, there is also pronounced variation in species composition from the limited upland areas to lowlands, and with variation in substrate. Fire patterns impose a further layer of environmental variability influencing the distribution and abundance of Northern Territory herpetofauna. Herpetofauna communities are also markedly unstable, varying with rainfall, humidity and temperature patternings within and between seasons. A feature of some Northern Territory environments is the remarkable diversity, density and biomass of herpetofauna assemblages.

The Northern Territory remains a frontier land for herpetologists. As many species have been described since 1960 as were described before that date. The environment generally remains little fragmented or modified. Few species have been studied in detail. There has been little research on the processes influencing the distributions of species or on the impact of threatening agents. Many regions have been subject to little or no herpetological survey. The conservation status of many taxa is unclear. The detailed knowledge about herpetofauna possessed by Aboriginal people has only recently been appreciated and documented by scientists.

INTRODUCTION

Reptiles have a higher public profile in the Northern Territory than they do in any Australian state. Crocodiles are a major icon of the Top End (perhaps the most publicized wildlife item, especially so since the recent decline in their dubious rival symbol, the introduced Water Buffalo). They feature on the majority of postcards and tourist advertisements. Crocodile farms and boat-trips taken to see wild crocodiles are features in the itinerary of most visitors. The most popular film portraying the Northern Territory ("Crocodile Dundee") played heavily upon the symbolism of dangerous crocodiles; and crocodile attacks comprise a strangely high proportion of the reporting of Northern Territory affairs in media beyond the Northern Territory. This idolatry is not confined to crocodiles. Reptile parks in both Darwin and Alice Springs are major tourist drawcards. The Frilled Lizard *Chlamydosaurus kingii* is a widely-publicized wildlife element of the Top End, being featured on many signs and postcards, and is the official symbol of Darwin's annual sports festival. The Thorny Devil *Moloch horridus* is a comparable feature of the arid southern half of the Northern Territory. Large reptiles are also a conspicuous component of the culture of Aboriginal people who comprise about 30 per cent of the Northern Territories population. Pythons, crocodiles and turtles feature commonly in rock art and bark paintings, and these, and goannas, remain a large component of the diet in many parts of the Northern Territory (e.g., Altman 1987).

Frogs are less revered or noticed, though Green Tree Frogs *Litoria caerulea* are a familiar and often appreciated feature in many Darwin households, and the invasion and spread of Cane Toads *Bufo marinus* into the Northern Territory is of much public interest and concern (e.g., Jacklyn 1992).

This apparently high public appreciation of herpetological matters in the Northern Territory occurs despite an information base which is often meagre and extraordinarily unevenly spread across taxa, regions and subject matter. In this paper I briefly review the herpetofauna of the Northern Territory and discuss the body of research directed at that herpetofauna. As with all mainland Australian States, the political boundaries of the Northern Territory do not coincide with ecological divisions, so that the consideration of one jurisdiction in isolation is something of a zoological nonsense. For the Northern Territory much of the herpetofauna

of arid and semi-arid areas is shared with inland regions of all mainland States and much of the herpetofauna of the monsoonal Top End occurs also in north Queensland and, particularly, the Kimberley Division of Western Australia.

There has been no previous review of the herpetofauna of the Northern Territory. However, Gow (1981a, 1981b) provided a list of all taxa recorded from the northern and southern halves of the Northern Territory, and recent review publications include a field guide to the frogs of the Northern Territory with a brief listing of relevant literature (Tyler and Davies 1986), and a field guide to the skinks of the Northern Territory with a complete listing of references for descriptions of skinks found in the Northern Territory (Horner 1991). Specht (1964) and Calaby (1974) provide bibliographies and accounts of early zoological collections from the Top End. Braithwaite *et al.* (1991) provide the most comprehensive overview of the herpetology of a significant region of the Northern Territory, the Alligator Rivers Region, including ecological relationships and conservation.

On the premise that herpetological research in the Northern Territory is mostly a recent phenomenon, I had thought I could provide a complete review of the literature dealing with the Northern Territory herpetofauna. However, I discovered that the research base is indeed quite rich and extremely diffuse, and hence my account is not complete. A summary of the Northern Territory herpetological literature considered is given in Table 1, and discussed in more detail in the rest of this paper. I have excluded "popular" articles, general taxonomic references prior to about 1970, most papers where consideration of Northern Territory herpetofauna is a very minor component of a broader scope, and the voluminous literature dealing with crocodiles.

Most of the research on herpetofauna of the Northern Territory has been directed at two species, *Crocodylus johnstoni* and *C. porosus*: for example Anon (1989) lists 133 papers reporting research conducted on crocodiles in the Northern Territory over the period 1977 to 1988. Research and management directed at these two species costs the Conservation Commission of the Northern Territory about one million dollars annually (Anon 1992), a figure far in excess of the internal budget for all other wildlife research undertaken by that body. Over the last decade, expenditure by governments on research and management of crocodiles in the Northern Territory has exceeded $15 million (Anon 1992) and there have been very large outlays on crocodile research in the Northern Territory by other organizations (most notably the University of Sydney). As recent reviews and bibliographies of this research have been published elsewhere (e.g., Anon 1989), I choose not to attempt to summarize that work again here, but concentrate instead on reviewing the more neglected components of the Northern Territory herpetofauna.

BRIEF DESCRIPTION OF THE NORTHERN TERRITORY

The Northern Territory occupies an area of 1.35 million km^2 (about one-sixth of Australia), spanning a north-south gradient from about 1 800 mm to 200 mm annual rainfall (Fig. 1). Scattered patches of monsoon rainforest occur in the northern half (the "Top End", otherwise vegetation consists of a gradual transition (associated with the rainfall gradient and variation in soil texture) from *Eucalyptus*-dominated open forest through savannah woodlands to *Acacia*-dominated low woodlands, hummock grasslands and chenopod shrublands. Isolated sandstone ranges with relatively low relief are conspicuous features of an otherwise fairly featureless landscape.

The environmental history of the Northern Territory is poorly defined, with interpretation based on a limited set of pollen cores, dune formation studies, inference from current zoogeographic patterns, a few fossil deposits and cave paintings. Major recent events include:

- the development of aridity throughout central Australia in the late Pleistocene, followed by gradual amelioration in the early Holocene (Ross *et al.* 1992);
- a rapid rise in sea level from about 18 000 years before present to 6 000 ybp, during which the extensive Lake Carpentaria and the lands connecting the Top End, New Guinea and Cape York Peninsula were engulfed (Nix and Kalma 1972; Woodroffe *et al.* 1992);
- rapid climatic fluctuations across northern Australia in the late Pleistocene and early Holocene which produced marked shuffling in vegetation patterns and the intermittent presence of marginal habitats such as monsoon rainforests (e.g., McKenzie *et al.* 1991).

Aboriginal occupation of the Northern Territory began at least 40 000 years ago and population densities in the pre-contact period have been estimated at up to 1 person/km^2 in resource-rich near-coastal areas (Hiscock and Kershaw 1992). The impact of Aboriginal people upon the landscape and ecology of northern

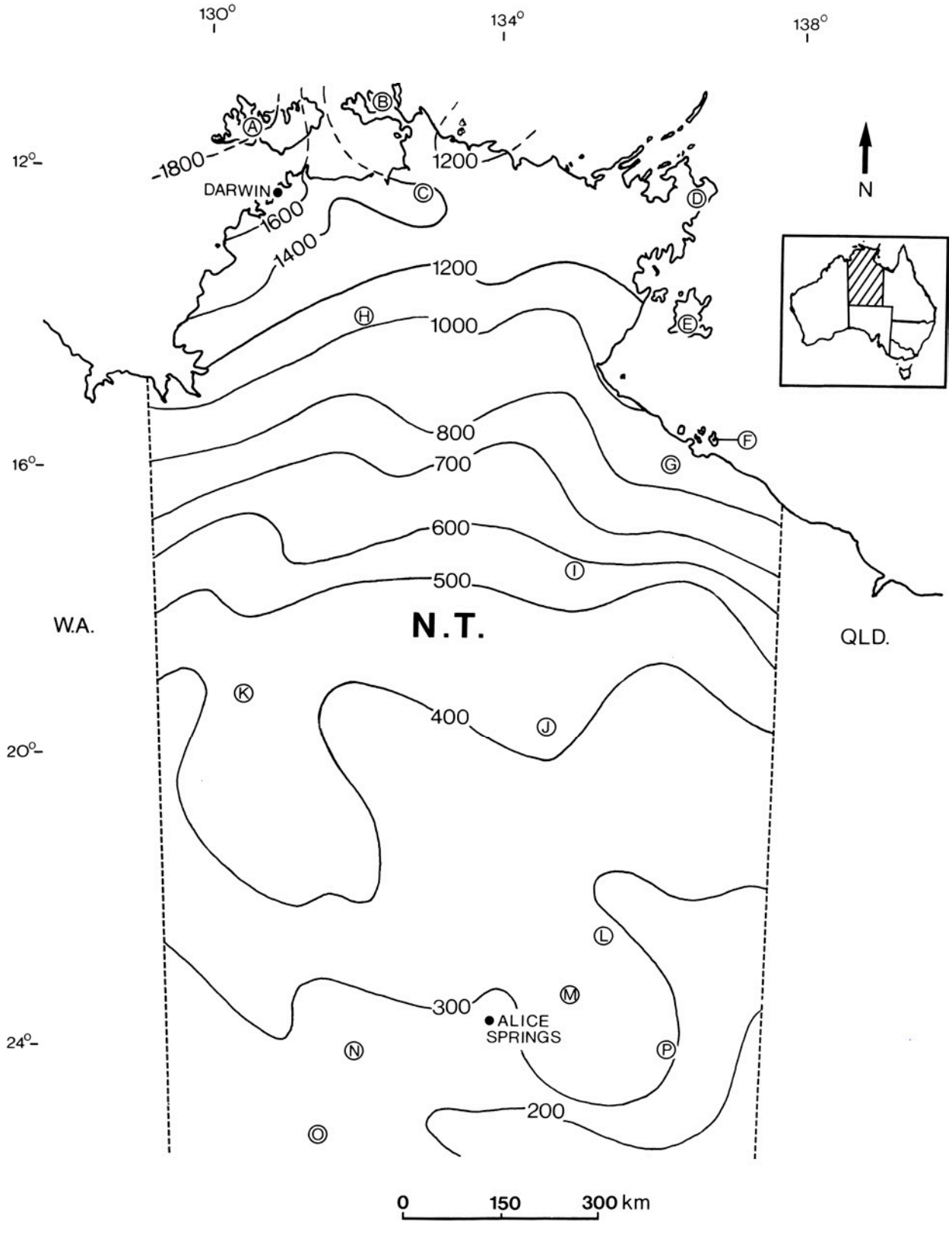

Fig. 1. The Northern Territory, showing rainfall isohyets and locations of main herpetological surveys. A — Tiwi Islands (Tyler *et al.* 1991; Fensham and Woinarski 1992). B — Cobourg Peninsula (Cogger and Lindner 1974). C — Alligator Rivers Region (including Kakadu) (Mitchell 1955, 1964; Cogger 1974, 1981; Legler 1980; Braithwaite 1985; Tyler and Crook 1987; Dames and Moore 1988; Martin and Goodfellow 1989; Friend and Cellier 1990; Sadlier 1990; Woinarski and Braithwaite 1990; Braithwaite *et al.* 1991; Woinarski and Gambold 1992). D — East Arnhem Land (Mitchell 1955, 1964). E — Groote Eylandt (Mitchell 1955, 1964; Gow 1981c; Tyler *et al.* 1986; Webb 1992). F — Sir Edward Pellew Islands (Cogger 1968; Johnson and Kerle 1991). G — Lower McArthur River (CSIRO 1976; Gambold and Menkhorst 1992b). H — Pine Creek/Katherine (Schulz and Menkhorst 1984; NSR 1992; Gambold and Menkhorst 1992a). I — Barkly Tablelands (Johnson *et al.* 1982; Fleming *et al.* 1983; Tyler *et al.* 1983a). J — Davenport/Murchison Range (Johnson *et al.* 1984). K — Tanami Desert (Gibson 1986). L — Dulcie Range (Gibson *et al.* 1989) M — Loves Creek (Gibson *et al.* 1992). N — George Gill Range (Latz *et al.* 1971). O — Uluru (Ayers Rock) (Reid *et al.* 1993). P — Simpson Desert (Gibson and Cole 1988).

Table 1. Summary of studies concerning Northern Territory herpetofauna other than crocodiles.

Family	Taxonomy/distribution/ biogeography	Reproduction/physiology	Diet/ecology/behaviour	Management/conservation	General/other
Myobatrachidae	Tyler 1971 Tyler *et al.* 1979 Tyler *et al.* 1981a,b	—	—	—	Tyler *et al.* 1985
Hylidae	Tyler 1968 Tyler 1969 Tyler and Martin 1975 Tyler and Martin 1977 Tyler and Davies 1978 Tyler *et al.* 1978a,b King *et al.* 1979 Tyler *et al.* 1981a Tyler *et al.* 1982 Maxson *et al.* 1982 Tyler 1990	—	—	—	Ridpath 1977 Tyler *et al.* 1985 Waugh *et al.* 1993a,b Stone *et al.* 1993
Microhylidae	Cogger and Lindner 1974 Zweifel 1985	—	—	—	—
Ranidae	Gambold and Woinarski 1993	—	—	—	—
Bufonidae	Freeland and Martin 1985 Jacklyn 1992	Freeland 1984 Freeland 1986	Freeland 1984 Freeland and Kerin 1988 Freeland and Kerin 1991	Freeland 1986 Freeland 1990 Jacklyn 1992	Freeland 1984 Dalvinquier and Freeland 1988a
Cheloniidae	Cogger and Lindner 1969 Guinea 1990 Guinea and Ryan 1990 Guinea 1993a	Guinea 1990 Guinea *et al.* 1991 Guinea 1993c Guinea 1993b	—	Limpus and Reed 1985 Bayliss 1986 Marsh *et al.* 1988 Cogger *et al.* 1993 Guinea and Chatto 1993	Guinea 1993a
Dermochelyidae	Cogger and Lindner 1969	—	—	Cogger *et al.* 1993	—
Carettochelyidae	Schodde *et al.* 1972 Dupe 1980 Legler 1980 Georges and Kennett 1989 Heaphy 1990	Webb *et al.* 1986 Heaphy 1990 Georges 1992	Legler 1980 Heaphy 1990 Georges and Kennett 1989	Georges 1990 Georges and Rose 1993 Georges and Rose in press	Georges 1988 Georges *et al.* 1989
Chelidae	Legler 1980 King and Horner 1987b Kennett *et al.* 1992 Georges and Adams 1992	Cann 1980 Smith and Wood 1985 Kennett 1993 Kennett *et al.* 1993a Kennett *et al.* 1993b	Legler 1976 Legler 1980 Kennett *et al.* 1992 Kennett 1993 Kennett and Russell-Smith in press	Kennett 1993	Kennett and Georges 1989 Kennett 1992
Gekkonidae	Cogger 1975 King 1979 King 1981 Fyfe 1981a King 1982a King 1982b King *et al.* 1982 King 1983a King 1983b King and Gow 1983 Strong and Gillam 1983 Storr 1988a Storr 1988b	Husband 1980 Bedford and Christian 1993 Christian and Bedford 1993	Gow 1979	—	Wright 1982

Family	Taxonomy/distribution/ biogeography	Reproduction/physiology	Diet/ecology/behaviour	Management/conservation	General/other
Pygopodidae	Shea 1991	—	Ehmann 1981	Ehmann and Metcalfe 1978 Ehmann 1981 Ehmann 1982 Cogger *et al.* 1993	—
Agamidae	Storr 1974a	Pengilley 1982 Christain and Green in press	Shine and Lambeck 1989 Fyfe 1981b Bedford 1992c	—	Shine 1990
Varanidae	King and Horner 1987a Rankin *et al.* 1987 Storr 1966	Dryden *et al.* 1990 Gow 1982 Shine 1986e	Pengilley 1981 Shine 1986e	—	—
Scincidae	Storr 1967 Storr 1970 Storr 1974b Storr 1974c Rankin 1978 Rankin 1979 Rankin and Gillam 1979 Greer 1980 Greer 1983 Horner 1984 Sadlier 1984 Fyfe 1985 Sadlier 1985 Sadlier *et al.* 1985 Horner and King 1985 Storr 1986 Ingram 1987 King *et al.* 1988 Ingram and Covacevich 1989 Greer 1990 Horner 1991 Storr 1991a Storr 1991b	James 1991a James 1991b James 1991c James and Losos 1991	Horner 1984 Horner 1991 James 1991d James and Losos 1991	—	Fyfe 1985a Horner 1991
Typhlopodidae	Storr 1968b Gillam 1979b Storr 1984a	Shine and Webb 1990	Swanson 1981 Shine and Webb 1990	—	—
Boidae	Gow 1977 Gow 1991d	—	—	—	—
Acrochordidae	—	Shine 1986c Shine 1986d Houston and Shine 1993b	Shine and Lambeck 1985 Shine 1986c Shine 1986d Houston and Shine 1993a	Shine 1986b	Shine 1986b
Colubridae	—	—	Bedford 1992a	—	Guinea *et al.* 1992
Elapidae	Storr 1968a Gillam 1979a Gow 1980 Gillam and Williams 1984 Storr 1984b Longmore 1986	Shine 1980 Shine 1981 Gow 1981e Shine 1983 Bedford 1991	Shine 1980 Shine 1981 Shine 1983 Shine and Covacevich 1983 Bedford 1992b	—	—
Hydrophiidae	Guinea 1992	—	—	—	—

Table 1 — continued.

