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Landscape and Man

THE AQUATIC INVERTEBRATE FAUNA OF WESTERN TASMANIA

R. Swain,* P. Allbrook* and P.S. Lake**
* Dept. of Zoology, University of Tasmania
** Dept. of Zoology, University of Monash

ABSTRACT

Although there are close associations with the south-western fauna, there are nevertheless some aquatic invertebrates found predominantly in western Tasmania, and some biological problems best studied by reference to such animals; examples from two families of crustacea and two insect orders are discussed in this paper.

Western Tasmania may be regarded as the freshwater crayfish (Parastacidae) centre of the State, all four Tasmanian genera being found there. Each genus is discussed in turn; the habitats utilised are considered and adaptation to these habitats is illustrated by particular reference to burrow systems, calcium distribution in the exoskeleton and where possible, breeding patterns. Data is also provided on distribution and associated zoogeographical questions are briefly considered.

Two genera of the family Koonungidae (Syncarida) are found in the west - *Micraspides* and *Koonunga*. Their habitats and distribution are discussed and attention is drawn to the need for more ecological data in order to formulate answers to the zoogeographical issues involved.

The Odonata exemplify an insect order with generally good dispersal powers. All dragonfly species found in western Tasmania, together with their nymphal habitats, are collated and discussed. The most interesting species are the cold-climate adapted species, especially archaics such as *Archipetalia auriculata* and *Synthemiopsis gomphomacromioides*. Attention is drawn to the probable importance of diapause as an adaptation to cold montane habitats. Three components are recognised in the odonatan fauna, - cosmopolitan groups, ancient Australasian groups, and very ancient Gondwanaland relicts.

The Plecoptera is an order demonstrating poor vagility and only 6 of 31 Tasmanian species are shared with mainland Australia. The majority of Tasmanian species are cold climate adapted forms and consequently western waters have a particularly conspicuous stonefly fauna. Data on the habitats and distribution of all species found in western Tasmania is collated and discussed.

The influence of man on aquatic environments in western Tasmania is briefly considered. Environmental modification results from mining activities, hydro-electric development, forestry practices and from the introduction of exotic species such as trout.

INTRODUCTION

Recent interest in the aquatic invertebrate fauna of western Tasmania has arisen largely as a consequence of the greatly increased awareness amongst biologists of the importance of the south-west as the source of a fascinating range of taxonomic, zoogeographical, ecological, and physiological problems. The appreciation of the scientific value of the south-west, which we can now extend to the West Coast, arose in turn from the belated discovery that Lake Pedder represented a great deal more than an extraordinarily beautiful lake in a magnificent montane setting, and a strong case for the biological importance of Lake Pedder and its environs was presented by Bayly *et al.* (1972). The literature concerning south-western and western faunas is predominantly taxonomic and frequently reflects the difficulties and limitations imposed on those wishing to travel and collect in terrain that is invariably rugged and usually remote. However, in recent years some ecological work has been published (Bayly 1973; Bayly *et al.* 1972; Knott and Lake 1974; Lake and Newcombe 1975; Suter 1976) and studies have commenced on some of the physiological adaptations utilised by the freshwater crustacean fauna (Lake *et al.* 1974; Newcombe 1975; Swain and Lake 1974). In addition the fauna of south-western Tasmania has been reviewed by Swain (1972) and by Lake *et al.* (in press) and many pertinent comments are to be found in the excellent review of Tasmanian freshwater crustacea provided by Williams (1974).

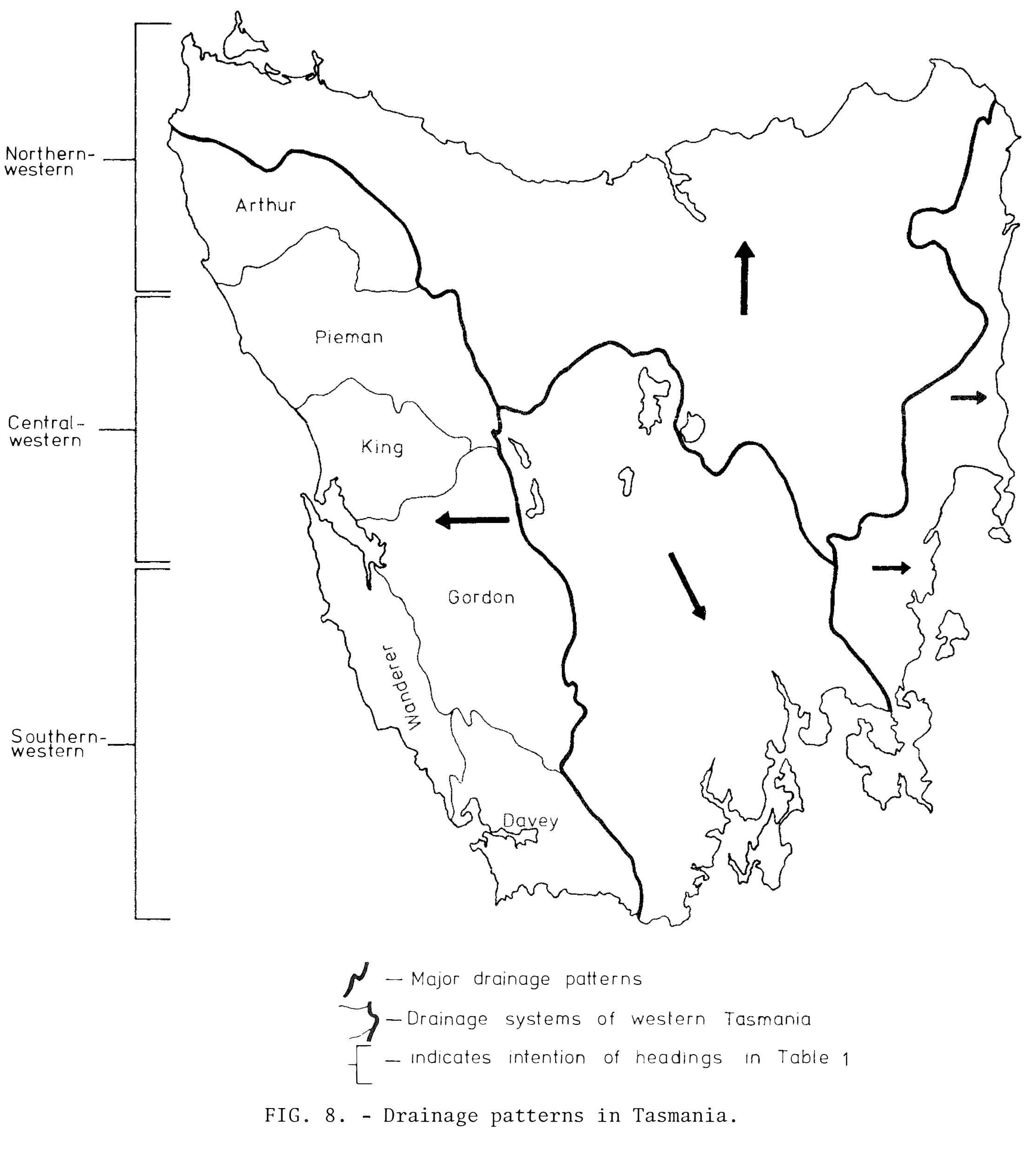

FIG. 8. - Drainage patterns in Tasmania.

