 J. Malac. Soc. Aust. 10: 25-34 1989

The association of *Glacidorbis occidentalis* Bunn and Stoddart 1983 (Gastropoda: Glacidorbidae) with intermittently-flowing, forest streams in south-western Australia

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ABSTRACT

The distribution of *Glacidorbis occidentalis* is considerably more widespread than previously recorded, occurring in streams throughout the northern jarrah forest, Western Australia. The species is largely restricted to forest streams with intermittent flow regimes and does not occur in lowland rivers west of the Darling Range. The association of this species with intermittently-flowing streams is atypical of the genus and cannot be attributed to differences in stream morphology or water chemistry.

G. occidentalis is one of the most common gastropods in the intermittent streams of the northern jarrah forest though it rarely comprises more than a few percent of the total fauna. Adult snails oversummer in the stream bed and emerge shortly after the first winter flows. The species produces brooded young which appear to be released as veligers during the winter months.

INTRODUCTION

The discovery of a new species of the tiny snail *Glacidorbis* in streams of the northern jarrah forest, Western Australia provided an important link between the lotic faunas of south-western and south-eastern Australia (Bunn and Stoddart, 1983). Its presence in south-western Australia was also viewed as additional support for the Gondwanic distribution of the genus, proposed by Meier-Brook and Smith (1975). *Glacidorbis occidentalis* was considered to be atypical of the genus as it was recorded from a warm, intermittently-flowing stream. Previous records of the genus were from fresh, slightly acidic waters which remained cold for much of the year (Smith, 1979). More recently, however, *G. hedleyi* was recorded from shallow pools and riffles in the upper reaches of two intermittent rivers in Victoria (Boulton and Smith, 1985). It is apparent that species of *Glacidorbis* are not restricted to cold habitats, or even permanent water, as was first thought.

G. occidentalis was originally described from only three streams out of twelve sampled in the northern jarrah forest (Bunn *et al.* 1986). Two of these localities were surrounded by strip-mining operations for bauxite. Additional information was needed to determine whether this species had a restricted distribution or was more widespread throughout the south-west. Recently, the Water Authority of Western Australia commissioned an extensive biological monitoring program of catchment streams and rivers of the northern jarrah forest. This study has greatly expanded knowledge of the stream fauna of south-western Australia. The purpose of this paper is to provide additional information on the distribution of *G. occidentalis* in south-western Australia and to record its association with intermittent, forest streams.

MATERIALS AND METHODS

A detailed description of the northern jarrah forest and catchment streams was given by Bunn *et al.* (1986). Briefly, this is a dry sclerophyll forest, dominated by two species of eucalypt, jarrah (*Eucalyptus marginata*) and marri (*E. calophylla*). The region experiences a Mediterranean climate with a yearly rainfall of approximately 125cm, of which about 85% falls between May and October (Seddon, 1972). Many of the streams of the northern jarrah forest are short, and flow only for a few kilometres before they empty into reservoirs or exit the Darling Range and flow into farmland on the coastal sand plain (Bunn *et al.* 1986).

Quantitative data on the macroinvertebrate fauna of 47 sites, ranging from temporary and perennial forest streams to lowland rivers in urban and rural areas, have been considered in this paper (Fig. 1). In December 1984, three-monthly sampling of 30 sites in two river systems began for the Water Authority of Western Australia. These include seven sites on the upper Canning catchment (CD), three sites on Stinton Creek (SC), nine sites on the lower Canning River (LC) and eleven sites in the upper and lower North Dandalup catchment (ND) (Table 1). Samples from December 1984 to October 1985 have been included in the analysis. Data from Bunn *et al.* (1986) for eight sites in Wungong catchment and four sites in North Dandalup catchment also have been included. Two of the latter sites also have been sampled in the Water Authority study (ND1 = Site 12, ND2 = Site 9). Bunn *et al.* (1986) considered Sites 5 and 8 to be on perennial streams because they flowed continuously throughout 1981-1983. However, these two upstream sites were reduced to a series of pools in the summer of 1984/1985 and, in drier years, may dry up completely. For this reason, they have been included with the temporary forest streams. Unpublished data from a stream survey in January 1983 have also been considered. These sites included Dirk Brook, Little Dandalup River, Marrinup Brook, McKnoe Brook and Samson Brook (Fig. 1, Table 1).