Assemblages	Taxonomy/distribution/ biogeography	Reproduction/physiology	Diet/ecology/behaviour	Management/conservation	General/other
Frogs	Tyler 1972 Tyler *et al.* 1981a,c Tyler *et al.* 1983a,c Tyler *et al.* 1986 Tyler and Davies 1986 Tyler and Crook 1987 Tyler *et al.* 1991	Tyler *et al.* 1983b Tyler and Crook 1987	Tyler and Crook 1987 Freeland and Kerin 1988	Freeland and Kerin 1988	Tyler and Crook 1987 Delvinquier and Freeland 1988a,b
Lizards	Pianka 1972 Morton and James 1988	James 1983 James and Shine 1985 James and Shine 1988	Pianka 1972 James *et al.* 1984 Pianka 1986 Morton and James 1988 Masters 1991 Trainor 1992	Fyfe 1980 Braithwaite 1987 Masters 1991 Trainor 1992	—
Snakes	—	—	—	—	—
Reptiles	Martin 1975 Gillem *et al.* 1978 Wells 1979 Cogger and Heatwole 1981 Cogger 1984 Woinarski 1992	Cogger 1984	Shine 1986a	Woinarski 1992	Swanson 1979
Herps	Loveridge 1949 Cogger 1981 Pianka and Schall 1981 Gow 1981a,b,c Fyfe 1985b Woinarski and Gambold 1992 Anderson and Marcus 1992 Gambold and Woinarski 1993 Woinarski and Braithwaite 1993	—	Martin and Freeland 1988 Friend and Cellier 1990 Gambold and Woinarski 1993 Baker *et al.* 1993	Friend and Taylor 1984 Braithwaite *et al.* 1984 Finlayson *et al.* 1988 Friend and Cellier 1990	Baker *et al.* 1993

and central Australia is uncertain and hotly debated (e.g., Flannery 1990). Much of the megafauna present at the time of Aboriginal entry to northern Australia has since disappeared (White and Flannery 1992): there is little information on the fate of herpetofauna during this period.

European colonization of the Northern Territory has proceeded fitfully since the 1830s, and the total population has remained low (<200 000 people). Consequently the Northern Territory environment has been less fragmented and modified than that of temperate Australia. However extensive pastoralism has been and remains the dominant land-use over much of the Northern Territory.

The historical record

Relatively few fossil-rich sites have been located in the Northern Territory. Of those discovered, the middle Miocene deposits at Bullock Creek and late Miocene deposits at Alcoota have provided evidence of very diverse herpetofauna communities, including *Australoabatrachus* and *Litoria* (Anura), *Yurlunggur* (Madtsoiidae), *Varanus* and *Megalania* (Varanidae), *Meiolania* (Meiolaniidae), *Baru, Harpacochampsa* and *Quinkana* (Crocodylidae) and unidentified species in the families Pythonidae, Elapidae, Chelidae and Emydidae (Megirian 1989; Willis *et al.* 1990; Megirian *et al.* 1991; Murray and Megirian 1992; Scanlon 1992). Other reptile records include ichthyosaurs (Murray 1985) and plesiosaurs (Murray 1987) from deposits near Darwin.

The proximity of Riversleigh (north-west Queensland) to the Northern Territory Gulf region suggests that much of the detailed inventory and evolutionary interpretation of that herpetofauna (e.g., Smith and Plane 1985; Covacevich *et al.* 1990; Hutchinson 1992) is applicable also to, at least adjacent areas of, the Northern Territory.

Inventory, census and geographic distribution

The date of description of species which are restricted to the Northern Territory, or for which the type locality occurs within the Northern Territory, provides a graphic representation of the development of Northern Territory herpetology (Fig. 2a). Perspective can be offered to this sequence by comparison with an equivalent chronology from the comparably sized area (1.03 million km^2) of New South Wales plus Victoria (Fig. 2b). A striking comparison between the scientific discovery or recognition of the herpetofaunas of these two regions is provided by the median date of description (i.e., the date by which half of the currently recognized species named from those regions were described): for the Northern Territory as many frog and reptile species have been named since the 1960s as before that date. The equivalent median figure for New South Wales plus Victoria is the 1890s for both reptiles and frogs (and even this date should be earlier as there are many taxa described before this date from specimens collected in New South Wales which were not included in this calculation because their type locality is missing or vague).

For the Northern Territory an initial burst of herpetological (and other zoological) discovery was associated with the establishment of the dismal and short-lived colony of Port Essington on the northern coast between 1838 and 1849 (Calaby 1974). Over the following four decades a few new species were collected and described in the Northern Territory, associated with sporadic settlement in the north and some exploratory forays through central Australia. The next major advance came with the Horn Expedition to central Australia in the 1890s (Lucas and Frost 1896), which resulted in 10 new reptile species being described from the Northern Territory. The period between 1900 and the late 1940s provided few new discoveries, although specimens trickled in from the frontier to the museums of Adelaide, Sydney and Melbourne, most notably with at least five reptile species being described in the decade from 1910 to 1920 from specimens sent from Hermannsburg Mission in central Australia. In 1948, the American-Australian Scientific Expedition to Arnhem Land provided a large series of specimens from a region hitherto unvisited by herpetologists, and the description of new species from material collected on this expedition continued intermittently for over a decade (Mitchell 1955, 1964). This safari marked the end of a colonial era, when herpetological development was characterised by expeditions organized either interstate or internationally, and when all or almost all specimens collected were subsequently removed from the Northern Territory.

It was not until biological surveys of the Northern Territory became more sustained and institutionalized in the late 1960s that a more comprehensive picture of the herpetofauna began to emerge. Initially these surveys were undertaken by agencies (notably CSIRO and the Australian Museum) based outside the Northern Territory. With the establishment over the last two decades of the Northern Territory Museum of Arts and Sciences (whose only two curators of terrestrial vertebrates have both been herpetologists), a Wildlife Research unit in the Conservation Commission of the Northern Territory, laboratories of CSIRO Wildlife Research in Darwin and Alice Springs, and the Northern Territory University in Darwin, there has been an increasingly large

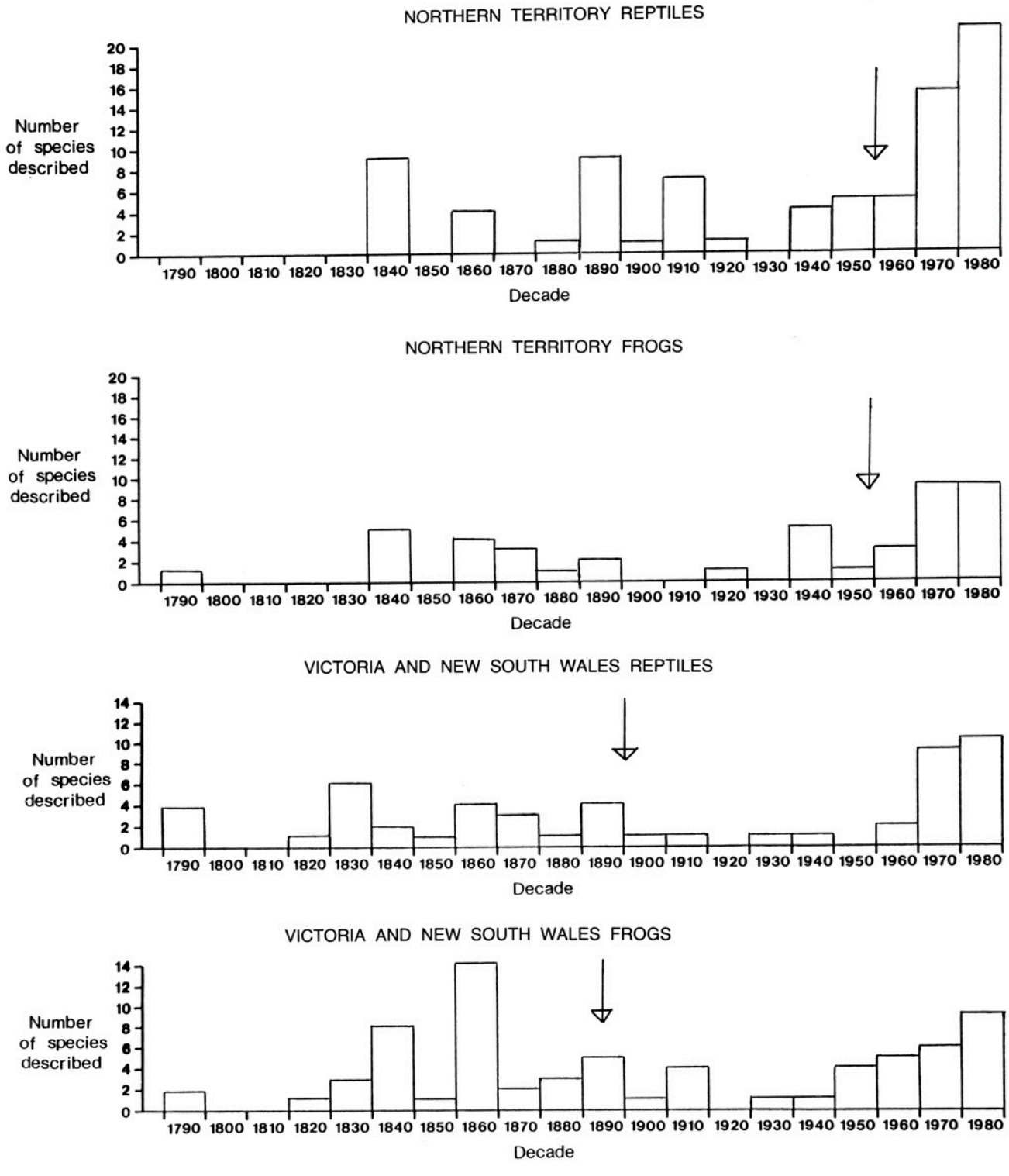

Fig. 2. Dates of descriptions of frog and reptile species (a) restricted to the Northern Territory or with type locality in the Northern Territory, (b) restricted to Victoria plus New South Wales or with type locality in Victoria plus New South Wales. Note that the date along the horizontal axis marks the beginning of the decade, i.e., 1980 indicates the decade 1980–1989. Arrows indicate the median date of description.

and stable local involvement in herpetological fieldwork and taxonomy.

Biological surveys in this period have provided herpetological inventories of many regions of the Northern Territory (Fig. 1), although this activity has been far from evenly dispersed, with much of it being concentrated on the Alligator Rivers Region (including Kakadu). For many large areas and environments the herpetofauna remains unsurveyed.

This body of work has included some development, testing and modification of herpetological survey techniques, including assessment of different pit-trapping methods

(Braithwaite 1983; Friend 1984; Brooker and Braithwaite 1988; Morton *et al.* 1988), aerial survey for marine turtles (Bayliss 1986), design of traps for turtles (Kennett 1992) and protocol for recording Aboriginal knowledge of herpetofauna (Baker *et al.* 1993).

A recent period of mining development and other land-use proposals, coupled with EIS legislation, has also contributed to knowledge of the distribution and composition of the Northern Territory herpetofauna, with notable local inventories of herpetofauna being those at Pine Creek (Schulz and Menkhorst 1984), Mount Todd (NSR 1992), Coronation Hill (Dames and Moore 1988) and MacArthur River (CSIRO 1976; Gambold and Menkhorst 1992b). The Office of the Supervising Scientist, established by the Federal Government to monitor the impact of the Ranger uranium mine on the wetlands of the Alligator Rivers Region, has also been responsible for comprehensive descriptions of local herpetofauna communities (e.g., Shine 1986a; Tyler and Crook 1987; Sadlier 1990).

Since 1970 extensive surveys have examined the distributions of taxonomic groups of species, most notably of crocodiles (e.g., Messel and Vorlicek 1986), but also sea-snakes (current studies by T. Ward), marine turtles (Guinea 1993a), aquatic turtles (e.g., Kennett *et al.* 1992; Georges and Adams 1992) and frogs (e.g., Tyler *et al.* 1981a, 1983a,c, 1986, 1991).

The Conservation Commission of the Northern Territory maintains a substantial data base, the Coastal Resource Atlas, which includes the location of nest sites of marine turtles. The development of a Biological Records Scheme (Johnson and Fleming 1984), which compiles specimen and observation data for terrestrial vertebrate species from any interested parties, has encouraged the reporting of herpetofauna distributions (notably from the many amateur herpetologists who visit the Northern Territory) and facilitated the examination of distribution patterns.

The establishment of a National Parks system in the Northern Territory, largely since the 1970s, has also greatly enhanced our knowledge of the herpetofauna, because resident rangers have included some very capable herpetologists, because they have attracted many visiting naturalists, and because park managers and planners have been obliged to determine the biological attributes of their parks.

Compilation of data from most of these sources reveals (Figs 3a and b) a reasonable spread of records over most areas of the Northern Territory. Nonetheless, a clustering of records around the major towns, National Parks and major road networks, with some substantial areas remaining without any recorded herpetological information, is evident. There are appreciably more records and better coverage for reptiles than for frogs.

Distribution and composition of the Northern Territory herpetofauna

A total of 325 herpetofauna species (about 34% of the Australian tally) has been recorded from the Northern Territory (based on data presented in Cogger 1992). The Northern Territory has representatives of all families recorded from Australia, other than Laticaudidae (the sea kraits). The taxonomic composition of this fauna is presented in Table 2, along with a comparison for New South Wales plus Victoria. The Northern Territory has appreciably more species in the families Cheloniidae, Agamidae, Varanidae, Boidae, Colubridae and Hydrophiidae than has New South Wales and Victoria, but appreciably fewer species in the families Myobatrachidae and Pygopodidae. There are far more species of frogs recorded from New South Wales plus Victoria but far fewer reptiles.

The number of frog species in the Northern Territory declines sharply from north to south down the rainfall gradient (Pianka and Schall 1981), and the proportion of frogs from the family Myobatrachidae increases along this gradient. The sole representatives in the families Ranidae and Microhylidae are restricted to high rainfall areas of some coastal parts of the Top End. Species richness of frogs, even in the highest rainfall areas of the Top End, are at best moderate by Australian standards (Pianka and Schall 1981; Anderson and Marcus 1992). The number of species in monsoon rainforests of the Top End is comparable to that in the Kimberley (Gambold and Woinarski, in press) but lower than that in rainforests of eastern Australia or in rainforests from a wide range of sites in tropical areas of Asia, South America and Africa, possibly because of the length of the Dry season in the Top End (Martin and Freeland 1988; Gambold and Woinarski 1993). In the Top End, frog species richness increases from sandstone escarpments and dry hills to lowland wet areas and monsoon rainforest patches (Braithwaite *et al.* 1991; Woinarski and Gambold 1992).