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It is becoming increasingly clear that although the aquatic faunas of western and south-western Tasmania are intimately linked, there are nevertheless some animal groups that are found predominantly, or even exclusively, in the west and some problems whose study is best facilitated by concentrating on such groups. It is to examples of such groups and the problems associated with them, that this paper is directed. To do this it is first necessary to provide loose boundaries to the region under consideration and to briefly outline the range of limnological, climatic, vegetational and geomorphological characteristics present.

THE WESTERN REGION

Tasmania is both a moist and a mountainous island; not surprisingly these two features provide a convenient basis for delineating a 'western region' suitable for present purposes. With the exception of a series of short and relatively small rivers along the east coast, Tasmanian rivers drain north into Bass Strait, south-easterly into Storm Bay, or west into the Indian Ocean (fig.8). The rivers draining west comprise six major drainage areas (fig.8) and collectively these will be regarded as 'western Tasmania', although it will be apparent that a number of the animals referred to are also found outside this area, particularly because of the faunal association between the Arthur River system and the minor drainage systems of the far north-west coast. These western rivers arise in a mountainous series of ranges running parallel to the west coast - the Western Ranges - and enter the sea across an uplifted and much dissected peneplain which extends almost the entire length of the coast. Tasmania is represented by two major structure provinces (Davies 1965), a fault structure province of post-Carboniferous rocks found in the centre, east and south-east of the state, and a fold structure province of exposed pre-Carboniferous rocks in the west and north-east. Western Tasmania, as defined above, therefore comprises the greater part of the western fold province. The mountains forming the Western Ranges are ridge-like as a result of river excavation and aligned along the axes of folding; the ridges are formed largely of metamorphosed quartzites and conglomerates. As Davies (1965) points out, the individual river systems show a pronounced trellis pattern and only the major systems have maintained their course across the line of mountain ranges, often by means of spectacular gorges. The general pattern of trans-structural drainage is radial and has resulted in the development of wide valley plains in many places. Sedgeland or wet-scrub communities are usually found in the plains and lower slopes; elsewhere scrub-forest or rainforest communities predominate, often dominated by *Eucalyptus nitida* and/or *E. ovata* but in some cases consisting of magnificent stands of virtually pure *Nothofagus* forest. Areas of coastal heath also occur behind Ocean Beach and in the north-west corner of the State.

The high rainfall and diverse topography combine to offer an abundant variety of water bodies. Lotic waters range from large rivers, often with extensive estuaries, through creeks of all sizes and degrees of turbulence, to the smallest of seepages. Lentic waters consist of swamps, both highland and lowland, lakes, mostly glacial cirques plus the coastal lagoons at Ocean Beach near Strahan. Although standing waters are undoubtedly important habitats, especially for highland species, the lotic systems probably provide a greater proportion of the aquatic habitats available.

Most of the waters are dilute with ionic dominance and ionic proportions similar to those of sea water (Tyler 1974). Ions are supplied largely by precipitation, the lack of any strong geochemical influence being due to the predominance of inert rocks which resist weathering and to the large areas of peat soil which isolate the water from underlying rock (Buckney and Tyler 1973). However, geochemical influences may be locally important where weatherable rocks are exposed as, for example, in the areas when Gordon Limestone outcrops. River waters range from pH 5.6 to 7.5 (Buckney and Tyler 1973, Table 1) whereas the leaching of humic materials by swamp waters results in these waters being more acidic, with a characteristic brown hue and high total dissolved solid values.

The Aquatic Invertebrate Fauna

THE FAUNA

Only selected groups will be considered here; the omission of many important groups, e.g. Amphipoda, Janiridae, Ephemeroptera, Trichoptera, reflects the incompleteness of our understanding in these areas whilst the Phreatoicoidea are omitted in the light of Knott's (1976) extensive work on this group and the expectation of future publications from that author.

The Parastacidae

Freshwater crayfish are widespread throughout the southern hemisphere with the exception of South Africa and India. Recognition of their common ancestry and of their separateness from northern hemisphere species was afforded by Huxley (1878) who established the family Parastacidae. Recently, Hobbs (1974) further emphasised their distinct nature by erecting the superfamily Parastacoidae with the Parastacidae as its single family. Western Tasmania may be regarded as the stronghold of freshwater crayfish in this state and all four genera known to occur in Tasmania are found there, but except where specifically stated neither the genera nor the species discussed below are restricted solely to the western region. Two of the four genera are endemic to Tasmania *(Astacopsis* and *Parastacoides)* whilst the remaining pair *(Engaeus* and *Geocharax)* occur also on the islands of Bass Strait and in the south-eastern corner of mainland Australia. At the species level, all except for *Geocharax falcata* are endemic. A simplified summary of distribution and habitat associations of Tasmanian parastacids is provided in table 1.

Astacopsis species are all inhabitants of lotic systems. *A. gouldi* and *A. tricornis* are both large crayfish and specimens of *A. gouldi* weighing 3 Kg are common (Lynch 1970); the species has the distinction of being the largest freshwater crayfish in the world. Whilst the afore-mentioned species are common in rivers and large creeks. *A. fluviatilis* appears to inhabit mainly creeks. However, it must be noted that the taxonomic status of astacopsids is uncertain and the apparent separation of habitat association suggested by table 1 may very well be misleading. It does appear though

Table 1.

Habitat characteristics of parastacid crayfish in western Tasmania

Taxon.	Water types utilised						Vegetational associations				Distribution within western Tasmania		
	Above water table	Below water table							Sedgelands				
		large rivers	large Creeks/ streams	Seepages	Small Creek beds/ banks	Flood -plains	Rainforest and wet - sclerophyll	'Ti-tree' swamps	sub-alpine	lowland	northern-western	central-western	southern - western
Astacopsis fluviatilis	0	+	+++	0	0	0	+++	0	0	++	0	0	+
A. tricornis	0	+++	+	0	0	0	+++	0	0	++	0	+++	++
A. gouldi	0	+++	+	0	0	0	+++	0	0	++	+++	+?	0
Parastacoides tasmanicus	0	0	(+) rarely	++	++	+++	+++	+++	+++	+++	+	+++	+++
Engaeus fossor	0	0	+	+++	+++	++	+++	+++	0	++	+++	+++	0
Engaeus sp.	+++	0	0	0	+	+ ‡	+++	+	0	+ ‡ rarely	+++	+++	0
Geocharax falcata	0	0	++	++	++	++	0	0	0	+++	+++	0	0

\+ - +++ indicates relative frequency of occurrence

0 - indicates does not occur in association with stated characteristic

‡ - apparently only where European man has removed original forest

Data compiled from personal observations of the authors and from Knott (1976) and Suter (1975) that the crayfish are absent from the headwaters of river systems and prefer shaded, reasonably still pools where protection is afforded by logs, rocks or overhanging banks. Some burrowing may occur to produce a retreat under such cover, but investigation of calcium distribution in the exoskeleton suggests that these crayfish are not strongly adapted for burrowing but rather concentrate calcium in areas where greatest structural rigidity is required and where greatest protection from the scouring action of gravel and small stones is provided (Mills and Lake 1976). Such areas are the lateral anterior region of the carapace and the terminal segments of the chelipeds. Adaptation to the relatively low calcium concentrations available in Tasmanian waters (3-5 mg/L) is indicated by the marked reduction in total exoskeletal calcium shown by astacopsids in comparison to stream-dwelling crayfish of the northern hemisphere.