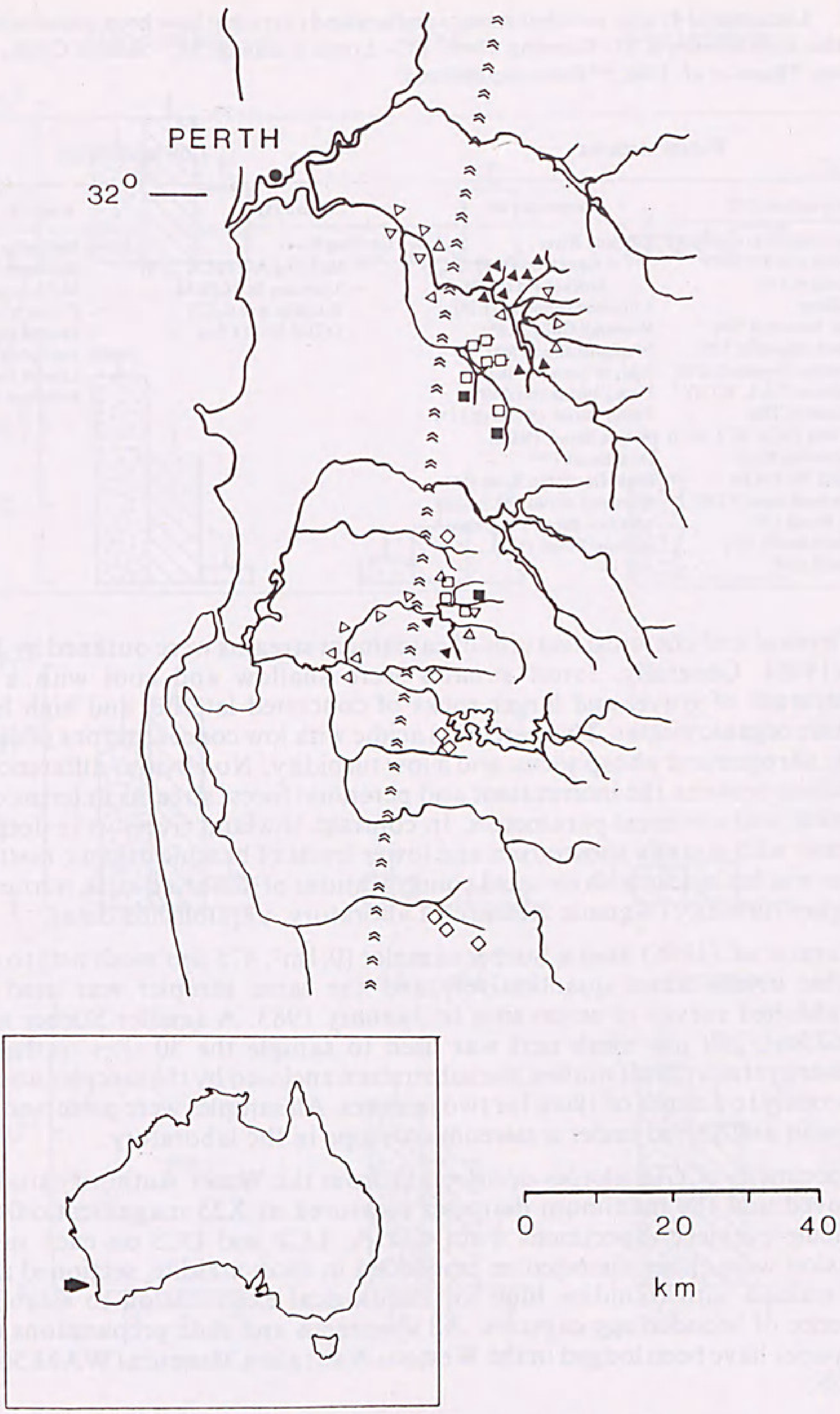

Figure 1: Localities of 47 sites on upland forest streams and lowland rivers in south-western Australia that have been quantitatively sampled for benthic macroinvertebrates. Solid symbols indicate sites with *G. occidentalis* and the dashed line represents the Darling Escarpment (△ Water Authority Study; □ Bunn *et al.*, 1986; ◇ Unpublished survey).