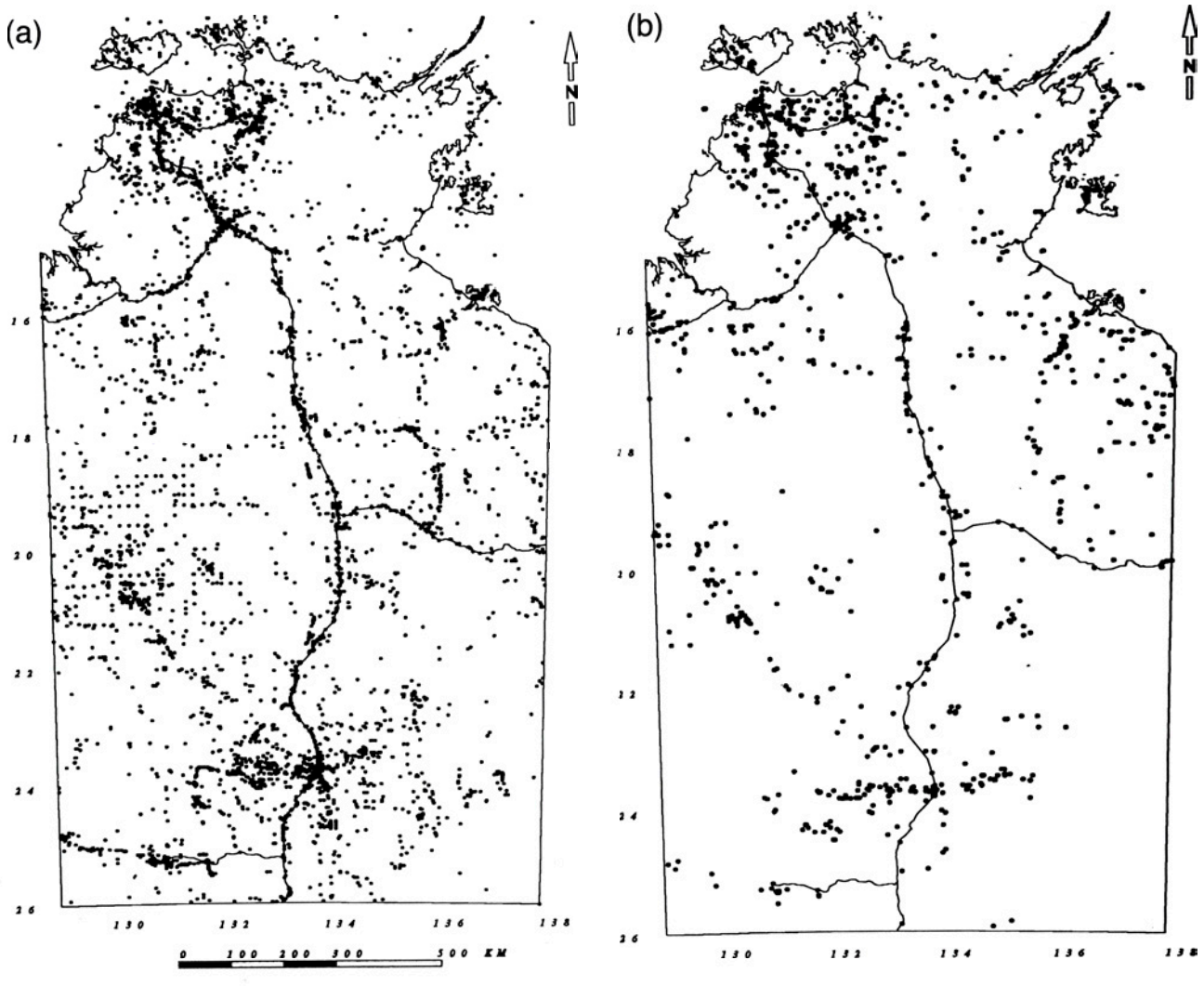

Fig. 3. Location of all records in CCNT data base for (a) frogs and (b) reptiles.

Within the Northern Territory, both crocodile species are restricted to the Top End. The number of freshwater turtle species declines sharply down the rainfall gradient (Pianka and Schall 1981). Species richness of freshwater turtles in the Top End is among the highest in Australia (Pianka and Schall 1981). All marine turtle species recorded from Australia are known from Northern Territory waters (Cogger 1992), although *Dermochelys coriacea* is rarely sighted.

The number of lizard species increases slightly down the rainfall gradient of the Northern Territory, but this relationship varies substantially between families and genera (Pianka and Schall 1981; Cogger and Heatwole 1981), being most pronounced for Gekkonidae, Pygopodidae, Agamidae and Scincidae (especially the genus *Ctenotus*), and reversed for Varanidae. Central Australia has among the highest species richness of Gekkonidae, Agamidae and Scincidae in Australia. The Top End (and Kimberley) has the highest diversity of varanids in Australia, and indeed the world. In the Top End, the richness of geckos increases, but that of skinks decreases, along a gradient from lowland wet areas to upland rocky areas (Woinarski and Gambold 1992). Pianka (1972, 1986) noted that the lizard fauna of central Australian deserts is possibly the richest in the world, and Morton and James (1988) argued that this high alpha-diversity is associated with the abundance and variety of termites. Among habitats of central Australia, spinifex grasslands have the greatest number of lizard species (Morton and James 1988).

The number of snake species declines gradually down the rainfall gradient (Pianka and Schall 1981), but this too varies substantially between families. Elapidae show a slight increase in drier areas (Cogger and Heatwole 1981; Longmore 1986), but Colubridae and Boidae decline in richness sharply down the rainfall gradient (Anderson and Marcus 1992) and the two species of Acrochordidae are restricted to coastal and estuarine waters and freshwater systems of the far north. The overall species richness for terrestrial snakes is low

Table 2. The number of species known from families of herpetofauna in the Northern Territory with comparison of those known from New South Wales plus Victoria. The number of endemic species is given in brackets.

	N.T.	NSW and Vic.
Frogs		
Myobatrachidae	18 (5)	43 (13)
Hylidae	24 (2)	33 (8)
Microhylidae	1 (1)	0
Ranidae	1*	0
Bufonidae	0	0
Total	44 (8)	76 (21)
Reptiles		
Crocodylidae	2	0
Turtles and Tortoises		
Cheloniidae	6	0
Dermochelyidae	1	1
Carettochelyidae	1	0
Chelidae	4	5
Total	12	6
Lizards		
Gekkonidae	32 (6)	22 (1)
Pygopodidae	8	13 (2)
Agamidae	28	15
Varanidae	19 (2)	4
Scincidae	96 (18)	80 (12)
Total	183 (36)	134 (15)
Snakes		
Typhlopidae	15 (4)	11
Boidae	9 (2)	4
Acrochordidae	2	0
Colubridae	8	3
Elapidae	29 (1)	37 (2)
Hydrophiidae	21	2
Laticaudidae	0	0
Total	84 (7)	57 (2)
TOTAL	325 (51)	273 (38)

*1 species in Northern Territory discovered since Cogger (1992). Additionally the Northern Territory has one introduced species in each of the families Bufonidae, Gekkonidae and Typhlopidae.

compared with eastern and southwestern Australia (Pianka and Schall 1981; Cogger and Heatwole 1981; Longmore 1986). The number of sea-snake species recorded from the Northern Territory is high and comparable to that of warm waters in Queensland and Western Australia (Cogger 1992).

Some high herpetofauna species tallies have been recorded for surveyed areas within the Northern Territory. For example, 41 lizard species were recorded from a 50 ha spinifex grassland site near Alice Springs (Morton and James 1988), 72 reptile species (including 16 species of *Ctenotus*) were identified from the 1 325 km^2 Uluru National Park (Reid *et al.* 1993) and 126 herpetofauna species (102 reptiles and 24 frogs) from the 6 683 km^2 Stage III of Kakadu National Park (Woinarski and Gambold 1992).

Densities and total population estimates have been recorded for few herpetofauna species in the Northern Territory. The total population of *Crocodylus porosus* in the Northern Territory was estimated at about 40 000 individuals (Webb *et al.* 1984), and that of *C. johnstoni* about 30 000 to 60 000 (Webb *et al.* 1987). These species may occur at very high densities (e.g., up to 35 individuals/km of channel for *C. porosus* (Webb *et al.* 1984); 100 individuals of *C. johnstoni* in a pool 75 m by 25 m (Webb 1991)). Extremely high densities (e.g., hundreds of snakes per hectare) have also been estimated for the Water Python *Bothrochilus fuscus* in coastal swamps (Shine 1991), possibly constituting the greatest biomass of vertebrate predators anywhere in the world. Comparable estimates (e.g., up to 400 individuals/ha) have been recorded for the file snake *Acrochordus arafurae* in freshwater billabongs of the Magela Creek system (D. Houston pers. comm.). Kennett (1993) estimated biomass of the turtle *Elseya dentata* at 105–170 kg/ha (from 49–78 individuals/ha or 19–31 individuals/100 m of river channel) in some Top End rivers, apparently the largest biomass yet recorded for freshwater turtles. He also recorded densities of *Chelodina rugosa* in Top End lagoons as 5–15 individuals/ha. The population density of the introduced Cane Toad *Bufo marinus* in the Gulf region has been recorded at up to 5 000 individuals/ha, with biomass exceeding 100 kg/ha (Freeland 1986; Freeland and Kerin 1988).

Figures for densities of species in arid Australia are not as spectacular, but Morton *et al.* (1993) estimated up to 34–68 individuals/ha for burrowing frogs in hummock grasslands on sandy substrates. James (1991a) estimated the total density of five species of *Ctenotus* skink at one arid site in spring at 100 individuals/ha, with densities of individual *Ctenotus* species reaching 163 adult individuals/ha over the course of his two-year study. Morton and James (1988) estimated abundance of the 11 most common lizards at a spinifex dune field near Alice Springs at 439 individuals/ha, with biomass of nearly 3 000 g/ha. Some subterranean reptiles may be present at very high densities (e.g., the skink *Lerista bipes* constituted 62% of total reptile captures at one site in the Tanami Desert: Morton and James 1988), but their abundance is difficult to estimate.

Curiously, given its relatively undisturbed environments, the Northern Territory has more feral herpetofauna species than any Australian state, with a toad from central America (*Bufo marinus*), a gecko from Asia (*Hemidactylus frenatus*), a blind snake from Asia (*Ramphotyphlops braminus*), and a frog (*Limnodynastes tasmaniensis*) probably introduced from southeastern Australia.

The pace at which species have been added to the Northern Territory herpetofauna suggests that our current listing is likely to be a substantial underestimate of the actual species composition. Evidence of this pace is the 19 per cent increase in the total number of frog species and 37 per cent increase in the number of reptile species recorded from the Northern Territory since 1981 (Gow 1981a,b). The large and distinctive python *Morelia oenpelliensis* was described as recently as 1977, the large python *Morelia bredli* was described in 1981, and a large *Chelodina* species occurring in Kakadu National Park remains undescribed. The belated recognition of such conspicuous elements of the herpetofauna suggests that many small or cryptic species or those occurring in remote areas may long remain undiscovered. Partly as a consequence of the idiosyncratic interests of taxonomists working on the Northern Territory herpetofauna, the taxonomy of some groups has been neglected or poorly resolved (e.g., *Diporiphora*), and the bewildering variety in other groups (e.g., *Ctenotus*) will present taxonomic challenges for many years to come. Also, most of the species definition in the Northern Territory has been based exclusively on morphological characteristics (with notable exceptions being King's karyotypic studies on *Gehyra* (e.g., King 1979, 1982a, 1983a) and recent electrophoretic studies of chelid turtles (Georges and Adams 1992). Further studies of karyotypy, electrophoresis and vocalizations may be expected to substantially refine taxonomic relationships within the Northern Territory herpetofauna and to appreciably increase the number of recognized species, as has occurred elsewhere in Australia.

Despite the uncertainty of distribution for many species, and the likelihood that many remain to be added, the recent publication of a field guide to the frogs of the Northern Territory (Tyler and Davies 1986) and to the skinks of the Northern Territory (Horner 1991) suggests that Northern Territory herpetology has come of age, and that there is now sufficient public interest and information available to justify these milestone publications. It is also likely that these guides will further encourage interest in the distribution patterns and definition of the Northern Territory herpetofauna.

Fifty-one species (15.7% of the total herpetofauna) are endemic to the Northern Territory. This is a comparable proportion to that in New South Wales and Victoria (38 species or 13.9% of that herpetofauna). However the proportion of endemic frogs in this latter area is far higher (27.6%) than that for reptiles (8.6%: Table 1). Altitudinal variation (with associated climatic and environmental characteristics) is far less in the Northern Territory than in eastern Australia, and the Northern Territory does not have a direct comparison to the suite of herpetofauna species restricted to isolated mountain tops in eastern Australia (Braithwaite *et al.* 1990). Perhaps the closest comparison and the most notable centre of endemism for Northern Territory herpetofauna is the Arnhem Land plateau, escarpment and surrounds, to which *Oedura gemmata, Pseudothecadactylus lindneri, Morelia oenpelliensis, Ctenotus arnhemensis, C. coggeri, C. gagudju, C. kurnbudj, Egernia arnhemensis, Menetia concinna, Uperoleia arenicola* and *Litoria personata* are restricted. The deeply fissured and dissected topography in this area can provide both microclimatic stability (in deep cracks and caves) and substantial local microclimatic variation (e.g., deeply shaded gorges, rock faces exposed to full sunlight), factors which may have buffered their associated fauna through the rapid climatic fluctuations which characterised the Pleistocene in this region.

Even this Arnhem Land herpetofauna has strong affinities with the Kimberley Division of Western Australia (Cogger and Lindner 1974; Cogger 1981; Cogger and Heatwole 1981; Tyler *et al.* 1981c; Cracraft 1991). The herpetofauna of monsoon rainforests in the Northern Territory is also closely related to that of the Kimberley and, to a lesser extent, Cape York Peninsula and New Guinea (Kendrick and Rolfe 1991; Gambold and Woinarski 1993), with the latter connection most evident in the sole Northern Territory representation of the frog families Microhylidae and Ranidae. Further analysis of relationships between components of the Northern Territory herpetofauna and that elsewhere in Australia (and New Guinea), and the evolutionary interpretation of these relationships, have been considered by Tyler (1968, 1969, 1971, 1972, 1991), Tyler and Davies (1978), Tyler and Martin (1975, 1977), Tyler *et al.* (1979, 1981b, 1986), Witten (1982), Cogger (1984) and Cogger and Heatwole (1981).

Ecological research

Even more than inventory and description, ecological research into the Northern Territory herpetofauna has a brief history. Some reproductive, habitat and dietary information has been documented in many of the wildlife surveys, notably those of Cogger and Lindner (1974), Braithwaite (1985), Woinarski and Gambold (1992), Tyler *et al.* (1986, 1991) and

Reid *et al.* (1993). In some cases, large numbers of museum specimens, mostly from such surveys, have been aggregated and examined for diet or reproductive characteristics (notably James 1983; James and Shine 1985, 1988; James *et al.* 1984; James and Losos 1991; Shine and Webb 1990). An unusual example of this research procedure is a current study of diet, reproduction and size/age structure in sea-snakes collected as fisheries by-catch (T. Ward, pers. comm.).

Other than the major research effort directed at crocodiles, there have been few detailed autecological studies of Northern Territory herpetofauna. The main works have been Freeland's studies on the introduced *Bufo marinus* (Freeland 1984, 1986; Freeland and Kerin 1991), studies of the dragon *Chlamydosaurus kingii* (Shine and Lambeck 1989; Christian and Green, in press, and current study by A. D. Griffiths), studies on the file snake *Acrochordus arafurae* (Shine and Lambeck 1985; Shine 1986b,c,d; Houston and Shine 1993a,b), Kennett's (1993) research on the turtles *Chelodina rugosa* and *Elseya dentata*, a series of studies on the turtle *Carettochelys insculpta* (Webb *et al.* 1986; Georges 1988, 1990, 1992; Georges and Kennett 1989; Heaphy 1990) and Shine and Madsen's (unpubl.) work on the python *Bothrochilus fuscus*.

Major comparative studies of herpetofauna communities in the Northern Territory include research on the diet and reproduction of skinks in both the Alligator Rivers Region and central Australia (James 1983, 1991a,b,c,d; James and Shine 1985, 1988; James *et al.* 1984), on the diet and reproduction of frog assemblages in the Alligator Rivers Region (Tyler *et al.* 1983b; Tyler and Crook 1987) and on the ecology of four species of Varanids in the Wet-Dry tropics (Shine 1986e; and studies in progress by K. Christian). Some ecological context for Northern Territory herpetofauna assemblages was provided by James and Shine (1985, 1988), who offered perspective on the reproductive characteristics of Top End skinks, with a comparison to those in temperate Australia. Braithwaite (1990) noted the lack of a seasonal peak in reproduction for reptiles relative to other tropical areas of the world, and argued that the heterogeneous reproductive patterns observed derive from the diverse geographic origins of the contemporary lizard fauna of Australia's Wet-Dry tropics.

The composition of herpetofauna communities has been examined for particular habitats, including monsoon rainforests (Martin and Freeland 1988; Gambold and Woinarski 1993), *Acacia* woodlands (Fyfe 1985b; Reid *et al.* 1993; Woinarski and Fisher unpubl.; N. Preece unpubl.), spinifex grasslands (Fyfe 1985b; Masters 1991; James 1991d; Reid *et al.* 1993; N. Preece, unpubl.) and wetlands (Freeland and Kerin 1988; Martin and Freeland 1988; Friend and Cellier 1990). For the fragmented monsoon rainforests, herpetofauna species composition varies substantially between patches, under the strong influence of adjacent habitats (Gambold and Woinarski 1993). This spatial variability in herpetofauna communities is observed also for patches of the fragmented Lancewood (*Acacia shirleyi*) forests and thickets (Woinarski and Fisher unpubl.).