Little is known of the biology of *Astacopsis* species except that newly hatched young are to be found attached to *A. gouldi* females in late spring (Lynch 1970).

Six species of the genus *Parastacoides* were recognised by Riek (1967) but subsequently much more extensive collections have become available and as a result of a comprehensive numerical taxonomic study utilising 22 characters and over 300 adult specimens, Sumner (in press) now recognises only the species *Parastacoides tasmanicus*. The species comprises three sub-species, *P. tas. tasmanicus*, *P. tas. inermis*, and *P. tas. insignis*. Despite Sumner's revision the taxonomy of *Parastacoides* is still not fully resolved since collections from the Olga and Gordon valleys have recently yielded 51 specimens which do not readily fit the available taxa. The ecological separation of the three (or four) sub-species is not yet clear and will not be considered here. The following comments relate mainly to *P. tas. tasmanicus*.

Parastacoides tasmanicus is abundant in south-western and western Tasmania and extends north almost to the coast near Penguin; however it is apparently absent from the north-west corner of the State (fig. 9). The species is found in a wide variety of habitats (table 1) but appears to be most numerous in areas of wet, button grass *(Gymnochoenus sphaerocephalus)* dominated moors and sedgelands, probably because of their apparent dependence on a permanent water table. Lake and Newcombe (1975) estimated an upper population limit of over 2,000 in a 10,000 sq. yd. study area near McPartlan Pass in south-western Tasmania. The animals are active burrowers excavating an often complex burrow system which terminates in a single bottom chamber at the level of the water table, sometimes as much as one metre below the surface. Frequently there are several openings at the surface, usually protected by overhanging vegetation or, if exposed, located at the lowest point of a small muddy 'pool'. Recent digging activity may be indicated by soil 'chimneys' which occasionally are more than 150 mm high although usually less than 70 mm. Occasionally animals site their burrows in situations where underlying quartz gravel prevents their reaching permanent water. This need not necessarily be disastrous since Fradd (pers. comm.) has determined that adult crayfish can survive in damp air (RH = 90%) at temperatures of 15-20°C for several weeks with only a 3-4% reduction in body weight. Juveniles however show poor tolerance and usually survive less than one week. Presumably adults at least have a good chance of surviving desiccation in the field either by waiting for the next rains or perhaps even by migrating to more favourable nearby localities. A more detailed account of burrow structure is provided by Lake and Newcombe (1975).

Adaptation for the burrowing habit is illustrated by the pattern of calcification found in the exoskeleton (Mills and Lake 1976). Calcium concentration is maximal in the dorsal anterior region of the carapace and the tips of the chelipeds, but high levels in relation to other parts of the body are also found in the telson, posterior carapace, dorsal surface of the anterior abdominal segments, and the first walking legs. Presumably this pattern of calcium distribution reflects the need for rigidity in those parts of the body used for burrowing and the need for protection of the areas most vulnerable to abrasion from the sides and roof of the burrow. Calcium values are extremely low for burrow water (0.1-1.0 mg/L) and not surprisingly total exoskeletal

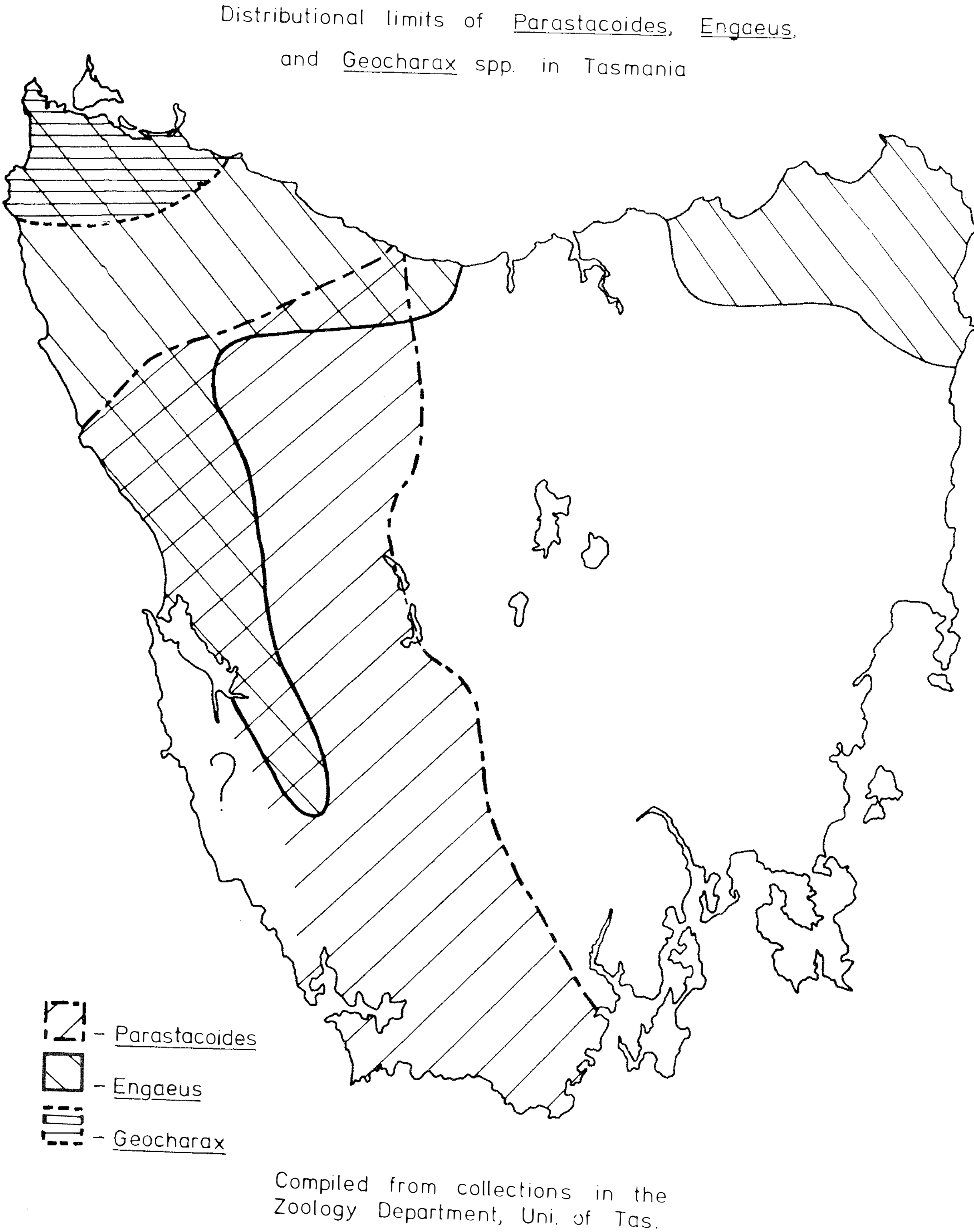

FIG. 9 .- Distributional limits of *Parastacoides*, *Engaeus* and *Geocharax* spp. in Tasmania.

calcium concentrations are also very low. Mills and Lake (1976) found that only 8.3% of the weight of the exoskeleton was calcium. As a further adaptation to their calcium deficient environment the crayfish eat their exuviae (Newcombe 1970).

