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# Invertebrate Communities of Relict Streams in the Arid Zone: the George Gill Range, Central Australia

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*Abstract*

The George Gill Range (24°S,132°E) 220 km south west of Alice Springs in the Northern Territory, lies within one of the driest regions of Australia. Diel and seasonal temperature differences are extreme and the average rainfall is 250 mm per annum. The streams of the Range are the largest group within the Central Ranges and are relatively pristine. Their flow regimes are episodic but deep rock pools appear to act as reservoirs of surface runoff and may also receive groundwater from the Mereenie aquifer.

The waterbodies of the Range and some nearby areas were sampled in July and December 1986 to determine the composition of the macroinvertebrate communities and biogeographical relationships with the fauna of lotic systems elsewhere in Australia. Macroinvertebrate species richness at the Range was comparable with that of other Australian streams but no Plecoptera, Isopoda or Amphipoda were collected. The almost complete absence of shredders may reflect low allochthonous inputs, because riparian vegetation in the arid zone is generally sparse. A small proportion of the fauna of the Range appears to be a relictual stream fauna. Species of low vagility such as the waterpenny, *Sclerocyphon fuscus*, would not be capable of dispersal across the large tracts of arid land that now separate the Range from southern Australia, where it is also found. The occurrence of new species at the Range suggests that it is also a site of allopatric speciation within some groups. The conservation values of the streams of the George Gill Range and other sites, such as Giles Springs in the Chewings Range, are extremely high. They represent unique aquatic communities of both ecological and evolutionary importance in the arid zone.

## Introduction

The George Gill Range (24°S,132°E) 220 km south west of Alice Springs in the Northern Territory (Figs 1*a* and 1*b*) lies within one of the driest regions of Australia. The climate is characterized by extreme diel and seasonal temperature differences. The average rainfall is 250 mm per annum but it is non-seasonal, and in some years no rain may fall. Despite the aridity of the area, a relatively large amount of fresh water is present, mainly within the gorges of the area known as the Central Ranges (Wasson 1982). The waters of the George Gill Range are of special interest because they represent the largest group of streams within the Central Ranges and are relatively pristine. Steep topography and the isolated location have greatly restricted the access of cattle and feral animals.

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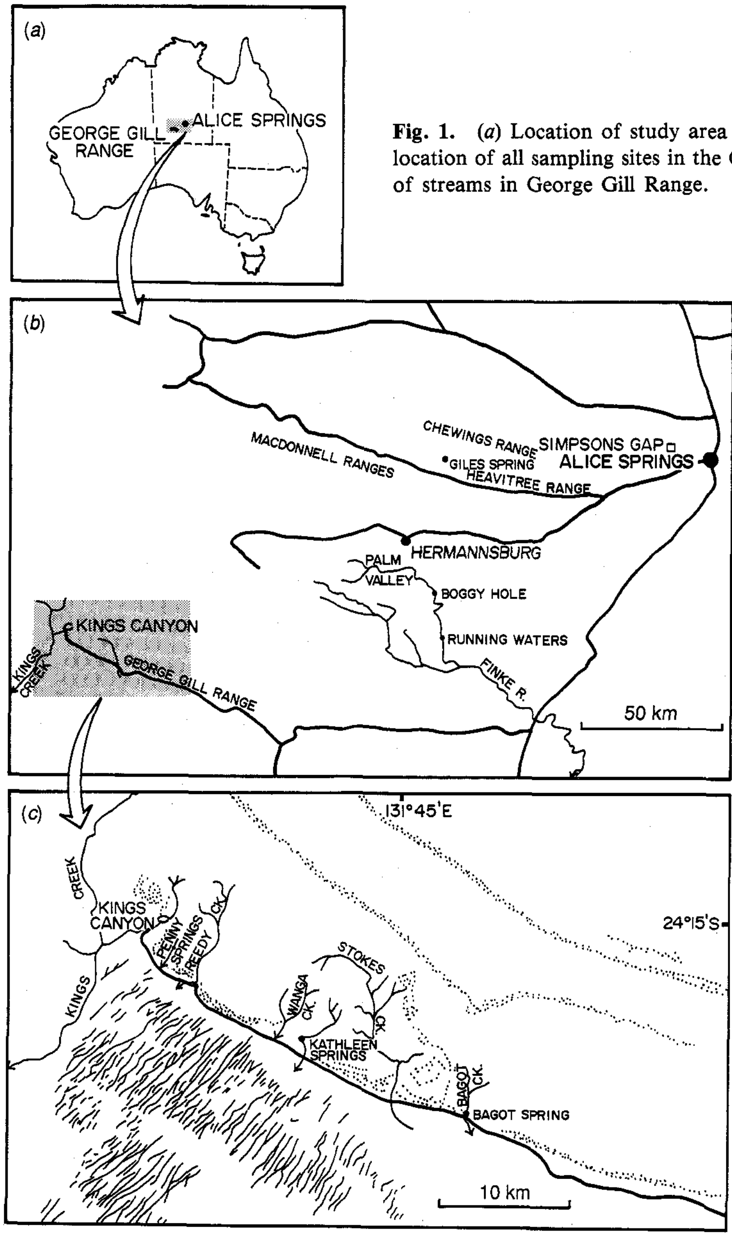



**Fig. 1.** (*a*) Location of study area in Central Australia; (*b*) location of all sampling sites in the Central Ranges; (*c*) detail of streams in George Gill Range.

The streams of the George Gill Range are episodic *sensu* Bayly and Williams (1973) in that flow events are unpredictable, occurring only after heavy rains. However, they are not ephemeral waterbodies. The deep pools that occur at intervals along the largest watercourses, usually at the bases of waterfalls, appear to act as permanent or near-permanent reservoirs of surface runoff. Some are also fed by groundwater seepage from the Mereenie aquifer (see below). The lack of current knowledge regarding episodic and intermittent streams in Australia, despite their occurrence over much of the continent, was noted in recent work by Boulton (1989), Boulton and Lake (1988) and Boulton and Suter (1986).

Although aboriginal people are thought to have inhabited the Range and its environs for over 20 000 years, European knowledge of the area began with the arrival of the explorer Ernest Giles in 1872. Giles was fortunate to arrive at the Range after substantial rains had fallen (Giles 1889). Twenty-two years later (in 1894), the Horn Expedition visited the George Gill Range as part of the first scientific expedition to central Australia (Spencer 1896). The Horn Expedition appears to have visited the Range in drier times than that of Giles; however, they recorded some aquatic fauna including water planarians, large *Nepa*-like insects, *Notonectors* (sic), water beetles, minute cyprids and molluscs such as *Ancylus* and *Bulinus*. Neither fish nor frogs were observed. From Penny Springs, the expedition collected two new species of mollusc and 'a curious Orthopteran insect resembling a small flattened-out cockroach which adheres almost as closely to the surface of submerged leaves as a limpet to a rock'. The latter was probably a larval waterpenny (Coleoptera: Psephenidae).

The object of the present study was to describe the composition of the macroinvertebrate communities of streams of the George Gill Range and to determine biogeographical relationships with the fauna of lotic systems elsewhere in Australia.

## Materials and Methods

### *Study Area*

The George Gill Range comprises Mereenie sandstone, deposited approximately 360 million years ago, overlying Carmichael sandstone deposited approximately 440 million years ago (Bagas undated). Lloyd and Jacobson (1987), in their description of the hydrogeology of the Amadeus Basin, noted that the lower permeability of the latter sandstone compared with the former was indicated by the intermittent presence of a seepage line at contact. This suggests that seepage from the Mereenie aquifer probably provides a permanent source of water in the George Gill Range. Lloyd and Jacobson (1987) noted that groundwater provides the only consistent water source in the Amadeus Basin. The water supply for Alice Springs, a township of approximately 25 000, is drawn from the eastern end of the Mereenie aquifer.

The George Gill Range stands 100 m above the surrounding area and contains a series of gorges with streams which arise on the sandstone plateaux. After rain, the streams flow through a system of waterfalls, pools and runnels before eventually running out into a series of sand dunes (Fig. 1*c*). The higher parts of the Range are bare sandstone plateaux, but the gorges and valleys are shaded owing to their southerly aspect. They contain pockets of vegetation dominated by river red gums (*Eucalyptus camaldulensis*), ghost gums (*E. papuana*), cycad palms (*Macrozamia macdonnellii*), native pines (*Callistris glaucophylla*) and native figs (*Ficus platypoda*).