A more conspicuous feature of the Northern Territory herpetofauna is its temporal instability. In the Top End the distinct wet-dry seasonality is associated with reproductive periodicity, and changes in activity levels, habitat relationships and foraging behaviour of the herpetofauna (e.g., James 1983; James and Shine 1985; Shine and Lambeck 1989; Guinea *et al.* 1991), leading to pronounced changes in species richness and composition at particular sites within a year (e.g., Braithwaite 1985; Martin and Freeland 1988; Friend and Cellier 1990; Gambold and Woinarski 1993). Variation in the timing, extent and amount of wet season rains may also lead to variability between years in herpetofauna species composition and richness (e.g., Cogger and Lindner 1974; Freeland and Kerin 1988), although this appears to be less pronounced for reptiles than for mammals or birds (Braithwaite 1985). The very few long-term studies limit the scope for generalizing this phenomenon. In the Top End, the existing research effort also tends to be seasonally biased, with the difficulties and discomfort of working during the wet season leading to relatively little research during this biologically important period.

In arid and semi-arid Northern Territory there is also marked variation in herpetofauna richness, composition, reproductive activity and behaviour within and between years associated with both rainfall and temperature patterns (e.g., Gibson 1986; James 1991a,b,c,d; Reid *et al.* 1993). Episodic events may be particularly important in these environments (e.g., Griffin and Friedel 1985; Stafford Smith and Morton 1990). Morton *et al.* (1993) document the sudden appearance of very large numbers of burrowing frogs following unusually heavy rain. In contrast to mammals of the arid and semi-arid regions, the herpetofauna may be relatively resilient to prolonged drought (Morton 1990), although little research has been directed to the influence of drought on herpetofauna.

Ecological studies conducted within similar environments in neighbouring States are broadly applicable to the Northern Territory herpetofauna. Important perspective on the reptile fauna of arid areas of the Northern Territory is provided by the detailed research by Pianka in Western Australian deserts (e.g., Pianka 1972; Pianka and Pianka 1976), and also by studies by Henle (e.g., 1991) in arid and semi-arid New South Wales, particularly since these studies include many species which occur in the Northern Territory.

Aboriginal knowledge

Reptiles are an important component of the culture of Aboriginal people throughout the Northern Territory. Many reptile species are hunted, and the eggs of turtles collected. Reptiles feature prominently in much Aboriginal art, and reptiles and frogs are often significant characters in stories and mythology. This close association has resulted in many Aboriginal people possessing a detailed knowledge of many aspects of the ecology and distribution of the herpetofauna. Some of this information has been tapped in wildlife surveys (most notably Reid *et al.* 1992; Baker *et al.* 1993; also Gibson 1986; Fensham and Woinarski 1992), in specific studies of Aboriginal taxonomy (Davis 1981; Waddy 1988) and in anthropological and popular accounts of Aboriginal lifestyles (e.g., Davis 1989). There has been little research on the ecological consequences of Aboriginal hunting, except for Shine's (1986b) study of selective hunting of a popular food item, the file snake *Acrochordus arafurae*.

The Northern Territory Department of Education is undertaking an ambitious programme to link computer education in Aboriginal settlements and outstations with the incorporation of local knowledge into a wildlife data base. This has been successfully trialled at a number of centres in Arnhem Land and the Tiwi Islands and this scheme will collate, preserve and disseminate Aboriginal information on Northern Territory herpetofauna (I. Morris and G. Sawyer, pers. comm.).

Rock art provides a line of evidence about the presence and distribution of herpetofauna and environmental conditions over periods of up to 40 000 years. However, some imprecision in dating, biases in the taxa represented and uncertainties about the identification of taxa pictured (either through painting decay or non-realistic figuration) mean that some caution is needed in the interpretation of this information (e.g., Lewis 1986). Additionally, the limited occurrence of suitable rock sites makes for a fragmentary record of distribution and history. It is impressive that good rock paintings of the python *Morelia oenpelliensis* were known to anthropologists well before this species was described. There are also detailed depictions of a large *Chelodina* species, which is still not described (R. Kennett, pers. comm.).

Conservation and management

In contrast to the substantial number of mammalian extinctions and declines from the Northern Territory over the last 100 years (Morton 1990), the Northern Territory herpetofauna appears to have generally fared well since European settlement. Other than marine turtles, Cogger *et al.* (1993) list only two reptile species, *Ophidiocephalus taeniatus* (Vulnerable) and *Egernia kintorei* (Vulnerable), from the Northern Territory as "endangered or vulnerable". Reflecting lack of information about population sizes and distribution, and uncertainty about threatening processes, they list a further 24 Northern Territory species as "Rare or insufficiently known": *Crocodylus johnstoni, C. porosus, Carettochelys insculpta, Diplodactylus occultus, Cryptagama aurita, Tympanocryptis uniformis, Varanus glauerti, V. primordius, Ctenotus arnhemensis, C. septenarius, C. tanamiensis, Egernia arnhemensis, Lerista carpentariae, L. stylis, Menetia concinna, Ramphotyphlops broomi, R. tovelli, R. yirrikalae, Morelia oenpelliensis, Cerberus rhynchops, Myron richardsonii, Acanthophis antarcticus, Vermicella annulata, Hydrelaps darwiniensis* and *Parahydrophis mertoni*. Illustrating the apparent conservation health of the Northern Territory herpetofauna but also the lack of information about many taxa, this proportion of "rare or insufficiently known" taxa amongst the total "threatened" taxa is far higher than for any other State (i.e. 92%, cf. 74% for the whole of Australia: Cogger *et al.* 1993).

The conservation status of the five "vulnerable" marine turtle species occurring in the Northern Territory is considered further by Cogger and Lindner (1969) and Guinea (1990, 1993a). That of *Egernia kintorei* is discussed by Reid *et al.* (1993), and that of *Ophidioscephalus taeniatus* by Ehmann (1981, 1992) and Ehmann and Metcalfe (1978).

Unlike many other parts of Australia, and elsewhere, there appears to be no evidence of recent decline in frog numbers in the Northern Territory. This may reflect a limited information base. Two Northern Territory frog species may be of some conservation concern: *Uperoleia orientalis*, known from only a few records in the Gulf/Barkly area (Tyler and Davies 1986) and *Rana daemeli*, known in the Northern Territory

from only a few sites in eastern Arnhem Land (but with secure populations in northern Queensland and New Guinea). The status of the former species is being investigated by Tyler, and that of the latter by Gambold.

One assessment of the conservation status of herpetofauna species is their representation within the National Park and Conservation Reserve system. Some qualifications associated with this evaluation include questions such as whether populations within reserves are sufficient for long-term survival, whether management of reserves is sympathetic to the requirements of the species, and whether management of lands outside reserves is or is not appropriate for the survival of the species. Nonetheless, representation of taxa within a reserve system is a definable and quantifiable goal and one measure of the protection of biodiversity. A further problem within the Northern Territory is that many reserves have almost no information about the wildlife occurring within them. In the Northern Territory, the 82 conservation reserves comprise 3.3 per cent of the total land area, and their distribution in the landscape is extremely biased to high rainfall areas, rocky landforms, and near the major population centres (Whitehead *et al.* 1992; Woinarski 1992). A total of 38 herpetofauna species (9 frogs = 20.5% of the Northern Territory frog fauna, and 29 reptiles = 8.9% of the Northern Territory reptile fauna) are not recorded from any reserves in the Northern Territory (Table 3), and a further 50 species are recorded from only one reserve. In many cases these species occur also beyond the Northern Territory or have only a small proportion of their total range within the Northern Territory, such that their conservation responsibility is shared with,

Table 3. Species recorded in the Northern Territory from fewer than five ¼ degree cells and/or fewer than two conservation reserves. Asterisks indicate species restricted to the Northern Territory. Note that marine species are not included.

	No. cells	No. reserves
Frogs		
Limnodynastes tasmaniensis	1	0
Neobatrachus aquilonius	16	0
Ranidella deserticola	13	0
Ranidella remota	6	0
*Uperoleia arenicola**	3	1
Uperoleia borealis	4	1
*Uperoleia micromeles**	5	0
*Uperoleia orientalis**	3	1
*Uperoleia trachyderma**	11	1
*Cyclorana cryptotis**	5	0
Cyclorana maculosa	9	1
Cyclorana vagita	1	0
Litoria alboguttata	22	0
Rana daemelli	1	0
Reptiles		
Diplodactylus byrnei	3	0
Diplodactylus jeanae	5	0
*Diplodactylus occultus**	1	1
Diplodactylus tessellatus	7	0
*Gehyra minuta**	8	0
Gehyra pilbara	3	1
*Oedura gemmata**	5	1
Pseudotheradactylus lindneri	8	1
Underwoodisaurus milii	6	1
Delma butleri	5	1
Delma haroldi	5	1
Cryptogama aurita	2	0
Ctenophorus clayi	9	1
Ctenophorus pictus	10	0
Ctenophorus reticulatus	7	0
Ctenophorus rufescens	1	0
Tympanocryptis intima	2	2
Tympanocryptis tetraporophora	5	1
Tympanocryptis uniformis	1	0
Varanus brevicauda	20	1
Varanus eremius	43	1
Varanus glauerti	1	1
Varanus kingorum	1	2
Varanus storri	11	1
Carlia longipes	11	0
Carlia macfarlani	6	0
Cryptoblepharus litoralis	4	1
*Ctenotus arnhemensis**	12	1
Ctenotus dux	12	1
*Ctenotus gagudju**	2	1
Ctenotus grandis	20	1
Ctenotus hanloni	1	1
Ctenotus joanae	17	1
*Ctenotus kurnbudj**	4	1
Ctenotus militaris	2	1
*Ctenotus pallescens**	5	1
Ctenotus regius	25	1
*Ctenotus septenarius**	5	1
*Ctenotus storii**	9	1
Ctenotus striaticeps	5	0
*Ctenotus tanamiensis**	7	0
*Egernia arnhemensis**	3	1
Egernia depressa	1	0
Egernia hosmeri	3	0
Egernia kintorei	18	1
Egernia slateri	9	1
Egernia stokesi	4	0
*Glaphyromorphus arnhemicus**	2	0
Glaphyromorphus nigricaudis	3	0
Lerista aericeps	9	1
Lerista borealis	3	1
*Lerista carpentariae**	4	0
Lerista griffini	2	1
Lerista ips	4	0
Lerista muelleri	1	0
*Lerista stylis**	2	1
*Lerista taeniata**	2	0
Lerista xanthura	6	0
Menetia concinna	5	1
Morethia adelaidensis	3	0
Proablepharus kinghorni	3	0
Tiliqua occipitalis	8	1
Ramphotyphlops bituberculatus	16	1
Ramphotyphlops broomi	1	1
*Ramphotyphlops minimus**	2	0
Ramphotyphlops wiedii	2	1
*Ramphotyphlops yirrikalae**	6	1
*Morelia bredli**	4	4
*Morelia oenpelliensis**	1	1
Acrochordus granulatus	3	1
Acanthophis antarcticus	25	1
Demansia simplex	1	0
Denisonia ordensis	2	0
Pseudonaja guttata	8	0
Pseudonaja ingrami	10	0
Simoselaps fasciolatus	6	1

or largely reliant upon, other States. Only seven herpetofauna species endemic to the Northern Territory are not known from reserves, with a further 17 endemic species known from only one reserve. The Conservation Commission of the Northern Territory is currently preparing reserve design options for such species. Flexibility in reserve placement to include such species may be enhanced if they have wide ranges or if many species with restricted ranges coincide. Many reptile and frog species in the Northern Territory appear to have very limited ranges (Table 3; Woinarski 1992), although in some cases this may represent inadequate sampling.

Factors which pose real or potential threats to the Northern Territory herpetofauna include: fire, pastoralism and feral livestock, Cane Toads, feral cats; hunting and exploitation, climate change, more intensive land use, and weed invasion.

The effects of fire upon herpetofauna have been considered in open forests and savanna woodlands of the Top End (Braithwaite 1987; Trainor 1992), and in Mulga woodlands and hummock grasslands of central Australia (Fyfe 1980; Masters 1991; Reid *et al.* 1993). For both regions, there was a range of idiosyncratic species responses to different fire regimes, and management to promote a fine mosaic of fire ages and intensities was recommended, a strategy which may approach that traditionally used by Aboriginal people. Both Masters (1991) and Reid *et al.* (1993) found a rich assemblage of herpetofauna species in long unburnt hummock grasslands on sandplains, and they advocated protection of such habitat. Long-term experimental research on the impact of a range of fire regimes on herpetofauna assemblages is being conducted by CSIRO at the Kapalga Research Station within Kakadu (L. Corbett pers. comm.). This includes a detailed current study of the responses to fire by the dragon *Chlamydosaurus kingii*, a species which appears to select recently burnt areas and areas with a consistent history of intense late Dry season fires, despite suffering substantial mortality rates in these late fires (A. D. Griffiths pers. comm.).

Despite its domination of land use in the Northern Territory, there has been remarkably little research directed at the effects of pastoralism on wildlife. Ehmann (1992) considered that trampling and denudation of vegetation by cattle may be contributing to decline in *Ophidiocephalus*. Friend and Cellier (1990) illustrated decline in some herpetofauna species associated with high densities of feral Water Buffalo *Bubalus bubalis*, and

Table 4. A comparison of the number of species records, number of ¼ degree cell blocks and number of reserves recorded from for amphibians, reptiles, birds and mammals in CCNT data base.

	No. records	Mean no. cells/species	Mean no. reserves/species
Amphibians	8 109	35.5	7.52
Reptiles	28 487	32.8	5.92
Birds	172 525	124.6	14.75
Mammals	14 671	36.7	6.65

Braithwaite *et al.* (1984) also found associations, both positive and negative, between different herpetofauna species and buffalo impacts. Both of these studies were correlative; there has been no long-term research or use of exclosure plots. Two recently commenced studies, by A. Fisher (on effects of pastoralism on vertebrate communities in Mitchell grasslands) and C. Slazenger (on effects of pastoralism on lizard communities in spinifex grasslands), may go some way toward assessing the consequences for herpetofauna of the pastoral industry.

The Cane Toad *Bufo marinus* spread to the Gulf district of the Northern Territory from northwestern Queensland in 1982–83 (Freeland and Martin 1985), and has since extended its range substantially northwestward (Jacklyn 1992). Its impact on herpetofauna has been subject to considerable research and debate. Freeland and Kerin (1988) were unable to detect significant changes in frog assemblages following the arrival of Cane Toads, but much anecdotal evidence suggests that populations of many elapid, varanid and chelonid species, at least, may undergo serious decline following invasion by Cane Toads (Jacklyn 1992, but cf. Freeland 1990).

Feral cats *Felis catus* are common in almost all areas of the Northern Territory, and the Fox *Vulpes vulpes* is common in arid and semi-arid areas of the Northern Territory. These species undoubtedly consume large quantities of reptiles and frogs, but it is not clear whether this constitutes significant impact and real conservation threat. Cogger *et al.* (1993) suggest that predation by foxes and cats may be a factor in the decline of *Egernia kintorei*. Studies of the diet and abundance of these feral predators and control mechanisms for them are now being undertaken by CCNT and CSIRO.

The human population in the Northern Territory is generally sparse (c. 1 person/km^2) and direct impacts are rarely serious. However, some herpetofauna species (notably varanids, turtles and their eggs, the dragon *Chlamydosaurus kingii*, the python *Morelia spilota*

and the file snake *Acrochordus arafurae*) are particularly sought by Aboriginal people as food (e.g., Shine 1986b, 1991; Davis 1989; Fensham and Woinarski 1992; Kennett 1993). Change in the dispersion and sedentariness of Aboriginal populations and in hunting methods may lead to at least local loss or decline in some species (e.g., Altman 1988).

Commercial exploitation of herpetofauna in the Northern Territory has a colourful history, with about 200 000 crocodiles (both *Crocodylus porosus* and *C. johnstoni*) harvested between 1945 and the introduction of protective legislation in 1971 (Webb *et al.* 1987). A crocodile industry in the Northern Territory has been rekindled, with six farms established since 1980 and about 60 people employed in the industry (Anon 1992). Current production is about 5 000 skins/year, but a more than 8-fold increase is planned over the next eight years (Anon 1992). This industry operates mostly under a "ranching" system, heavily dependent upon collection of eggs from wild populations.

Other herpetofauna species have been considered for commercial utilization, with the most recent vision being the marketing of sea-snake by-catch from fishing operations. The resource base for this proposal, and market demands, are being considered by T. Ward, and this scheme does not appear to be commercially viable. The commercial fishing industry may also produce by-catch of marine turtles, with occasional large numbers being killed incidental to fishing operations (Guinea and Chatto 1993).