Usually, only one adult animal occupies a burrow system. Leggett (1971) concluded that burrow occupancy is controlled by ritualized sequences of agonistic behaviour in which death rarely occurs, except where retreat of the loser is impossible. In laboratory encounters the larger and more vigorous animal invariably won. The behavioural sequences observed were similar to those recorded in other decapod crustacea, except that in *Parastacoides tasmanicus* the communication pathway is tactile rather than visual. Newcombe (1970) determined that less than 1% of the animal's time is spent outside the burrow and the retention of what is normally a visually orientated behavioural pathway is perhaps suggestive of a relatively recent adoption of the burrowing habit by *Parastacoides* species.

Parastacoides tasmanicus has a long breeding season, due to the fact that eggs are carried through the winter. Females with eggs are first found in April with the largest animals carrying the greatest number - up to 80 have been recorded (Lake and Newcombe 1975); however, only about 40% of sexually mature females carry eggs. Hatching commences in August and is largely completed by November, the hatchlings subsequently remaining attached to the pleopods of the female until February-March. Attachment is achieved using the posterior two pairs of periopods of the young. The young crayfish remain in the parental burrow for some time and ultimately, if they avoid being eaten by their mother, disperse in the late autumn - early winter when the rains have raised the water table and surface water is abundant. The adults moult in March - April, immediately prior to the onset of a new breeding cycle. Mills and Lake (1975) describe a moult cycle of 52-53 weeks so that mature crayfish will only moult once per year.

Although animal material is often found when gastric mill contents are examined, and the crayfish will certainly utilise such material when given the opportunity, it is probable that plant material, particularly roots, forms the greater part of the diet. In addition, recent studies on the energetics of feeding in *Parastacoides tasmanicus* (Fradd, *pers. comm.*) indicate that the large quantity of detrital material ingested also contributes significantly as a food source.

Although *Parastacoides tasmanicus* is probably the most familiar of Tasmanian 'terrestrial' crayfishes, the distinction of having been first described belongs to *Engaeus fossor*. Indeed, this crayfish, described by Erichson (1846), was the first terrestrial species recorded from Australia. Important data on the taxonomy and ecology of Tasmanian engaeids has recently been provided by Suter (1975). He has shown that crayfish previously regarded as *E. fossor* represent a mixture of two species, *E. fossor* and a new, as yet undescribed species referred to here as *Engaeus sp.* *Engaeus sp.* is regarded as a fairly recent evolutionary offshoot from *E. fossor*, and although the two species are morphologically distinct the significant feature of Suters' study is that for the first time two closely related species of Australian crayfish have been shown to be ecologically distinct, even though they may frequently occur within a few yards of each other. *Engaeus fossor* is found only where the burrows can reach a permanent water table (table 1, fig. 9) frequently even within the watercourse itself. Such situations are found in rainforests, wet sclerophyll forests, titree swamps, buttongrass plains and even in coastal heath, though the former appear to be the most favoured. *Engaeus* sp. is found in similar general habitats although the association with rainforest is even more pronounced. However, except for one locality (Bird River to Pillinger Track) where *Engaeus fossor* is absent and *Engaeus sp.* occurs in ti-treee swamp, the burrows of the latter species are always found above permanent water.

This differing dependence on permanent water is reflected in differences in burrow structure between the two species. *Engaeus fossor* burrows tend to have many entrances, located similarly to those described for *Parastacoides tasmanicus*. In contrast to *P. tasmanicus*, however, the 'chimneys' are often pronounced, being as high as 0.4 m on occasion. The upper 0.3m of the burrow system is characterised by numerous lateral burrows that terminate in (feeding?) chambers in plant root systems; ultimately all chambers converge to a single vertical shaft which terminates with a living chamber located in water. The depth of the burrow system is determined by the depth of the water table, sometimes as deep as 1.5 m.

The burrow systems of *Engaeus sp.* are normally only about 0.3 m deep and rarely deeper than 0.75 m, even in much deeper substrates. Even though they fail to reach the water table occupied living chambers are always found to contain water. The systems are usually much more extensive than those of *E. fossor* - some have ramified over a 4 x 2m area - and usually several terminal chambers are present, each with a short retreat passage. *Engaeus sp.* supports Riek's contention (1972) that engaeids occur in social groups since adults of both sexes occur in the burrows, each animal occupying separate living quarters. As would be predicted from its burrow structure, *E. fossor* resembles *Parastacoides tasmanicus* in exhibiting solitary burrow occupancy.

Mills *et al.* (1976) have shown that, like *Parastacoides tasmanicus*, Tasmanian engaeids have concentrations and distributions of exoskeletal calcium that are appropriate both to the low calcium concentrations available in the external medium and to the burrowing habits of the species. Calcium concentrations in the exoskeleton are low in both species (6.16% total exoskeleton weight in *E. fossor*, and 5.30% in *Engaeus sp.*) but whilst the distribution of calcium in *E. fossor* is similar to that found in *P. tasmanicus*, reflecting the similarity of burrowing activities, a low degree of calcification is found in the carapace of *Engaeus sp.* except for the branchiostegites. In this case the shallow burrows, often following the line of least resistance along tree roots, would not necessitate extensive strengthening of the anterior exoskeleton, but the branchiostegites would need increased calcification to protect the gills from the pressure of the surrounding loose clay soil.

Both species of *Engaeus* show similar breeding characteristics (Suter 1975). Unlike *Parastacoides tasmanicus*, eggs do not appear to be overwintered and berried females first appear in October. Hatching occurs throughout February and the young are then carried for a further two months. Subsequently they remain in the parental burrow system until spring.

Tasmanian engaeids also differ from *P. tasmanicus* in their feeding habits. The food source is mainly plant material, particularly roots and rotten logs, but whereas Newcombe (1970) claims that feeding activity of *P. tasmanicus* is greatest at night, Suter (1975) has concluded the engaeids feed largely in the early afternoon.

The final genus of burrowing crayfish found in Tasmania is represented by *Geocharax falcata*. The species is restricted to the north-west of the island and only brief comments are appropriate here. *G. falcata* is frequently collected from the surface waters of swamps and creeks, often in the early afternoon, and it is assumed that the animal leaves its burrow in order to forage for food amongst the surface vegetation. The burrows always require access to a permanent water table, which may be as much as 2 m deep. Where burrows adjoin watercourses it is common to find entrances to both terrestrial and aquatic environments. In keeping with its burrowing capabilities *G. falcata* shows similar calcium distribution in its exoskeleton to *Parastacoides tasmanicus* and *Engaeus fossor* (Mills *et al.* 1976).

