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Research Report 1

The Macroinvertebrates of Magela Creek, Northern Territory

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CONTENTS

FIGURES

SUMMARY

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The littoral zones of five permanent billabongs in Magela Creek were sampled monthly for macroinvertebrates (>500 μm in length). Greatest numbers of taxa and individuals were caught in the late wet season and early dry season in the shallow billabongs; in the deep (or channel) billabongs, seasonal variations were not so marked. These changes appeared to be associated with the development of macrophytes, which offered food and shelter to the invertebrate fauna.

The dominant groups were the Chironomidae, Oligochaetae and Ephemeroptera. The life spans of some of the Ephemeroptera and Trichoptera were probably about a month; other groups such as the Gastropoda lived longer. The seasonal patterns of the catches were sufficiently consistent for future samples to be able to be compared with these initial ones with some confidence that any changes are real. Further study of the taxonomy and life history of those taxa suitable as biological monitors (e.g. Atyidae, Ephemeroptera) should be made.

1 INTRODUCTION

Magela Creek is a seasonally flooding tributary of the East Alligator River in the Northern Territory about 250 km east of Darwin. Its catchment consists of flood plain, forested lowland and sandstone plateau and has a tropical monsoon climate. This report deals with the larger (>500 µm in length) aquatic invertebrates (macroinvertebrates) of five permanent billabongs located in the lowlands near the Ranger uranium deposit. It is part of a larger study into the biota and water quality of this creek (Hart 1980; Walker and Tyler 1979; Pollard and Bishop 1979; Chaney et al. 1979) designed to provide data on the aquatic communities before mining of uranium starts.

This study consists of systematic seasonal collections at a number of sites. No collections of macroinvertebrates have been made in this region before; the nearest previous collections made so far were taken in northwestern Australia in and around the Kimberleys (Miles and Burbidge 1975; Kabay and Burbidge 1977; Williams 1979). These collections consist of single samples from various localities and do not provide information on seasonal changes in the fauna. It is useful to document such changes in initial surveys so that there is some basis for deciding whether future changes are natural or man-made, in this case induced by the mining.

The potential impact of mining on the macroinvertebrates in the billabongs is through the release of heavy metals such as copper and zinc (Hart 1980) which are known to be toxic to such animals. It is also possible that the release of human effluent from associated towns may have an effect. The study of macroinvertebrate populations to assess the effects of the above pollutants is a method that has been widely and successfully used (Hellawell 1978).

2 STUDY AREA

Five billabongs were sampled: Georgetown, Coonjimba, Goanna, Mudginberri, Buffalo; their relation to Magela Creek is shown in Figure 1. The map references of the billabongs (from the 1:100 000 Topographic Survey, Cahill Sheet 5472) are: Georgetown - 755970, Coonjimba - 723993, Goanna - 690002, Mudginberri - 692070, Buffalo - 693082. These billabongs always contained water during the study (November 1978 to March 1980); the creek, however, only flowed during the wet season (approximately December to April). The average annual rainfall recorded at Jabiru is 1560 mm (Ranger Uranium Mines, personal communication) with an average annual evaporation of 2400 mm (Walker and Tyler 1979; Williams 1979); the 1978-79 wet season (November to March) delivered 1509 mm and the 1979-80 season (December to April) delivered 1889 mm of rain.

Of the five billabongs sampled, the two furthest upstream (Georgetown and Coonjimba) are shallow (2-3 m during the wet season) and are separated from the creek by a levee through which a channel enables them to fill and empty. These two have been classified as backflow billabongs by Walker and Tyler and are presumably the result of former tributaries of the Magela silting up. The two billabongs furthest downstream (Mudginberri and Buffalo) are on the main channel of the creek, thus having separate inlets and outlets, and are deep (7-10 m during the wet season). Walker and Tyler classify these as channel billabongs. According to their scheme, Goanna is intermediate between these two types in that it is on the main channel of a tributary of Magela Creek, but is shallow (2-3 m during the wet season) and sometimes fills with water from its own catchment and sometimes with water flowing up from the main stream.

The billabongs chosen for sampling are downstream of the uranium deposit and are therefore the ones likely to be affected in the event of pollution. Georgetown receives runoff partially from the deposit and Coonjimba receives runoff from the present temporary town of Jabiru East and from a retention pond below the dam which will contain tailings from the processed ore. Goanna will receive treated effluent from the permanent town of Jabiru; Mudginberri and Buffalo receive all flow from the upper catchment of the Magela.

All the billabongs undergo seasonal and diurnal fluctuations in various physical (temperature, depth, turbidity) and chemical variables (pH, dissolved oxygen, conductivity). These have been documented in detail by Walker and Tyler (1979). Water depth (Fig. 2) is greatest in February and March and then decreases steadily during the dry season, but none of the billabongs dried out during the study. Surface water temperatures vary between a minimum of 22°C in July and a maximum of 38°C in November, with diurnal fluctuations being more marked in the dry season than in the wet season when an average temperature of 30°C prevails. Turbidity generally increases throughout the dry season, but is reduced during the wet season; the backflow billabongs and Goanna are invariably more turbid than the channel billabongs. Conductivity increases during the dry season, but generally indicates that the waters are very dilute. The pH mostly varies between 6.0 and 7.0, while oxygen levels depend to a large extent on ambient temperature and the photosynthesis of phytoplankton and macrophytes.

Bankside vegetation of the backflow billabongs and Goanna consists of stands of *Melaleuca viridiflora* Gaertn., while the channel billabongs are lined with *Pandanus aquaticus* F. Muell., *Barringtonia acutangula* Gaertn. and several species of *Melaleuca*. During the wet season, considerable growth of macrophytes occurs along the shallow edges of the billabongs. Some of the more common of these plants are: *Nymphaea gigantea* Hook, *Nymphoides* spp., *Utricularia* sp., *Najas tenuifolia* R.Br., *Caldesia oligococca* (F. Muell.) Buch., *Aponogeton* sp., *Eleocharis* sp. As water levels in the billabongs fall, the macrophytes die. Mudginberri Billabong generally has the least extensive development of these plants because its banks are steep and only at highest water levels are there suitable shallow areas. Buffalo Billabong, although it also has steep banks, has a permanent stand of *N. gigantea* around much of its shore.

3 METHODS

Samples of macroinvertebrates were taken monthly using a triangular hand net (30 cm wide) with 500 μm mesh. In each billabong six 10-second sweeps were made in the littoral (<1 m deep) region. Each sweep vigorously disturbed any macrophytes present as well as the bottom debris, which usually consisted of decaying leaves of *Melaleuca* spp., *P. aquaticus* and *B. acutangula* overlying a mixture of sand and silt. Inevitably such debris was collected along with the animals. Samples were washed in the laboratory with water to remove the larger debris, before being preserved in 90% ethanol. They were later sorted, identified and counted under a dissecting microscope. It was not possible to use differential flotation in a dense medium, e.g. concentrated $CaCl_2$, to separate the invertebrates from the debris because most of this was organic and it floated equally as well as the animals. When large numbers of a particular taxon were present, usually only 100 individuals were picked.

Initially, five 1-minute sweeps were made in each billabong, but the amount of debris collected required so much sorting that monthly samples could not be taken. The smaller size of sample (10 s) was therefore used. By noting the cumulative number of taxa as each series of six samples was sorted, it was found that after four or five samples, little increase in number of taxa occurred, indicating that the six 10-second samples provided a reasonably comprehensive collection for each billabong.

The deeper areas of some of the billabongs were also sampled with an Ekman grab. However, the fauna was so sparse that this zone was not sampled regularly. In addition, one of the flood plain billabongs, Jabiluka, was sampled but less intensively and regularly, as its fauna was similar to the fauna in the upstream billabongs.

In a remote area such as Magela Creek where no collections have been made before, there are immediate taxonomic difficulties when attempting to identify specimens. Although some specimens were submitted to authorities to confirm identifications, it was only possible to identify individuals from the less well-known groups to the level of family, order, or class.

4 RESULTS

As mentioned above, the fauna in the deeper areas of the billabongs was sparse. The only common invertebrates in this zone are the mussel *Velesunio angasi* (Sowerby), the subject of another study, and the Palaemonid prawn *Macrobrachium rosenbergii* (de Man); neither of these would be readily caught by the grab. The fauna actually caught consisted of dipteran larvae (Ceratopogonidae, Chironomidae and Chaoborinae) and some Oligochaetae, all of which were also caught in the littoral zone. As the results below demonstrate, the littoral zone undoubtedly contains a far greater diversity of macroinvertebrates than the deeper areas and sampling was concentrated here.

Although the sampling procedure described above enables the catches to be expressed as number of animals per minute (6 x 10 s), interpretation of this index of density is not always plain. Changes in the monthly counts could result, not only from changes in total population size, but also from changes in the spread of the population, as the extent of the littoral zone varies with fluctuating water level. Therefore, if the highest densities (i.e. counts) occur during the wet season, the total population size is probably then also greatest. If, however, they occur during the dry season when water levels are low, this does not necessarily follow. It should also be realised that the area of the littoral zone on any particular date differs between billabongs and thus similar densities do not imply similar total populations inhabiting the billabongs. Finally, in the absence of estimates of variance for the counts it is not possible to make statistically valid comparisons, but the fact that similar trends emerge in different billabongs indicates that comparisons of the counts are meaningful.

The monthly counts in number per minute are given in Tables 1 to 5. Counts given as >100 indicate that the actual number per minute was between 10^2 and 10^3. In the following interpretation of the counts, the various taxa have been grouped under a number of headings and terms such as rare, common and abundant, used to describe density.

4.1 Minor Taxa

The taxonomy of Australian representatives of these groups is generally not well known and with some exceptions they were never abundant. They include the Porifera, Hydridae, Tricladida, Gordiidae, Oligochaeta, Hirudinea and Hydracarina. Only the Oligochaeta were continually caught throughout the year. They reached their greatest density during the wet season at all sites. The Hydracarina were perhaps the next commonest group, particularly in Goanna, but in the other billabongs they were only common at the beginning of the wet season. The Tricladida became common in the dry season in the channel billabongs and in the wet season in the others, but were never as abundant as the other two groups. The remaining taxa occurred sporadically, mainly during the wet season or early dry season, except for the sponge, *Pectispongilla botryoides* (Haswell), which was present throughout the year in the channel billabongs, but only during the wet season and early dry season in the others.