Herpetological collectors and keepers have long been attracted by the Northern Territory herpetofauna, and illegal collecting and smuggling may well be commonplace. Anecdotal evidence suggests that collectors may be responsible for local declines in some species (possibly including the python *Morelia oenpelliensis* in Kakadu National Park). Many species can be caught and kept without permit, including all but four species (*Litoria splendida, L. personata, Cyclorana vagitus* and *Uperoleia orientalis*) of frogs, most skinks (all *Carlia, Cryptoblepharus, Ctenotus* and *Sphenomorophus* species and *Tiliqua multifasciata* and *T. scincoides*), two agamids, two geckos and two pygopodids (see Davis and Heard in this volume for a more detailed account of the relevant legislation).

Intensive land use, mostly associated with horticulture and mining is, and will probably remain, of limited extent in the Northern Territory, and as such affords little general threat to herpetofauna. However, there have been some recent cases where proposed developments may threaten local populations of rare or restricted species. Probably the most notable example was that of the Coronation Hill mining proposal and the turtle *Carettochelys insculpta* (Woinarski and Braithwaite 1990; Georges 1990).

A formidable complement of alien plants has invaded the wetlands, the *Eucalyptus* open forests, the monsoon rainforests and the savanna woodlands of the Top End (Braithwaite *et al.* 1989; Russell-Smith and Bowman 1992; Cowie and Werner 1993; Woinarski 1993; Lonsdale 1993) and riparian areas, grasslands and chenopod shrublands in central Australia (Humphries *et al.* 1992). There has been little research directed at the impact of these habitat changes upon herpetofauna, although CSIRO is studying faunal changes associated with invasion and control of the shrubby weed *Mimosa pigra* (e.g., Cook 1993).

Natural disturbances may pose local and regional threats to some herpetofauna populations. Cyclones are frequent in the Top End and can substantially modify terrestrial habitats (with unknown impact on their herpetofauna) and lead to occasional spectacular mortality of marine herpetofauna (e.g., Marsh *et al.* 1988). Extremely heavy rainfalls can also reduce the suitability of some habitats for long periods (e.g., Ehmann 1992) and lead to widespread loss of adults and eggs, a process documented for crocodiles and some freshwater turtles of the Top End (e.g., Webb 1991; Georges and Rose 1993). In contrast, poor or late rains in the Top End can reduce the annual survivorship of turtles aestivating through the dry season (Kennett 1993). Long periods of below-average rainfall in arid and semi-arid areas drastically alter ecological conditions and the composition of plant and animal communities (e.g., Morton 1990; Reid *et al.* 1993). However a lack of explicit studies means that the effects of drought upon Northern Territory herpetofauna cannot be properly considered.

There are only imprecise models of the influence of global climate change upon the Northern Territory (Moffatt 1991). Small changes in temperature and rainfall may lead to substantial variation in fire regimes and jeopardize the persistence of marginal vegetation communities, such as monsoon rainforests, and their associated herpetofauna. Changes in the duration and timing of the monsoon rains may be expected to affect herpetofauna species which aestivate during the long dry season, perhaps most notably the turtle *Chelodina rugosa* (Kennett 1993). Changes in rainfall in central Australia may lead to increased

frequency, intensity and duration of drought. Climate change may also influence sex ratios in species which have temperature-sensitive sex determination (e.g., both species of crocodiles and *Carettochelys insculpta*: Georges 1992).

There are at least three characteristics of the Northern Territory environment which suggest that most herpetofauna species may tolerate moderate climate change. The herpetofauna of this region may be robust, as those species now present must have survived the rapid climatic fluctuations in the late Pleistocene. The deeply dissected sandstone ranges, especially in the Top End, may provide microclimatic security and relief for the herpetofauna associated with them (Freeland *et al.* 1988). The extent of vegetation clearing and fragmentation in the Northern Territory is minor: at least theoretically this allows fauna the luxury of easy dispersal in response to climate change.

Conclusions and priorities

Herpetology in the Northern Territory offers a marked contrast between research on two species of crocodiles (which has been well-organized, well-funded and long-term) and that on the remaining 99.4 per cent of the herpetofauna (which has typically been piecemeal and short-term). In this paper I have sought to review the scattered but surprisingly rich body of work falling in the latter category.

This overview suggests that the Northern Territory remains an exciting area for herpetology. Much basic taxonomy and survey remains to be done, but the broad framework is now in place to interpret new discoveries. For some groups (most notably skinks) there have been comprehensive regional analyses of patterns of ecological/reproductive parameters, and these studies provide a basis for comparison for those groups yet to be considered. There have been few detailed autecological studies, and these few have not provided a systematic sampling of the taxonomic or ecological range of the herpetofauna. To a large extent, the patchy knowledge of the Northern Territory herpetofauna (e.g., Table 1) reflects the idiosyncratic interests and approaches of a handful of extremely productive research workers, mostly not resident within the Northern Territory.

Arguably the largest gaps in this research body, and hence priorities for future work, are:

1. experimental studies of the impacts of different land uses, particularly pastoralism, on the herpetofauna;
2. long-term studies of population dynamics, community composition and reproductive patterns, which consider responses to climatic variability;
3. studies on the impacts of Cane Toads, especially on reptile assemblages;
4. more precise definition of the conservation status, threats and management requirements for that large body of species considered "insufficiently known";
5. increased emphasis on research directed at the distribution, abundance and management requirements of, and threats to, marine turtles;
6. survey of those regions of the Northern Territory where only meagre herpetological data are currently available;
7. additional autecological studies, especially of a more representative selection of taxa than that already considered;
8. continued taxonomic assessments, including such "messy" genera as *Diporiphora* and *Ctenotus*, and perhaps especially using a variety of investigative techniques.

ACKNOWLEDGEMENTS

This contribution was heavily dependent upon the advice and knowledge of others, and in particular I wish to record much appreciation to Rick Shine, Nic Gambold, Ross Sadlier, Peter Whitehead, Arthur Georges, Rod Kennett, Paul Horner, Max King, Sally Stephens, Grahame Webb, Graeme Davis, Mike Tyler, Keith Christian, Mick Guinea, Steve Morton and Craig James. I am grateful to Nic Gambold, Rod Kennett, Paul Horner, Peter Whitehead, Darryl Houston, Colin Trainor, Dick Braithwaite and Dan Lunney for constructive comments on an earlier draft. Some of the information contained here is based on the Conservation Commission's Reserve Design data base, and I acknowledge the provision of information to this source from the Australian Museum, CSIRO National Wildlife Collection, Northern Territory Museum of Arts and Sciences, Museum of Victoria, South Australian Museum, Western Australian Museum, Queensland Museum and the many individuals who have contributed to the Biological Records Scheme of the Northern Territory. Greg Connors and Donna Jackson created the figures, for which I am most grateful.

REFERENCES

ALTMAN, J. C., 1987. *Hunter-gatherers today: an Aboriginal economy in northern Australia.* Australian Institute of Aboriginal Studies: Canberra.

ALTMAN, J. C., 1988. Aborigines, tourism and development: the Northern Territory experience. North Australia Research Unit: Darwin.

ANDERSEN, A. N. AND BRAITHWAITE, R. W., (in press). Plant-animal interactions in the Kakadu region of Australia's Northern Territory. In *Geobotany of the Alligator Rivers Region* ed by M. Finlayson. W. Junk: The Hague.

ANDERSON, S. AND MARCUS, L. F., 1992. Areography of Australian tetrapods. *Aust. J. Zool.* **40:** 627–51.

ANON., 1989. A management programme for *Crocodylus porosus* and *Crocodylus johnstoni* in the Northern Territory of Australia. Conservation Commission of the Northern Territory: Darwin.

ANON., 1992. *Northern Territory Crocodile industry strategy.* Northern Territory Government: Darwin.

BAKER, L., WOENNE-GREEN, S. AND THE MUTITJULU COMMUNITY, 1993. Anangu knowledge of vertebrates and the environment. Pp. 79–132 in *Uluru fauna: the distribution and abundance of vertebrate fauna of Uluru (Ayers Rock–Mount Olga) National Park, Northern Territory* ed by J. R. W. Reid, J. A. Kerle and S. R. Morton. Australian National Parks and Wildlife Service: Canberra.

BAYLISS, P., 1986. Factors affecting aerial surveys of marine fauna, and their relationship to a census of dugongs in the coastal waters of the Northern Territory. *Aust. Wildl. Res.* **13:** 27–37.

BEDFORD, G. S., 1991. Notes on the incubation and hatching of the Black Whip Snake *(Demansia atra). Herpetofauna* **20:** 24–25.

BEDFORD, G. S., 1992a. Record of roadkill predation by the Freshwater Snake *(Amphiesma mairii). Herpetofauna* **21:** 35.

BEDFORD, G. S., 1992b. Two records of roadkill predation by the King Brown Snakes *(Pseudechis australis). Herpetofauna* **21:** 39.

BEDFORD, G. S., 1992c. Additional nocturnal sightings of three species of dragon lizards. *Herpetofauna* **21:** 30.

BEDFORD, G. S. AND CHRISTIAN, K. A., 1993. Egg size of the Prickly Knob-tailed Gecko (*Nephrurus asper*, Gunther, 1876) with a preliminary comparison of investment per progeny among geckos. *Dactylus* **1:** 38–41.

BRAITHWAITE, R. W., 1983. A comparison of two pitfall trap systems. *Vic. Nat.* **100:** 163–66.

BRAITHWAITE, R. W. (ed), 1985. The Kakadu Fauna Survey: an ecological survey of Kakadu National Park. CSIRO Wildlife and Rangelands Research: Darwin.

BRAITHWAITE, R. W., 1987. Effects of fire regimes on lizards in the wet-dry tropics of Australia. *J. Trop. Ecol.* **3:** 265–75.

BRAITHWAITE, R. W., 1990. Australia's unique biota: implications for ecological processes. *J. Biogeog.* **17:** 347–54.

BRAITHWAITE, R. W., DUDZINSKI, M. L., RIDPATH, M. G. AND PARKER, B. S., 1984. The impact of water buffalo on the monsoon forest ecosystem in Kakadu National Park. *Aust. J. Ecol.* **9:** 309–22.

BRAITHWAITE, R. W., LONSDALE, W. M. AND ESTBERGS, J. A., 1989. Alien vegetation and native biota: the impact of *Mimosa pigra. Biol. Conserv.* **48:** 189–210.

BRAITHWAITE, R. W., FRIEND, G. R. AND WOMBEY, J. C., 1991. Reptiles and amphibians. Pp. 109–24 in *Monsoonal Australia. Landscape, ecology and man in the northern lowlands* ed by C. D. Haynes, M. G. Ridpath and M. A. J. Williams. AA Balkema: Rotterdam.

BROOKER, M. G. AND BRAITHWAITE, R. W., 1988. The Kakadu Fauna Survey: description and evaluation of methodology for the census of vertebrates. CSIRO Division of Wildlife and Ecology Technical Memorandum no. 29: Canberra.

CALABY, J. H., 1974. Historical background. Pp. 7–20 in *Fauna survey of the Port Essington district, Cobourg Peninsula, Northern Territory of Australia* ed by H. J. Frith and J. H. Calaby. CSIRO Division of Wildlife Research Technical paper no. 28. CSIRO: Canberra.

CANN, J., 1980. Notes on the reproduction of the Northern Longnecked Tortoise *(Chelodina rugosa). NT Natur.* **3:** 4–5.

CHRISTIAN, K. A. AND BEDFORD, G., 1993. High reproductive expenditure per progeny in geckos relative to other lizards. *J. Herpetol.* **27:** 351–54.

CHRISTIAN, K. A. AND GREEN, B., (in press). Seasonal energetics and water turnover of the frillneck lizard, *Chlamydosaurus kingii,* in the wet-dry tropics of Australia. *Herpetologica.*

COGGER, H., 1968. Reptiles of the Pellew Islands. *Mimag* **December 1968:** 21–23.

COGGER, H. G., 1974. Amphibians and reptiles. In *Alligator Rivers Region Environmental Fact-finding study. Wildlife.* CSIRO: Canberra.

COGGER, H. G., 1975. New lizards of the genus *Pseudothecadactylus* (Lacertilia: Gekkonidae) from Arnhem Land and north-western Australia. *Rec. Aust. Mus.* **30:** 87–97.

COGGER, H. G., 1981. A biogeographic study of the Arnhem Land herpetofauna. Pp. 148–55 in *Proceedings of the Melbourne Herpetological Symposium, 1980* ed by C. B. Banks and A. A. Martin. Zoological Board of Victoria: Melbourne.

COGGER, H. G., 1984. Reptiles in the Australian arid zone. Pp. 235–52 in *Arid Australia. Proceedings of a symposium on the origins, biota and ecology of Australia's arid regions* ed by H. G. Cogger and E. E. Cameron. Australian Museum: Sydney.

COGGER, H. G., 1992. *Reptiles and amphibians of Australia. Revised edition.* Reed: Sydney.

COGGER, H. G. AND HEATWOLE, H., 1981. The Australian reptiles: origins, biogeography, distribution patterns and island evolution. Pp. 1331–73 in *Ecological biogeography of Australia* ed by A. Keast. W. Junk: The Hague.

COGGER, H. G. AND LINDNER, D. A., 1969. Marine turtles in northern Australia. *Aust. Zool.* **15:** 150–59.

COGGER, H. G. AND LINDNER, D. A., 1974. Frogs and reptiles. Pp. 63–107 in *Fauna survey of the Port Essington district, Cobourg Peninsula, Northern Territory* ed by H. J. Frith and J. H. Calaby. CSIRO Division of Wildlife Research Technical paper no. 28.

COGGER, H., CAMERON, E., SADLIER, R. AND EGGLER, P., 1993. *The action plan for Australian reptiles.* Australian Nature Conservation Agency: Canberra.

COOK, G. D., 1993. Control of *Mimosa pigra* at Oenpelli: report of the research and monitoring programme, November 1991 to August 1993. Report to the steering committee of the programme to control *Mimosa* on Aboriginal lands in the Northern Territory by chemical and mechanical methods. CSIRO: Darwin.

COVACEVICH, J., COUPER, P., MOLNAR, R. E., WITTEN, G. AND YOUNG, W., 1990. Miocene dragons from Riversleigh: new data on the history of the family Agamidae (Reptilia: Squamata) in Australia. *Mem. Qld Mus.* **29:** 339–60.

COWIE, I. D. AND WERNER, P. A., 1993. Alien plant species invasive in Kakadu National Park, tropical northern Australia. *Biol. Cons.* **63:** 127–35.

CRACRAFT, J., 1991. Patterns of diversification within continental biotas: hierarchical congruence among the areas of endemism of Australian vertebrates. *Aust. Syst. Bot.* **4:** 211–27.

CSIRO DIVISION OF WILDLIFE RESEARCH, 1976. A survey of the fauna of the lower McArthur River region, Northern Territory. CSIRO: Canberra.

DAMES AND MOORE, 1988. Coronation Hill gold, platinum, palladium project. Draft Environmental Impact Statement. Dames and Moore: Darwin.

DAVIS, G. AND HEARD, D., 1993. Legislation in relation to herpetofauna in the Northern Territory. In *Herpetology in Australia: a diverse discipline* ed by D. Lunney and D. Ayers. Royal Zoological Society of NSW: Mosman.

DAVIS, S., 1981. Dictionary by domains. Natural species. Gupapuyngu language. Northern Territory University Planning Authority: Darwin.

DAVIS, S., 1989. *Man of all seasons.* Angus and Robertson: Sydney.

DELVINQUIER, B. L. J. AND FREELAND, W. J., 1988. Protozoan parasites of the Cane Toad, *Bufo marinus*, in Australia. *Aust. J. Zool.* **36:** 301–16.

DELVINQUIER, B. L. J. AND FREELAND, W. J., 1988. On some trypanosomes of the Australian Anura. *Proc. Roy. Soc. Qld* **100:** 79–87.

DRYDEN, G., GREEN, B., KING, D. AND LOSOS, J., 1990. Water and energy turnover in a small monitor lizard, *Varanus acanthurus*. *Aust. Wildl. Res.* **17:** 641–46.

DUPE, K. V., 1980. The Pitted-shelled Turtle *Carettochelys insculpta* in the Northern Territory. *NT Nat.* **3:** 14.

EHMANN, H., 1981. The natural history and conservation of the bronzeback (*Ophidiocephalus taeniatus* Lucas and Frost) (Lacertilia, Pygopodidae). Pp. 7–13 in *Proceedings of the Melbourne Herpetological Symposium, 1980* ed by C. B. Banks and A. A. Martin. Zoological Board of Victoria: Melbourne.

EHMANN, H. F. W., 1992. The apparent severe decline of the Bronzeback Legless Lizard *(Ophidiocephalus taeniatus)* at Abminga. *Herpetofauna* **22:** 31–33.