Table 1: Localities of 47 sites on forest streams and lowland rivers that have been quantitatively sampled for benthic invertebrates (CD - Canning Dam, LC - Lower Canning, SC - Stinton Creek, ND - North Dandalup. *Bunn *et al.* 1986; **Bunn unpublished)

Forest streams		Lowland rivers	
Intermittent (17)	Perennial (19)	Urban (5)	Rural (6)
Kangaroo Gully (CD1, CD1A)	Canning River	Canning River	North Dandalup River
Death Adder Creek (CD2)	— Kangaroo Gully (LC1)	—Manning Ave (LC5, LC6)	— Southwest Hway (ND6)
Poison Gully (CD3)	—Stocker Rd (LC4)	— Lissiman St. (LC6A)	— McMahon Rd (ND7)
Canning River	Unnamed tributary (1,2*)	— Burslem Ave (LC7)	— Corio (ND8)
— East branch (CD4)	Waterfall Gully (3,4*)	— O'Dell St. (LC7A)	— Lanstal Park (ND9)
— South branch (CD5)	Wungong Brook (6*)		South Dandalup River
— Araluen V-notch (LC2)	Seldom Seen Brook (7*)		— Lanstal Park (ND10)
— Araluen Y.A.L. (LC3)	Finlay Brook (ND2=9*)		— Patterson Rd (ND11)
31 Mile Creek (CD6)	Foster Brook (ND1=12,11*)		
Stinton Creek (SC1, SC2, SC3)	Wilson Brook (ND4)		
North Dandalup River	Dirk Brook (**)		
— North Rd (ND3)	Little Dandalup River (**)		
— Pipehead dam (ND5)	Marrinup Brook (** 2 sites)		
Wungong Brook (5*)	McKnoe Brook (** 2 sites)		
Seldom Seen Brook (8*)	Samson Brook (**)		
Dillon Brook (10*)			

Physical and chemical features of catchment streams were outlined by Bunn *et al.* (1986). Generally, forest streams were shallow and cool with a coarse substratum of gravel and larger rocks of concreted laterite, and high levels of benthic organic matter. The water was acidic with low concentrations of dissolved salts, nitrogen and phosphorus, and a low turbidity. No obvious differences were apparent between the intermittent and perennial forest streams in terms of these physical and chemical parameters. In contrast, lowland rivers were deeper and warmer with a sandy substratum and lower levels of benthic organic matter. The water was less acidic with elevated concentrations of dissolved salts, nutrients and a higher turbidity (Aquatic Research Laboratory, unpublished data).

Bunn *et al.* (1986) used a Surber sampler (0.1m^2, 475 μm mesh net) to sample benthic invertebrates quantitatively and the same sampler was used in the unpublished survey of seven sites in January 1983. A smaller Surber sampler (0.0625m^2, 250 μm mesh net) was used to sample the 30 sites in the Water Authority study. In all studies, the substratum enclosed by the sampler was stirred vigorously to a depth of 10cm for two minutes. All samples were preserved in 10% formalin and sorted under a stereomicroscope in the laboratory.

Specimens of *Glacidorbis occidentalis* from the Water Authority study were removed and the maximum diameter measured at X25 magnification using a graticule eyepiece. Specimens from CD1A, LC2 and LC3 on each sampling occasion were either dissected or embedded in epon araldite, sectioned at 1 μm and stained with toluidine blue for histological examination to establish the presence of brooded egg capsules. All specimens and slide preparations used in this paper have been lodged in the Western Australian Museum (WAM 569.88 to 574.88)

RESULTS

Glacidorbis occidentalis was present at only 14 of the 47 sites in the south-west of Western Australia that have been sampled quantitatively for stream