Zoogeography of Tasmanian parastacids

Astacopsis and *Parastacoides* species may be regarded as cold climate adapted crayfish with a long history of Tasmanian occupancy. Knott (1976) argues cogently for the derivation of *Parastacoides* from an astacopsid stock in contrast to Riek's (1972) view of an origin via a *Cherax* lineage. *Engaeus* and *Geocharax* on the other hand may have entered Tasmania at the time of the Pleistocene land bridge. Rawlinson (1974) estimates that Tasmania was linked with the Australian mainland from 22,500 until 12,750 years BP. If this view is taken then *Engaeus* and *Geocharax* species now found in western Tasmania presumably entered by the Cape Otway, King Island link which Rawlinson considers was broken about 14,750 years BP. Subsequent distribution of *Geocharax* has probably been restricted by an apparent preference for coastal heaths and exposed flood plains, whilst engaeids have capitalised on post-glacial changes in flooding and river capture to extend further and further south wherever suitable rainforest or ti-tree habitats were available. An alternative view is that *Engaeus* and *Geocharax* in Tasmania represent remnant populations of once more widespread Bassian ancestral stocks which were finally isolated when Bass Strait was submerged.

In any event, although it is a matter for speculation whether *Parastacoides* populations have been moving northwards from glacial retreats in the south and south-west whilst *Engaeus* populations have progressed southwards through adjacent drainage systems, or whether only one or other genus has increased its distributional range in post glacial times, it is clear that their distributions now overlap considerably (fig. 9). The significance of this overlap and the extent of the ecological interaction between the two genera is a problem of great current interest to zoologists. The work of Suter (1975) has shown that *Engaeus fossor* and *Engaeus sp.* are largely confined to rainforest and ti-tree swamp at altitudes below 600m, although it is uncertain what ecological parameter(s) associated with altitude is effective. Several localities (e.g. the Tyndalls) are known where *Parastacoides tasmanicus* occurs at higher altitudes and engaeids occur at lower altitudes, suggesting that *P. tasmanicus* is better adapted to colder, more exposed conditions where climatic factors show greater fluctuation. Conversely, although *P. tasmanicus* inhabits rainforest in southern areas of western Tasmania it is not normally found in such situations when engaeids are present - an exception to this generalisation is the Bird River.

P. tasmanicus inermis has recently been collected from several creeks running into the Gordon River in the vicinity of the Franklin-Gordon River junction. Although *Engaeus fossor* has not so far been found in these creeks, creeks elsewhere in the Lower Gordon drainage system currently represent the southern limit of this species and intergeneric competition for lotic habitats may therefore be a possibility.

The Syncarida

Information on Tasmanian syncarids has been summarised by Williams (1965, 1974). Only the family Koonungidae will be considered here. Two monospecific genera are currently recognised in this family. The genus *Koonunga* was erected by Sayce (1907) for the species *Koonunga cursor*, so named because of its distinctive mode of locomotion. Although the animal can swim actively it is more usually observed running rapidly over the substrate and Nicholls' (1931, p.474) description of a 'swift gliding movement, strikingly like that of a cilia-clad organism' for *Micraspides calmani* is particularly apt for both species. Although the original locality for *K. cursor* (Ringwood, Victoria) has long since been converted to a storm-water drain the species is now known to occur sporadically throughout southern Victoria (Drummond 1959). The genus has not been officially reported from Tasmania, although Williams (1974) records a personal communication of its occurrence, and in fact, the Department of Zoology, University of Tasmania, has established quite large collections from several localities in the far north-west of the island, as well as from King Island and Hunter Island. The known distribution in Tasmania closely follows that given for *Geocharax falcata* (fig. 9). The Tasmanian species is probably *K. cursor* but this remains to be confirmed with certainty. The animal appears to be largely surface dwelling, inhabiting permanent or semi-permanent swamps around water-courses as well as pools in intermittent runnels and seepages. Such habitats are also favoured by *Geocharax falcata* and *Engaeus fossor* and although *Koonunga sp.* has not been recorded from the burrow waters of crayfish in Tasmania it undoubtedly does take advantage of them in dry spells as Drummond (1959) has reported for *K. cursor* in Victoria. Cannon and Manton (1929) concluded from an examination of mouthparts' structure that *K. cursor* utilises a solely raptatory feeding mechanism and this is supported both by Drummond's (1959) statement that the diet is predominantly plant material (although dead animal tissue will also be taken), and by personal observation on *Koonunga sp.*

The other described Koonungid, *Micraspides calmani* is widespread throughout much of western Tasmania. The species was described by Nicholls (1931) from material collected in seepages and crayfish burrows near Lake Margaret, on the slopes of Mt. Heemskirk, and by the Lyell Highway in the King River Valley. In recent years the genus, though possibly not the species, has been found at several localities in the area covered by Nicholls, as well as from the Port Davey area (around Melaleuca Inlet, Kelly Basin, junction of Davey and Crossing rivers), the Gordon River drainage system (Olga Valley, Waterfall Creek), the King River drainage system (Crotty), the Pieman River system (Savage River pipeline road), coastal heathland near Rebecca Lagoon, and in the Dip River system of the north-west. Although some specimens have been caught in surface pools and seeps most have been obtained from the burrows of *Parastacoides tasmanicus* and *Engaeus fossor*. This observation, together with the animals' lack of eyes and greatly reduced pigmentation support Nicholls' (1931) conclusion that *Micraspides* leads a 'wholly cryptozoic life'. *Micraspides sp.* is one of at least 18 species of crustacea (Lake and Newcombe 1975) found inhabiting the waters of crayfish burrows. Many if not all of these species appear to be true burrow dwellers rather than interstitial species caught accidently, and Lake and Coleman (in preparation) have proposed the term *"pholeteros"* for this important faunal assemblage. If such species are not primarily interstitial then surface flood-waters must presumably provide the most important means of dispersal from one burrow system to another.

The distribution of Koonungids tempts one to speculate that *Koonunga* is a relatively recent immigrant to Tasmania via the Cape Otway, King Island Pleistocene land bridge. *Micraspides* has presumably been in Tasmania for a much longer period, and would have experienced little difficulty surviving the Pleistocene Ice Age along with *Parastacoides tasmanicus* since large areas of its distribution in western Tasmania were unaffected by glacial or periglacial activity. However, the limited distribution of *Koonunga* in the island could equally be due to particular habitat requirements that may not be readily available, coupled with an apparently greater dependence on surface waters. At the same time the comment from Drummond (1959) that several blind, unpigmented and fully subterranean koonungids from Victorian localities await description suggests that *Micraspides* may well turn out to occur in mainland Australia also. What we really need is not speculation but a great deal more ecological information about these interesting and ancient crustaceans with particular reference to such matters as habitat needs and preferences and dispersal pathways available.

The Parastacidae and the Koonungidae are of course not the only crustacean groups of great biological interest in western Tasmania, but they do illustrate most of the problems raised by this component of the freshwater fauna. Interesting questions are also raised by the insect fauna, and two orders will be discussed here, one, the Odonata, an example of a group with generally good dispersal ability and the other, the Plecoptera, a group of insects generally regarded as having poor dispersal powers.