EHMANN, H. AND METCALFE, D., 1978. The rediscovery of *Ophidiocephalus taeniatus* Lucas and Frost (Pygopodidae, Lacertilia) — the Bronzeback. *Herpetofauna* **9:** 8–10.

FENSHAM, R. J. AND WOINARSKI, J. C. Z., 1992. Yawulama: the ecology and conservation of monsoon forest on the Tiwi Islands, Northern Territory. Conservation Commission of the Northern Territory: Darwin.

FINLAYSON, C. M., BAILEY, B. J., FREELAND, W. J. AND FLEMING, M. R., 1988. Wetlands of the Northern Territory. Pp. 103–26 in *The conservation of Australian wetlands* ed by A. J. McComb and P. S. Lake. Surrey Beatty and Sons: Sydney.

FLANNERY, T. F., 1990. Pleistocene faunal loss: implications of the aftershock for Australia's past and future. *Arch. Ocean.* **25:** 45–55.

FLEMING, M. R., JOHNSON, K. A., LATZ, P. K. AND MCKEAN, J. R., 1983. A biological survey of Junction Stock Reserve and Newcastle Waters pastoral lease on the Barkly Tablelands. Conservation Commission of the Northern Territory: Alice Springs.

FREELAND, W. J., 1984. Cane Toads: a review of their biology and impact on Australia. Technical report no. 19. Conservation Commission of the Northern Territory: Darwin.

FREELAND, W. J., 1986. Populations of Cane Toad, *Bufo marinus,* in relation to time since colonization. *Aust. Wildl. Res.* **13:** 321–29.

FREELAND, W. J., 1990. Effects of the Cane Toad *Bufo marinus* on native Australian wildlife: a review of past and current research. Unpublished report. Conservation Commission of the Northern Territory: Darwin.

FREELAND, W. J. AND KERIN, S. H., 1988. Within-habitat relationships between invading *Bufo marinus* and Australian species of frog during the tropical dry season. *Aust. Wildl. Res.* **15:** 293–305.

FREELAND, W. J. AND KERIN, S. H., 1991. Ontogenetic alteration of activity and habitat selection by *Bufo marinus*. *Wildl. Res.* **18:** 431–44.

FREELAND, W. J. AND MARTIN, K. C. 1985. The rate of range expansion by *Bufo marinus* in northern Australia, 1980–84. *Aust. Wildl. Res.* **12:** 555–59.

FREELAND, W. J., WINTER, J. W. AND RASKIN, S., 1988. Australian rock-mammals: a phenomenon of the seasonally dry tropics. *Biotropica* **20:** 70–79.

FRIEND, G. R., 1984. Relative efficiency of two pitfall-drift fence systems for sampling small vertebrates. *Aust. Zool.* **21:** 423–33.

FRIEND, G. R. AND CELLIER, K. M., 1990. Wetland herpetofauna of Kakadu National Park, Australia: seasonal richness trends, habitat preferences and the effects of ungulates. *J. Trop. Ecol.* **6:** 131–52.

FRIEND, G. R. AND TAYLOR, J. A., 1984. Ground surface features attributable to feral buffalo, *Bubalus bubalis* II. Their relationship to the abundance of small animal species. *Aust. Wildl. Res.* **11:** 311–23.

FYFE, G., 1980. The effect of fire on lizard communities in central Australia. *Herpetofauna* **12:** 1–9.

FYFE, G., 1981a. Range extension for *Hemidactylus frenatus, the* Asian House Gecko. *Herpetofauna* **13:** 33.

FYFE, G., 1981b. Nocturnal sightings of two dragon species. *Herpetofauna* **13:** 34.

FYFE, G., 1985a. Some notes on sympatry between *Tiliqua occipitalis* and *Tiliqua multifasciata* in the Ayers Rock region and their association with Aboriginal people of the area. *Herpetofauna* **15:** 18–19.

FYFE, G., 1985b. A comparison of the ground-dwelling vertebrate faunas found in hummock grassland and mulga shrubland in central Australia. *Herpetofauna* **16:** 49–52.

GAMBOLD, N. J. AND MENKHORST, K. A., 1992a. Katherine Region heritage study: significant natural features and the impact of tourism. Report to the Australian Heritage Commission from the Environment Centre of the Northern Territory Inc.

GAMBOLD, N. J. AND MENKHORST, K. A., 1992b. Terrestrial vertebrate fauna of the MIM McArthur River mine project area. Consultants report to MIM Ltd.

GAMBOLD, N. AND WOINARSKI, J. C. Z., 1993. Distribution patterns of herpetofauna in monsoon rainforests of the Northern Territory, Australia. *Aust. J. Ecol.* **18:**

GEORGES, A., 1988. The Warradjan *Carettochelys insculpta* — a literature review and annotated bibliography. Report to ANPWS, February 1988.

GEORGES, A., 1990. The Pig-nosed Turtle in Kakadu National Park — a submission to the Kakadu Conservation Zone Inquiry. Resource Assessment Commission, August, 1990.

GEORGES, A., 1992. Thermal characteristics and sex determination in field nests of the pig-nosed turtle *Carettochelys insculpta* (Chelonia: Carettochelydidae) from northern Australia. *Aust. J. Zool.* **40:** 511–21.

GEORGES, A. AND ADAMS, M., 1992. A phylogeny for Australian chelid turtles based on allozyme electrophoresis. *Aust. J. Zool.* **40:** 453–76.

GEORGES, A. AND KENNETT, R. M., 1989. Dry-season distribution and ecology of *Carettochelys insculpta* (Chelonia: Carettochelydidae) in Kakadu National Park, northern Australia. *Aust. Wildl. Res.* **16:** 323–35.

GEORGES, A. AND ROSE, M., 1994. *Carettochelys insculpta* Ramsay 1886, Pig-nosed Turtle. In *The conservation biology of freshwater turtles* ed by P. H. Pritchard and A. Rhodin. IUCN/SSC: Gland.

GEORGES, A. AND ROSE, M., 1993. The conservation biology of the pig-nosed turtle *Carettochelys insculpta. Chelonian Biol.* **1**

GEORGES, A., CHOQUENOT, D., COVENTRY, A. J. AND WELLINGS, P., 1989. A note on *Carettochelys insculpta* (Testudinata: Carettochelydidae) from northern Australia. *NT Nat.* **11:** 11.

GIBSON, D. F., 1986. A biological survey of the Tanami Desert in the Northern Territory. Technical report no. 30. Conservation Commission of the Northern Territory: Alice Springs.

GIBSON, D. F. AND COLE, J. R., 1988. A biological survey of the northern Simpson Desert in the Northern Territory. Technical report no. 40. Conservation Commission of the Northern Territory: Alice Springs.

GIBSON, D. F., KUBE, P. D, GINNS, A. J., COLE, J. R., AND PARSONS, D. J., 1989. A resource survey of the Dulcie Range, Northern Territory. Technical report. Conservation Commission of the Northern Territory: Alice Springs.

GIBSON, D. F., THOMPSON, B. G., COLEMAN, M. N., COLE, J. R., GINNS, A. J. AND SOOS, A., 1992. A resource survey of northern Loves Creek pastoral lease and Ruby Gap Nature Park, Northern Territory. Technical report no. 53. Conservation Commission of the Northern Territory: Alice Springs.

GILLAM, M. W., 1979a. The genus *Pseudonaja* (Serpentes: Elapidae) in the Northern Territory. Territory Parks and Wildlife Commission Res. Bull. **1:** 1–28.

GILLAM, M. W., 1979b. Notes on the status of the 'blind' snake *Typhlina tovelli* (Loveridge). *Herpetofauna* **11:** 2–4.

GILLAM, M. W. AND WILLIAMS, O. J., 1984. The Curl Snake *Denisonia suta* (Peters) — a dangerous elapid in the Northern Territory. *NT Nat.* **7:** 12–17.

GILLAM, M. W., CAWOOD, I. S. AND HONNER, G. J. 1978. New reptile records from central Australia, Northern Territory. *Herpetofauna* **9:** 18–25.

GOW, G. F., 1977. A new species of python from Arnhem Land. *Aust. Zool.* **19:** 133–41.

GOW, G., 1979. Notes on the biology of *Nephrurus asper. NT Nat.* **1:** 19–20.

GOW, G. F., 1980. History of the Taipan *Oxyuranus scutellatus* — with two new distribution records. *NT Nat.* **3:** 15–19.

GOW, G., 1981a. Checklist of reptiles and amphibians in the southern sector of the Northern Territory. *NT Nat.* **4:** 14–16.

GOW, G., 1981b. Checklist of reptiles and amphibians in the northern sector of the Northern Territory. *NT Nat.* **4:** 16–19.

GOW, G., 1981c. Herpetofauna of Groote Eylandt, Northern Territory. *Aust. J. Herpetol.* **1:** 62–70.

GOW, G. F., 1981d. A new species of Python from central Australia. *Aust. J. Herpetol.* **1:** 29–34.

GOW, G., 1981e. Notes on the Desert Death Adder, (*Acanthophis pyrrhus* Boulenger, 1898), with the first reproductive record. *NT Nat.* **4:** 21–22.

GOW, G. F., 1982. Notes on the reproductive biology of the Pygmy Mulga Goanna *Varanus gilleni* Lucas and Frost, 1895. *NT Nat.* **5:** 4–5.

GREER, A. E., 1980. A new species of *Morethia* (Lacertilia: Scincidae) from northern Australia, with comments on the biology and relationships of the genus. *Rec. Aust. Mus.* **33:** 89–122.

GREER, A. E., 1983. A new species of *Lerista* from Groote Eylandt and the Sir Edward Pellew group in northern Australia. *J. Herpetol.* **17:** 48–53.

GREER, A. E., 1990. The taxonomic status of *Lerista aericeps* Storr 1986 with a diagnosis of the *Lerista orientalis* species group. *Rec. WA Mus.* **14:** 443–48.

GRIFFIN, G. F. AND FRIEDEL, M. H., 1985. Discontinuous change in central Australia: some implications of major ecological events for land management. *J. Arid Environ.* **9:** 63–80.

GUINEA, M., 1990. Notes on sea turtle rookeries on the Arafura Sea islands of Arnhem Land, Northern Territory. *NT Nat.* **12:** 4–12.

GUINEA, M., 1992. The yellow-bellied sea-snake in the waters of the Northern Territory. *NT Nat.* **13:** 37–39.

GUINEA, M., 1993a. Sea turtles of the Northern Territory. In *Proceedings of the Australian marine turtle conservation workshop. November 14–17, 1990. Gold Coast, Australia* ed by C. J. Limpus and R. Jenkins.

GUINEA, M., 1993b. Nesting seasonality of the flatback sea turtle *Natator depressus* (Garman) at Fogg Bay, Northern Territory. In *Proceedings of the Australian marine turtle conservation workshop. November 14–17, 1990. Gold Coast, Australia* ed by C. J. Limpus and R. Jenkins.

GUINEA, M., 1993c. A possible model to explain winter nesting by the flatback *Natator depressus* at Fogg Bay, Northern Territory. In *Proceedings of the Australian marine turtle conservation workshop. November 14–17, 1990. Gold Coast, Australia* ed by C. J. Limpus and R. Jenkins.

GUINEA, M. AND CHATTO, R., 1993. Sea turtles killed in Australian shark fin fishery. *Marine Turtle Newsl.* **57:** 5–6.

GUINEA, M. AND RYAN, P., 1990. Observations on sea turtles and birds on Bare Sand Island. *NT Nat.* **12:** 26–27.

GUINEA, M., RYAN, P., UMBACK, L. AND HILLS, L., 1991. Nesting seasonality of the flatback turtle at Bare Sand Island, Northern Territory, Australia. *Marine Turtle Newsl.* **52:** 4–5.

GUINEA, M., MCMORROW, L., SRIPRAKASH, K. S, AND PEERZADA, N., 1992. Yield and molecular weight of the Duvernoy's gland secretions of the dog-faced mud snake *Cerberus rhynchops* (Serpentes Colubridae; Homalopsinae). Pp. 386–96 in *Recent advances in toxinology research. Volume 1* ed by P. Gopalakrishnakone and C. K. Tan. NUS: Singapore.

HEAPHY, L. J., 1990. The ecology of the pig nosed turtle, *Carettochelys insculpta,* in northern Australia. Ph.D. thesis. University of New South Wales.

HENLE, K., 1991. Life history patterns in lizards of the arid and semiarid zone of Australia. *Oecologia* **88:** 347–58.

HISCOCK, P. AND KERSHAW, A. P., 1992. Palaeoenvironments and prehistory of Australia's tropical Top End. Pp. 43–75 in *The naive lands: prehistory and environmental change in Australia and the south-west Pacific* ed by J. Dodson. Longman Cheshire: Melbourne.

HORNER, P. G., 1984. Notes on the scincid lizard *Cryptoblepharus litoralis* (Mertens, 1958) in the Northern Territory. *NT Nat.* **7:** 4–7.

HORNER, P., 1991. *Skinks of the Northern Territory.* Northern Territory Museum of Arts and Sciences: Darwin.

HORNER, P. AND KING, M., 1985. A new species of *Ctenotus* (Scincidae: Reptilia) from the Northern Territory. *The Beagle* **2:** 143–48.

HOUSTON, D. L. AND SHINE, R., 1993a. Sexual dimorphism and niche divergence: feeding habits of the Arafura filesnake. *J. Anim. Ecol.*

HOUSTON, D. L. AND SHINE, R., 1993b. Slow growth rates and delayed maturation in Arafura filesnakes (Serpentes: Acrochordidae) in tropical Australia. *Copeia.*

HUSBAND, G. A., 1980. A note on egglaying by *Hemidactylus frenatus* (House Gecko) in Darwin. *Herpetofauna* **12:** 36.

HUMPHRIES, S., GROVES, R. H. AND MITCHELL, D. S., 1992. Plant invasions: the incidence of environmental weeds in Australia. *Kowari* **2.**

HUTCHINSON, M. H., 1992. Origins of the Australian scincid lizards: a preliminary report on the skinks of Riversleigh. *The Beagle* **9:** 61–70.

INGRAM, G., 1987. Does the skink *Mabuya multifasciata* occur in Australia? *NT Nat.* **10:** 11–12.

INGRAM, G. AND COVACEVICH, J., 1989. Revision of the genus *Carlia* (Reptilia, Scincidae) in Australia with comments on *Carlia bicarinata* of New Guinea. *Mem. Qld Mus.* **27:** 443–90.

JACKLYN, P., 1992. *The status of Cane Toads in the Northern Territory.* Environment Centre of the Northern Territory: Darwin.

JAMES, C. D., 1983. Reproduction in lizards from the wet-dry tropics of Australia. B.Sc. (Hons.) thesis. University of Sydney.

JAMES, C. D., 1991a. Population dynamics, demography, and life history of sympatric scincid lizards *(Ctenotus)* in central Australia. *Herpetologica* **47:** 194–210.

JAMES, C. D., 1991b. Annual variations in reproductive cycles of scincid lizards *(Ctenotus)* in central Australia. *Copeia* **1991:** 742–58.

JAMES, C. D., 1991c. Growth rates and ages at maturity of sympatric scincid lizards *(Ctenotus)* in central Australia. *J. Herpetol.* **25:** 284–95.

JAMES, C. D., 1991d. Temporal variation in diets and trophic partitioning by coexisting lizards *(Ctenotus)* in central Australia. *Oecologia* **85:** 225–48.

JAMES, C. D. AND LOSOS, J. B., 1991. Diet and reproductive biology of the Australian sand-swimming lizards, *Eremiascincus* (Scincidae). *Wildl. Res.* **18:** 641–54.

JAMES, C. D. AND SHINE, R., 1985. The seasonal timing of reproduction: a tropical-temperate comparison in Australian lizards. *Oecologia* **67:** 464–74.

JAMES, C. D. AND SHINE, R., 1988. Life-history strategies of Australian lizards: a comparison between the tropics and the temperate zone. *Oecologia* **75:** 307–16.

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 Technical Memorandum 6. Australian Government Publishing Sevice: Canberra.

JOHNSON, K. A. AND FLEMING, M. R., 1984. A biological records scheme for the Northern Territory. Pp. 206–12 in *Survey methods for nature conservation* ed by K. Myers, C. R. Margules and I. Musto. CSIRO Division of Water and Land Resources: Canberra.

JOHNSON, K. A. AND KERLE, J. A., 1991. Flora and vertebrate fauna of the Sir Edward Pellew Group of islands, Northern Territory. Conservation Commission of the Northern Territory: Alice Springs.

JOHNSON, K. A., LATZ, P. K. AND FLEMING, M. R., 1982. A biological survey of Connell's Lagoon Stock Reserve in the Barkly Tablelands. Technical Report. Conservation Commission of the Northern Territory: Alice Springs.