No rainfall records exist for the George Gill Range but monthly mean totals for Alice Springs for the 13 years up to and including this study and the monthly totals for 1986–87 are given in Fig. 2. The area has a predominantly summer rainfall but heavy falls in both June and November 1986 resulted in the presence of flowing water on the first sampling occasion and pools were well filled, although not flowing, on the second.

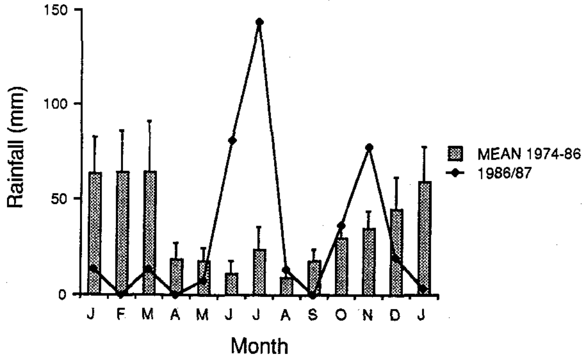



**Fig. 2.** Mean monthly rainfall at Alice Springs over the 13-year period 1974–1986 (vertical bars indicate standard errors) and monthly rainfall totals for the period January 1986 to January 1987.

Seven stream systems in the George Gill Range were sampled during this study: Kings Creek (KC), Penny Springs (PS), Reedy Creek at Tjindri Tjindri (TT) (upper reaches) and Reedy Rockhole (RR) (lower reaches), Kathleen Springs (KS), Stokes Creek (SC), Wanga Creek (WC) and Bagot Springs (BS). Sampling was undertaken on two separate occasions: in winter from 8 to 17 July 1986 and in summer from 27 December 1986 to 2 January 1987. Much of the length of each stream was traversed during the winter field trip and samples of macroinvertebrates were collected from as many different microhabitats as possible. When it became evident that not all samples could be sorted and identified within the time available for the study, attention was focussed on the wettest, shadiest and most well vegetated regions of each stream. These areas were then sampled a second time in summer.

Limited macroinvertebrate sampling was also undertaken in other waterbodies in the Central Ranges area to determine the uniqueness or otherwise of the fauna of the George Gill Range. Areas sampled included Oasis Creek (OC) (a tributary of the Finke River at Palm Valley) and the Boggy Hole (BH) and Running Waters (RW) sections of the Finke River, all of which were sampled in July 1986. Simpsons Gap (SG) in the West MacDonnell Range and Giles Springs (GS) in the Chewings Range were sampled in January 1987. All of these sites were situated to the west or south west of Alice Springs (Fig. 1*b*).

### *Physico-chemistry*

Water samples were collected from selected sites on each of the two sampling occasions. Conductivity and pH were measured in the field. Nutrient analyses were carried out on filtered and unfiltered water samples that were frozen ($-20°C \pm 2°C$) shortly after collection and thawed prior to analysis. For the analysis of soluble reactive phosphate ($PO_4$), nitrite/nitrate ($NO_2/NO_3$) and ammonia ($NH_3$), water was filtered in the field using a syringe and 0·45-$\mu$m Millipore filters. The filters were retained for chlorophyll-*a* analysis. Unfiltered water was collected for analysis of total phosphorus and total nitrogen. Nutrient analyses were performed at the Water Authority of Western Australia using an autoanalyser and a spectrophotometer.

No meteorological data were available for the Range but rainfall and temperature data for Alice Springs were obtained from the Alice Springs Meteorological Station.

### *Macroinvertebrate Sampling*

Semi-quantitative and qualitative collection methods were used to sample as wide a range of aquatic habitats as possible. Many sites could only be reached on foot via a combination of walking and rock climbing. Timed (20 s) sweep samples were taken using a modified version of an FBA pond net (250-$\mu$m mesh). Qualitative collection methods included untimed sweeps, hand collections made with forceps or pipettes, aerial netting and light trapping.

Samples were preserved in ethanol except for water mites collected by hand which were preserved in a solution of acetic acid and glycerol. In the laboratory, sweep samples were washed through three sieves (2 mm, 500 $\mu$m and 250 $\mu$m). When very large numbers of macroinvertebrates were present in a sample, the 500 $\mu$m and/or 250 $\mu$m samples were subsampled using a cylinder-type subsampler. Animals were stored in 70% ethanol and identified to species level where possible. In most cases, identifications were confirmed by specialist taxonomists. Identified material is stored at Murdoch University.

### *Data Analysis*

Invertebrates were classified into four functional feeding groups (shredders, collectors, grazers and predators) according to Cummins and Wilzbach (1985). Those taxa that could not be assigned to a single discrete group were split evenly between the two closest groups. Chironomidae were not sorted to species level for individual sites; for functional feeding analyses they were arbitrarily designated as 90% collectors and 10% predators after Cummins and Wilzbach (1985). A small number of taxa that could not be confidently assigned to any group were classed as undesignated.

## Results

### *Physico-chemistry*

Spot water temperatures recorded at the Range in July 1987 ranged from 10·5 to 11·5°C and those recorded in December ranged from 22 to 30°C (Table 1). pH was generally just below neutral; the lowest value, 5·7, was recorded at Kings Canyon and the highest

**Table 1. Physico-chemical parameters recorded at waterbodies in the George Gill Range in July and December 1986**

For site abbreviations see Appendix

| | Month | Site | | | | | |
|---|---|---|---|---|---|---|---|
| | | SC | PS | KS | KC | TT | RR |
| Water temperature | July | 11·5 | 11·0 | 10·5 | 10·5 | 11·0 | – |
| (°C) | December | 23·0 | 22·5 | 30·0 | 22·0 | 24·0 | 24·0 |
| pH | July | 6·3 | 6·7 | 6·8 | 5·7 | 6·6 | 6·3 |
| | December | 6·9 | 6·3 | 6·8 | 6·6 | 6·5 | 6·3 |
| Conductivity | July | 73 | – | 540 | 27 | 76 | 362 |
| ($\mu$S cm$^{-1}$) | December | 153 | 99 | 573 | 25 | 70 | 365 |

value, 6·9, at Stokes Creek (Table 1). The waters of the Range were generally very dilute; the lowest conductivity recorded was 27 $\mu$S cm$^{-1}$ at Kings Canyon and the highest 573 $\mu$S cm$^{-1}$ at Kathleen Springs (Table 1). The cause of the much higher conductivities at Kathleen Springs and Reedy Rockhole is not known. The fresher sites may receive more groundwater whereas evapoconcentrative processes may predominate at the less dilute sites.

Values for pH and conductivity were recorded at other waterbodies in central Australia. Giles Spring in the Chewings Range was the freshest (53 $\mu$S cm$^{-1}$) and most acidic (4·8). The other waterbodies assessed were Oasis Creek in Palm Valley (1000 $\mu$S cm$^{-1}$ and pH 8·6) and Running Waters and Boggy Hole on the Finke River (1880 and 6110 $\mu$S cm$^{-1}$, pH 8·2 and 9·6, respectively).

Nutrients were measured at the waterbodies sampled most intensively for macroinvertebrates (Table 2). On the basis of total phosphorus concentration, these waterbodies appeared to be mesotrophic according to Wetzel's (1983) classification of trophic status for lakes and reservoirs. Total phosphorus concentrations were generally higher in summer than in winter. Stokes Creek and Reedy Rockhole were eutrophic with respect to total nitrogen, and Kings Canyon and Tjindri Tjindri were mesotrophic in both summer and winter. The concentration of total nitrogen in Kathleen Springs was much higher in winter (eutrophic) than in summer

**Table 2. Nutrient concentrations recorded at waterbodies in the George Gill Range in July and December 1986**

Chl-*a*, chlorophyll *a*. For site abbreviations see Appendix

| Nutrient | Month | Site | | | | | |
|---|---|---|---|---|---|---|---|
| | | SC | PS | KS | KC | TT | RR |
| $PO_4$ (mg m$^{-3}$) | July | 2 | – | 6 | 2 | 3 | 2 |
| | December | 5 | 5 | 4 | 5 | 5 | 4 |
| $NO_2$ (mg m$^{-3}$) | July | 3 | – | 3 | 1 | 1 | 2 |
| | December | 11 | 2 | 4 | 3 | 2 | 17 |
| $NO_3$ (mg m$^{-3}$) | July | 2017 | – | 1097 | 419 | 11 | 2628 |
| | December | 1889 | 48 | 164 | 53 | 10 | 1943 |
| $NH_3$ (mg m$^{-3}$) | July | 23 | – | <5 | 419 | <5 | <5 |
| | December | <5 | 10 | 17 | 53 | <5 | 26 |
| Total P (mg m$^{-3}$) | July | 13·0 | – | 15·0 | 13·0 | 11·0 | 4·0 |
| | December | 16·0 | 31·0 | 10·0 | 28·0 | 27·0 | 17·0 |
| Total N (mg m$^{-3}$) | July | 2660 | – | 1450 | 770 | 812 | 2860 |
| | December | 2630 | 800 | 498 | 747 | 582 | 2420 |
| Chl-*a* (mg m$^{-3}$) | July | 0·6 | – | 6·5 | 5·2 | 1·2 | 1·2 |
| | December | 7·5 | 42·7 | 5·6 | 10·4 | 13·3 | 8·4 |

(mesotrophic). Penny Springs, Kings Canyon and Tjindri Tjindri were classified as eutrophic on the basis of chlorophyll *a*, whereas Stokes Creek, Kathleen Springs and Reedy Rockhole appeared to be mesotrophic.