4.2 Gastropoda

Five species of Gastropoda were found, but only two species were common. *Amerianna* sp.A and *Gabbia australis* Tryon were most abundant in the wet season, when they were commonly found on macrophytes. Presumably those collected at the beginning of the wet season had survived the dry season by aestivating in the mud, a well-known ability of gastropods (Pennak 1978). *Amerianna* sp.A was present in all the billabongs, although non-aestivating individuals persisted in some longer into the dry season. *G. australis* was only found in three of the billabongs and appeared to have the densest populations in Georgetown and Goanna. As these snails were often found grazing on periphyton on the surface of the macrophytes, the distribution and abundance of these macrophytes may influence the snails' abundance. Egg laying and recruitment of young of both species probably occurred during the middle and late wet season when suitable substrates for deposition of eggs, such as macrophytes, occurred widely. It was during this period that the smallest individuals, which presumably are the youngest, were caught.

Ferrissia sp.A was caught in all billabongs, but generally only during the dry season. This species was invariably attached to fronds of *P. aquaticus* or leaves and could easily have been overlooked in collections. It may well have been present in the wet season, but the greater water depth prevented sampling of the debris where it was most likely to occur. Whatever the cause, it never occurred abundantly. *Gyraulus* sp.A and *Austropeplea lessoni* (Deshayes) also did not occur abundantly. Each was found in only two billabongs, mainly during the early dry season. Unlike *Ferrissia* sp.A there is no reason to think that these two species were sampled less effectively than the other gastropods.

4.3 Crustacea

The small Crustacea comprised the Ostracod, Conchostraca, Cladocera and Copepoda (not shown in Tables 1-5) and were present in all the billabongs. The Cladocera contained the genera *Diaphanosoma*, *Ceriodaphnia*, *Simocephalus*, *Ilyocryptus* and *Macrothrix*; and the Copepoda the genera *Diaptomus* and *Mesocyclops*. All groups were most abundant in the early wet season. Undoubtedly they have short life cycles, probably lasting only a few weeks at the prevailing 30^{o}C of the wet season. However, excluding the conchostraca, sampling of these groups was not strictly representative of their density, because the smallest individuals would not have been retained by the 500 μm mesh.

The large crustacea, the Atyidae and Palaemonidae, were also present in all the billabongs. The Atyidae were generally more abundant in the littoral than the two species of *Macrobrachium*, probably because Atyidae tend to congregate along banks (Williams 1980). *Caridinides wilkinsi* Calman was the commoner of the two Atyidae. In the shallow billabongs it was common only in the early dry season and bred only at this time. In the channel billabongs *C. wilkinsi* was common for more of the year and breeding persisted into the wet season when the highest densities were reached. *Caridina* sp.A was present in all billabongs but usually for only 1-5 months in the dry season; ovigerous females were recorded in all billabongs except Coonjimba.

The monthly counts of the *Macrobrachium* species are affected by two factors. First, it is possible that neither of the species is confined to the littoral zone, but also coexists with *M. rosenbergii* in the deeper regions. Second, as no ovigerous females were ever caught it is probable that the larvae can only develop in saline water and thus the females must migrate during the wet season. *Macrobrachium* sp.A is similar to *M. tolmerum* as described by Riek (1951); Kneipp (1979) has shown that larvae of this species do not survive in fresh water. *Macrobrachium* sp.A was common in all the billabongs, especially during the dry season, but was generally at its highest density in the channel billabongs; sp.B was only common in the channel billabongs and rarely occurred in the others. The absence of both species at all sites at the beginning of the wet season is perhaps due to migration downstream as well as migration away from the littoral zone.

Two other groups of crustaceans occurred occasionally. Branchiurans, which spend most of their life cycle as ectoparasites of fish, were present in four billabongs, but in three of these they only occurred as single specimens on one occasion. The crab, *Holthusiana transversa*, lives in burrows and is only active above the surface during the wet season. It was commonly present along the banks of Goanna (but was never caught in the net) and in the catchment of the tributary which contains this billabong. It was also seen occasionally near Georgetown.

4.4 Ephemeroptera

Seven species were encountered, but only two were found at all sites, *Cloeon fluviatile* Ulmer and *Tasmanocoenis* sp.A (Lestage). In the shallow billabongs *C. fluviatile* was most abundant in the late wet season and early dry season. Much the same pattern occurred in the channel billabongs but, in these, the species was caught in every month instead of disappearing towards the end of the dry season as in the other billabongs. There were also peaks in density at the beginning of the wet season. Generally, highest densities occurred in the backflow billabongs.

Tasmanocoenis sp.A was most common in the channel billabongs and Goanna and persisted in these longer into the dry season than in the others. Its pattern of seasonal abundance was similar to that of *C. fluviatile*, although in Mudginberri it remained at high densities till almost the end of the dry season. During the first week of August, adult *Tasmanocoenis* sp.A was commonly seen at lights around the temporary town of Jabiru East. This explains the marked reduction at this time in its population density in Coonjimba and Goanna, both of which are nearby. Also at this time large numbers of adult *C. fluviatile* were attracted to the same lights and there were marked declines in its population density in Georgetown and Goanna. This was not the only period when adults of these species emerged and breeding occurred; they did so, but to a lesser extent than in August, throughout the period during which the species were common.

Tasmanocoenis sp.B was only common in Mudginberri where it was caught most of the year. Its pattern of abundance was similar to that of the other two species, but it was usually at lower densities than *Tasmanocoenis* sp.A. *Thraulus* sp.A occurred at a low, but almost continuous level in the channel billabongs; probably it was only missing from some samples because of its low density. *Atalonella* sp.A, *Centrophilum* sp.A and *Baetis* sp.A, which only appeared occasionally in the wet season, are all species common in running water and were undoubtedly washed into Mudginberri and Buffalo from Magela Creek. The smallest instars of all the above species probably passed through the 500 μm mesh, but this should not seriously alter conclusions about the seasonal variations in abundance of the mayflies. The smallest instars probably soon reached a catchable size at the fast growth rates likely to prevail in the high temperatures of the billabongs.

4.5 Odonata

Watson (1979) who surveyed the adult Odonata of the region recorded 57 species from Magela Creek, 37 from Buffalo Billabong alone. Few of these adults have been associated with their nymphs. According to Watson the two families with the greatest number of species are the Coenagrionidae and the Libellulidae. Nymphs of the two Coenagrionid genera *Ischnura* and *Pseudagrion* (each with three species recorded from

Magela Creek) were present in all billabongs and reached their highest density in the late wet season and early dry season. Libellulidae (with 27 species recorded from Magela Creek) also occurred in all the billabongs. Their nymphs appeared most abundant during the wet season in the backflow billabongs, but occurred at lesser densities throughout the year in the channel billabongs. The Protoneuridae were found in all billabongs, but only for a restricted period at the beginning of the wet season or the end of the dry season. In Mudginberri they occurred occasionally throughout the year. The Gomphidae, *Austrogomphus turneri* Martin, *Antipodogomphus neophytus* Fraser, *Ictinogomphus australis* (Selys), occur in most of the billabongs, but sporadically and at very low densities. The same comments apply to the Corduliidae, *Hemicordulia intermedia* Selys, *Pentathemis membranulata* Karsch, and to the Aeshnidae, *Hemianax papuensis* (Burmeister). Because many of the odonatan nymphs only occurred at very low densities, it is not surprising that samples did not contain as many species as Watson recorded from some billabongs by sampling the adults. Breeding of all species probably only occurs during the wet season.

4.6 Hemiptera

Twelve species were recorded, but only four commonly. This does not include the widespread surface-dwelling forms whose presence or absence only is indicated. Both nymphs and adults were caught on any particular occasion. Because the adults are generally good fliers, interpretations of counts cannot be as certain as for those groups in which the stages caught are only aquatic, for example, Ephemeroptera.

Of the common species the two unidentified species of *Agraptocorixa* were found most abundantly during the wet season or early dry season, except in Coonjimba and Goanna where greatest densities occurred in the late dry season. The other two species, *Plea brunni* Kirklady and *Nychia ?marshalli* (Scott), were only abundant in the dry season and disappeared during the wet season, except in Mudginberri where *N. ?marshalli* reached its highest density in January. *P. brunni* became very abundant towards the end of the dry season in the channel billabongs. The other species (including *Ranatra diminuta* Montandon) were found at lower densities for restricted periods, again mainly during the dry season. *Anisops paracrinita* Brooks and *Agraptocorixa halei* Hungerford were exceptions, occurring in the early wet season. It is probably as a result of low density that some of these less common species were not recorded in all the billabongs. Of the surface-dwelling forms the Gerridae were found throughout the year, while the Veliidae, *Microvelia* sp.A and *Hydrometra* sp.A, mainly occurred during the dry season.

4.7 Neuroptera

The one species, *Sisyra* sp.A, feeds exclusively on sponges. It was present in all billabongs but at very low densities. In the shallow billabongs it only occurred during the wet season when the sponge *P. botryoides* was present. In the channel billabongs it occurred in both seasons and perhaps was present continuously as was the sponge, but at densities too low to catch.

4.8 Diptera

Undoubtedly the larval Diptera were the most abundant of all the aquatic insects in the billabongs. However, the taxonomy of Australian representatives is poorly known. The Chironomidae were the only group that was continuously present at each site and were usually the most abundant dipteran. They consisted of two subfamilies the Chironominae and the Tanypodinae, of which the former were usually the commonest, except at the end of the dry season when the latter predominated. High densities occurred in all billabongs except at the end of the dry season and the beginning of the wet season, although low densities persisted somewhat longer in Georgetown. Emergence of adults, and breeding, appeared to occur continuously during the time that large numbers of larvae were present.

The Ceratopogonidae were found in all billabongs and reached their greatest density during the dry season, but tended to disappear in the early wet season. The Chaoborinae were most common in the backflow billabongs where they sometimes reached high densities at the end of the dry season. The other families occurred sporadically at low densities. As mentioned above, the Chironomidae, Ceratopogonidae and Chaoborinae were also found in the deepest regions of the billabongs.

4.9 Lepidoptera

A number of species of Pyralidae larvae were caught in small numbers at all sites. The larvae live in cases made of plant material, often the leaves of the water lily, *N. gigantea*. In Buffalo they were nearly always caught and perhaps were only missing from some samples because they were at densities too low to catch. *N. gigantea* was always present in this billabong. In the other billabongs they appeared to be restricted to the wet season, although Coonjimba was an exception perhaps because some *N. gigantea* lasted well into the dry season here.