JOHNSON, K. A., LATZ, P. K. AND FLEMING, M. R., 1984. A resource survey of the Davenport and Murchison Ranges in the Tennant Creek district. Technical Report. Conservation Commission of the Northern Territory: Alice Springs.

KENDRICK, P. G. AND ROLFE, J. K., 1991. The reptiles and amphibians of Kimberley rainforests. Pp. 347–59 in *Kimberley rainforests of Australia* ed by N. L. McKenzie, R. B. Johnston and P. G. Kendrick. Surrey Beatty & Sons: Sydney.

KENNETT, R. M., 1992. A new trap design for catching freshwater turtles. *Wildl. Res.* **19:** 443–45.

KENNETT, R. M., 1993. Population ecology and Aboriginal use of the Northern Long-necked Turtle *(Chelodina rugosa)* and the Northern Snapping Turtle *(Elseya dentata).* PhD thesis. Northern Territory University.

KENNETT, R. M. AND GEORGES, A., 1989. Turtles of the Top End. *NT Nat.* **11:** 11.

KENNETT, R. AND RUSSELL-SMITH, J., 1993. Seed dispersal by freshwater turtles in northern Australia. Pp. 69–70 in *Herpetology in Australia* ed by D. Lunney and D. Ayers. Royal Zoological Society of New South Wales: Mosman.

KENNETT, R. M., GEORGES, A. AND PALMER-ALLEN, M., 1993a. Early developmental arrest during immersion of eggs of a tropical chelid turtle, *Chelodina rugosa* (Testudinata: Chelidae), from northern Australia. *Aust. J. Zool.* **41:** 37–45.

KENNETT, R. M., CHRISTIAN, K. AND PRITCHARD, D., 1993b. Underwater nesting by the tropical freshwater turtle, *Chelodina rugosa* (Testudinata: Chelidae), from northern Australia. *Aust. J. Zool.* **41:** 47–52.

KENNETT, R. M., GEORGES, A., THOMAS, K. AND GEORGES, T. C., 1992. Distribution of the long-necked freshwater turtle *Chelodina novaeguinea* and new information on its ecology. *Mem. Qld Mus.* **32:** 179–82.

KING, M., 1979. Karyotypic evolution in *Gehyra* (Gekkonidae: Reptilia) I. The *Gehyra variegata-punctata* complex. *Aust. J. Zool.* **27:** 373–93.

KING, M., 1981. Notes on the distribution of *Gehyra nana* Storr and *Gehyra punctata* (Fry) in Australia. *Aust. J. Herpetol.* **1:** 55–56.

KING, M., 1982a. Karyotypic evolution in *Gehyra* (Gekkonidae: Reptilia) II. A new species from the Alligator Rivers Region in northern Australia. *Aust. J. Zool.* **30:** 93–101.

KING, M., 1982b. A new species of *Gehyra* (Reptilia: Gekkonidae) from Central Australia. *Trans. Roy. Soc. SA* **106:** 155–58.

KING, M., 1983a. Karyotypic evolution in *Gehyra* (Gekkonidae: Reptilia) III. The *Gehyra australis* complex. *Aust. J. Zool.* **31:** 723–41.

KING, M., 1983b. The *Gehyra australis* species complex (Sauria: Gekkonidae). *Amphibia-Reptilia* **4:** 147–69.

KING, M. AND GOW, G., 1983. A new species of *Oedura* (Gekkonidae: Reptilia) from the Alligator Rivers Region of northern Australia. *Copeia* **1983:** 445–49.

KING, M. AND HORNER, P., 1987a. A new species of monitor (Platynota: Reptilia) from northern Australia and a note on the status of *Varanus acanthurus insulanicus* Mertens. *The Beagle* **4:** 73–79.

KING, M. AND HORNER, P., 1987b. An additional freshwater turtle species and the confirmation of *Chelodina novaeguineae* in the Northern Territory, Australia. *The Beagle* **4:** 83–84.

KING, M., TYLER, M. J., DAVIES, M. AND KING, D., 1979. Karyotypic studies on *Cyclorana* and associated genera of Australian frogs. *Aust. J. Zool.* **27:** 699–708.

KING, M., BRAITHWAITE, R. W. AND WOMBEY, J. C. 1982. A new species of *Diplodactylus* (Reptilia: Gekkonidae) from the Alligator Rivers region, Northern Territory. *Trans. Roy. Soc. SA* **106:** 5–18.

KING, M., HORNER, P. AND FYFE, G., 1988. A new species of *Ctenotus* (Reptilia: Scincidae) from central Australia, and a key to the *Ctenotus leonhardii* species group. *The Beagle* **5:** 147–53.

LATZ, P. K., JOHNSON, K. A. AND GILLAM, M. W., 1971. A biological survey of the King's Canyon area of the George Gill Range. Technical report. Conservation Commission of the Northern Territory: Alice Springs.

LEGLER, J., 1976. Feeding habits of some Australian short-necked tortoises. *Vic. Nat.* **93:** 40–43.

LEGLER, J. M., 1980. *Taxonomy, distribution, and ecology of freshwater turtles in the Alligator Rivers Region, Northern Territory.* Report to the Office of the Supervising Scientist: Sydney.

LEWIS, D., 1986. 'The dreamtime animals': a reply. *Arch. Oceania* **21:** 140–45.

LIMPUS, C. J. AND REED, P. C., 1985. Green sea turtles stranded by Cyclone Kathy on the south-western coast of the Gulf of Carpentaria. *Aust. Wildl. Res.* **12:** 523–33.

LONGMORE, R., (ed) 1986. Atlas of elapid snakes of Australia. *Australian Flora and Fauna Series no. 7.*

LONSDALE, W. M., 1993. Rates of spread of an invading species — *Mimosa pigra* in northern Australia. *J. Ecol.* **81:** 513–21.

LOVERIDGE, A., 1949. On some reptiles and amphibians from the Northern Territory. *Trans. Roy. Soc. SA* **72:** 208–15.

LUCAS, A. H. S. AND FROST, C., 1896. Reptilia. Pp. 112–51 in *Report on the work of the Horn scientific expedition to central Australia. Part II — Zoology* ed by B. Spencer. Melville, Mullen and Slade: Melbourne.

MARSH, H., FREELAND, W. J., LIMPUS, C. J. AND REED, P. C., 1988. The stranding of dugongs and sea turtles resulting from Cyclone Kathy, March 1984: a report on the rescue effort and the biological data obtained. Technical Report no. 25. Conservation Commission of the Northern Territory: Darwin.

MARTIN, K. (1975). Reptiles of the Alice Springs area. *Herpetofauna* **7:** 6–7.

MARTIN, K. C. AND FREELAND, W. J., 1988. Herpetofauna of a northern Australian monsoon rain forest: seasonal changes and relationship to adjacent habitats. *J. Trop. Ecol.* **4:** 227–38.

MARTIN, K. C. AND GOODFELLOW, D., 1989. The vertebrate fauna of a part of Mount Bundey Station (PL 933) proposed army Mount Bundey training area. Report to Kinhill Engineers: Darwin.

MASTERS, P., 1991. Fire-driven succession: the effects on lizards and small mammals in spinifex grasslands. M.Ap.Sc. thesis. Curtin University of Technology: Perth.

MCKENZIE, N. L., BELBIN, L., KEIGHERY, G. J. AND KENNEALLY, K. F., 1991. Kimberley rainforest communities: patterns of species composition and Holocene biogeography. Pp. 423–51. in *Kimberley rainforests of Australia* ed by N. L. McKenzie, R. B. Johnston and P. G. Kendrick. Surrey Beatty & Sons: Sydney.

MEGIRIAN, D., 1989. A description of Horned-Turtle remains (Testudines: Meiolaniidae) from the mid-Miocene Camfield beds of northern Australia. *The Beagle* **6:** 105–14.

MEGIRIAN, D., MURRAY, P. F. AND WILLIS, P., 1991. A new crocodile of the gavial ecomorph morphology from the Miocene of the Northern Territory. *The Beagle* **8:** 135–58.

MESSEL, H. AND VORLICEK, G. C., 1986. Population dynamics and status of *Crocodylus porosus* in the tidal waterways of northern Australia. *Aust. Wildl. Res.* **13:** 71–111.

MITCHELL, F. J., 1955. Preliminary account of the Reptilia and Amphibia collected by the National Geographic Society — Commonwealth Government — Smithsonian Institution Expedition to Arnhem Land (April to November 1948). *Rec. SA Mus.* **11:** 373–408.

MITCHELL, F. J., 1964. Reptiles and amphibians of Arnhem Land. Pp. 309–44 in *Records of the American-Australian scientific expedition to Arnhem Land. 4. Zoology* ed by R. L. Specht. Melbourne University Press: Melbourne.

MOFFATT, I., 1991. Possible ecological impacts of the greenhouse effect on the Northern Territory, Australia. *Global Ecol. Biogeog. Let.* **1:** 102–07.

MORTON, S. R., 1990. The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. *Proc. Ecol. Soc. Aust.* **16:** 201–13.

MORTON, S. R. AND JAMES, C. D., 1988. The diversity and abundance of lizards in arid Australia: a new hypothesis. *Amer. Natur.* **132:** 237–56.

MORTON, S. R., GILLAM, M. W., JONES, K. R. AND FLEMING, M. R., 1988. Relative efficiency of different pit-trap systems for sampling reptiles in spinifex grasslands. *Aust. Wildl. Res.* **15:** 571–77.

MORTON, S. R., MASTERS, P. AND HOBBS, T. J., 1993. Estimates of abundance of burrowing frogs in spinifex grasslands of the Tanami Desert, Northern Territory. *The Beagle* **10:** 67–70.

MURRAY, P. F., 1985. Ichthyosaurs from Cretaceous Mullaman beds near Darwin, Northern Territory. *The Beagle* **2:** 39–56.

MURRAY, P. F., 1987. Plesiosaurs from Albian aged Bathurst Island formation siltstones near Darwin, Northern Territory, Australia. *The Beagle* **4:** 95–102.

MURRAY, P. AND MEGIRIAN, D., 1992. Continuity and contrast in middle and late Miocene vertebrate communities from the Northern Territory. *The Beagle* **9:** 195–218.

NIX, H. A. AND KALMA, J. D., 1972. Climate as a dominant control in the biogeography of northern Australia and New Guinea. Pp. 61–91 in *Bridge and barrier: the natural and cultural history of Torres Strait* ed by D. Walker. ANU Press: Canberra.

NSR ENVIRONMENTAL CONSULTANTS PTY LTD, 1992. Mt Todd Gold Project. Draft Environmental Impact Statement. NSR: Melbourne.

PENGILLEY, R., 1981. Notes on the biology of *Varanus spenceri* and *V. gouldii*, Barkly Tablelands, Northern Territory. *Aust. J. Herpetol.* **1:** 23–26.

PENGILLEY, R., 1982. Note on the reproductive biology of the Ring-tailed Dragon *(Chelosania brunnea). NT Nat.* **5:** 6.

PIANKA, E. R., 1972. Zoogeography and speciation of Australian desert lizards. An ecological perspective. *Copeia* **1972:** 127–44.

PIANKA, E. R., 1986. Ecology and natural history of desert lizards. Princeton University Press: Princeton.

PIANKA, E. R. AND PIANKA, H. D., 1976. Comparative ecology of twelve species of nocturnal lizards (Gekkonidae) in the Western Australian desert. *Copeia* **1976:** 125–42.

PIANKA, E. R. AND SCHALL, J. J., 1981. Species densities of Australian vertebrates. Pp. 1676–94 in *Ecological biogeography of Australia* ed by A. Keast. W. Junk: The Hague.

RANKIN, P. R., 1978. A new species of lizard (Lacertilia: Scincidae) from the Northern Territory, closely allied to *Ctenotus decaneurus* Storr. *Rec. Aust. Mus.* **31:** 395–407.

RANKIN, P. R., 1979. A taxonomic revision of the genus *Menetia* (Lacertilia: Scincidae) in the Northern Territory. *Rec. Aust. Mus.* **32:** 491–99.

RANKIN, P. R. AND GILLAM, M. W., 1979. A new lizard in the genus *Ctenotus* (Lacertilia: Scincidae) from the Northern Territory with notes on its biology. *Rec. Aust. Mus.* **32:** 501–11.

RANKIN, P., HORNER, P. AND KING, M., 1987. An additional Varanid species in the Northern Territory. *The Beagle* **4:** 81–82.

REID, J., BAKER, L., MORTON, S. R. AND MUTITJULU COMMUNITY, 1992. Traditional knowledge + ecological survey = better land management. *Search* **23:** 249–51.

REID, J. R. W., KERLE, J. A. AND MORTON, S. R., 1993. Uluru fauna. The distribution and abundance of vertebrate fauna of Uluru (Ayers Rock–Mount Olga) National Park, Northern Territory. *Kowari* **4:** 1–152.

RIDPATH, M., 1977. Predation on frogs and small birds by *Hierodula werneri* (Giglio-Tos) (Mantidae) in tropical Australia. *J. Aust. Entomol. Soc.* **16:** 153–54.

ROSS, A., DONNELLY, T. AND WASSON, R., 1992. The peopling of the arid zone: human–environment interactions. Pp. 76–114 in *The naive lands: prehistory and environmental change in Australia and the south-west Pacific* ed by J. Dodson. Longman Cheshire: Melbourne.

RUSSELL-SMITH, J. AND BOWMAN, D. M. J. S., 1992. Conservation of monsoon rainforest isolates in the Northern Territory, Australia. Biological Conservation **59:** 51–63.

SADLIER, R., 1984. A new Australian scincid lizard, *Menetia concinna*, from the Alligator Rivers Region of the Northern Territory. *Rec. Aust. Mus.* **36:** 45–49.

SADLIER, R., 1985. A new Australian scincid lizard, *Ctenotus coggeri*, from the Alligator Rivers Region of the Northern Territory. *Rec. Aust. Mus.* **36:** 153–56.

SADLIER, R. A., 1990. The terrestrial and semiaquatic reptiles (Lacertilia, Serpentes) of the Magela Creek region, Northern Territory. Supervising Scientist for the Alligator Rivers Region Technical Memorandum 32. Australian Government Publishing Sevice: Canberra.

SADLIER, R., WOMBEY, J. C. AND BRAITHWAITE, R. W., 1985. *Ctenotus kurnbudj* and *Ctenotus gagudju*, two new lizards (Scincidae) from the Alligator Rivers Region of the Northern Territory. *The Beagle* **2:** 95–103.

SCANLON, J. D., 1992. A new large madstoiid snake from the Miocene of the Northern Territory. *The Beagle* **9:** 49–60.

SCHODDE, R., MASON, I. AND WILFE, T. O., 1972. Further records of the pitted-shelled turtle *(Carettochelys insculpta)* from Australia. *Trans. Roy. Soc. SA* **96:** 115–17.

SCHULZ, M. AND MENKHORST, K. A., 1984. Fauna. In *Pine Creek Gold Mine.* Draft Environmental Impact Statement. Kinhill Stearn: Darwin.

SHEA, G. M., 1991. Revisionary notes on the genus *Delma* (Squamata: Pygopodidae) in South Australia and the Northern Territory. *Rec. SA Mus.* **25:** 71–90.

SHINE, R., 1980. Reproduction, feeding and growth in the Australian burrowing snake *Vermicella annulata. J. Herpetol.* **14:** 71–77.

SHINE, R., 1981. Ecology of Australian elapid snakes of the genera *Furina* and *Glyphodon. J. Herpetol.* **15:** 219–24.

SHINE, R., 1983. Food habits and reproductive biology of Australian elapid snakes of the genus *Denisonia. J. Herpetol.* **17:** 171–75.

SHINE, R., 1986a. Diet and abundances of aquatic and semi-aquatic reptiles in the Alligator Rivers Region. Supervising Scientist for the Alligator Rivers Region Technical Memorandum 16. Australian Government Publishing Sevice: Canberra.

SHINE, R., 1986b. Predation upon filesnakes *(Acrochordus arafurae)* by aboriginal hunters: selectivity with respect to size, sex, and reproductive condition. *Copeia* **1986:** 238–39.

SHINE, R., 1986c. Ecology of a low-energy specialist: food habits and reproductive biology of the Arafura filesnake (Acrochordidae). *Copeia* **1986:** 424–37.

SHINE, R., 1986d. Sexual differences in morphology and niche utilization in an aquatic snake, *Acrochordus arafurae. Oecologia* **69:** 260–67.

SHINE, R., 1986e. Food habits, habitats and reproductive biology of four sympatric species of varanid lizards in tropical Australia. *Herpetologica* **42:** 346–60.

SHINE, R. 1990. Function and evolution of the frill of the frillneck lizard, *Chlamydosaurus kingii* (Sauria: Agamidae). *Biol. J. Linn. Soc.* **40:** 11–20.