### *Macroinvertebrates*

#### *Species richness*

In total, 109 species were recorded at the Range (see Appendix), although this is undoubtedly an underestimate of the entire fauna. Year-round sampling and greater taxonomic effort for some groups (e.g. Chironomidae) would yield further species. Individuals of some taxa (Oligochaeta, Cladocera) were identified to species level, but their occurrence across the different sites was not established. Species found at sites outside the Range are listed at the end of the Appendix and include a further four species at Giles Springs, one at Simpsons Gap, six at the Finke River sites (Running Waters and Boggy Hole) and one at Oasis Creek (Palm Valley). The Appendix also lists the abbreviations used for the sampling sites.

The total number of taxa found at each site within the Range and numbers at sites elsewhere in central Australia are given in Table 3. The numbers of sweep samples from which this information was obtained are also given as a general, but not absolute (because qualitative collections were also made) indication of the amount of sampling effort expended at each waterbody. The low number of taxa recorded from Wanga Creek and sites outside the George Gill Range would be at least partly a result of the less intensive sampling of these sites.

**Table 3. Total number of taxa recorded at the George Gill Range and other waterbodies in Central Australia in 1986**

Numbers of sweep samples on which totals were based are also given. Totals include additional taxa recorded by various qualitative methods of collection. For site abbreviations see Appendix

| Site | SC | PS | KS | KC | TT | RR | WC | BS | GS | SG | RW | BH | OC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of taxa | 64 | 54 | 49 | 39 | 44 | 40 | 11 | 32 | 30 | 22 | 11 | 16 | 14 |
| No. of sweeps | 8 | 5 | 8 | 7 | 6 | 6 | 1 | 2 | 2 | 2 | 1 | 1 | 1 |

The following species were common to all waterbodies where sampling effort was most intensive and approximately equal (SC, PS, KS, KC, TT, RR): *Limnesia* sp. (Hydracarina), *Cypricercus salinus* (Ostracoda), *Macrocyclops albidus* (Copepoda), *Atalophlebia australis* (Leptophlebiidae), *Cloeon* sp. (Baetidae), *Austroagrion watsoni* (Coenagrionidae), *Anisops occipitalis* (Notonectidae), *Micronecta* nr *annae* (Corixidae), *Necterosoma penicillatum* (Dytiscidae), *Necterosoma* sp. (larva—possibly the juvenile of *N. penicillatum*) and *Ecnomus continentalis* (Ecnomidae).

### *Species Composition*

#### *Lower taxa*

No Porifera, Cnidaria, Turbellaria, Nematoda, Annelida and Hirudinea were abundant, although small individuals may have been lost through the 250 $\mu$m net. Little time was devoted to the identification of these taxa because of the lack of keys and expert taxonomic help. However, as an indication of the state of knowledge of central Australian oligochaetes, three of four species from the collections have been identified as new species (W. Fulton, personal communication).

*Mollusca*

Seven species of molluscs were collected. The planorbid, *Gyraulus* sp. A, was abundant at Kathleen Springs. Of the remaining species, all except *Ferrissia* sp. A and *Pisidium* sp. A, were uncommon. None of the molluscs could be assigned to species (W. Ponder, personal communication).

*Acarina*

The aquatic Acarina comprised one mesostigmatid, six hydracarinid and two oribatid species, none of which could be assigned to species because of the poor knowledge of this group in the arid zone (M. Harvey, personal communication). The large numbers of nymphs of an unidentified mite found attached to the thorax of a dragonfly, *Hemicordulia flava*, suggest a method of dispersal for this group.

*Cladocera*

The cladoceran fauna was not fully investigated and may be more extensive than represented here. All of the genera identified have widespread distributions in Australia.

*Ostracoda*

Ostracods were often abundant and nine species were collected. *Alboa fitzroyi* has previously been recorded only from the north Kimberley (described as *Candonocypris fitzroyi*, McKenzie 1966). *Cypricercus salinus* is generally limited to southern Australia (De Deckker 1981) including slightly saline lakes in the Snowy Mountains but also mound springs in Queensland. *Ilyodromus viridulis* is a common ostracod confined to fresh waters. *Newnhamia fenestrata* has a southern distribution in Australia, but also occurs in the Kimberley and in New Zealand (De Deckker, personal communication). A new species, *Cypricercus* sp. A, was found at the Range. A further species, *Heterocypris salinus*, found in the Finke River, inhabits saline pools in North Africa and Europe and is found in pools in creek beds in the Flinders Ranges in South Australia (De Deckker, personal communication).

*Copepoda*

Copepods were moderately abundant with six of the species being widespread in Australia. A new species, *Paracyclops* sp. A is known from only one locality, just southeast of Perth, W.A.

*Decapoda*

The yabby, *Cherax destructor*, was collected at Stokes Creek; the species was apparently introduced to the Range 18 years ago for sport fishing (I. Conway, personal communication).

*Ephemeroptera*

Two of the three species found could not be assigned to known species and may represent new taxa. *Atalophlebia australis* has an otherwise southern distribution, being found in South Australia, Victoria and Tasmania (Suter 1986).

*Odonata*

Nymphs of six species were found, with a further five species being collected only as adults. The damselfly *Austroagrion watsoni* and the dragonfly *Diplacodes haematodes* were the most widespread over the collecting sites. Distributional records for Australian Odonata (Watson 1974; Watson *et al.* 1991) indicate that seven species (*Austroagrion watsoni*, *Ischnura aurora*, *Xanthagrion erythroneurum*, *Hemianax papuensis*, *Diplacodes bipunctata*, *D. haematodes* and *Orthetrum caledonicum*) are widespread throughout Australia. *Orthetrum migratum* occurs in coastal Queensland and northern and central Australia. *Trapezostigma stenoloba* has a similar distribution to *O. migratum*, but is also found in south-western W.A. Previous records for *Austrogomphus gordoni* indicated it to be restricted to the Pilbara region of W.A., but this study provides a new locality record for the species. The previous record for *Hemicordulia flava* was limited to a single individual from central Australia. This species appears to be endemic to the Central Ranges region.

*Hemiptera*

Of the eight species of hemipterans found, only three were common: the notonectids *Enithares* sp. A and *Anisops occipitalis*, and the corixid *Micronecta* nr *annae*. These species were widely distributed at the Range, but were not found at the Finke River sites or at Palm Valley. Elsewhere, *A. occipitalis* is known from north-eastern Queensland, New Guinea, Asia and the Pacific. *Micronecta* nr *annae* shows some variation in the form of the parameres from both of the subspecies of *M. annae* described by Wróblewski (1970). A further species of notonectid, *Anisops* nr *leucothea*, occurred at Simpsons Gap. Individuals collected in this study vary from the description of *A. leucothea* (Brooks 1951), a species known from Wallis Island in the Pacific Ocean.

*Coleoptera*

Ten species of dytiscids were collected, although it is likely that larvae of *Necterosoma* sp. A (listed as a separate taxon) are in fact *N. penicillatum*. One additional species was found at Boggy Hole and at Giles Springs. Five other Coleopteran families, Gyrinidae, Hydrochidae, Hydrophilidae, Psephenidae and Helodidae, were represented in the George Gill Range collections. The gyrinid, identified tentatively as *Macrogyrus* (*Tribolomimus*) *gouldi*, is a northern Australian species (Ochs 1949). The water penny *Sclerocyphon fuscus* is known from South Australia and Victoria only (Davis 1986). One further family, Hydraenidae, represented by *Hydraena simplicicollis*, was collected at Giles Springs. This is a northern species, the lectotype having been collected at Reedy Creek by the Horn Expedition (Zwick 1977).