4.10 Trichoptera

At least nine species were caught in each of the billabongs. In the backflow billabongs and Goanna the commonest of these were *Oecetis* spp. (possibly three species), *Orthotrichia* sp.A and *Ecnomus* spp. (possibly two species). *Oecetis* spp. were continuously present except in Coonjimba where it was not found during the early wet season. The other two species were only present during the late wet season and the first half of the dry season. Maximum densities of all three species were reached in the early dry season, although *Oecetis* spp. showed less seasonal variation than the others. Lesser numbers of *Tricholeiochiton* sp.A and *Hellyethia* sp.A were caught, and only during the late wet and early dry seasons, while the other four species occurred sporadically.

These four species, *Anisocentropus muricatus* (Neboiss), *Triaenodes* sp.A and sp.B, and *Triplectides* sp.A, were much better represented in the channel billabongs, probably because here there are apparently more twigs and leaves, which are used by these species for cases. Maximum density was generally reached in the dry season and they were present for much more of the year. *Tricholeiochiton* sp.A and *Hellyethia* sp.A were also caught for more of the year in Buffalo, but not in Mudginberri. Densities of *Orthotrichia* sp.A and *Ecnomus* spp. were often less than those in the shallow billabongs, but *Ecnomus* spp. were caught continuously in Buffalo and were only absent during the early wet season in Mudginberri. *Oecetis* spp. were continuously present (except once in Buffalo) and were most abundant during the wet season. In Mudginberri they also reached a peak density towards the end of the dry season. *Cheumatopsyche* sp.A, a species usually only found in running water, was washed into Buffalo once during a period of high flow.

Adult Trichoptera were caught throughout the year at a light trap set monthly near Goanna and adults probably emerged and bred throughout the period when a particular species was present. The smallest instars of many of the species were probably not caught, but this should not alter the patterns of abundance, as mentioned already for the Ephemeroptera.

4.11 Coleoptera

Most specimens were only identified to family, but a few were identified to genus. Adult Dytiscidae were the commonest taxon and reached maximum density at the end of the dry season at all sites. Their larvae (including the Hydroporinae) largely occurred during the wet season, although single specimens were found during the dry season in the channel billabongs. A similar pattern was evident for the Hydrophilidae (which includes *Berosus* sp.A) in the channel billabongs. However, in the shallow billabongs both adults and larvae were mainly caught in the dry season, except for *Berosus* sp.A which was only recorded in the wet season. The other taxa occurred occasionally, except for the adult gyrinid *Dineutus* sp.A which was often seen at Mudginberri and Buffalo. The larvae of the less common taxa were restricted to the wet season. Thus, except for the Hydrophilidae in the shallow billabongs, breeding of all families occurred during the wet season.

5 DISCUSSION

The previous account can be summarised by tabulating the seasonal variation of the total number of taxa and individuals in the various billabongs (Table 6). This table includes taxa whose presence or absence only, was indicated in Tables 1 to 5. A more sophisticated analysis using, for instance, diversity indices was not warranted, because some of the most abundant taxa, e.g. Chironomidae, were not identified to species. The total number of individuals is generally underestimated, because only 100 specimens of each of the abundant taxa were picked for any set of six samples. However, this should not alter the general conclusions and will mainly affect only the highest estimates by reducing the extent of their fluctuations.

From Table 6 it is clear that in Georgetown, Coonjimba and Goanna the greatest number of taxa and density of macroinvertebrates occur during the early dry season (May to July). Numbers and density then fall markedly for the rest of the dry season, but recover rapidly when the wet season starts and water levels in the billabongs rise (Fig. 2). As they rise, the fauna are likely to be diluted to some extent, especially in February and March, and lower catches are to be expected. Thus, the period when the maximum number of taxa and greatest abundance of individuals are found within a billabong probably starts in the wet season, but this only becomes obvious in the catches of the early dry season. The numbers of taxa and individuals in the three billabongs are similar, except that the maxima are reached somewhat later in Coonjimba and Goanna. In Goanna there is also a rise in number of individuals but not taxa at the end of the dry season, owing to large catches of Coleoptera and Hydracarina. Finally, within these billabongs the similarity of numbers of taxa and individuals caught at either end of the period of study indicates that sampling was consistent and suggests that these seasonal comparisons are valid.

In the channel billabongs the seasonal fluctuations in the number of taxa and individuals (Table 6) are not so marked; the number of taxa rarely falls below 30 and the number of individuals varies by a factor of two rather than five as in the shallow billabongs. In Buffalo the highest numbers of taxa and individuals also occur in the early dry season (May), but their subsequent decline only continues until September, after which both indices rise near to maximal levels again. During the early wet season there is another decline in both taxa and numbers, probably because the rising water levels dilute the fauna. More or less the same sequence occurs in Mudginberri, but here both indices fluctuate after August from their lowest to almost their highest levels, reaching their maxima in January.

The probable cause of this seasonal fluctuation in numbers of taxa and individuals is that the macrophytes are best developed during the late wet season and early dry season (March to July) and these offer the macroinvertebrates shelter and food, thus promoting a large and diverse community. In the backflow billabongs and Goanna the macrophytes have largely disappeared, except for a few *N. gigantea* and *Eleocharis* sp., by August or September, after which marked declines in numbers and taxa were evident. Changes in the littoral zone of the channel billabongs were less marked, as were fluctuations in the fauna. Macrophytes were only common around Mudginberri during February and March, while *N. gigantea* and others were common throughout the year in Buffalo. In Mudginberri the absence of macrophytes is perhaps made up for by the complex array of roots of *P. aquaticus*, which line the banks, and large quantities of detritus such as leaves and twigs. Both these habitats offer shelter and probably food.

Organic detritus is probably a major source of food within the littoral zone. The guts of the Ephemeroptera and Trichoptera were often full of it. The exact nature of this detritus is unknown, but decomposing leaves from *P. aquaticus*, *B. acutangula* and *Melaleuca* spp. appear to make up much of it. When well developed zones of macrophytes are present, epiphytic algae on the macrophytes (periphyton) must also be widely eaten. The macrophytes themselves do not seem to be used by the macroinvertebrates except by the Pyralidae larvae, which make cases out of the leaves of *N. gigantea*.

During the wet season when there are large numbers of fish fry, the macrophytes probably provide the macroinvertebrates with a refuge against predators such as fish. But fish are not the only predators in these billabongs, although they perhaps consume more than the others as a result of their larger size. The Odonata, the Tricladida, the Hirudinea, some of the Hemiptera and some of the Coleoptera are also predatory. Generally, only the Odonata are common when the macrophytes are well developed; they probably subsist on microcrustaceans and small instars of the various insects. In the backflow billabongs there is possibly a further hazard in that low oxygen levels (20% saturation) can occur within a bed of macrophytes close to the bottom (Walker and Tyler 1979). Very few of the macroinvertebrates could withstand anoxia, but perhaps levels even as low as 20% saturation are not harmful. Although large numbers of dead or dying invertebrates might have been expected, these were never seen.

Once the macrophytes have died in the shallow billabongs, the fauna, which disappear from the samples, survive by various means. A few groups such as the Gastropoda and the crab *H. transversa* aestivate in the mud or the banks, re-emerging when these are submerged in the next wet season. Insects such as the Ephemeroptera and Trichoptera may lay aestivating eggs, or produce resistant pupae or instars which burrow or are too small to be caught, as they do in temperate streams which dry up in summer (Williams and Hynes 1976); or they may rely on a few individuals surviving, but at such low densities that they are not, or only rarely, caught. It is also possible that some taxa in these two groups are actually exterminated and have to be re-established from eggs laid by flying adults from nearby billabongs. Usually, ephemeropteran adults only live a few days, but trichopteran adults may live for a few weeks (Pennak 1978). Other common insects such as the Odonata have adults that survive a month or so (Watson 1979), but they probably pass much of the dry season as aestivating eggs. On the other hand, the Hemiptera and Coleoptera, which usually disappear during the wet season, may survive as flying adults that are rarely caught.

Of the non-insect groups that disappear from the samples in various seasons some, e.g. *C. wilkinsi*, probably also rely on the survival of a few individuals which then reproduce rapidly, while others, e.g. the Porifera and Tricladida, may produce resistant stages. As already mentioned, the *Macrobrachium* spp. appear to migrate during the wet season, probably downstream, which would account for their disappearance.

The fauna in the channel billabongs undoubtedly survive unfavourable periods by the same methods, but in these billabongs fewer taxa disappear from the samples (Table 6) or else do so for shorter periods. This suggests that food supply, which is presumably more consistent in the less variable littoral zone of these billabongs, determines to some extent how the fauna fluctuate. For instance, the fact that there are more species of gastropods and that they persist at higher densities for longer in Buffalo than in Mudginberri may well be due to the lack in Mudginberri of macrophytes and therefore of the periphyton that these animals eat. It should also be recognised that, because of the greater persistence of the faunas in the channel billabongs, these may well act as reservoirs for some species that are actually exterminated in the dry season in the shallow billabongs. Hynes (1975) in a study of the fauna of an intermittent stream in tropical Africa (Ghana) suggested that most recolonisation of aquatic insects took place from eggs laid by flying adults rather than through survival of resistant stages. As the billabongs in Magela Creek do not dry up completely, resistant stages are not as improbable as in Hynes' stream which became dry and sunbaked.

The rapid resurgence of the fauna at the beginning of the wet season (Table 6), which is especially evident in the shallow billabongs, suggests fast growth and reproductive rates for at least some of the fauna. It is not possible to determine exactly the duration of the life cycle of any of the taxa, but some reasonable guesses can be made. *C. fluviatile* showed marked increases in density in every billabong between December and January. At the same time water levels rose rapidly and probably stimulated rapid development and reproduction among the surviving individuals. Not all the *C. fluviatile* caught in January were ready to emerge, but evidently the animals hatched and grew rapidly within 5.5 weeks. Considering that they probably did not hatch until 3 or 4 January 1980, when the billabongs filled up, it would be reasonable to suggest that some *C. fluviatile* nymphs have a life span of about two weeks, and the average individual, a life cycle of a month. The other Ephemeroptera and the Trichoptera may also have life cycles of about this length, while those of the Diptera would probably be shorter.