The Odonata

The extant dragonflies of the world comprise three sub-orders, the Zygoptera (damselflies) and Anisoptera ('true' dragonflies), both cosmopolitan, plus the Anisozygoptera, an archaic, relict group found only in Japan and the Himalayas. All dragonflies are obligate carnivores, both as nymphs and as adults and with few, non-Tasmanian, exceptions all nymphs are aquatic. Table 2 summarises the number of genera and species of Tasmanian dragonflies found in western Tasmania, whilst Table 3 summarises the habitats in which their nymphs are found. Although Tasmania contains several very interesting dragonflies, it possesses only a small number of species; 27 of a total of 263 Australian species are present (Watson 1974).

Table 2

The Odonata of Western Tasmania

	Family	Tasmania No. of genera	Tasmania No. of species	Western Tasmania No. of genera	Western Tasmania No. of species
ZYGOPTERA	Coenagrionidae	5	6	3	3
	Lestidae	1	5	1	4
(10)					
ANISOPTERA	Gomphidae	1	1	1	1
	Aeshnidae	4	7	4	6
	Synthemidae	2	3	2	3
	Corduliidae	2	3	2	2
	Libellulidae	2	2	0	0
(6)					
(16)	7	17	27	13	19

(n) = no. of Australian families

Table 3.

Habitats utilised by dragonfly nymphs in Western Tasmania.

Family	Species	Habitat: Large rivers	Rainforest creeks	Small creeks in open buttongrass or light ti-tree	Pools in buttongrass	Lakes and tarns	Lagoons and marshes	Remarks
Coenagrionidae	Coenagrion lyelli	0	0	0	0	0	+	rare in western Tasmania; adults only
	Ischnura aurora aurora	0	0	0	0	0	+	rare in western Tasmania; adults only
	Xanthagrion erythroneurum	0	0	0	0	0	+	rare in western Tasmania; adults only
Lestidae	Austrolestes analis	0	0	0	0	+	(+)	(+) elsewhere in Tasmania
	Austrolestes annulosus	0	0	0	0	0	+	locally common; e.g.Port Davey
	Austrolestes io	0	0	0	0	(+)	+	rarely in N.W.Tasmania; (+) lowland only
	Austrolestes psyche	0	0	0	(+)	+	0	alpine swamps and cold,coastal lowlands
Gomphidae	Austrogomphus guerini	0	0	0	0	+	0	in mud
Aeshnidae	Acanthaeschna parvistigma	0	0	+	0	+	0	slower water than A. hardyi.
	Acanthaeschna tasmanica	0	+	0	0	0	0	only 1 nymph recorded
	Acanthaeschna hardyi	+	+	+	0	0	0	widespread; nymphs under stones and logs
	Archipetalia auriculata	0	0	+	0	0	0	very restricted habitat records
	Aeshna brevistyla	0	0	0	0	+	+	common elsewhere but rare in western Tasmania
	Hemianax papuensis	0	0	0	0	0	+	rarely, in N.W. Tasmania
Synthemidae	Sythemiopsis gomphomacro-mioides	0	0	+	0	0	0	especially runnels and seepages
	Synthemis eustalacta tasmanica	0	0	+	+	+	0	nymphs in decaying vegetation or mud
	Synthemis macrostigma orientalis	0	0	0	+	0	0	marginal to alpine swamps; mud-dwelling
Corduliidae	Hemicordulia tau	0	0	0	0	+	+	in weed or under debris
	Procordulia jacksoniensis	0	0	0	0	+	+	in weed or under debris

The Zygoptera are poorly represented in western Tasmania, as indeed they are in Tasmania as a whole, - only two of a total of ten Australian families are found in Tasmania (Watson 1974). The distribution of dragonflies is of course largely determined by the availability of suitable habitats. For example *Coenagrion lyelli* adults are characterised by short flights above marshes and over weed beds surrounding open water in lowland areas; such habitats are scarce in western Tasmania and only one adult, obtained twenty years ago, has been caught in the region. The only species of damselfly found more commonly in the west than elsewhere is *Austrolestes psyche*. In Tasmania it appears to be a low temperature adapted species since it is the only member of the Lestidae to use alpine areas above 1000 m for nymphal development and is able to emerge, in sub-alpine habitats, as early as September (Allbrook 1975).

In contrast to the Zygoptera the Tasmanian Anisoptera are well represented in western Tasmania and several important species may be regarded as being centred there. Four of the five families of Anisoptera found in Tasmania (Watson 1974) occur in the western region (tables 2 and 3), the Australian total being only six families, and the world total seven.

Austrogomphus guerini, the only Tasmanian representative of the Gomphidae, is widespread. Typically a cold water species the mud-burrowing nymphs are found in open tarns and lakes at all altitudes up to 1000 m although it is a riverine species on mainland Australia. Adults are poor flyers and unlike many other dragonflies they apparently do not migrate any distance from the area of emergence.

Several dragonflies in the family Aeshnidae are worthy of mention. *Acanthaeschna hardyi*, an endemic species, is very common in western Tasmania where the adults may be caught as they hunt up and down rivers and creeks in rainforest. *A. tasmanica* closely resembles *A. hardyi* in appearance, habitat needs and hunting behaviour, and the two species are sympatric in some rainforests. Only one nymph of *A. tasmanica* has ever been collected (Allbrook 1975) but it is presumed that ecological separation between the two species is on the basis of nymphal habitat requirements.

Hemianax papuensis, although common in mainland Australia, has not previously been recorded from Tasmania. Nymphs have been found only in northern waters, including the Arthur River system (Allbrook 1975). Distribution on the mainland is often associated with waters having high summer temperatures and the adults are large and active flyers. It is possible therefore that the species is not well established in Tasmania and is at least partly dependent on replenishment by immigration.

The aeshnid of greatest interest, however, is the endemic species *Archipetalia auriculata*. This is a member of the sub-family Neopetaliinae, an extremely archaic but little studied group which at one time was given family status. Recent, unfinished work (Allbrook 1975) suggests that this level of recognition may have to be reconsidered. The Neopetaliinae is a small group of five genera, three of which occur in South America and two, both monotypic, in Australia. The Australian species are found in south-east Australia and Tasmania, each being endemic to its own region. All five genera are restricted to cold waters in mountainous regions. *Archipetalia auriculata* is undoubtedly the most archaic member of the Neopetaliinae, and indeed of the Aeshnidae, and further information, particularly concerning the nymphal stages would provide important insights into the evolutionary relationships of the Odonata. However, the nymph of *A. auriculata* was unknown until a single individual was captured near the Tyndall Ranges in March 1975. Since then two breeding colonies have been discovered in streams flowing into the Gordon River. These collections are particularly valuable since all previous records of any neopetaliine nymphs have been isolated captures.

The Synthemidae is also of great antiquity but whereas the Neopetaliinae are believed to consist of remnants of an original Gondwanaland distribution, the synthemids are confined to, and probably evolved in, the Australasian continent. Although clearly primitive the adults and nymphs display characters considered to be more advanced than those in the Neopetaliinae. The family is important in odonatan phylogeny for its affinities with the Corduliidae. Western and south-western Tasmania are important as they provide the habitat for the most archaic species in the Synthemidae, *Synthemiopsis gomphomacromioides*. The genus *Synthemiopsis* is endemic and monospecific. The nymph of *S. gomphomacromioides* was inadequately described by Tillyard (1917) but to date no other late nymphal stages of the species have been found. However, the capture of nine adults in the Olga Valley during 1976, suggests that this area may harbour significant breeding colonies and is encouraging for future work.