*Diptera*

The Chironomidae were by far the most important family of Diptera, both in terms of number of species and abundance of individuals. These included three species of the subfamily Tanypodinae and nine species of the subfamily Chironominae. Apart from the Ceratopogonidae, of which several species often occurred in great abundance, the other Dipteran families were represented by single species that occurred in small numbers. The simulid *Simulium ornatipes* was found in shallow waters flowing over rock surfaces. This species has an Australia-wide distribution that includes central Australia (Colbo 1976). Studies of chromosomal polymorphisms in *Simulium ornatipes* suggest that this species is undergoing speciation (Bedo 1979).

*Trichoptera*

Six species of caddisfly were recorded, with an additional species (*Triplectides volda*) found at Giles Springs in the Chewings Range. Larvae of *Ecnomus continentalis*, a free-living trichopteran, occurred at most sites in the Range and adults of the species were caught in light traps at Reedy Rockhole. The species has a coastal distribution from Queensland to South Australia and this is the only record for inland Australia (Cartwright 1990). *Triplectides australis* is a common and widespread species, whereas *Hellyethira simplex* and *Triplectides volda* were previously known from south-eastern Australia only (Neboiss 1983).

The relative importance of the major taxa at the Range together with comparative information compiled by Boulton and Suter (1986) for temporary streams in South Australia and Victoria, are presented in Fig. 3. Of the total aquatic invertebrate fauna collected during summer and winter at the Range, three major groups (Crustacea, Coleoptera and Diptera) contributed 54% of the species. Similar results were obtained for species composition at sites within the Range and within each sampling period.

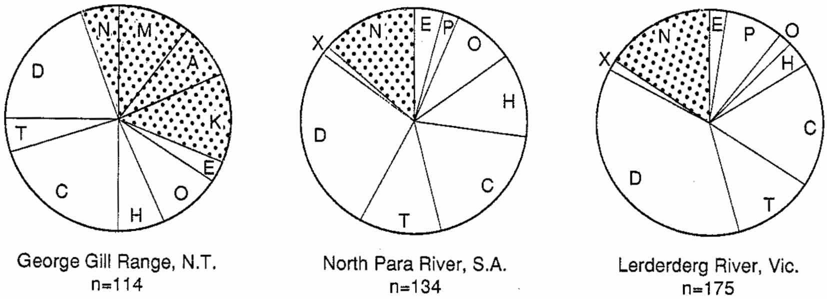



**Fig. 3.** The relative importance of major taxa at the George Gill Range, the North Para River in South Australia and the Lerderderg River in Victoria [the latter two after Boulton and Suter (1986)]. Shading indicates non-insect groups. A, Acarina; C, Coleoptera; D, Diptera; E, Ephemeroptera; H, Hemiptera; K, Crustacea; M, Mollusca; O, Odonata; P, Plecoptera; T, Trichoptera; X, other insects; N, other non-insects.

*Species Abundance*

The total numbers of macroinvertebrates collected in the George Gill Range in winter and in summer, and on both sampling occasions combined, reveal that there were three dominant taxa: Ostracoda, Copepoda and Chironomidae (Fig. 4). Ostracods were generally more abundant and copepods less abundant in winter than in summer. The relative abundance of chironomids was approximately the same at both sampling periods.

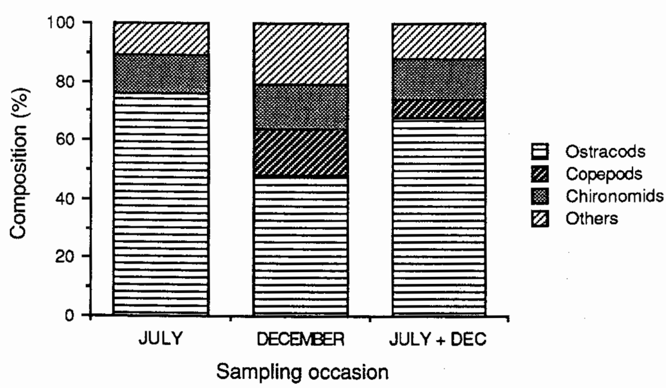



**Fig. 4.** Percentage composition of macroinvertebrate communities (based on total numbers of individuals collected in sweep samples) at the George Gill Range in July and December, and both months combined in 1986.

Individual sites differed markedly in the dominant taxa present (Fig. 5). No single major taxon comprised more than 5% of the total number of individuals at every site. Chironomids, however, occurred at every site, but accounted for only 4% of the total individuals at Reedy Rockhole (winter) because of the masking effect of massive numbers of ostracods at that site. Ostracods were the dominant major taxon at Penny Springs, Kathleen Springs and Reedy Rockhole (where they made up 94% of the total individuals).

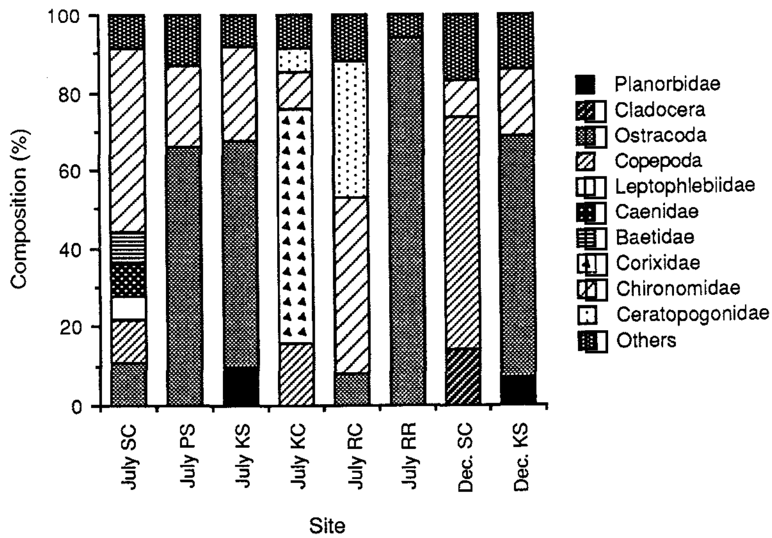



**Fig. 5.** Percentage composition of macroinvertebrate communities (based on total numbers of individuals collected in sweep samples) at selected sites in the George Gill Range in July and December 1986. Only taxa comprising >5% of the total number of individuals at any site are included. For site abbreviations see the Appendix.

By contrast, ostracods represented fewer than 5% of the total individuals at Kings Canyon (July) and Stokes Creek (December). Kings Canyon (July) and Reedy Creek (July) were distinguished from the other sites in that corixids and dipteran larvae (chironomids and ceratopogonids) respectively, were the most abundant taxa.

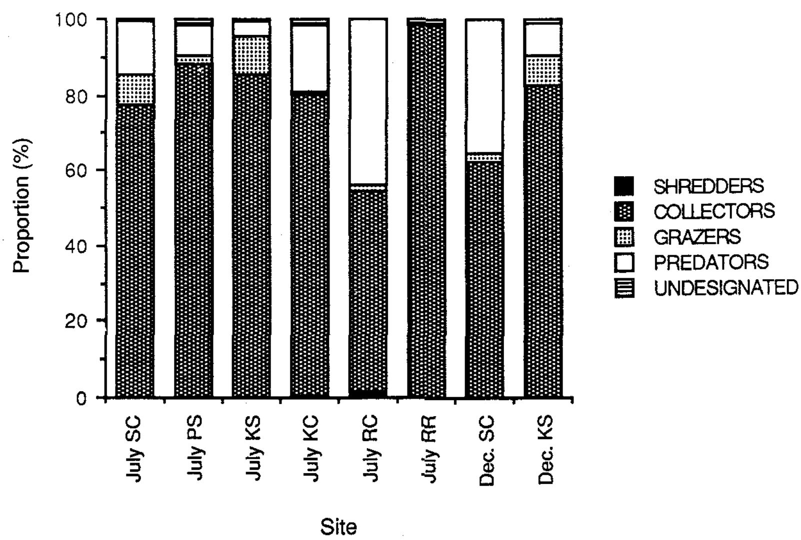



**Fig. 6.** Proportions of functional feeding groups recorded at sites in the George Gill Range in July and December 1986. Proportions are based on the total numbers of individuals in each group.