The life cycles of most of the other taxa are probably longer than this. The Odonata and Coleoptera that develop during the wet season probably spend up to a few months in the non-flying stages. Some of the non-insect groups may have life cycles of this length, while those of the Gastropoda could be much longer. Life cycles of one month to a few months are similar to those suggested by others who have studied tropical insects in streams. Hynes and Williams (1962) found that many larvae and nymphs were fully grown after a month in a stream in Uganda that they had denuded with DDT. Hynes (1975) concluded from his study of the seasonal changes of the fauna of a stream in Ghana that the average life cycle was 2.5 months.

The fauna in the billabongs is, as might be expected, typical of that in still water. Only occasionally during the wet season were taxa caught that were normally found in flowing water, and then only in the channel billabongs, which receive the full flow of the Magela Creek. The bed of the creek is largely shifting sand and it is only in a few areas, where the substrate is more consolidated with algae and rocks, that any macroinvertebrates are found. These consist mainly of Ephemeroptera (*Baetis* sp.A, *Atalonella* sp.A, *Tasmanocoenis* sp.A, dytiscid larvae, dipteran larvae (Chironomidae, Simuliidae) and a few Trichoptera (*Cheumtopsyche* sp.A, *Chimarra* sp.A).

The dominant taxa in the billabongs are shown in Table 7. The Chironomidae and Oligochaeta were usually the most abundant taxa, followed by *C. fluviatile* in the shallow billabongs and either this species or *Tasmanocoenis* sp.A in the channel billabongs. The Ostracoda and sometimes the Hydracarina were also abundant, while the remaining taxa were only common in single billabongs.

The lists in Table 7 reasonably represent the order of abundance in each billabong, but biases are inherent in the sampling and the taxa are probably not represented (mean catch, Tables 1-5) in the exact proportions in which they actually occur, even if it had been possible to count all individuals caught. Not only are no individuals less than 500 µm caught, thus excluding the smallest instars and stages of many taxa, but some groups are not so readily caught as others. For instance the Trichoptera in general are easy to miss because they are harder to dislodge from the substrate, as are others such as *Ferrissia* sp.A. Nevertheless, the predominant taxa are more or less the same in each billabong and the mean catches of some taxa, e.g. *C. fluviatile*, are surprisingly consistent, though this consistency is helped to some extent by taking all catches greater than 100 as equal to 100. Therefore future samples, provided they are taken with similar methods, can be compared with these original ones with some confidence that any changes are real. It must be realised that the fauna as a whole has a wider range of tolerances than individual taxa and thus is less likely to fluctuate rapidly in numbers. This encourages consistent trends, as has already been shown (Table 6).

As the predominant taxa (Chironomidae, Oligochaeta) contain a number of unidentified species it is not sensible to calculate diversity indices for the whole fauna in each billabong. Table 6 shows that the maximum number of taxa (currently distinguished) is more or less the same in each billabong and Tables 1-5 indicate no marked differences between billabongs in the taxa present; even the billabong on the flood plain (Jabiluka), which was only sampled occasionally, had a fauna which was similar to that at the upstream localities.

It is, however, reasonable to calculate diversity indices for groups in which all species were recognised (Table 8). Simpsons's index (Hellawell 1978) was used and was calculated as :

$$D = \left(\sum_i p_i^2 \right)^{-1}$$

where p_i is the proportion of individuals in the *i*th species; this index goes from 1 to infinity as diversity increases. Three of the groups vary a maximum of 1.0 - 1.4 units between billabongs with no consistent pattern. The other two groups, the Ephemeroptera and Trichoptera, vary more, with highest diversities in the channel billabongs. This results mainly from the better representation in these billabongs of the rare species and, in the case of the Ephemeroptera, the occurrence also of lotic species.

Comparisons of the macroinvertebrate fauna in the billabongs with those in nearby regions cannot yet be done rigorously because few collections have been made in northern tropical Australia and the taxonomy of many groups is poorly or incompletely known. However, some comment is possible. The nearest collections from comparable habitats were taken in northwest Australia in the Kimberleys (Miles and Burbidge 1975; Kabay and Burbidge 1977; Williams 1979) and consist of single samples scattered over much more extensive areas than Magela Creek. A number of genera are found in both regions: in the Mollusca, *Austropeplea*, *Gabbia*, *Amerianna*, *Gyraulus* and *Ferrissia*; in the Crustacea, *Macrobrachium*, *Caridina* and *Holthusiana*; in the Ephemeroptera, *Cloeon* and *Tasmanocoenis*; in the Hemiptera, *Naucoris*, *Ranatra*, *Nychia*, *Anisops* and *Agraptocorixa*; in the Trichoptera, *Triplectides*, *Oecetis*, *Anisocentropus*, *Chimarra*, *Ecnomus* and *Cheumatopsyche*. (The collections of Ephemeroptera and Trichoptera consisted of adults only, collected at lights.) This list indicates similarities between the regions, which can only be settled with more extensive collecting and better known taxonomy. It is of interest that two species caught in the Magela billabongs are known to be widespread in Australia: *G. australis*, and *C. fluviatile*, according to Smith and Kershaw (1979) and Suter (personal communication); and that the ephemeropteran genus *Thraulus*, found in the channel billabongs, has not been recorded for Australia before (Suter 1979). The distribution of the Odonata (taxonomically the best known group) within Australia has already been well studied by Watson (1972), who found that 26 of the 86 species within the Alligator Rivers Region (which includes Magela Creek) also occur in other parts of northern Australia, while 46 of the species are known from outside Australia.

Welcomme (1979) in his review of the fisheries ecology of flood plain rivers comments that information on the benthic macroinvertebrates of slow rivers associated with tropical flood plains is very sparse. The profundal areas of the few rivers that have been sampled are dominated by sparse communities of Oligochaeta and Chironomidae. The same areas in the permanent standing waters of the flood plains are somewhat richer. In addition they often contain molluscs, which sometimes constitute the majority of the biomass. Apparently the littoral areas of the standing waters are the richest in species. Welcomme quotes studies which report high densities of Ephemeroptera, Trichoptera, Mollusca, Hemiptera and Chironomidae during the flood season, especially in beds of macrophytes. Thus, what little that is already known, supports the general conclusions from the Magela billabongs.

6 RECOMMENDATIONS

Two major recommendations for future research can be made. First, taxonomic research should be encouraged, as only in a very few cases was it possible to name species. This could be done by financing taxonomists, e.g. from State museums, to visit Magela Creek at suitable times of the year (see Tables 1-5) so that they could collect immature and adult stages of the groups they specialise in. For the insects, the association of immature stages with adults is particularly important, because much of their taxonomy is based on the flying adults, but it is the aquatic larvae or nymphs that are commonly collected in the billabongs.

Such study has begun for the Chironomidae, but it should be started in particular for the Ephemeroptera, Trichoptera, Mullusca, Atyidae and Palaemonidae. These are widespread and often abundant groups which spend most or all of their life cycles in the water and are not able to migrate readily if conditions become unsuitable, as are adult Coleoptera and Hemiptera. They are thus the most suitable groups for future monitoring of specific billabongs. Watson (1979) has already commented on the difficulties of using the adult Odonata as biological monitors; it should be remembered that few of these have been associated with their nymphs.

The second type of research that should be encouraged is the detailed study of the life history, population dynamics and food preferences of some of these potential biological monitors. Not only might this indicate whether it would be possible to rear such taxa in the laboratory for toxicity tests, but more importantly it might also help decide whether future changes in the fauna are natural or man-made. The importance of the macrophytes and detritus to the macroinvertebrate fauna has already been stressed. A feasible initial project would be a study of the use of these sources of food by such abundant consumers as the mayflies, and the effect of variations in the level of detritus on the life history of these animals.

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TABLE 1 MONTHLY COUNTS OF MACROINVERTEBRATES IN GEORGETOWN BILLABONG

Date	1979										1980		Mean Catch
	5 Mar	2 Apr	30 Apr	11 Jun	9 Jul	6 Aug	3 Sep	1 Oct	6 Nov	4 Dec	14 Jan	11 Feb	
	(number caught/min)												
Porifera													
Pectispongilla botryoides	+	+	+	+	+	+						+	
Hydridae			1	1	4	6		1					1.1
Tricladida sp.A		2	3	31	17	2							4.6
sp.B											9	18	2.3
Gordiidae		1	2	1								1	0.4
Gastropoda													
Amerianna sp.A	15	22	46	27	13	1						3	10.3
Gabbia australis	25	18	209	64	7	1					10	35	17.9
Ferrissia sp.A		1											0.1
Austropeplea lessoni			8	6	1								1.3
Oligochaeta	87	105	72	90	104	79	87	48	17	9	11	>100	66.7
Hirudinea													
Glossiphoniidae sp.A		8	3										0.9
Hydracarina	4	9	3	8	3	2		2	5	5	76	7	10.3
Conchostraca													
Cyzicus sp.A	1		5	5						12	>100	70	16.1
Limnadia sp.A											1		0.1
Ostracoda	77	28	66	38	14						67	>100	32.5
Branchiura				1									0.1

Date	1979										1980		Mean Catch
	5 Mar	2 Apr	30 Apr	11 Jun	9 Jul	6 Aug	3 Sep	1 Oct	6 Nov	4 Dec	14 Jan	11 Feb	
	(number caught/min)												
Atyidae													
Caridinides wilkinsi	3	2	4	27^e	76^e	20^e	3	1				5	11.8
Caridina sp.A				4^e	26^e	7^e	2						3.3
Palaemonidae													
Macrobrachium sp.A	3	5	23	72	51	13	11	4	1				15.3
sp.B					1								0.1
Ephemeroptera (nymphs)													
Cloeon fluviatile	92	83	122	307	239	31	2		1		20	29	46.5
Tasmanocoenis sp.A	8	3	27	30	4	1			1	1	1	3	6.6
Tasmanocoenis sp.B											2		0.2
Odonata (nymphs)													
Protoneuridae											6	2	0.7
Ischnura spp.	8	14	106	57	19	3					2	1	17.0
Pseudagrion spp.	1	1	11	22	17	6						2	5.0
Austrogomphus turneri	2		3										0.4
Antipodogomphus neophytus							1						0.1
Ictinogomphus australis	3			2			2			1			0.8
Libellulidae	15	11	23	4	5	1	2			2	2	1	5.5
Hemicordulia intermedia				1	1							1	0.3
Pentathemis membranulata			3								2		0.4
Hemianax papuensis											1		0.1

+ = present but not counted; ^{e} = ovigerous females.
Mean catches were calculated assuming all counts >100 were equal to 100.