SHINE, R., 1991. *Australian snakes: a natural history.* Reed: Sydney.

SHINE, R. AND COVACEVICH, J., 1983. Ecology of highly venomous snakes: the Australian genus *Oxyuranus* (Elapidae). *J. Herpetol.* **17:** 60–69.

SHINE, R. AND LAMBECK, R., 1985. A radiotelemetric study of movements, thermoregulation and habitat utilization of Arafura filesnakes (Serpentes, Acrochordidae). *Herpetologica* **41:** 351–61.

SHINE, R. AND LAMBECK, R., 1989. Ecology of frillneck lizards *Chlamydosaurus kingii* (Agamidae) in tropical Australia. *Aust. Wildl. Res.* **16:** 491–500.

SHINE, R. AND WEBB, J. K., 1990. Natural history of Australian Typhlopid snakes. *J. Herpetol.* **24:** 357–63.

SMITH, A. M. A. AND WOOD, T. C., 1985. A nest and hatchlings of *Emydura victoriae* (Gray 1842). *NT Nat.* **8:** 3–4.

SMITH, M. J. AND PLANE, M., 1985. Pythonine snakes (Boidae) from the Miocene of Australia. Bureau Min. Res. J. Aust. Geol. Geophy. **9:** 191–95.

SPECHT, M. M., 1964. The history of zoological collections made in and on the shores of the Arnhem Land Aboriginal Reserve. Pp. 1–8 in *Records of the American-Australian scientific expedition to Arnhem Land. 4. Zoology* ed by R. L. Specht. Melbourne University Press: Melbourne.

STAFFORD SMITH, D. M. AND MORTON, S. R., 1990. A framework for the ecology of arid Australia. *J. Arid Environ.* **18:** 255–78.

STONE, D. J. M., WAUGH, R. J., BOWIE, J. H., WALLACE, J. L. AND TYLER, M. J., 1993. Peptides from Australian frogs. The structure of the caerins from *Litoria caerulea*. *J. Chem. Res.* **1993:** 138.

STORR, G. M., 1966. Rediscovery and taxonomic status of the Australian lizard, *Varanus primordius*. *Copeia* **1966:** 583–84.

STORR, G. M., 1967. The genus *Sphenomorphus* (Lacertilia: Scincidae) in Western Australia and the Northern Territory. *J. Roy. Soc. WA* **50:** 10–20.

STORR, G. M., 1968a. The genus *Vermicella* (Serpentes: Elapidae) in Western Australia and the Northern Territory. *J. Roy. Soc. WA* **50:** 80–92.

STORR, G. M., 1968b. First Australian record of the asian blind-snake *Typhlops braminus*. *J. Herpetol.* **1:** 98.

STORR, G. M., 1970. The genus *Ctenotus* (Lacertilia: Scincidae) in the Northern Territory. *J. Roy. Soc. WA* **52:** 7–108.

STORR, G. M., 1974a. Agamid lizards of the genera *Caimanops, Physignathus* and *Diporiphora* in Western Australia and Northern Territory. *Rec. WA Mus.* **3:** 121–46.

STORR, G. M., 1974b. The genus *Carlia* (Lacertilia: Scincidae) in Western Australia and Northern Territory. *Rec. WA Mus.* **3:** 151–65.

STORR, G. M., 1974c. The genus *Notoscincus* (Lacertilia: Scincidae) in Western Australia and the Northern Territory. *Rec. WA Mus.* **3:** 111–14.

STORR, G. M., 1984a. A new *Ramphotyphlops* (Serpentes: Typhlopidae) from central Australia. *Rec. WA Mus.* **11:** 313–14.

STORR, G. M., 1984b. Revision of *Denisonia suta* (Serpentes: Elapidae) and the description of a new species closely related to it. *Rec. WA Mus.* **11:** 249–57.

STORR, G. M., 1986. A new species of *Lerista* (Lacertilia: Scincidae) with two subspecies from central Australia. *Rec. WA Mus.* **13:** 145–49.

STORR, G. M., 1988a. A new species of *Diplodactylus* (Lacertilia: Gekkonidae) from northern Australia. *Rec. WA Mus.* **14:** 183–87.

STORR, G. M., 1988b. Three new *Diplodactylus* (Lacertilia: Gekkonidae) from the arid zone of Australia. *Rec. WA Mus.* **14:** 217–23.

STORR, G. M., 1991a. Revision of *Lerista orientalis* (Lacertilia: Scincidae) of northern Australia. *Rec. WA Mus.* **15:** 413–17.

STORR, G. M., 1991b. Revision of *Lerista aericeps* (Lacertilia: Scincidae) of central Australia. *Rec. WA Mus.* **15:** 365–81.

STRONG, B. W. AND GILLAM, M. W., 1983. A new record for the Northern Territory of the Thick-tailed Gecko *(Underwoodisaurus milii). NT Nat.* **6:** 18–19.

SWANSON, S., 1979. Some rock-dwelling reptiles of the Arnhem Land escarpment. *NT Nat.* **1:** 14–18.

SWANSON, S., 1981. *Typhlina bramina:* an arboreal blind snake? *NT Nat.* **4:** 13.

TRAINOR, C., 1992. Response of lizards to three experimental fire regimes in the savanna forests of Kakadu National Park. B.Sc. (Hons.) thesis, Northern Territory University.

TYLER, M. J., 1968. A taxonomic study of hylid frogs of the *Hyla lesueri* complex occurring in north-western Australia. *Rec. SA Mus.* **15**(4)**:** 711–27.

TYLER, M. J., 1969. A synopsis of the frogs of the genus *Hyla* of north-western Australia, with the description of a new species. *Rec. SA Mus.* **16**(1)**:** 1–11.

TYLER, M. J., 1971. Superficial mandibular musculature, vocal sacs and the phylogeny of Australo-Papuan leptodactylid frogs. *Rec. SA Mus.* **16**(9)**:** 1–20.

TYLER, M. J., 1972. An analysis of the lower vertebrate faunal relationships of Australia and New Guinea. Pp. 231–56 in *Bridge and barrier: the natural and cultural history of Torres Strait* ed by D. Walker. ANU Press: Canberra.

TYLER, M. J., 1990. Geographic distribution of the fossorial hylid frog *Cyclorana platycephala* (Gunther) and the taxonomic status of *C. slevini* Loveridge. *Trans. Roy. Soc. SA* **114:** 81–85.

TYLER, M. J., 1991. Australian fossil frogs. Pp. 591–604 in *Vertebrate palaeontology of Australasia* ed by P. Vickers-Rich, J. M. Monaghan, R. F. Baird and T. H. Rich. Pioneer Design Studio: Melbourne.

TYLER, M. J. AND CROOK, G. A., 1987. Frogs of the Magela Creek system. Supervising Scientist for the Alligator Rivers Region Technical Memorandum 19. Australian Government Publishing Sevice: Canberra.

TYLER, M. J. AND DAVIES, M., 1978. Species groups within the Australo-Papuan hylid frog genus *Litoria Tschudi. Aust. J. Zool. Suppl.* **63:** 1–47.

TYLER, M. J. AND DAVIES, M., 1986. *Frogs of the Northern Territory.* Conservation Commission of the Northern Territory: Darwin.

TYLER, M. J. AND MARTIN, A. A., 1975. Australian leptodactylid frogs of the *Cyclorana australis* complex. *Trans. Roy. Soc. SA* **99:** 93–99.

TYLER, M. J. AND MARTIN, A. A., 1977. Taxonomic studies of some Australian leptodactylid frogs of the genus *Cyclorana* Steindachner. *Rec. SA Mus.* **17**(15)**:** 261–76.

TYLER, M. J., DAVIES, M. AND KING, M., 1978a. The Australian frog *Chiroleptes dahlii* Boulenger: its systematic position, morphology, chromosomes and distribution. *Trans. Roy. Soc. SA* **102:** 17–24.

TYLER, M. J., DAVIES, M. AND MARTIN, A. A., 1978b. A new species of hylid frog from the Northern Territory. *Trans. Roy. Soc. SA* **102:** 151–57.

TYLER, M. J., MARTIN, A. A. AND DAVIES, M., 1979. Biology and systematics of a new limnodynastine genus (Anura: Leptodactylidae) from north-western Australia. *Aust. J. Zool.* **27:** 135–50.

TYLER, M. J., DAVIES, M. AND MARTIN, A. A., 1981a. Frog fauna of the Northern Territory: new distributional records and the description of a new species. *Trans. Roy. Soc. SA* **105:** 149–54.

TYLER, M. J., DAVIES, M. AND MARTIN, A. A., 1981b. Australian frogs of the leptodactylid genus *Uperoleia* Gray. *Aust. J. Zool., Suppl. Ser.* **(79):** 1–64.

TYLER, M. J., WATSON, G. F. AND MARTIN, A. A., 1981c. The amphibia: diversity and distribution. Pp. 1277–1301 in *Ecological biogeography of Australia* ed by A. Keast. W. Junk: The Hague.

TYLER, M. J., DAVIES, M. AND MARTIN, A. A., 1982. Biology, morphology and distribution of the Australian fossorial frog *Cyclorana cryptotis* (Anura: Hylidae). *Copeia* **1982:** 260–64.

TYLER, M. J., DAVIES, M. AND MARTIN, A. A., 1983a. The frog fauna of the Barkly Tablelands, Northern Territory. *Trans. Roy. Soc. SA* **107:** 237–42.

TYLER, M. J., CROOK, G. A. AND DAVIES, M., 1983b. Reproductive biology of the frogs of the Magela Creek system, Northern Territory. *Rec. SA Mus.* **18:** 415–40.

TYLER, M. J., WATSON, G. F AND DAVIES, M., 1983c. Additions to the frog fauna of the Northern Territory. *Trans. Roy. Soc. SA* **107:** 243–45.

TYLER, M. J., DAVIES, M. AND WALKER, K. F., 1985. Abrasion injuries in burrowing frogs (Amphibia, Anura) from the Northern Territory, Australia. *Zool. Anz.* **214:** 54–60.

TYLER, M. J., DAVIES, M. AND WATSON, G. F., 1986. The frog fauna of Groote Eylandt, Northern Territory, Australia. *J. Linn. Soc. (Lond.)* **88:** 91–101.

TYLER, M. J., DAVIES, M. AND WATSON, G. F., 1991. The frog fauna of Melville Island, Northern Territory. *The Beagle* **8:** 1–9.

WADDY, J. A., 1988. Classification of plants and animals from a Groote Eylandt Aboriginal point of view. North Australia Research Unit: Darwin.

WAUGH, R. J., STONE, D. J. M., BOWIE, J. H., WALLACE, J. L. AND TYLER, M. J., 1993. Peptides from Australian frogs. The structure of the caeridins from *Litoria caerulea*. *J. Chem. Soc. Perkin. Trans.* **1:** 573–76.

WAUGH, R. J., STONE, D. J. M., BOWIE, J. H., WALLACE, J. L. AND TYLER, M. J., 1993. Peptides from Australian frogs. The structures of the caerins and caeridins from *Litoria gilleni*. *J. Chem. Res.* **1993:** 139.

WEBB, G. PTY LTD, 1992. Flora and fauna surveys on the western side of Groote Eylandt, Northern Territory (1991–92). Report to BHP Manganese: GEMCO.

WEBB, G. J. W., 1991. The influence of season on Australian crocodiles. Pp. 125–31 in *Monsoonal Australia. Landscape, ecology and man in the northern lowlands* ed by C. D. Haynes, M. G. Ridpath and M. A. J. Williams. AA Balkema: Rotterdam.

WEBB, G. J. W., MANOLIS, S. C., WHITEHEAD, P. J. AND LETTS, G. A., 1984. A proposal for the transfer of the Australian population of *Crocodylus porosus* Schneider (1801), from Appendix I to Appendix II of CITES. Conservation Commission of the Northern Territory Technical Report no. 21.

WEBB, G. J. W., CHOQUENOT, D. AND WHITEHEAD, P. J., 1986. Nests, eggs and embryonic development of *Carettochelys insculpta* (Chelonia: Carettochelidae) from northern Australia. *J. Zool.* **81:** 521–50.

WEBB, G. J. W., WHITEHEAD, P. J. AND MANOLIS, S. C., 1987. Crocodile management in the Northern Territory of Australia. Pp. 107–124 in *Wildlife management: crocodiles and alligators* ed by G. J. W. Webb, S. C. Manolis and P. J. Whitehead. Surrey Beatty & Sons: Sydney.

WELLS, R., 1979. New reptile records from the Northern Territory. *NT Nat.* **1:** 3–4.

WHITE, P. AND FLANNERY, T., 1992. The impact of people on the Pacific world. Pp. 1–8 in *The naive lands: prehistory and environmental change in Australia and the south-west Pacific* ed by J. Dodson. Longman Cheshire: Melbourne.

WHITEHEAD, P. J., BOWMAN, D. M. J. S. AND TIDEMANN, S. C., 1992. Biogeographic patterns, environmental correlates and conservation of avifauna in the Northern Territory, Australia. *J. Biogeog.* **19:** 151–61.

WILLIS, P., MURRAY, P. AND MEGIRIAN, D., 1990. *Baru darrowi* gen. et sp. nov., a large, broad-snouted crocodyline (Eusuchia: Crocodylidae) from mid-Tertiary freshwater limestones in northern Australia. *Mem. Qld Mus.* **29:** 521–40.

WITTEN, G. J., 1982. Phyletic groups within the family Agamidae (Reptilia: Lacertilia) in Australia. Pp. 225–28 in *Evolution of the flora and fauna of arid Australia* ed by W. R. Barker and P. J. M. Greenslade. Peacock Publications: Frewville, SA.

WOINARSKI, J. C. Z., 1992. Biogeography and conservation of reptiles, mammals and birds across north-western Australia: an inventory and base for planning an ecological reserve system. *Wildl. Res.* **19:** 665–705.

WOINARSKI, J. C. Z., 1993. Australian tropical savannas, their avifauna, conservation status and threats. In *Status and conservation of birds and their habitats in Queensland* ed by C. Catterall, P. Driscoll, A. Taplin and K. Hulsman. Queensland Ornithological Society: Brisbane.

WOINARSKI, J. C. Z. AND BRAITHWAITE, R. W., 1990. The terrestrial vertebrate fauna and vegetation of the Kakadu Conservation Zone. Resource Assessment Commission Consultancy Series. Resource Assessment Commission: Canberra.

WOINARSKI, J. C. Z. AND BRAITHWAITE, R. W., 1993. The distribution of terrestrial vertebrates and plants in relation to vegetation and habitat mapping schemes in Stage III of Kakadu National Park. *Wildl. Res.* **20:** 355–70.

WOINARSKI, J. C. Z. AND GAMBOLD, N., 1992. Gradient analysis of a tropical herpetofauna: distribution patterns of terrestrial reptiles and amphibians in Stage III of Kakadu National Park, Australia.

WOODROFFE, C. D., BRYANT, E. A., PRICE, D. M. AND SHORT, S. A., 1992. Quaternary inheritance of coastal landforms, Cobourg Peninsula, Northern Territory. *Aust. Geogr.* **23:** 101–15.

WRIGHT, P., 1982. Observations of predator/prey relationships between praying mantids and geckos. *NT Nat.* **5:** 10–11.

ZWEIFEL, R. G., 1985. Australian frogs of the family Microhylidae. *Bull. Amer. Mus. Nat. Hist.* **82:** 267–388.

Upper left: Aboriginal people have detailed knowledge of much of the Northern Territory herpetofauna and continue to hunt many reptile species, including this *Elseya dentata*. (Photo by Nic Gambold).

Centre left: Rana daemeli, one of the Northern Territory's largest frogs and its only representative of the family Ranidae, was discovered in the Northern Territory only in 1990. It is one of several species with a distribution restricted to the rim of the Gulf of Carpentaria (eastern Arnhem Land, Cape York Peninsula and southern New Guinea). (Photo by Nic Gambold).

Lower left: Herpetological research in the Northern Territory has progressed rapidly in the last decade. Much detail of the biology of even common species remains to be discovered. Here Tony Griffiths releases a Frilled Lizard with attached radiotransmitter to record its response to wildfire. (Photo by Nic Gambold).

Upper right: Many species of birds, plants, invertebrates and reptiles are restricted to the rugged sandstone plateau of western Arnhem Land, including this *Ctenotus coggeri*. (Photo by Nic Gambold).

Centre right: Oedura gemmata, a species restricted to the sandstone plateau of western Arnhem Land. (Photo by Nic Gambold).

Lower right: The Northern Territory has been little fragmented by land clearing; however, much of its environment has been modified by pastoralism. The impact of this extensive industry upon herpetofauna remains unknown. (Photo by Nic Gambold).