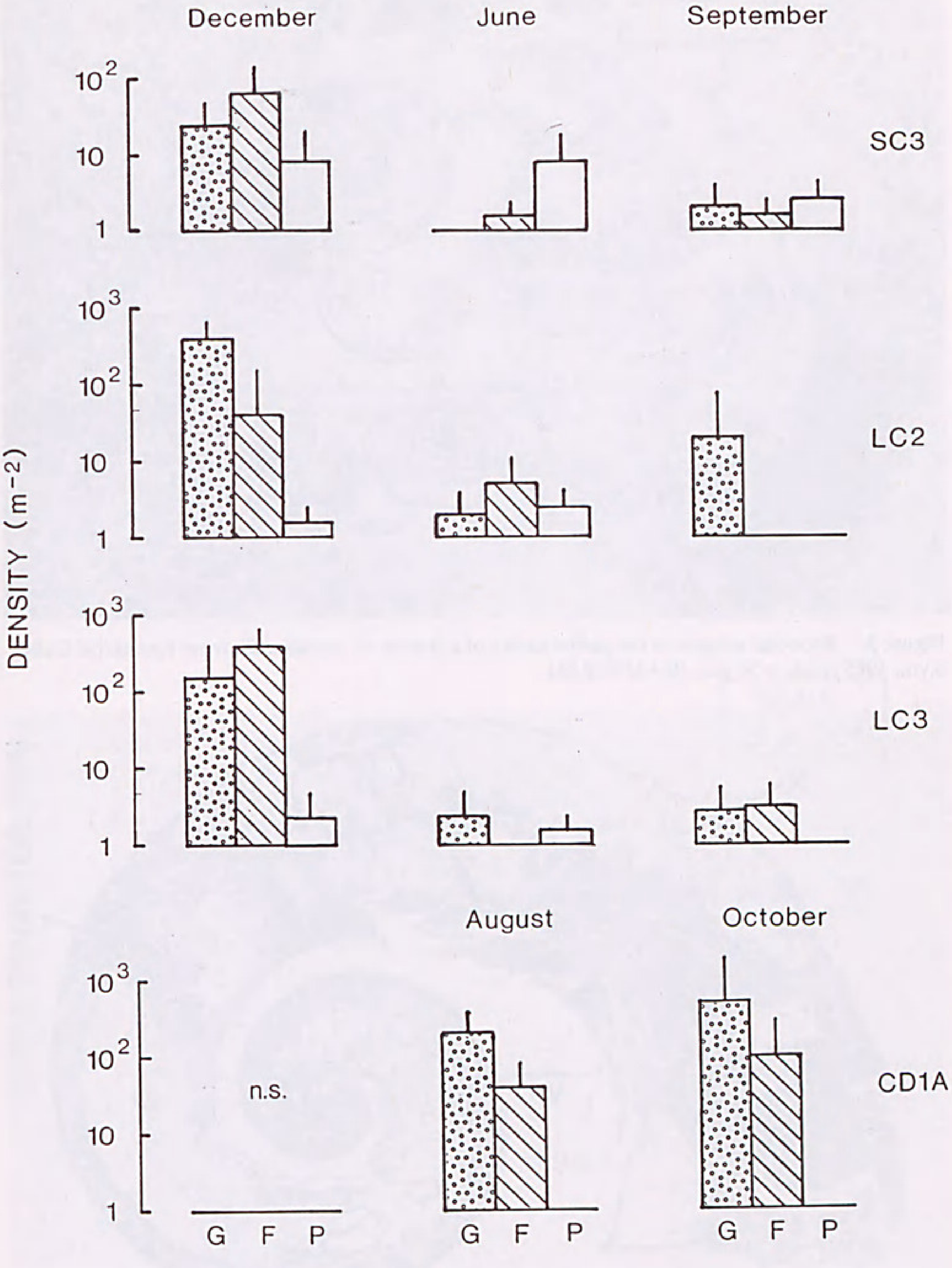

Figure 2. Mean density (m^{-2}; ± 1 s.e.) of *G. occidentalis* (G), *F.* cf. *petterdi* (F) and *Glyptophysa* sp. (P) in Stinton Creek (SC3), Canning River (LC2, LC3) and Kangaroo Gully (CD1A) from December 1984 to October 1985. The number of samples (n) = 6, except at SC3 in December 1984, where n = 10. (n.s. not sampled).