Table 1 Monthly counts in Georgetown Billabong (ctd)

Date	1979										1980		Mean Catch
	5 Mar	2 Apr	30 Apr	11 Jun	9 Jul	6 Aug	3 Sep	1 Oct	6 Nov	4 Dec	14 Jan	11 Feb	
	(number caught/min)												
Hemiptera													
Agraptocorixa sp.A	20	8	4	13	7	1			1	32	21		8.9
sp.B	7	2	3	1				1		12	13	1	3.3
Agraptocorixa halei											2		0.2
Plea brunni		2	3	27	73	30	4	1		2	3		12.1
Ranatra diminuta				5	8								1.1
Nychia ?marshalli				20	11	6	8	2			1		4.0
Enithares sp.A								1					0.1
Anisops paracrinita										1	26		2.3
Naucoris sp.A		1	5	7	3	1			1		3		1.7
Naucoridae sp.A			1	1	4					1			0.6
Hydrometra sp.A			+										
Gerridae	+	+	+	+	+	+	+	+	+			+	
Veliidae	+			+	+	+	+						
Mesovelia sp.A			+	+									
Neuroptera (larvae)													
Sisyra sp.A	1	2											0.3
Diptera (larvae except where indicated)													
Chironomidae	>100	>100	>100	>100	89	20	9	2	4	2	27	43	49.7
Chironomidae pupae	10	18	10	10	5	2							4.6
Ceratopogonidae		10	36	84	46	28	27	9	26	21		1	24.0
Thaumaleidae				1									0.1
Chaoborinae	1	12	5	3		9	9	>100	79	>100		12	27.5
Culicinae		3	3	2	1	2					4		1.3
Culicinae pupae		3	1			1		10	5	2	1	1	2.0

Date	1979										1980		Mean
	5 Mar	2 Apr	30 Apr	11 Jun	9 Jul	6 Aug	3 Sep	1 Oct	6 Nov	4 Dec	14 Jan	11 Feb	Catch
	(number caught/min)												
Lepidoptera (larvae)													
Pyralidae	1	3	2	1									0.6
Trichoptera (larvae)													
Tricholeiochiton sp.A	2	3	2	2		1	1			1			1.0
Hellyethia sp.A	2		4	18	7		1			1			2.8
Orthotrichia sp.A	11	4	11	17	2	5					1	1	4.3
Anisocentropus muricatus			3										0.3
Ecnomus spp.	1	13	10	32	8	3						1	5.7
Oecitis spp.	9	10	18	29	27	17	21	35	21	8	7	28	19.2
Triaenodes sp.A	3										4	4	0.9
sp.B						3							0.3
Triplectides sp.A												3	0.3
Coleoptera													
Dytiscidae larvae		1									1		0.2
Hydroporinae larvae	13	1	1		1						3		1.6
Dytiscidae adults	2	3	4	1	9	12	5	7	2	38	16	1	8.3
Hydrophilidae larvae			1	1									0.2
Berosus sp.A (larvae)	12	5	3			1					2	20	3.6
Hydrophilidae adults				1		1							0.2
Helodidae larvae sp.A												1	0.1
Haliplus sp.A (larvae)		1										1	0.2
Haliplus sp.A (adults)				1							12		1.1

+ = present but not counted. Mean catches were calculated assuming all counts >100 were equal to 100.

TABLE 2 MONTHLY COUNTS OF MACROINVERTEBRATES IN COONJIMBA BILLABONG

	1979										1980		Mean
Date	6 Mar	4 Apr	1 May	12 Jun	11 Jul	7 Aug	4 Sep	2 Oct	7 Nov	7 Dec	15 Jan	12 Feb	Catch
	(number caught/min)												
Porifera													
Pectispongilla botryoides	+	+	+	+	+	+						+	
Hydridae							4				27		2.6
Tricladida sp.A	4	11	12		3	1		1					2.7
sp.B						1	1				11	29	3.5
Gordiidae	1		1	1								1	0.3
Gastropoda													
Amerianna sp.A	58	26	21	49	28	16	5	1			4	49	21.4
Ferrissia sp.A			2	4	2	1							0.8
Oligochaeta	105	109	>100	65	72	42	28	20	7	39	>100	>100	79.4
Hirudinea													
Richardsonianidae sp.A	+	+	1								+		
Glossiphoniidae sp.A	2			6	16	26	1						4.3
Hydracarina	3	4	6	31	42	31	54	35	85	84	>100	10	40.4
Conchostraca													
Cyzicus sp.A	3	2	15	42	36	17	8	1	10	64	>100	135	33.2
Ostracoda	60	53	>100	>100	26	48	11	2		1	>100	56	46.4
Branchiura								1					0.1
Atyidae													
Caridinides wilkinsi	1	11	6	34^{e}	60^{e}	57^{e}	33^{e}	16	3	1	1	2	18.8
Caridina sp.A								1					0.1

Date	1979										1980		Mean
	6 Mar	4 Apr	1 May	12 Jun	11 Jul	7 Aug	4 Sep	2 Oct	7 Nov	7 Dec	15 Jan	12 Feb	Catch
	number caught/min)												
Palaemonidae													
Macrobrachium Sp.A.		3	8	13	8	18	7	6	6				5.8
Ephemeroptera (nymphs)													
Cloeon fluviatile	5	78	66	360	>100	>100	>100	61			3	1	51.2
Tasmanocoenis sp.A		1	3	14	37	7	5	3					5.8
Odonata (nymphs)													
Protoneuridea											3		0.3
Ischnura spp.	1	1	20	57	33	45	15	2	5	2	2	3	15.5
Pseudagrion spp.	2	1	1	4	4	5	1	1				1	1.7
Austrogomphus turneri	1		3										0.3
Ictinogomphus australia		3		3	3			1			1		0.9
Libellulidae	15	6	12	23	11	2	3	2	2	1		1	6.5
Hemicordulia intermedia											3		0.3
Pentathemis membranulata			2	1							3		0.5
Hemianax papuensis											1		0.1
Hemiptera													
Agraptocorixa sp.A			2	12	45	33	18	19	46		1		14.7
sp.B				5	5	7	40	34	10		2		8.6
Plea brunni				14	14	42	78	8	4	3			13.6
Ranatra diminuta			1		1	6	4	4	1				1.4
Nychia ?marshalli				1	1	5	20	11					3.2
Enithares sp.A							2						0.2
sp.C				1									0.1

+ = present but not counted; ^{e} = ovigerous females.
Mean catches were calculated assuming all counts >100 were equal to 100.

Table 2 Monthly counts in Coonjimba Billabong (ctd)

Date	1979										1980		Mean
	6 Mar	4 Apr	1 May	12 Jun	11 Jul	7 Aug	4 Sep	2 Oct	7 Nov	7 Dec	15 Jan	12 Feb	Catch
	(number caught/min)												
Hemiptera (ctd)													
Anisops paracrinita									6				0.5
Naucoridae sp.A			+	3	1	10	4			2			1.7
Hydrometra sp.A				+	+								
Gerridae	+	+	+	+	+	+	+	+			+	+	
Veliidae					+	+	+	+	+				
Mesovelia sp.A			+	+	+	+		+					
Neuroptera (larvae)													
Sisyra sp.A	1				1								0.2
Diptera (larvae except where indicated)													
Chironomidae	27	>100	>100	>100	>100	>100	>100	>100	32	11	16	10	66.3
Chironomidae pupae	1	16	23	49	8	15	13	1			2		10.7
Ceratopogonidae	1	11	43	77	20	32	78	25	8	1	16		26.0
Thaumaleidae						1							0.1
Chaoborinae		7	10	21	13	2	3	4	1	4		5	5.8
Culicinae		1	2	5	2		3			10			1.9
Culicinae pupae					2					9		2	1.1
Tabanidae					2		1						0.3
Lepidoptera (larvae)													
Pyralidae		1	10	1	2	8	9	11		1		1	3.7
Trichoptera (larvae)													
Tricholeiochiton sp.A	1	5		1	1	1	18						2.3
Hellyethia sp.A		16	1										1.4
Orthotrichia sp.A		31	27	42	92	7	9						17.3
Anisocentropus muricatus					1								0.1

Date	1979										1980		Mean
	6 Mar	4 Apr	1 May	12 Jun	11 Jul	7 Aug	4 Sep	2 Oct	7 Nov	7 Dec	15 Jan	12 Feb	Catch
	(number caught/min)												
Trichoptera (larvae) (ctd)													
Ecnomus spp.		10	5	2	4	4	23	2					4.2
Oecetis spp.	1	8	8	13	3	5	10	13	12				6.1
Triaenodes sp.A												1	0.1
sp.B		1											0.1
Triplectides sp.A						1	1						0.2
Coleoptera													
Dytiscidae larvae									1	5			0.5
Hydroporinae larvae	2	2	4	1						1	5	3	1.5
Dytiscidae adults		2	1	3	7	11	11	15	46	61	3		13.3
Hydrophilidae larvae				1	1	3	1		2				0.7
Berosus sp.A (larvae)	2	4				1							0.6
Hydrophilidae adults							6	4	4				1.2
Haliplus sp.A (larvae)		1	1	1		1							0.3
Haliplus sp.A (adults)											1	3	0.3
Spercheidae adults		1											0.1
Ptilodactylidae adults				1									0.1

+ = present but not counted. Mean catches were calculated assuming all counts >100 were equal to 100.