The two other Tasmanian synthemid species, *Synthemis eustalacta tasmanica* and *S. macrostigma orientalis* are also widespread throughout western Tasmania, although the former species is more common. Both are found in buttongrass swamps (table 3), especially at higher altitudes. The apparent rarity of *S. macrostigma orientalis* may perhaps be accounted for by more specific habitat requirements; nymphs have only been collected in small, muddy 'pools' where there is very little surface water. It is interesting to note that nymphs of the family Petaluridae, an extremely archaic family in the Anisoptera, also inhabit muddy holes in swamps. It is possible that such habitats provided a major 'invasion route' into the aquatic environment.

The two species of the family Corduliidae(table 3) found in western Tasmania are also common elsewhere in Tasmania and mainland Australia. Both are large active dragonflies found where large areas of low altitude marshes abound. Large swarms of *Hemicordulia tau* have been observed in the Gordon drainage network.

One important area of ecological adaptation worthy of study using the western Tasmanian dragonfly fauna is that of nymphal diapause. This provides a convenient means of synchronizing emergence with the time when climatic conditions are compatible with the predatory aerial existence of the adult. Diapause usually occurs in the final nymphal instar, thereby compensating for differing rates of growth that may have occurred due to food availability and temperature. Its consequence is a mass emergence, which provides the maximum probability for mating and at the same time coincides with the summer bloom of flying insects. Diapause is usually facultative in dragonflies although some species are probably obligatory. For example, *Acanthaeschna* spp. cannot complete their development in less than one year, and Hodgkin and Watson (1958) showed that rate of growth is unaffected by temperature. In Tasmania diapause is presumably unavoidable in the cold climate adapted species. On the other hand growth in the cordulid *Hemicordulia tau* is dependent on temperature and is an adaptation to shallow waters in pools and lake margins where high summer temperatures obtain. Temperature dependent growth is most effective in *Procordulia jacksoniensis* where it enables the adults to emerge as early as October and may make possible the completion of two generations within a twelve period. Since both the above species occur in western Tasmania it is to be expected that several strategies have been developed by the dragonfly fauna in adapting to local climatic conditions, some of which must involve diapause, either on a facultative or on an obligatory basis.

This summary of the odonatan fauna of western Tasmania may be concluded by pointing out that in keeping with the rest of Australia the fauna consists of three basic components. There is first a group of cosmopolitan families, and often species, e.g. the Corduliidae, an old family, are known from the Oligocene, and the Libellulidae, (the most recently evolved anisopteran family and not found in western Tasmania). Secondly there are groups of ancient origin restricted to the Australian province and associated with cold waters, mainly in mountainous regions, e.g. the Synthemidae. Finally there is the very ancient sub-family Neopetaliinae, also cold climate adapted, whose present day distribution is probably relictual from an early montane Gondwanaland distribution. The presence in Tasmania of the most archaic member of this group (*Archipetalia auriculata*) suggests that the environment provided by western Tasmania has undergone relatively little change throughout the species' long history.

The Plecoptera

The stoneflies show an almost complete separation into northern and southern hemisphere families. Zwick (1973) in a major revision of the world Plecoptera recognised this as a fundamental phylogenetic division and used it to create two sub-orders, the Arctoperlaria and the Antarctoperlaria. The pattern of distribution is broken by the Notonemouridae, which although in the Arctoperlaria, is exclusive to the southern hemisphere. The family is well represented in Tasmania (table 4). The Antarctoperlaria exhibits an amphinotic distribution and is represented in Australia by three families, the Eustheniidae, the Austroperlidae and the Gripopterygidae (Zwick 1973). Tasmanian species are shown in table 4.

Adult Plecoptera are poor fliers and are generally found on rocks, stones and vegetation along the edges of cold water-bodies; their aquatic nymphs occur under stones and within crevices in submerged logs. The plecopteran fauna of western Tasmania can be broadly categorised into four components: - species whose nymphs inhabit larger rivers - species largely restricted to smaller creeks and streams - lacustrine species - species inhabiting hygropetric situations. The last-named group contains highly specialised forms best exemplified by *Notonemoura lynchi*. Nymphs of this species live in thin films of cold water flowing over rock surfaces, especially vertical rock faces (Illies 1975). Such habitats are commonly available at high altitude springs and seepages. The nymphs may even be found on damp stones at some distance from the watercourse (Illies 1975) and so may be regarded as being semi-terrestrial. They are able to hold fast and climb on vertical surfaces using the strong gemora of their hind legs. In the adults these strong hind legs permit the animal to jump considerable distances when disturbed (Illies 1975).

Considering the wide range of suitable habitats it is not surprising to find that western Tasmania has an abundant and diverse plecopteran fauna (table 4). Furthermore the Tasmanian plecopteran fauna as a whole is characterised by a high degree of endemicity. Of the 31 species listed in table 4 only 6 (excluding *Neboissoperla sp.* whose specific status is undetermined) are also to be found on the mainland. Of these six the three most common are essentially cold highland species *Notonemoura lynchi, Austrocerca tasmanica* and *Dinotoperla serricauda)*, whilst the remaining three are all lowland species and rare in Tasmania (*Newmanoperla thoreyi, Illiesoperla australis* and *Rieloperla rugosa)* (Hynes 1976a). Of the species not recorded from western Tasmania in table 4, only the above lowland species are unlikely to be found there eventually. The richness of western Tasmania's stonefly fauna is particularly impressive when it is remembered that much of the region is relatively inaccessible and collections of material are still in an embryonic state.

The high level of endemicity of Tasmanian stoneflies suggests a long period of isolation that has been little affected by Pleistocene land bridges. Certainly Plecoptera are known to be easily stopped by small ecological barriers (Illies 1955, cited Hynes 1976a), but it is surprising that so few species are common to both sides of Bass Strait. It seems reasonable to agree with Hynes (1976a) that long periods of isolation allowed separate faunas to evolve in Tasmania and mainland Australia, so that when Pleistocene land bridges did make mixing possible most available ecological niches were already filled and firmly held.

Several examples appear to support this argument, with related species occupying widely differing habitats. Where such related species appear to be sympatric relatively recent speciation is probably a less likely explanation than our lack of information about life histories and our inability to accurately characterise habitats. Thus within the Eustheniidae both *Eusthenia spectabilis* and *E. costalis* are found in rivers and rocky, fast flowing creeks, but *E. costalis* is also common in cold lakes and mountain tarns. A similar pattern is exhibited by the Austroperlidae: *Tasmanoperla thalia* and *T. larvalis* both endemic species, inhabit lotic waters but only *T. larvalis* occurs in standing water whilst the monospecific and endemic genus *Crypturoperla*

TABLE 4.

Distribution and habitats of Tasmanian stonefly nymphs.