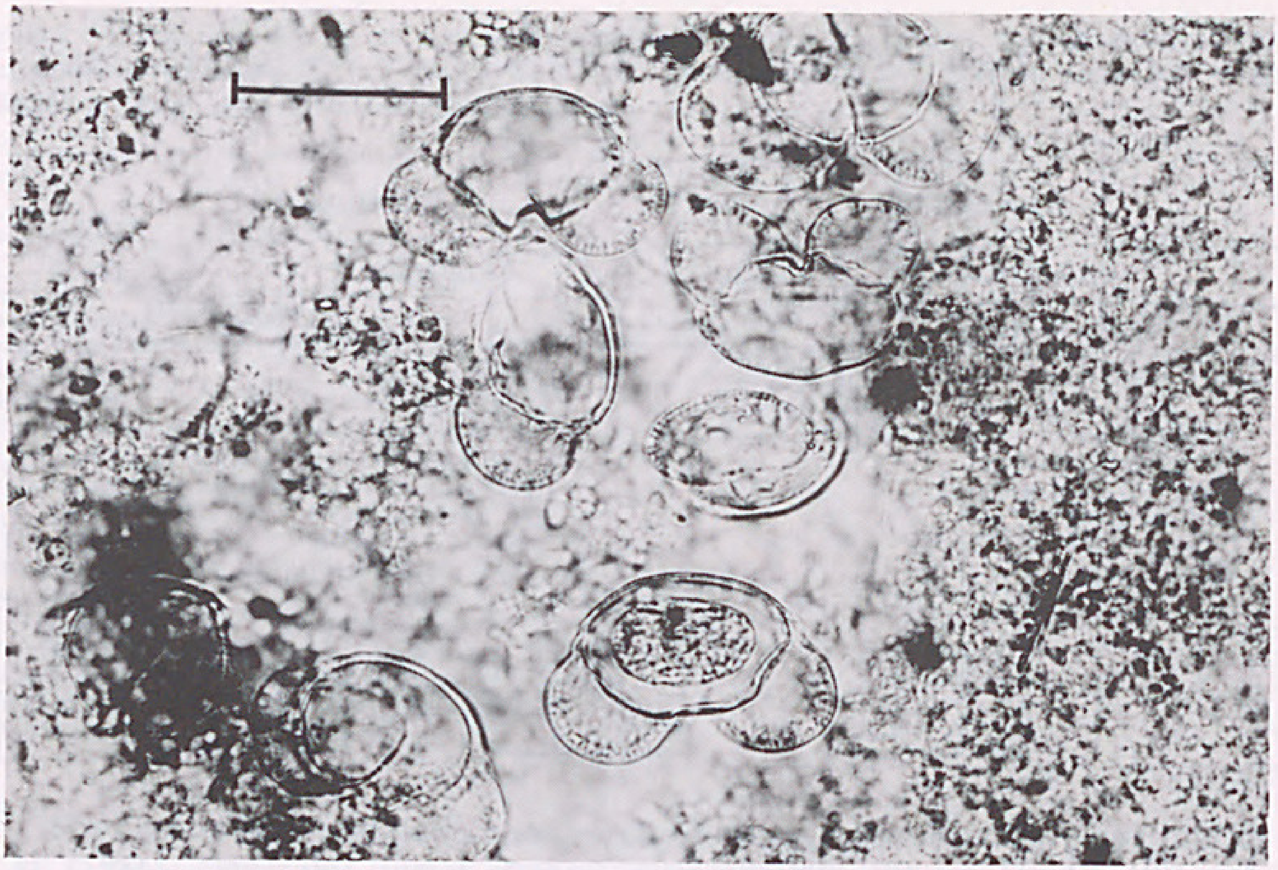

Figure 3: Brooded veligers in the pallial cavity of a female *G. occidentalis* from Kangaroo Gully, 6.viii. 1985 (scale = 50 μm; WAM 569.88).