TABLE 3 MONTHLY COUNTS OF MACROINVERTEBRATES IN GOANNA BILLABONG

Date	1979										1980		Mean
	7 Mar	5 Apr	2 May	13 Jun	12 Jul	8 Aug	5 Sep	3 Oct	8 Nov	6 Dec	16 Jan	13 Feb	Catch
	(number caught/min)												
Porifera													
Pectispongilla botryoides	+	+	+		+							+	
Hydridae					1	6	1	7	2		2		1.6
Tricladida sp.A		2											0.2
sp.B					2						7		0.8
Gordiidae	1		1										0.2
Gastropoda													
Amerianna sp.A	26	6	22	13	35	1						11	9.5
Gabbia australis	59	73	61	23	37	2					17	111	31.0
Ferrissia sp.A			2	4	4	3	2		3				1.5
Gyraulus sp.A	1				2								0.3
Austropeplea lessoni			1										0.1
Oligochaeta	61	36	40	60	47	34	25	21	>100	>100	>100	>100	60.3
Hirudinea													
Richardsonianidae sp.A	+												
Glossiphoniidae sp.A	6	10	3	1	5	3						3	2.6
Hydracarina	6	44	59	105	>100	>100	>100	72	36	>100	>100	15	69.3
Conchostraca													
Cyzicus sp.A	10	6	14	1							>100	72	16.9
Ostracoda	35	>100	72	87	11	2	1				>100	>100	42.3
Branchiura				1	1		1						0.3
Atyidae													
Caridinides wilkinsi		4	4	48[e]	163[e]	11	7						19.8
Caridina sp.A		8	4[e]	26[e]	44[e]	31							9.4

Date	1979 7 Mar	5 Apr	2 May	13 Jun	12 Jul	8 Aug	5 Sep	3 Oct	8 Nov	6 Dec	1980 16 Jan	13 Feb	Mean Catch
	(number caught/min)												
Palaemonidae													
Macrobrachium sp.A	3	9		17	6	2	1	2	1				3.4
sp.B			1										0.1
Sundatelphusidae													
Holthusiana transversa	+		+								+	+	
Ephemeroptera (nymphs)													
Cloeon fluviatile	71	180	194	261	>100	55	8	9			39	21	50.3
Tasmanocoenis sp.A	33	58	85	88	101	40	10	15	1		4	5	36.5
Odonata (nymphs)													
Protoneuridae											35		2.9
Ischnura spp.	6	10	50	32	31	25					1	4	13.3
Pseudagrion spp.	4	3	7	10	6	6						4	3.3
Austrogomphus turneri			2										0.2
Ictinogomphus australis				1	2		1		1			1	0.5
Libellulidae	7	5	7	7	1	4		2	1	1	2	2	3.3
Hemicordulia intermedia		2			1						1		0.3
Pentathemis membranulata			2										0.2
Hemiptera													
Agraptocorixa sp.A	6	11	3	12	9	>100		2	52	71		1	22.3
sp.B	1	1	1	1	9	42	1	10	72	131	4		20.2
Agraptocorixa halei									15	1	1		1.4
Plea brunni			3	11	124	13	3		18	5	1		12.8
Ranatra diminuta					4	5							0.8
Nychia ?marshalli			1	3	20				1	1			2.2
Enithares sp.B				1	2								0.3
Anisops paracrinita										4	10		1.2

+ = present but not counted; ^{e} = ovigerous females.
Mean catches were calculated assuming all counts >100 were equal to 100.

Table 3 Monthly counts in Goanna Billabong (ctd)

Date	1979 7 Mar	5 Apr	2 May	13 Jun	12 Jul	8 Aug	5 Sep	3 Oct	8 Nov	6 Dec	1980 16 Jan	13 Feb	Mean Catch
	(number caught/min)												
Hemiptera (ctd)													
Naucoris sp.A		1	2										0.3
Naucoridae sp.A					2								0.2
Hydrometra sp.A	+												
Gerridae	+	+	+	+	+	+	+	+	+	+		+	
Veliidae				+	+	+	+	+					
Mesovelia sp.A		+	+	+	+	+							
Neuroptera (larvae)													
Sisyra sp.A	1	2										1	0.3
Diptera (larvae except where indicated)													
Chironomidae	155	>100	>100	>100	>100	>100	43	85	>100	34	23	34	76.6
Chironomidae pupae	24	35	26	53	69	13	2	1		1	1		18.8
Ceratopogonidae		9	7	36	14	71	2	4	12	7		2	13.7
Thaumaleidae				1								2	0.3
Chaoborinae		1		1	1	1	2	4			2		1.0
Culicinae		2	8	36	6	1				3			4.7
Culicinae pupae				1				1		2		2	0.5
Lepidoptera (larvae)													
Pyralidae	2		4		3								0.8
Trichoptera (larvae)													
Tricholeiochiton sp.A	1	3	2		28		4						3.2
Hellyethia sp.A	2	1	8	4	2	1							1.5
Orthotrichia sp.A	2	4	77	103	>100	24	6				11		27.0
Anisocentropus muricatus		1											0.1
Ecnomus spp.	9	4	18	29	45	13	2	2	1				10.3

Date	1979										1980		Mean
	7 Mar	5 Apr	2 May	13 Jun	12 Jul	8 Aug	5 Sep	3 Oct	8 Nov	6 Dec	16 Jan	13 Feb	Catch
	(number caught/min)												
Trichoptera (larvae) ctd)													
Oecetis spp.	11	11	13	7	2	7	5	1	8	3	4	12	7.0
Triaenodes sp.A		1											0.1
sp.B						2							0.2
Triplectides sp.A				1									0.1
Coleoptera													
Dytiscidae larvae				1							22		1.9
Hydroporinae larvae	2										107	2	8.7
Dytiscidae adults		3	4	2	1	4		10	106	117			18.7
Hydrophilidae larvae			2		2					1	1		0.5
Berosus sp.A (larvae)	10	2									2	9	1.9
Hydrophilidae (adults)				2	2	3					4		0.9
Dineutus sp.A (larvae)											1		0.1
Dineutus sp.A (adults)		+											
Haliplus sp.A (larvae)		1	1									4	0.5
Haliplus sp.A (adults)											3		0.3
Helminthidae adults							1						0.1

+ = present but not counted. Mean catches were calculated assuming all counts >100 were equal to 100.

TABLE 4 MONTHLY COUNTS OF MACROINVERTEBRATES IN MUDGINBERRI BILLABONG

	1979										1980		Mean
Date	9 Mar	6 Apr	3 May	14 Jun	13 Jul	9 Aug	6 Sep	4 Oct	9 Nov	7 Dec	17 Jan	14 Feb	Catch
	(number caught/min)												
Porifera													
Pectispongilla botryoides	+	+	+	+	+	+	+	+	+	+		+	
Hydridae												2	0.2
Tricladida sp.A		7		13	12	8	14	48	2				8.7
sp.B				1	1		6			3	12	13	3.0
Gordiidae		2	1							1			0.3
Gastropoda													
Amerianna sp.A	22	29	5					1	1	2	1	16	6.4
Ferrissia sp.A		1	1	1	1	2			2				0.7
Oligochaeta	101	22	39	56	72	40	33	35	>100	78	>100	>100	64.6
Hirudinea													
Richardsonianidae sp.A	+						+						
Glossiphoniidae sp.A	1	2		1	3	1							0.7
Hydracarina	15	21	9	7	1	5	10	11	2	4	>100	12	16.4
Conchostraca													
Cyzicus sp.A	63	2	2	1	4	5	1		2	1	>100	>100	23.4
Ostracoda	87	8			2		6		20	34	91	34	23.5
Branchiura								1					0.1
Atyidae													
Caridinides wilkinsi	65[e]	39[e]	30[e]	20	3	3	8	49[e]	7[e]			11[e]	19.6
Caridina sp.A			2	1[e]			3[e]	9	6	28[e]	1[e]		4.2
Palaemonidae													
Macrobrachium sp.A	5	70	44	31	15	54	34	36	15	17			26.8
sp.B			6	26	19	20	19	6	2	1			8.3

Date	1979										1980		Mean
	9 Mar	6 Apr	3 May	14 Jun	13 Jul	9 Aug	6 Sep	4 Oct	9 Nov	7 Dec	17 Jan	14 Feb	Catch
	(number caught/min)												
Ephemeroptera (nymphs)													
Cloeon fluviatile	30	67	57	76	14	23	31	28	108	48	104	20	49.5
Tasmanocoenis sp.A	8	54	73	77	19	45	68	112	43	12	12	6	43.1
Tasmanocoenis sp.B	10	33	55	35	1	12	10	25	4	2			15.6
Thraulus sp.A		7	5	5	3		13	5	1	4	1		3.7
Atalonella sp.A											1		0.1
Centroptilum sp.A	4												0.3
Baetis sp.A												6	0.5
Odonata (nymphs)													
Protoneuridae		1	1			1			1	3			0.6
Ischnura spp.	2	3	5	2			1	1				1	1.3
Pseudagrion spp.	3	6	3	1			1		1		2	4	1.8
Austrogomphus turneri	2	1	1	3	1	3	8	2	1	1			1.9
Antipodogomphus neophytus				1									0.1
Ictinogomphus australis				1		1	1						0.3
Libellulidae	4	3				2				1	1		0.9
Hemicordulia intermedia	2												0.2
Pentathemis membranulata									1				0.1
Hemianax papuensis											2	1	0.3
Hemiptera													
Agraptocorixa sp.A	6	6					1	6			32		4.3
sp.B	3		1						14	12	33	1	5.3
Agraptocorixa halei											5		0.4
Plea brunni			1		3		7	5	>100	9	13		11.5
Ranatra diminuta							1				2		0.3

+ = present but not counted; ^{e} = ovigerous females.
Mean catches were calculated assuming all counts >100 were equal to 100.

Table 4 Monthly counts in Mudginberri Billabong (ctd)

Date	1979										1980		Mean
	9 Mar	6 Apr	3 May	14 Jun	13 Jul	9 Aug	6 Sep	4 Oct	9 Nov	7 Dec	17 Jan	14 Feb	Catch
	(number caught/min)												
Hemiptera (ctd)													
Nychia ?marshalli			3				3	4	28	39	52		10.8
Anisops paracrinita											2		0.2
Naucoris sp.A	1										1		0.2
Naucoridae sp.A									1		1		0.2
Gerridae	+	+	+	+	+	+	+	+	+		+		
Veliidae							+						
Mesovelia sp.A							+				+		
Neuroptera (larvae)													
Sisyra sp.A				1	1								0.2
Diptera (larvae except where indicated)													
Chironomidae	278	>100	>100	>100	>100	>100	>100	>100	>100	90	58	25	89.4
Chironomidae pupae	32	8	26	9	11	10	21	32	18	6	10	1	15.3
Ceratopogonidae	8	3	11	18	31	36	17	30	14	15	1		15.3
Thaumaleidae				6	1	1			1	3			1.0
Culicinae			2							8	2		1.0
Culicinae pupae											16	4	1.7
Tabanidae											2		0.2
Lepidoptera (larvae)													
Pyralidae	2	1									2		0.4
Trichoptera (larvae)													
Tricholeiochiton sp.A	9	1	3									1	1.2
Hellyethia sp.A	12	12				3	2	5			3		3.1
Orthotrichia sp.A			3	3		1			2			1	0.8
Anisocentropus muricatus		1	8	29	31	18	46	34	4	1			14.3
Ecnomus spp.	2	12	3	10	15	5	3	5	3	1			3.8

Date	1979										1980		Mean
	9 Mar	6 Apr	3 May	14 Jun	13 Jul	9 Aug	6 Sep	4 Oct	9 Nov	7 Dec	17 Jan	14 Feb	Catch
	(number caught/min)												
Trichoptera (larvae) (ctd)													
Oecetis spp.	45	32	10	13	8	11	11	56	11	5	2	42	20.5
Triaenodes sp.A	2	5	8	1	1	7		3	2		5	1	2.9
sp.B	6	5	6	5	12	6	2	4	1				3.9
Triplectides sp.A		1	10	16	14	22	17	13	1		1		7.9
Coleoptera													
Dytiscidae larvae							1				1		0.2
Hydroporinae larvae	3										35	6	3.7
Dytiscidae adults	1					7	3	16	64	17	11	1	10.0
Hydrophilidae larvae			1						1		7		0.8
Berosus sp.A (larvae)	2	1									6	7	1.3
Hydrophilidae adults							1	1	15	2	61	1	6.8
Dineutus sp.A (adults)		+	+	+	+		+		+				
Haliplus sp.A (larvae)		1											0.1
Haliplus sp.A (adults)											5		0.4
Austrolimnius sp.A (larvae)	2		1		1								0.3

+ = present but not counted. Mean catches were calculated assuming all counts >100 were equal to 100.