*Functional Feeding Groups*

Most of the taxa collected at the George Gill Range were either predators (51 taxa) or collectors (36 taxa). However, in terms of abundance, collectors were by far the most important feeding group (Fig. 6). Collectors constituted 80% of the winter samples and 74% of the summer samples. Grazers and predators were marginally more numerous in summer than in winter. Shredders accounted for $<1\%$ of the total individuals collected on both sampling occasions.

Collectors comprised mainly ostracods and chironomids at at all sites. Grazers were generally relatively unimportant except at Kathleen Springs where large numbers of molluscs (mainly *Gyraulus* sp.) occurred. Shredders comprised $<2\%$ of the total individuals at any site.

*Biogeographic Affinities of the Fauna*

The level of knowledge of the various groups of Australian aquatic invertebrates is, for the most part, inadequate. Of the George Gill Range fauna, only 51 taxa (45%) could be identified to species, although 95 (83%) were identified to genus. Some groups such as the Odonata and Dytiscidae are relatively well known, but for the majority of taxa keys are nonexistent or incomplete and distributional records may be misleading because only part of the species' total range has been sampled.

The distributional information that was available for species found at the Range (Table 4) is presented according to their occurrence in each of the 16 biogeographical regions (Fig. 7*a*) proposed by Watson (1974).

The majority of species occurring at the Range have cosmopolitan (or widespread) or southern distributions. Relatively few species have primarily northern distributions. This (Fig. 7*b*) indicates that the southern coastal regions (and north-eastern Queensland where some cool, high-altitude habitat is present) contain the greatest numbers of species in common with central Australia.

The eleven species of Odonata that occur at the George Gill Range comprise seven widespread species, two species with very restricted ranges (*Austrogomphus gordoni* and *Hemicordulia flava*) and two with basically northern distributions (*Orthetrum migratum* and *Trapezostigma stenoloba*; Table 4). There are fewer species in common with southern or eastern inland Australia than there are with northern and western Australia (Fig. 7*c*).

The corresponding picture for the Dytiscidae is less clear (Fig. 7*d*). Some species (e.g. *Necterosoma penicillatum* and *Rhantus saturalis*) appear to have southern distributions, whereas others (e.g. *Hydaticus bihamatus* and *Sandracottus bakewelli*) have more northerly ranges (Table 4). There are more species in common with coastal Queensland, south-western Australia and South Australia than elsewhere, a situation which may reflect reality, as well as relatively thorough collecting in those areas. Conversely, the absence of species from isolated biogeographical regions (Cape York, the Kimberley, inland Queensland) may be the result of inadequate collecting.

A number of other species such as the water penny *Sclerocyphon fuscus*, the mayfly *Atalophlebia australis*, the blackfly *Simulium ornatipes*, and the caddisflies *Hellyethira simplex* and *Ecnomus continentalis* have ranges limited to southern Australia (Fig. 7*e*). For species with widespread but disjunct distributions that appear inexplicable on an ecological basis (e.g. the ostracod *Newnhamia fenestrata*), future collecting may fill gaps in the species distributions.

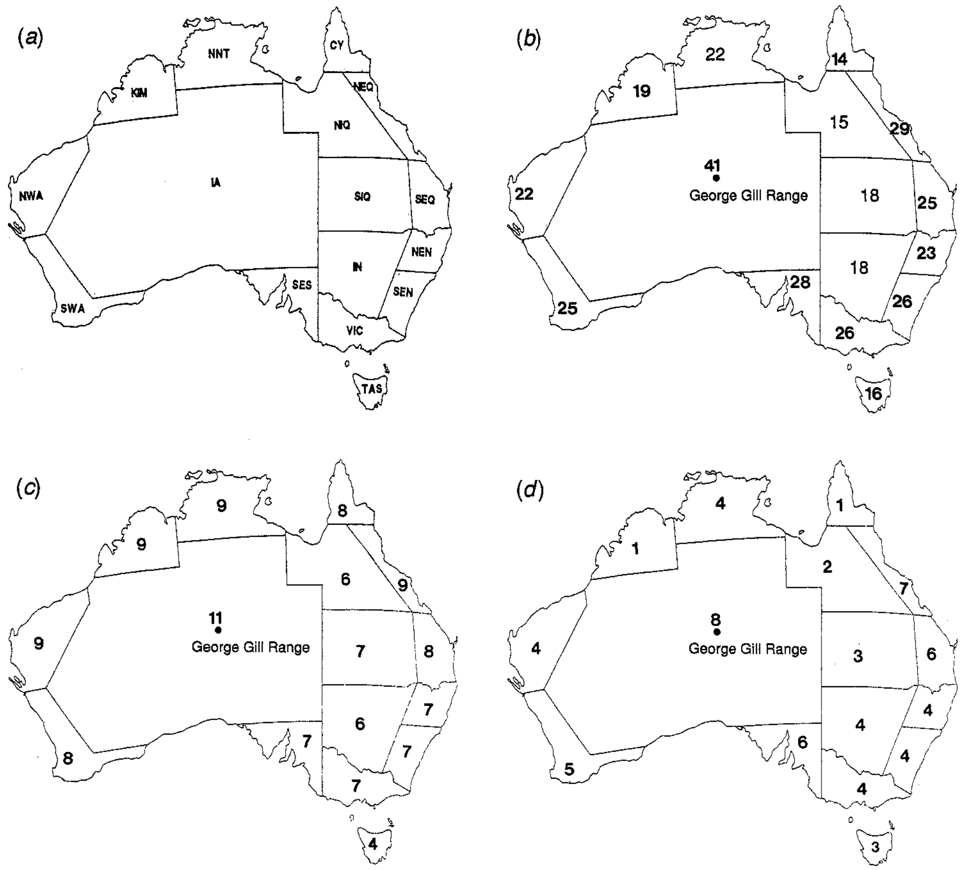
## Discussion

The species richness of the Range appears to be comparable with that of temporary and permanent streams elsewhere in Australia and overseas (Boulton and Suter 1986), given the seasonally-limited sampling and low taxonomic precision for some taxa in this study.

**Table 4. Distribution, in the 16 biogeographical regions in Australia proposed by Watson (1974), of taxa that occur at the George Gill Range**

See Fig. *7a* for location of the regions

| TAXON | SWA | SES | VIC | TAS | SEN | NEN | SEQ | NEQ | CY | NNT | KIM | NWA | IN | SIQ | NIQ | IA | SOURCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alboa fitzroyi* | | | | | | | | | | | + | | | | | + | McKenzie (1966) |
| *Newnhamia fenestrata* | + | + | + | + | + | + | | | | | + | | | | | + | " |
| *Cypricercus salinus* | | | + | | | | | | | | | | | | | + | De Deckker (1981) |
| *Boeckella triarticulata* | + | + | + | + | + | + | + | + | | | + | + | + | + | + | + | D. Morton (pers.comm.) |
| *Calamoecia lucasi* | + | + | + | + | + | + | + | + | | | + | + | + | + | + | + | " |
| *Macrocyclops albidus* | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Eucyclops* sp. A | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Mesocyclops albicans* | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Ectocyclops rubescens* | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Paracyclops* sp. A | + | | | | | | | | | | | | | | | + | " |
| *Atalophlebia australis* | | + | + | + | | | | | | | | | | | | + | Suter (1986) |
| *Austroagrion watsoni* | | + | + | + | + | + | + | + | + | + | + | | | + | | + | Watson (1974); Watson *et al.* (1991) |
| *Ischnura aurora* | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Xanthagrion erythroneurum* | + | + | + | + | + | + | + | + | | + | + | + | + | + | + | + | " |
| *Austrogomphus gordoni* | + | | | | | | | | | | | + | | | | + | " |
| *Hemianax papuensis* | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Hemicordulia flava* | | | | | | | | | | | | | | | | + | " |
| *Diplacodes haematodes* | + | + | + | | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Diplacodes bipunctata* | + | + | + | | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Orthetrum caledonicum* | + | + | + | | + | + | + | + | + | + | + | + | + | + | + | + | " |
| *Orthetrum migratum* | | | | | | | | + | + | + | + | + | | | | + | " |
| *Trapezostigma stenoloba* | + | | | | | | + | + | + | + | + | + | | | | + | " |
| *Anisops occipitalis* | | | | | | | | + | | | | | | | | + | Brooks (1951) |
| *Platynectes decempunctatus* | + | + | + | + | + | + | + | + | + | + | | | + | + | | + | Watts (1978) |
| *Necterosoma penicillatum* | + | + | + | + | + | + | + | + | | | | | + | + | | + | " |
| *Hydrovatus opacus* | | + | | | | | | + | | + | | | | | + | + | " |
| *Hyphydrus elegans* | + | + | | | + | + | + | + | | | | + | | | | + | " |
| *Hydaticus bihamatus* | | | | | | | + | + | | + | | | | | | + | " |
| *Sandracottus bakewelli* | | | | | | | + | + | | + | | + | | | | + | " |
| *Eretes australis* | + | + | | | | | | + | | | + | + | + | + | + | + | " |
| *Rhantus suturalis* | + | + | + | + | + | + | + | | | | | + | + | | | + | " |
| *Sclerocyphon fuscus* | | + | + | | | | | | | | | | | | | + | Davis (1986) |
| *Polypedilum watsoni* | | | | | + | | | | | + | | + | | | | + | Freeman (1961); Cranston (1990) |
| *Polypedilum oresitrophus* | | | | | + | | | | | + | | | | | | + | " |
| *P. (Pentapedilum) leei* | + | + | | | + | | | + | | + | | | | | | + | " |
| *Kiefferulus intertinctus* | + | + | + | | + | + | + | | | + | | | | | | + | " |
| *Stenochironomus watsoni* | | | + | | | | | + | | | | + | | | | + | Freeman (1961) |
| *Simulium ornatipes* | + | + | + | | + | + | + | + | | | | | + | + | | + | Colbo (1976) |
| *Hellyethira simplex* | | + | + | + | + | + | + | + | | | | | | | | + | Wells (1985) |
| *Ecnomus continentalis* | | + | + | | + | + | + | + | | | | | | | | + | Cartwright (1990) |
| *Triplectides australis* | + | + | + | | + | + | + | + | + | + | + | + | + | + | + | + | Neboiss (1983) |