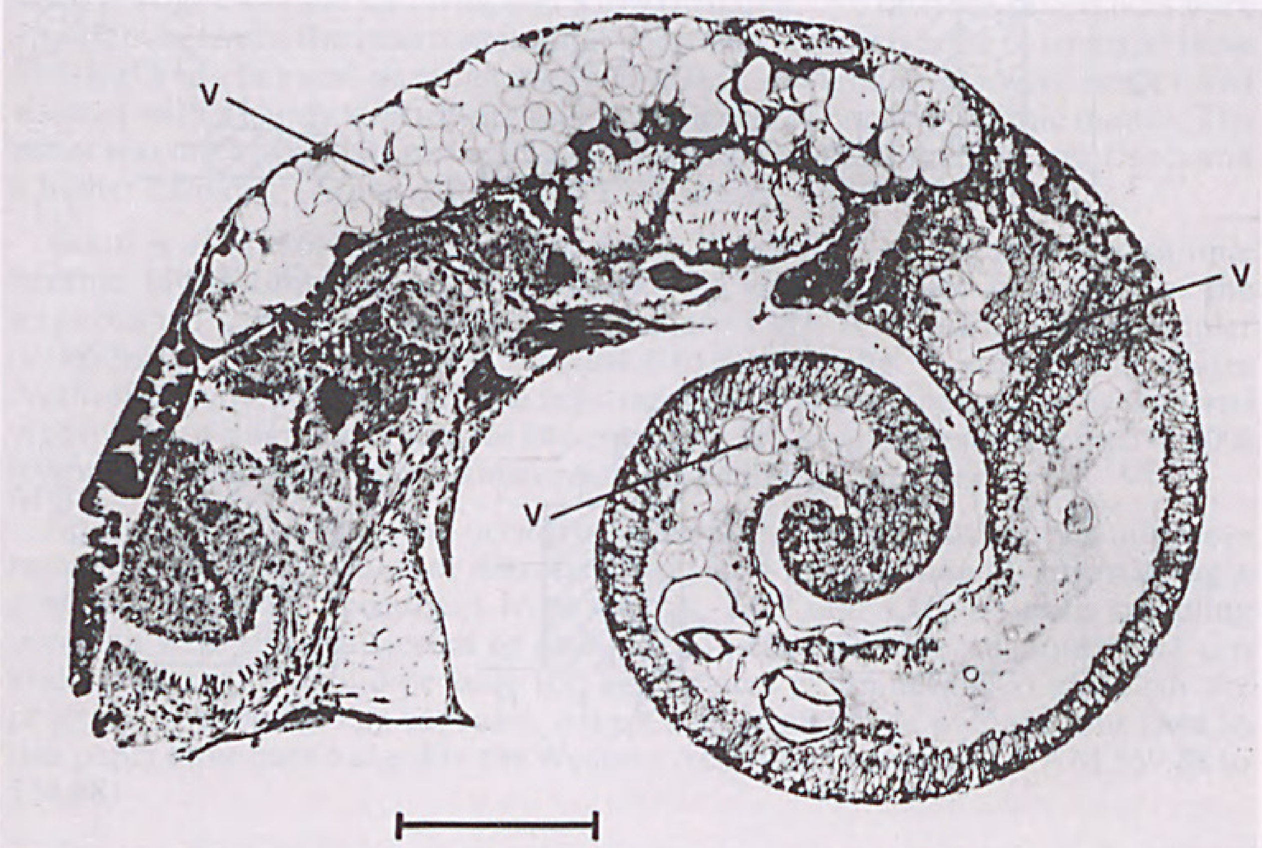

Figure 4: Longitudinal transverse section of a female *G. occidentalis* from Kangaroo Gully, 6.viii. 1985 showing veligers (V) filling the pallial cavity and continuing along the length of the spire (scale = 200 μm; WAM 570.88).