TABLE 5 MONTHLY COUNTS OF MACROINVERTEBRATES IN BUFFALO BILLABONG

Date	1979										1980		Mean
	10 Mar	7 Apr	4 May	15 Jun	14 Jul	10 Aug	7 Sep	5 Oct	10 Nov	8 Dec	18 Jan	15 Feb	Catch
	(number caught/min)												
Porifera													
Pectispongilla botryoides	+	+	+	+	+	+	+	+	+	+	+	+	
Hydridae				2		1			5			1	0.8
Tricladida sp.A	3	3	3	28	25	37	34	26				1	13.3
sp.B					1	1	3	2		1	6	8	1.8
Gordiidae	1	1											0.2
Gastropoda													
Amerianna sp.A	21	31	31	16	6	5		1	6	1	2	23	11.9
Gabbia australis	2	8	33								1	9	4.4
Ferrissia sp.A		1	1	1		1							0.3
Gyraulus sp.A		1	3	8									1.0
Oligochaeta	83	73	>100	>100	>100	46	39	63	>100	>100	>100	>100	83.7
Hirudinea													
Richardsonianidae sp.A	+												
Hydracarina	9	8	9	14	15	5	2		2	3	16	5	7.3
Conchostraca													
Lynceus sp.A												1	0.1
Cyzicus sp.A	25	2	6	1			1	1	2	10	54	28	10.8
Ostracoda	71	44	86	7	16	9	3	13	25	113	>100	>100	47.8
Atyidae													
Caridinides wilkinsi	62^e	133^e	208^e	97^e	83^e	63^e	18	33^e	25	4	2	8	61.3
Caridina sp.a					5^e	1							0.5

Date	1979										1980		Mean
	10 Mar	7 Apr	4 May	15 Jun	14 Jul	10 Aug	7 Sep	5 Oct	10 Nov	8 Dec	18 Jan	15 Feb	Catch
	(number caught/min)												
Palaemonidae													
Macrobrachium sp.A	5	54	38	16	11	20	12	15	6	19			16.3
sp.B				4	4	3	13	2		2			2.3
Ephemeroptera (nymphs)													
Cloeon fluviatile	50	80	139	50	31	18	8	13	41	17	76	29	42.8
Tasmanocoenis sp.A	121	124	86	77	68	80	36	17	18	21	12	14	52.4
Tasmanocoenis sp.B	2	14	5										1.9
Thraulus sp.A		6	2	1			8	1	1	4	1		2.0
Baetis sp.A	7											17	2.0
Atalonella sp.A											4		0.3
Odonata (nymphs)													
Protoneuridae								2	1				0.3
Ischnura spp.	5	16	18	23	13	10		23	15	7	8		11.5
Pseudagrion spp.	1	8	6	11	6	4		5	4	2	3	1	4.3
Austrogomphus turneri				2		1				1			0.3
Antipodogomphus neophytus	1		1				1						0.3
Ictinogomphus australis						2			1		1		0.3
Libellulidae	5	7	9	5	1	5	1	4	9	6	1		4.4
Hemicordulia intermedia		1			1								0.2
Pentathemis membranulata										1			0.1
Hemianax papuensis											1		0.1
Hemiptera													
Agraptocorixa sp.A	1	3	17	2	51			1	12	9	27	1	10.3
sp.B	2	6	45	4	88	1	3		50	20	8		18.9

+ = present but not counted; ^{e} = ovigerous females.
Mean catches were calculated assuming all counts >100 were equal to 100.

Table 5 Monthly counts in Buffalo Billabong (ctd)

Date	1979										1980		Mean
	10 Mar	7 Apr	4 May	15 Jun	14 Jul	10 Aug	7 Sep	5 Oct	10 Nov	8 Dec	18 Jan	15 Feb	Catch
	(number caught/min)												
Hemiptera (ctd)													
Plea brunni			1	7	6	5	6	>100	>100	>100	2		27.3
Ranatra diminuta								2					0.2
Nychia ?marshalli			1			1	13	6	22	12			4.6
Enithares sp.A								1	7				0.7
sp.B								4	7				0.9
Naucoris sp.A				2									0.2
Naucoridae sp.A		1						3					0.3
Hydrometra sp.A	+		+		+			+					
Gerridae	+		+	+	+	+	+	+	+	+	+	+	
Veliidae					+	+	+	+	+	+			
Mesovelia sp.A		+	+	+	+		+	+	+	+			
Neuroptera (larvae)													
Sisyra sp.A	2			2			1	1	1				0.6
Diptera (larvae except where indicated)													
Chironomidae	323	>100	>100	>100	>100	>100	>100	>100	>100	>100	51	71	93.5
Chironomidae pupae	32	9	20	16	15	14	9	10	19	7	1		12.7
Ceratopogodinae	2	4	14	22	17	12	10	46	31	11	4	3	14.7
Thaumaleidae				3	3					2		1	0.8
Chaoborinae					1								0.1
Culicinae	3	1	6	1			2			1	3		1.4
Culicinae pupae								4		23	25	3	4.6
Tabanidae	1											1	0.2
Simuliidae												2	0.2
Lepidoptera (larvae)													
Pyralidae	3		1	4	2	5		14	10	11		1	4.3

Date	1979										1980		Mean
	10 Mar	7 Apr	4 May	15 Jun	14 Jul	10 Aug	7 Sep	5 Oct	10 Nov	8 Dec	18 Jan	15 Feb	Catch
	(number caught/min)												
Trichoptera (larvae)													
Tricholeiochiton sp.A	5			2	1			1	6	7	2		2.0
Hellyethia sp.A		16	8	9	7	11	3		2	1	1	1	4.9
Orthotrichia sp.A		2	2	4	1	5		1	2				1.4
Anisocentropus muricatus	1	7	2	9	9	14	5	4	2	5			4.8
Ecnomus spp.	9	18	1	6	10	9	4	2	6	1	1	2	5.8
Oecetis spp.	3	22	7		4	4	3	5	5	7	1	18	6.6
Triaenodes sp.A	6			1		4					3	4	1.5
sp.B	2	4	5	5	28	8	6						4.8
Triplectides sp.A		2	5	19	6	11	11	5	3	3		1	5.5
Cheumatopsyche sp.A												1	0.1
Coleoptera													
Dytiscidae larvae			1			1	1				1		0.3
Hydroporinae larvae	2										15	1	1.5
Dytiscidae adults		1		2	6			19	32	19		1	6.7
Hydrophilidae larvae		2	4	2			1	2	1	1	3		1.3
Berosus sp.A (larvae)	5	1	1								3	8	1.5
Hydrophilidae adults			4				1	12	30	12	6		5.4
Dineutus sp.A (larvae)	2											3	0.4
Dineutus sp.A (adults)		+	+	+	+	+	+	+	+	+			
Haliplus sp.A (larvae)			1									1	0.2
Noteridae larvae		1											0.1
Austrolimnius sp.A (larvae)					1								0.1
Hydrochidae adults						1	1						0.2

+ = present but not counted. Mean catches were calculated assuming all counts >100 were equal to 100.

TABLE 6 SEASONAL VARIATION IN TOTAL NUMBER OF TAXA AND INDIVIDUALS CAUGHT IN THE BILLABONGS

Date		Total Number of Taxa	Total Number of Individuals
Georgetown			
1979	5 Mar	34	539
	2 Apr	40	518
	30 Apr	46	833
	11 Jun	48	968
	9 Jul	37	758
	6 Aug	35	316
	3 Sep	19	195
	1 Oct	16	224
	6 Nov	13	163
	4 Dec	19	251
1980	14 Jan	33	457
	11 Feb	32	496
Coonjimba			
1979	6 Mar	25	292
	4 Apr	34	517
	1 May	36	613
	12 Jun	42	904
	11 Jul	44	808
	7 Aug	41	712
	4 Sep	39	728
	2 Oct	33	405
	7 Nov	21	282
	7 Dec	18	300
1980	15 Jan	25	505
	12 Feb	21	503
Goanna			
1979	7 Mar	32	500
	5 Apr	41	669
	2 May	42	817
	13 Jun	42	1023
	12 Jul	46	1113
	8 Aug	34	763
	5 Sep	24	228
	3 Oct	19	248
	8 Nov	19	524
	6 Dec	18	534
1980	16 Jan	30	698
	13 Feb	26	507

Table 6 (ctd)

Date		Total Number of Taxa	Total Number of Individuals
Mudginberri			
1979	9 Mar	36	657
	6 Apr	39	569
	3 May	37	535
	14 Jun	36	571
	13 Jul	31	399
	9 Aug	32	453
	6 Sep	40	503
	4 Oct	32	671
	9 Nov	40	689
	7 Dec	32	448
1980	17 Jan	44	893
	14 Feb	27	417
Buffalo			
1979	10 Mar	40	634
	7 Apr	41	758
	4 May	45	883
	15 Jun	44	685
	14 Jul	40	781
	10 Aug	41	519
	7 Sep	36	358
	5 Oct	44	544
	10 Nov	42	709
	8 Dec	42	651
1980	18 Jan	37	545
	15 Feb	36	469