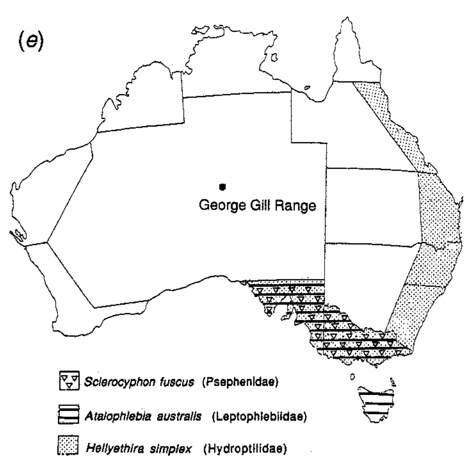




**Fig. 7.** (*a*) Biogeographical regions of Australia after Watson (1974). (*b*) Distribution of 41 species of macroinvertebrates that occur at the George Gill Range (as listed in Table 5) in Watson's (1974) biogeographical regions of Australia. (*c*) Distribution of Odonata that occur at the George Gill Range. (*d*) Distribution of Dytiscidae that occur at the George Gill Range. (*e*) Distributions of *Sclerocyphon fuscus* (Psephenidae) *Atalophlebia australis* (Leptophlebiidae) and *Hellyethira simplex* (Hydroptilidae), all of which also occur at the George Gill Range.

Our data do not support the idea of a trend towards lower species richness for streams with shorter periods of flow (Williams and Hynes 1976). Rather, the high habitat diversity and consequent adaptations of species of temporary streams may result in high species richness (Lake *et al.* 1985).

Within the George Gill Range the most species-rich waterbodies, Penny Springs and Stokes Creek, contained the shadiest, coolest and most well-vegetated microhabitats and appeared to be least disturbed by either human or animal impacts. Of the other waterbodies sampled in central Australia during this study, Giles Springs contained the richest macroinvertebrate fauna. The lower number of species recorded at other sites may be a consequence of much harsher thermal regimes and anthropogenic disturbance. The waters of Oasis Creek in Palm Valley appeared to be largely ephemeral. Boggy Hole and Running Waters on the Finke River were semi-permanent wetlands with much evidence of disturbance by cattle.

The streams of the George Gill Range appeared to contain more non-insect taxa than recorded from other waterbodies such as the North Para and Lerderderg Rivers (Fig. 3). However, previous researchers may have concentrated on macroinvertebrates rather than microcrustaceans and so underestimated non-insect species diversity. Groups such as the Mollusca would be favoured by the presence of extensive rock platforms (at Penny Springs and Stokes Creek) and emergent macrophytes such as *Typha* (at Kathleen Springs), both of which represent microhabitats well suited to grazers. The molluscs, crustaceans and water mites may also be favoured by the standing-water habitats of the deep rock pools present throughout the stream systems of the Range.

In terms of species composition, the streams of the George Gill Range are generally similar to temporary and permanent streams elsewhere (Boulton and Suter 1986) with the following exceptions. One major group, the Plecoptera, was not found. Although stoneflies are known to inhabit intermittent aquatic habitats and streams of fluctuating temperature (Merritt and Cummins 1984), in Australia they are confined to temperate southern Australia and the Queensland highlands (Williams 1980). The most likely explanation for their apparent absence from central Australia is that their thermal tolerances are exceeded during summer. Neither isopods nor amphipods were recorded in this study. The absence of these groups may reflect lower inputs of riparian plant material. Riparian vegetation in the arid region is sparser than that associated with streams in temperate regions, except in very moist microhabitats.

The almost total absence of shredders from the low-order streams of the Range contradicts the distributions of functional groups originally hypothesized by the River Continuum Concept (Vannote *et al.* 1980). The RCC predicted the codominance of shredders and collectors in headwaters of streams as a reflection of the importance of the riparian zone, but several other studies have not supported these predictions (Winterbourn *et al.* 1981; Fisher and Gray 1983; Dudgeon 1984; Bunn 1986). However, our results do agree with the modified concept of Minshall *et al.* (1985) that desert streams enter the continuum at a point equivalent to a more downstream position for a forest stream (owing to the lack of shading and reduced input of allochthonous detritus). The main explanation for a lack of shredders is that some rivers have little input of coarse particulate organic matter (Fisher and Gray 1983; Dudgeon 1984). This also appears to be the case in regulated streams below dams (Short and Ward 1980), a situation that could be seen as analagous to the episodic flow regime and deep rock pool reservoirs of the Range streams. The shaded, shallow areas that do receive litter input from overhanging ferns (Penny Springs and Stokes Creek) might be expected to support a shredder community, except that the only available refuges during non-flow periods are deep pools without overhanging vegetation and presumably without CPOM for shredding. In the absence of significant CPOM and shredder invertebrates, what provides fine food material for collectors? Algal growth may be enhanced by the high insolation levels found in desert streams (Busch and Fisher 1981), and the increased microbial activity at high temperatures may break down algal material (Reice 1974; Short and Ward 1980) for feeding by collectors.

The fauna of the George Gill Range appeared to be quite different to that of other non-ephemeral arid-zone aquatic habitats such as the mound springs of South Australia. The mound springs to the south and west of Lake Eyre are moderately saline environments with conductivities ranging from 5600 to 14 700 $\mu$S cm$^{-1}$ (Mitchell 1985). Important elements of the fauna of these springs (Mitchell 1985), such as the phreatoicid *Phreatomerus latipes*, hydrobiid gastropods, an unidentified amphipod and the gobiid teleost *Chlamydogobius eremius*, were not recorded at the George Gill Range.

Chippendale (1963) regarded some of the ranges of Central Australia, including the MacDonnell, James, Krichauff and George Gill Ranges, as relict areas 'where plants of a higher rainfall period have survived'. A biological survey of the George Gill Range (Latz *et al.* 1981) showed that the area is very rich floristically and that a small but significant percentage of the flora is rare or of relict distribution. Similarly, a small proportion of the aquatic fauna present at the George Gill Range appear to be a relictual stream fauna. Species such as the waterpenny *Sclerocyphon fuscus*, with an aquatic larva and a cryptic adult beetle capable of only limited flight (Davis 1986), would not be capable of dispersal across the large tracts of arid land that now separate the George Gill Range from the southern regions of Australia where it also occurs. The presence of other stream dwelling species of apparently low vagility such as *Atalophebia australis*, *Hellyethira simplex* and *Ecnomus continentalis* supports this notion of a relictual lotic fauna. These species were probably more widespread when the continent was much wetter than it is today. The exact period when the George Gill Range may have been in some form of aquatic continuity with other regions of Australia is not known. Some of the fauna present at the Range may have survived from ancestral forms present since the early Tertiary when Australia was characterized both by widespread humidity and by temperatures warmer than at present (Kemp 1981). However, there may have been several arid cycles in the Tertiary (Frakes *et al.* 1987). Nix (1982) concluded that the major radiation and differentiation of the Australian biota took place long before the Quaternary and that the climatic fluctuations of the Quaternary may have caused differential extinctions. These fluctuations may have largely determined the present day distributions of plants and animals (Bowler 1982). The only information available that indicates that elements of the present-day lotic fauna at the Range may have been the result of dispersal during a pluvial phase of the Quaternary rather than earlier in the Tertiary is the reconstruction of the phylogenetic history of the waterpenny genus, *Sclerocyphon*. This places *S. fuscus*, the species that occurs at the Range and also in southern Australia, in one of the most recently derived species-groups (Davis 1986) suggesting that dispersal of this species is likely to have occurred under suitable conditions in recent, rather than earlier, times.