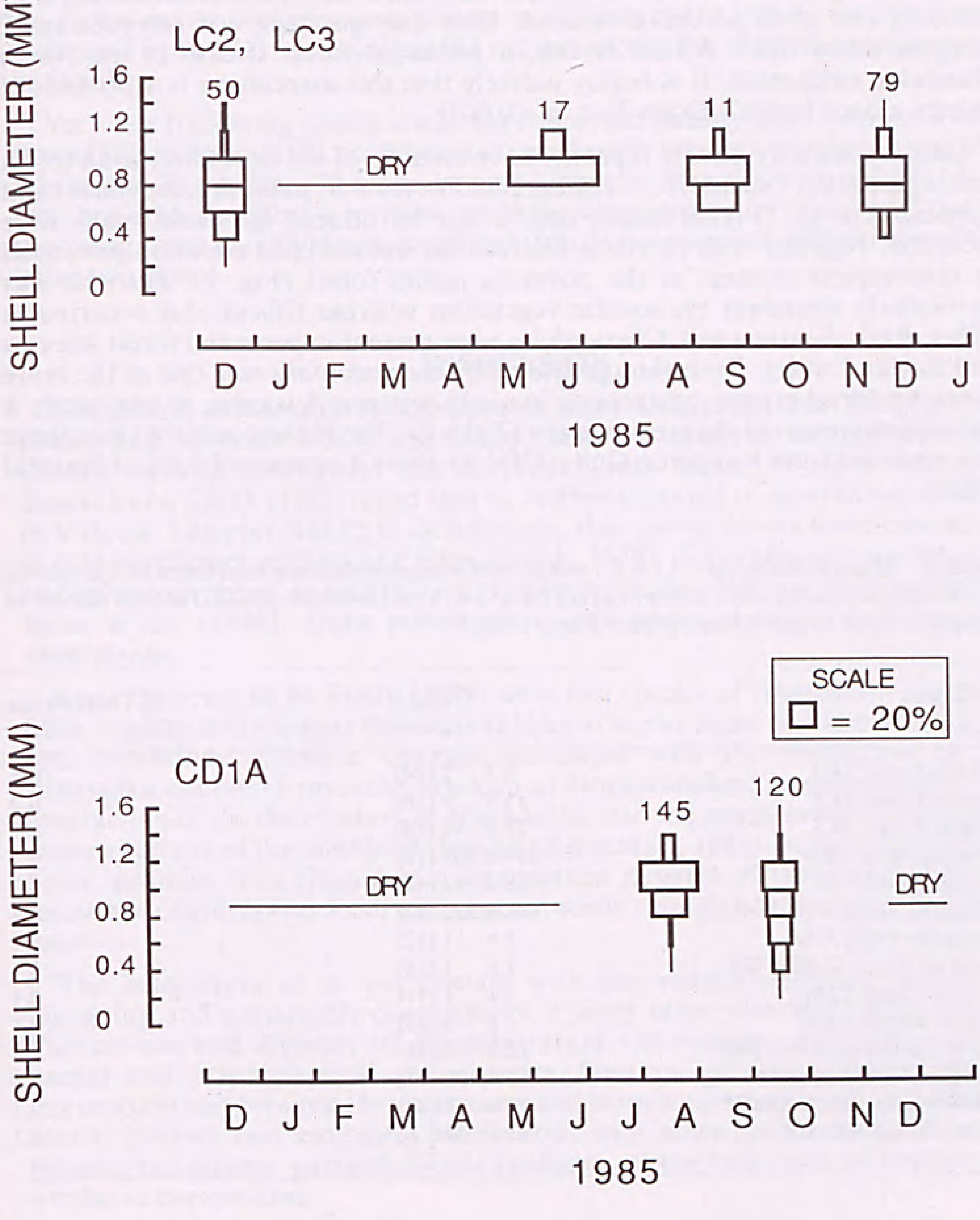

Figure 5: Size-frequency (%) histogram of *Glacidorbis occidentalis* from Canning River (LC2, LC3) and Kangaroo Gully (CD1A) from December 1984 to October 1985. Data from six samples on each occasion are pooled and the number of measured specimens presented.

invertebrates (Fig. 1). The species did not occur in the lowland rivers, west of the Darling Range and was restricted to the smaller streams of the northern jarrah forest. Of these, it was recorded from 13 of 17 streams with an intermittent flow but only one of 19 perennial streams. Only one specimen was recorded in 22 samples taken from Wilson Brook, a perennial forest stream in the North Dandalup catchment. It is highly unlikely that this association is a product of chance alone (Fisher's Exact Test, $p < 0.001$).

Gastropods were poorly represented in streams of the northern jarrah forest and, apart from *Glacidorbis occidentalis, Ferrissia* cf. *petterdi* (Ancylidae) and *Glyptophysa* sp. (Planorbidae), only a few introduced lymnaeid snails were recorded. Together with *Ferrissia, Glacidorbis* was the most common gastropod in intermittent streams of the northern jarrah forest (Fig. 2). *Ferrissia* was particularly abundant on aquatic vegetation whereas *Glacidorbis* occurred in riffles. Both *Ferrissia* and *Glyptophysa* were present in perennial forest streams and lowland rivers. Even though *Glacidorbis occidentalis* was one of the more common forest stream gastropods in south-western Australia, it was rarely a major component of the stream fauna (Table 2). The highest relative abundance was recorded from Kangaroo Gully (CD1A) where it comprised 6.4% of the total fauna.

Table 2. Mean densities (m^{-2}; ± 1 S.E.) and percent composition of the total fauna of *Glacidorbis occidentalis* in streams of the northern jarrah forest over a twelve-month period. The total number of samples is given in parentheses. (*from Bunn, 1985).

Location	Density m^{-2}	% Total Fauna
Stinton Creek SC1	4 ± 2 (24)	<0.1
Stinton Creek SC2	15 ± 9 (18)	0.2
Stinton Creek SC3	28 ± 14 (18)	0.7
Canning River LC2	314 ± 105 (18)	5.1
Canning River LC3	179 ± 88 (18)	1.3
Kangaroo Gully CD1A	1048 ± 322 (12)	6.4
Kangaroo Gully CD1	1 ± 1 (12)	<0.1
Canning River, south CD5	1 ± 1 (18)	<0.1
31 Mile Creek CD6	5 ± 4 (12)	0.1
Wilson Brook ND4	1 ± 1 (22)	<0.1
North Dandalup River ND5	12 ± 10 (18)	0.3
Wungong Brook Site 5*	64 ± 20 (18)	1.6
Seldom Seen Brook Site 8*	13 ± 6 (18)	0.3
Dillon Brook Site 10*	83 ± 44 (8)	5.3

Developed young were not observed in any of the specimens examined and brooding snails carried embryos only up to the veliger stage (65 to 83 μm in diameter; Fig. 3). Free veligers were present in many specimens along the entire length of the snail and into the pallial cavity (Fig. 4), with a mean number of 106 ($n=10$) and a range of 33 to 218. In other specimens, between 2 and 34 veligers (mean = 15; $n=9$) were held only in the anterior part of the pallial cavity. In all cases, the veligers were of similar size along the length of the snail and did not increase in size or stage of development toward the pallial area (Fig. 4).