Family	Species	Habitat: slow flowing, lowland rivers	Habitat: cold, fast flowing rivers	Habitat: riffle zones & stony creeks	Habitat: small gravelly streams	Habitat: Hygropetric places	Habitat: lakes	Habitat: alpine tarns	Habitat: lagoons and marshes	Distribution within western Tasmania*: northern western	Distribution within western Tasmania*: central western	Distribution within western Tasmania*: southern western	
Eustheniidae	Eusthenia spectabilis		+	+							+	+	ANTARCTOPERLARIA
	Eusthenia costalis		+	+			+	+		+	+	+	
Austroperlidae	Crypturoperla paradoxa					+					+	+	
	Tasmanoperla thalia		+	+	+						+	+	
	Tasmanoperla larvalis			+	+		(+)				+	+	
Gripopterygidae	Leptoperla varia	+	+	+			+		+	+	+	+	
	Leptoperla beroë						+					+	
	Newmanoperla thoreyi		a							Not in west			
	Cardioperla nigrifons		+	+	+					+	+	+	
	Riekoperla triloba		+	+						+	+		
	Rickoperla sp. (=rugosa?)	a		a						Not in west			
	Dinotoperla serricauda		+	+			+			+	+		
	Dinotoperla fusca		a	a			a					+	
	Dinotoperla opposita			a						Not in west			
	Dinotoperla elegans			a							+		
	Dinotoperla marmorata						+			Not in west			
	Trinotoperla hardyi			+	+						+		
	Trinotoperla zwicki		+	+						+	+	+	
	Trinotoperla agricola			+	+						+	+	
	Illiesoperla australis	+	+							Not in west			
	Neboissoperla sp.			+								+	
Notonemouridae	Notonemoura lynchi					+					+	+	ARCTOPERLARIA
	Austrocerca tasmanica		+	+			+			+		+	
	Austrocerca rieki		+				+					+	
	Austrocercella christinae			a			a					+	
	Austrocercoides bullata		+				+				+		
	Austrocercoides zwicki		+	+						+	+	+	
	Kimminsoperla albomacula		+	+						Not in west			
	Kimminsoperla biloba					+					+		
	Kimminsoperla williamsi					+						+	
	Tasmanocerca bifasciata			+	+						+	+	

* - refer Fig. 1 for definition.
a - adults only - no nymphal records.

Compiled from Hynes (1974a,1976a), Illies (1969,1975), McLellan (1971) and from collections in the Zoology Dept., University of Tasmania.

(C. paradoxa) is a specialised hygropetric dweller. Within the Gripopterygidae the species *Leptoperla beroë* is exclusively lacustrine whilst *L. varia* occupies a very wide variety of habitats. In the same family, the genus *Trinotoperla* also displays similar characteristics.

Although most Tasmanian Plecoptera are cold adapted, high altitude forms, it is clear that in many cases no such altitudinal limitation is imposed in western Tasmania, and species elsewhere restricted to alpine and sub-alpine localities occur there near sea level. Common examples include the gripopterygian *Trinotoperla cagricola* and the notonemourids, *Austrocerca tasmanica* and *Austrocercoides zwicki*. It may be that the animals are adapted not so much to cold climates but to environments characterised by transient and extreme fluctuations in weather. In such conditions emergence and adult life might be rather hazardous and observations of mixed species swarms (apparently newly-emerged) of stoneflies in south-western Tasmania suggests that diapause might be an important nymphal adaptation. Certainly serious study of life histories and ecological requirements similar to that by Hynes and Hynes (1975) for mainland species would be well worthwhile. In their study Hynes and Hynes investigated 27 species; they concluded that the life cycles of Australian species of Plecoptera were "generally much less rigid than those found in the Northern Hemisphere," and suggested that this was an adaptation to the relatively "uncertain climate" of mainland Australia. However, they were mainly concerned with adaptations such as extended emergence periods and egg diapauses which would facilitate survival in times of low water or even drought, conditions that western Tasmania is not noted for. In view of their conclusions it would be particularly interesting to compare life histories in mainland and western Tasmanian populations of those species common to both land masses. *Dinotoperla serricauda* would be an ideal example since a full description of the very flexible life history shown by this species in Victoria is provided by Hynes and Hynes (1975).

Little information is available concerning the food sources utilised by plecopteran nymphs. The large 30 mm and long-lived (up to three years) nymphs of the Eustheniidae are carnivorous whilst their adults have been reported to feed on rotten wood (Hynes 1974b, 1976b). Austroperlid nymphs (10-20 mm) have been found to be detritivores specialising in eating rotten wood (Hynes and Hynes 1975, Hynes 1976b). These nymphs also grow slowly and live for up to three years before emerging. Gripopterygiid nymphs are small and herbivorous. It is evident that a great deal remains to be done in this area and in view of the great abundance of plecopterans found in most West Coast waters, studies of the role and significance of these animals in aquatic communities offer a great deal of scope.

THE INFLUENCE OF MAN

In view of the theme of this symposium it is appropriate to conclude this paper with a few brief remarks about the consequences of human activities in western Tasmania. Four such activities in particular exert significant, and usually damaging, effects on aquatic environments; these are mining, hydro-electric development, forestry and the introduction of exotic species, especially trout.

Mining for a number of metals has had an obvious and very destructive effect on the waters of numerous rivers in northern and central-western Tasmania. The pollution of the Queen and King Rivers by mine effluents is especially notorious (Lynch 1969; Parliament of the Commonwealth of Australia 1970). Elsewhere in this symposium Lake *et al.* (1977) provide the first documentation of the effects of metal pollution on the fauna of a West Coast river in their account of copper, and to a lesser extent zinc and lead, pollution of the King River by Comstock and Linda Creeks. Evidence of pollution caused by mining is also apparent in the Savage River (Parliament of the Commonwealth of Australia 1970), the Pieman River and the Arthur River.

Unfortunately, serious pollution by 'heavy metals' such as zinc and copper is most probably irreversible in terms of the timespan of a human generation.

The development of dams and impoundments for hydro-electric purposes has already resulted in the loss of Lakes Edgar and Pedder with as yet undetermined effects on a rich invertebrate fauna (Bayly *et al.* 1972; Lake 1974; Lake *et al.* (in press); Lake Pedder Committee of Enquiry 1974). Progress continues with four dams under construction on the Pieman, Murchison and Mackintosh Rivers and the Gordon River Power Development - Stage 1 nearing completion. Despite the low rate of increase in the use of electricity active field investigation is in progress for the Gordon River Power Development - Stage 2. This last development would involve the Lower Gordon River, the Franklin River, the Olga River and possibly even the Davey River, and would severely modify the largest and most impressive range of cold climate aquatic habitats remaining in Australia.

Forestry management practices also pose a threat to parts of the freshwater environments available in western Tasmania. Extensive exploitation of timber with associated road building and consequent soil and drainage disturbance is now occurring in State Forest south of the Arthur River (Anon. 1976). Such disturbance may deleteriously alter streams, and even rivers, by altering run-off characteristics and increasing siltation.

Trout, especially brown trout, are now widespread throughout western Tasmania and undoubtedly such exotic predators have a significant effect on many native freshwater invertebrates and fish. However, western Tasmania is fortunate in still retaining some waters free of both introduced fish and alien aquatic plants and it is to be hoped that such waters can be retained in their intact state.

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