Although elements of a temperate-zone stream fauna are present at the George Gill Range the communities appear to be unique to central Australia. Increasing seasonality of both thermal and water regimes are considered to have been a primary factor in the evolution of the Australian flora and fauna (Nix 1982). Increasing aridity, unpredictable flow and a highly seasonal thermal regime have probably resulted in the local extinction of stream-dwelling species that were intolerant of warmer waters, episodic flow regimes and possibly a lack of CPOM (as riparian vegetation diminished with increasing aridity) in central Australia.

The change in climatic conditions and the isolated nature of the waterbodies of the George Gill Range also suggest that it is an obvious site for allopatric speciation. A new species of dragonfly, *Hemicordulia flava*, has been recorded only at this range and the Chewings Range. Species such as *Micronecta* nr *annae*, which appears closely related but displays some variation from the species originally dsecribed, also indicate that speciation may be occurring within this fauna. The true extent of speciation at the George Gill Range or within the Central Ranges cannot be determined, however, until the taxonomy of many of the groups present is much better known. Generally, the greatest amounts of taxonomic information are available for groups such as the Odonata and Dytiscidae, which contain the largest and most mobile members of the aquatic fauna, and much less is known about many of the less vagile and more cryptic organisms.

There is still much to learn about the aquatic ecosystems of central Australia. In addition to overcoming the taxonomic impediment, information regarding the life history strategies of macroinvertebrates and the trophic basis of these waterbodies is required. Further, a better knowledge of thermal and hydrological regimes will assist understanding of the way in which these systems function. However, the information obtained in the present study is sufficient to indicate that the conservation value of the aquatic habitats and communities of the George Gill Range is extremely high.

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**Appendix. List of taxa recorded at the George Gill Range and other waterbodies in central Australia in 1986**

+, present in sweep samples; *, present in qualitative collections; SC, Stokes Creek; PS, Penny's Springs; KS, Kathleen Springs; KC, Kings Canyon; TT, Tjindri Tjindri (upper Reedy Creek); RR, Reedy Rockhole (lower Reedy Creek); WC, Wanga Creek; BS, Bagot Springs; GS, Giles Spring; SG, Simpsons Gap; RW, Running Waters; BH, Boggy Hole; OC, Oasis Creek

L, larva; N, nymph; A, adult

| Taxon | | George Gill Range | | | | | | | | Other sites | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SC | PS | KS | KC | TT | RR | WC | BS | GS | SG | RW | BH | OC |
| PORIFERA | | | | | | * | | | | | | | | |
| CNIDARIA | | + | | | + | | | | | + | | | | |
| PLATYHELMINTHES | | | + | | + | * | + | | | | | | | |
| NEMATODA | | | + | + | + | + | + | + | | | + | | | |
| Oligochaeta | | + | + | + | | * | + | | | | + | | | |
| | Oligochaeta sp. A | | | | | | | | | | | | | |
| | Oligochaeta sp. B | | | | | | | | | | | | | |
| | Oligochaeta sp. C | | | | | | | | | | | | | |
| | Oligochaeta sp. | | | | | | | | | | | | | |
| HIRUDINEA | | | | | + | * | | | | * | | | | |
| Ancylidae | *Ferrissia* sp. | + | + | + | | | | | + | + | | | | |
| Planorbidae | *Physastra* sp. A | * | | | | | | | | | | | | |
| | *Physastra* sp. B | | | | * | | | | | | | | | |
| | *Isidorella* sp. A | * | | | | | | * | | | + | | | |
| | *Isidorella* sp. B | * | | | + | + | | | + | | | | | + |
| | *Gyraulus* sp. | + | | + | | | | | | | | | | |
| Sphaeriidae | *Pisidium* sp. | + | + | + | * | | + | | + | | | | | |
| Mesostigmata | | | | | + | | | | | | | | | |
| Hydracarina | *Limnesia* sp. | + | + | + | + | + | + | + | | + | + | | | * |
| | *Hydrachna* sp. | + | | + | + | | | | | | | | | |
| | *Unionicola* sp. | + | | | + | | + | + | | | | + | + | |
| | *Barwontius* sp. | | + | | + | * | | | | + | + | | | |
| | *Tiphys* sp. | * | | | | | | | | | | | | |
| | *Arrenurus* sp. | | | + | + | | + | | | | | | | |
| Oribatida | Species A | + | + | + | | | + | | | * | | | | |
| | Species b | | | + | | | | | | | | | | |