Brooded veligers were not observed in 8 specimens of *G. occidentalis* from LC2 and LC3 in December 1984 nor in four specimens in June 1985, however, two of the three specimens examined from these sites in September 1985 had veligers in the pallial cavity. Veligers were present in eighteen of the twenty-five specimens examined from CD1A in August 1985 though in only five of the eleven examined in October.

Very few free-living young snails were recorded shortly after the first winter flows (Fig. 5), though the proportion of small snails was much higher in samples taken later in the year. This can be seen clearly in the samples from CD1A in October 1985, though it is not obvious in the samples from LC2 and LC3 due to the low number of individuals. Small individuals were present in December at the latter two sites.

DISCUSSION

Glacidorbis occidentalis is considerably more widespread than first reported (Bunn and Stoddart, 1983) and occurs almost exclusively in intermittently-flowing streams throughout the northern jarrah forest, Western Australia. Boulton and Smith (1985) noted that *G. hedleyi* occurred in intermittent streams in Victoria, however, unlike *G. occidentalis*, this species occurs more commonly in cold permanent streams and lakes (Smith, 1979). *G. occidentalis* was listed as an "indicator species" of intermittent streams in the classification analysis used by Bunn *et al.* (1986). Data presented in this paper strongly reinforce this observation.

Early impressions by Smith (1979) were that species of *Glacidorbis* preferred fresh, slightly acidic waters that were subject to winter snow and almost constant cold conditions. Climatic changes associated with the movement of the Australian continent since the breakup of Gondwanaland have resulted in the contraction of the distribution of *Glacidorbis* into the south-western and south-eastern corners of the mainland (Bunn and Stoddart, 1983). In common with all other localities with *Glacidorbis*, intermittent streams of the northern jarrah forest are oligotrophic, fresh and slightly acidic though never subject to winter snow.

The association of *G. occidentalis* with intermittently-flowing streams is intriguing and apparently distinguishes it from other members of the genus. Particle-size and diversity of the substratum, the amount of benthic organic matter and other physical and chemical features are very similar between intermittent and perennial forest streams and cannot account for this association. Nor is it likely that biological interactions with other species are responsible because the faunas, particularly the molluscs, of the two types of streams are similar in composition.

Adults of *G. occidentalis* spend late summer/autumn (January to May) in the stream bed, presumably in moist gravel beneath rocks and logs or even further down in the hyporheal zone. Brooded young develop in the mature females and are present as veligers soon after the adults emerge during winter. Members of the genus *Glacidorbis* were considered to be viviparous and brooding females carry only a few embryos at all stages of development, from egg capsule to shelled juvenile (Smith, 1979; Ponder, 1986). In contrast, *G. occidentalis* carries a large number of brooded veligers. The production of veligers, rather than shelled juveniles, in a lotic snail is not usual. Presumably the veligers are released either as a single mass or as a number of smaller masses, since they are not present later in the year and there is insufficient room in the pallial cavity or time for them to continue development within the parent. Small snails appear during late winter-spring and appear to reach adult size by summer, though a more detailed analysis of the life history would be required to confirm this. The intermittent streams are generally dry by late summer (January-February) and adult snails presumably retreat into the stream bed at this time. Ponder (1986) found that most populations of *Glacidorbis* he examined had all size classes represented at the time of collection, suggesting that there was no preferred time of breeding. *G. occidentalis* appears to have a more seasonal breeding cycle which is obviously a response to the highly seasonal changes in its environment.

ACKNOWLEDGMENTS

The Water Authority of Western Australia provided unpublished data on the water chemistry of the streams and rivers examined here. A. Kendrick and G. Pobar are thanked for their assistance in the field and laboratory. T. Stewart prepared the histological sections and S. Hopwood provided the photographic plates. We are also grateful to Dr F. Wells, Western Australian Museum, for constructive comments on an earlier draft of this paper.

Much of the work was funded by a grant from the Water Authority of Western Australia, though contributions from the Department of Conservation and Environment and Alcoa of Australia Ltd are also gratefully acknowledged. This paper was completed while the senior author received funding from an NSERC grant to Professor H.B.N. Hynes, Department of Biology, University of Waterloo.

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