TABLE 7 THE PREDOMINANT TAXA IN EACH BILLABONG BASED ON THOSE WITH A MEAN CATCH GREATER THAN 25
(The most abundant taxon is at the top)

Georgetown	Coonjimba	Goanna	Mudginberri	Buffalo
Oligochaetae	Oligochaetae	Chironomidae	Chironomidae	Chironomidae
Chironomidae	Chironomidae	Hydracarina	Oligochaetae	Oligochaetae
C. fluviatile	*C. fluviatile*	Oligochaetae	*C. fluviatile*	*Tasmanocoenis* sp.A
Ostracoda	Ostracoda	*C. fluviatile*	*Tasmanocoenis* sp.A	*C. wilkinsi*
Chaoborinae	Hydracarina	Ostracoda	*Macrobrachium* sp.A	Ostracoda
	Cyzicus sp.A	*Tasmanocoenis* sp.A		*C. fluviatile*
	Ceratopogonidae	*G. australis*		*P. brunni*
		Orthotrichia sp.A		

TABLE 8 SIMPSON'S INDEX OF DIVERSITY FOR GROUPS IN WHICH ALL SPECIES WERE RECOGNISED

Group	Georgetown	Coonjimba	Goanna	Mudginberri	Buffalo
Gastropoda	2.05	1.07	1.71	1.22	1.91
Large Crustacea	2.42	1.58	2.17	2.91	1.52
Ephemeroptera	1.29	1.22	1.95	2.79	2.24
Hemiptera	4.49	3.95	3.53	3.73	3.26
Trichoptera	2.82	2.80	2.73	4.63	7.53

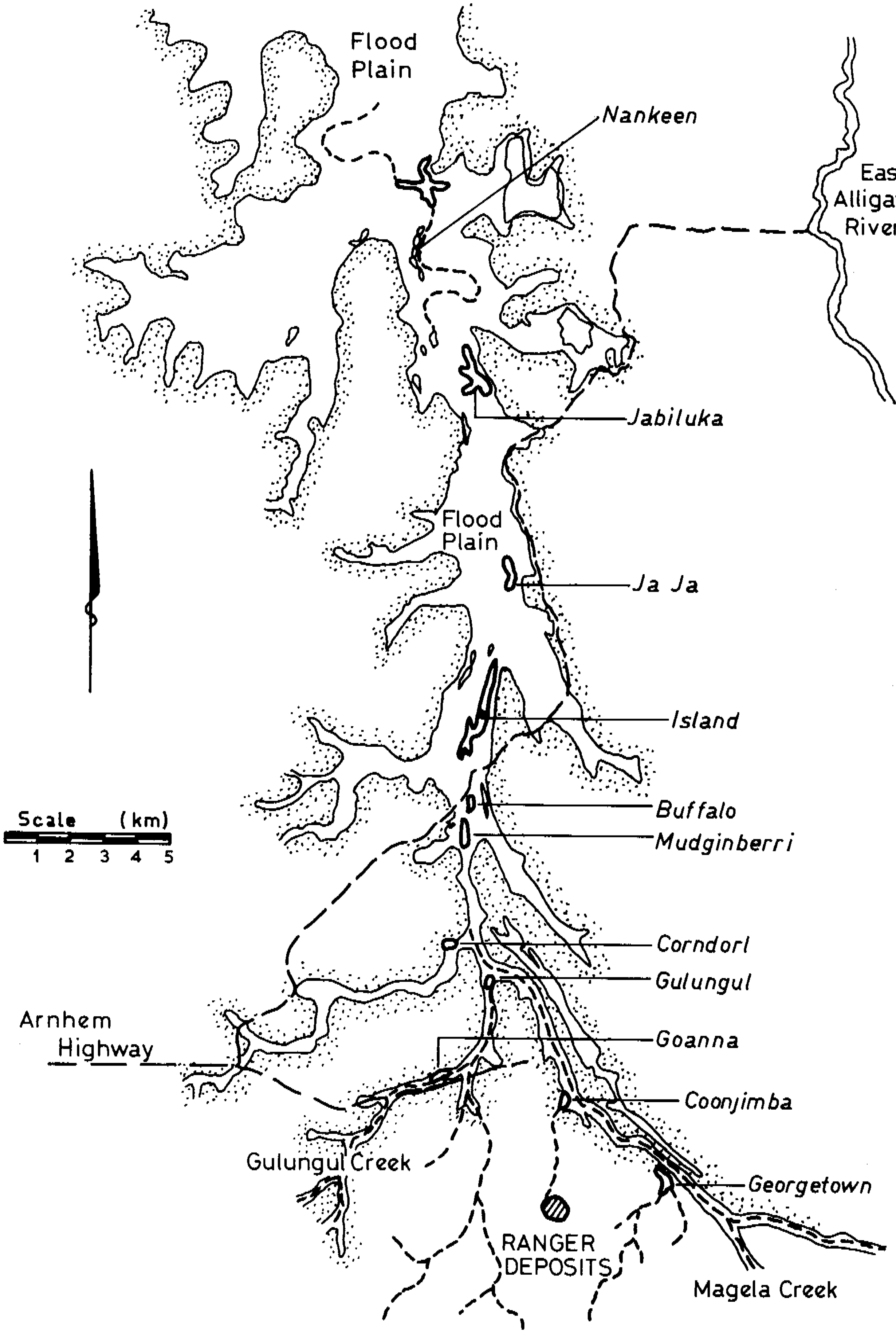

FIG. 1 MAGELA CREEK AND ITS MAJOR BILLABONGS

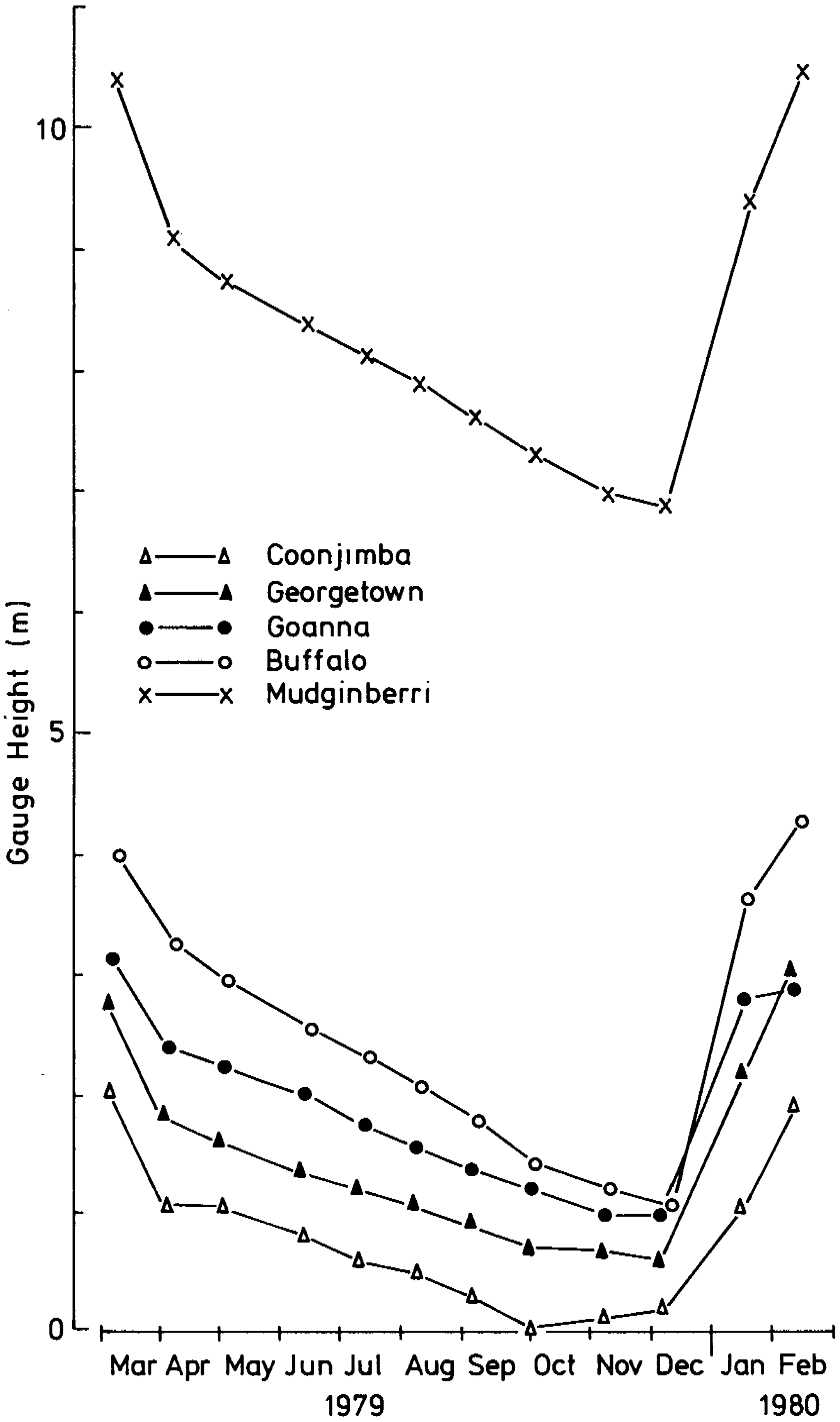

FIG. 2 WATER LEVELS IN THE BILLABONGS BETWEEN MARCH 1979 AND FEBRUARY 1980

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RESEARCH PUBLICATIONS

Research Reports (RR) and Technical Memoranda (TM)

TM 1	Transport of trace metals in the Magela Creek system, Northern Territory. I. Concentrations and loads of iron, manganese, cadmium, copper, lead and zinc during flood periods in the 1978-1979 wet season. December 1981 (26 pp)	Hart, B.T., Davies, S.H.R. & Thomas, P.A.
TM 2	Transport of trace metals in the Magela Creek system, Northern Territory. II. Trace metals in the Magela Creek billabongs at the end of the 1978 dry season. December 1981 (23 pp)	Davies, S.H.R. & Hart, B.T.
TM 3	Transport of trace metals in the Magela Creek system, Northern Territory. III. Billabong sediments. December 1981 (23 pp)	Thomas, P.A. Davies, S.H.R. & Hart, B.T.
TM 4	The foraging behaviour of herons and egrets on the Magela Creek flood plain, Northern Territory. March 1982 (20 pp)	Recher, H.F. & Holmes, R.T.