**Appendix** (*continued*)

| | Taxon | | George Gill Range | | | | | | | | Other sites | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | SC | PS | KS | KC | TT | RR | WC | BS | GS | SG | RW | BH | OC |
| Cladocera | | | + | + | + | + | + | + | | + | | + | | | |
| Chydoridae | *Alona* sp. | | | | | | | | | | | | | | |
| Macrothricidae | *Ilyocryptus* sp. | | | | | | | | | | | | | | |
| Daphniidae | *Daphnia* sp. | | | | | | | | | | | | | | |
| | *Ceriodaphnia* sp. | | | | | | | | | | | | | | |
| | *Simocephalus* sp. | | | | | | | | | | | | | | |
| Ostracoda | *Alboa fitzroyi* (McKenzie) | | | | + | | | | | | | | | | |
| | *Cypretta* af *minna* | | + | + | + | | | | | | | | | | |
| | *Ilyodromus viridulis* (Brady) | | + | + | + | + | | + | | + | | + | | + | |
| | *Newnhamia fenestrata* King | | + | + | + | + | | | | | + | + | | | |
| | *Cypricercus salinus* De Deckker | | + | + | + | + | + | + | | + | + | + | | | + |
| | *Cypricercus* sp. | | + | | | | + | + | + | | | | | | |
| | *Candonopsis* sp. | | | | | | | + | | | | | | | |
| | *Darwinula* sp. | | | | + | | | | | + | | | | + | |
| | *Limnocythere* sp. | | | | | | + | | | | | | | | |
| Copepoda | | | | | | | | | | | | | | | |
| Calanoida | *Boeckella triarticulata* (Thomson) | | + | | | | + | | | | | + | | | |
| | *Calamoecia lucasi* Brady | | + | | | + | | | | | | | | | |
| Cyclopoida | *Macrocyclops albidus* (Jurine) | | + | + | + | + | + | + | | | | | | | |
| | *Eucyclops* sp. *australiensis* Morton | | + | + | | | + | | | + | | | | | |
| | *Mesocyclops* sp. | | + | + | + | | + | | | + | + | + | | | |
| | *Ectocyclops rubescens* Brady | | | + | | | | | | | | | | | |
| | *Paracyclops* sp. nov. | | | + | | | | | | | | | | | |
| Decapoda | | | | | | | | | | | | | | | |
| Parastacidae | *Cherax destructor* (Clark) | | + | | | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | | | | | | |
| Leptophlebiidae | *Atalophlebia australis* (Walker) | L | + | + | + | + | + | + | | | + | + | | | |
| Caenida | *Tasmanocoenis* sp. | L | + | | + | + | + | | | | | | + | | |
| Baetidae | *Cloeon* sp. | L | + | + | + | + | + | + | | + | | + | + | + | + |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Odonata | | | | | | | | | | | | | | | | | | |
| Zygoptera | | | | | | | | | | | | | | | | | | |
| | Coenagriidae | *Austroagrion watsoni* Lieftinck | N, A | + | + | + | + | * | + | | + | | | | + | + | |
| | | *Ischnura aurora* (Brauer) | A | * | | | | * | | | * | | | | | | |
| | | *Xanthagrion erythroneurum* (Selys) | A | | | | | * | | | | | | | | | |
| Anisoptera | | | | | | | | | | | | | | | | | | |
| | Gomphidae | *Austrogomphus gordoni* Watson | N, A | | | + | | * | + | | | | | | | | |
| | Aeschnidae | *Hemianax papuensis* (Burmeister) | N | + | | + | | * | | | | | | | | | |
| | Corduliidae | *Hemicordulia flava* Thieschinger & Watson | | * | | | * | * | * | | | | * | | | | |
| | Libellulidae | *Diplacodes haematodes* (Burmeister) | N, A | + | | + | + | + | | | | | | | + | | |
| | | *Diplacodes bipunctata* (Brauer) | A | | | * | | * | | | | | | | | | |
| | | *Orthetrum caledonicum* (Brauer) | N, A | + | + | + | | | | | + | | * | | | | |
| | | *Orthetrum migratum* Lieftinck | A | | + | | | | | | | | | | | | |
| | | *Trapezostigma stenoloba* Watson | N, A | | | + | | + | + | | | | | | | | |
| Hemiptera | | | | | | | | | | | | | | | | | | |
| | Veliidae | *Microvelia* sp. | | + | * | + | | | + | | + | | * | | | | |
| | Mesoveliidae | *Mesovelia* sp. | | | | + | | | + | | | | | | | | |
| | Notonectidae | *Enithares* sp. | | + | + | + | + | + | | | + | | + | + | | | |
| | | *Anisops occipitalis* Breddin | | + | + | + | + | + | + | + | + | | | | | | |
| | Corixidae | *Micronecta* nr *annae* | | + | + | + | + | + | + | | + | | + | + | | | |
| | | *Agraptocorixa eurynome* (Kirkaldy) | | * | | | | + | | | + | | | + | | | |
| | Nepidae | *Laccotrephes tristis* Stal | | | * | | | * | | | | | | | | | |
| | | *Ranatra* sp. | | | | | | | | | + | | | | | | |
| Coleoptera | | | | | | | | | | | | | | | | | | |
| | Dytiscidae | *Platynectesdecempunctatus* (Fabricius) | A | | | | | | | | + | | | | | | |
| | | *Limbodessus* sp. | A | | | | | * | | | | | + | + | | | |
| | | *Necterosoma* sp. | L | + | + | + | + | + | + | | + | | | | + | + | + |
| | | *Necterosoma penicillatum* (Clark) | A | + | + | + | + | + | + | + | + | | + | + | + | + | + |
| | | *Hydrovatus opacus* Sharp | L, A | * | | | | | | | | | | | | | |
| | | *Hyphydrus elegans* (Montrouzier) | A | + | + | | | | | | + | | | | | | |
| | | *Hydaticus bihamatus* Aube | A | + | + | | | | | | | | | | | | |
| | | *Sandracottus bakewelli* (Clark) | A | + | + | | | * | | | | | | + | | | |
| | | *Eretes australis* (Erichson) | A | * | | | | | | | | | | | | | |
| | | *Rhantus saturalis* Macleay | L, A | * | | + | | | | | + | | + | | | | |
| | Gyrinidae | *Macrogyrus* (*Tribolomimus*) *gouldi*? (Hope) | | + | + | + | + | | | | | | + | * | | | |

**Appendix** (*continued*)

| | Taxon | | George Gill Range | | | | | | | | Other sites | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | SC | PS | KS | KC | TT | RR | WC | BS | GS | SG | RW | BH | OC |
| Hydrochidae | *Hydrochus* sp. A | A | | + | | | | | | | * | | | | |
| | *Hydrochus* sp. B | A | * | | | | | | | + | | | | | |
| Hydrophilidae | *Paracymus* sp. | A | | + | | | | | | | | | | | |
| | *Sternolophus* sp. | A | | + | | | | | | | + | | | | |
| | *Hydrobius* sp. | A | * | + | | | | | | | | | | | |
| | *Enochrus* sp. A | L | * | * | | | | | | | | | | | |
| | *Enochrus* sp. B | L | | + | | | | | | | | | | | |
| Staphylinidae | | L | | | | | | | | | | | | | |
| Psephenidae | *Sclerocyphon fuscus* Bertrand & Watts | L | * | + | | + | | | | | + | | | | |
| Helodidae | | L | | + | | | | | | | | | | | |
| Diptera | | | | | | | | | | | | | | | |
| Tipulidae | | L | | | | | | * | | | * | | | | |
| Culicidae | | L | | + | | + | * | + | | | | | | | |
| Chironomidae | | | | | | | | | | | | | | | |
| Tanypodinae | *Procladius* nr *paludicola* | L | + | + | + | | + | | | | | | | | |
| | *Paramerina levidensis* (Skuse) | L | + | + | | | + | + | | | | | | | |
| | *Paramerina* nr *parva* | L | | | + | | | | | | | | + | + | + |
| Chironominae | | | | | | | | | | | | | | | |
| Chironomini | *Polypedilum watsoni* Freeman | L | | | + | | | | | | | | | | |
| | *Polypedilum oresitrophus* (Skuse) | L | | + | | | | | | | | | | | |
| | *Polypedilum* (*Pentadilum*) *leei* Freeman | L, A | + | | + | | | * | | | | | | | |
| | *Dicrotendipes* nr *taylori* | L, A | + | + | + | | + | + | | | | | | | |
| | *Rietha* sp. A | L | | | + | + | | | | | | | | | |
| | *Kiefferulus intertinctus* Skuse | L | | | | | | | + | | | | | | |
| | *Chironomus* nr *februarius* | L | | | | | | | + | | | | | | + |
| | *Stenochironomus watsoni* Freeman | L | | | | | | * | | | | | | | |
| Tanytarsini | *Tanytarsus* sp. A | L | + | + | | | | | | | | | | + | + |
| Ceratopogonidae | spp. | L | + | + | + | + | + | + | + | + | + | + | | + | + |
| Simulidae | *Simulium ornatipes* Skuse | L | * | | | | | | | | | | | | |
| Thaumaleidae | | L | | | | + | * | | | | | | | | |
| Tabanidae | | L | * | * | | | | | | + | | | | | |
| Stratiomyidae | | L | * | * | + | | | + | | + | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trichoptera | | | | | | | | | | | | | | | | |
| Hydroptilidae | *Hellyethira simplex* (Mosely) | L | | + | | | | + | | | | | | | + | |
| Ecnomidae | *Ecnomus continentalis* Ulmer | L, A | + | + | + | + | + | + | | | | + | | | | |
| Leptoceridae | *Oecetis* sp. A | L | + | | + | | | | | | | | | + | | |
| | *Oecetis* sp. B | L | | | | | + | + | | | | | | | | |
| | *Oecetis* sp. C | L | | | | | + | + | | | | | | | | |
| | *Triplectides australis* Navas | L | * | | + | | | | | + | | + | | | | |
| | | Giles Springs | | | | | | | | | | | | | | |
| Ostracoda | *Candonidae* sp. A | | | | | | | | | | | + | | | | |
| Coleoptera | | | | | | | | | | | | | | | | |
| Dytiscidae | *Copelatus irregularis* Macleay | A | | | | | | | | | | + | | | | |
| Hydraenidae | *Hydraena simplicicollis* Zwick | A | | | | | | | | | | + | | | | |
| Trichoptera | | | | | | | | | | | | | | | | |
| Leptoceridae | *Triplectides volda* Mosely | L | | | | | | | | | | + | | | | |
| | | Simpsons Gap | | | | | | | | | | | | | | |
| Notonectidae | *Anisops* nr *leucothea* | | | | | | | | | | | | + | | | |
| | | Finke River | | | | | | | | | | | | | | |
| Thiaridae | *Thiara* sp. | | | | | | | | | | | | | + | + | |
| Ostracoda | *Heterocypris salina* Brady | | | | | | | | | | | | | + | | |
| Palaemonidae | *Macrobrachium* sp. | | | | | | | | | | | | | | + | |
| Chironomidae | *Polypedilum nubifer* (Skuse) | L | | | | | | | | | | | | | + | |
| | *Cladopelma curtivalva* Kieffer | L | | | | | | | | | | | | | + | |
| Dytiscidae | *Antiporus* sp. A | L | | | | | | | | | | | | | + | |
| | | Oasis Creek (PV) | | | | | | | | | | | | | | |
| Notostraca | *Triops australiensis australiensis* Spencer and Hall | | | | | | | | | | | | | | | + |

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