

Distribution of benthic invertebrates at different depths in a shallow reservoir in the KwaZulu-Natal Midlands

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Samways, M.J., R. Osborn and I. van Heerden. 1996. Distribution of benthic invertebrates at different depths in a shallow reservoir in the KwaZulu-Natal Midlands. *Koedoe* 39(2): 69-76. Pretoria. ISSN 0075-6458.

The bottom of a freshwater reservoir in the KwaZulu-Natal Midlands was sampled for macro-invertebrates and macrophytes at depths of 0.5 m, 1 m, 2 m, and 3 m. The water plants *Elodea* spp. which did not occur much beyond 1 m appeared to be a major determinant for the presence of invertebrates. At 2 m and 3 m, when temperature and light decreased greatly, it was replaced by the algae *Chara* spp. Over 98 % of the macro-invertebrate individuals in 21 species and 14 families occurred in water 1 m or less in depth. At 2 m and deeper, there was a rapid decline of species, with only one, a snail, occurring at 3 m. Odonata species occurred only in water 1 m or less in depth. Among the Ephemeroptera, *Caenis* sp. was abundant at 0.5 m and the most dominant species of all. At 1 m, the most dominant species was *Cleon palidulosum* of the Baetidae. Both in terms of food for waterfowl and trout, and as a reserve for aquatic macroinvertebrates, the shallow fringe of the reservoir was playing by far the major role compared with the deeper, open water. It is recommended both for biotic conservation and fishing that reservoirs have a shallow rim and constant water levels.

Keywords: benthic macro-invertebrates, reservoir, aquatic vegetation, depth distribution.

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Introduction

Trout fishermen in the KwaZulu-Natal Midlands frequently ask where in the reservoir the insect prey of these polyphagous and predatory fish (Swisher & Richards 1971; Whitlock 1982) occur. This preliminary paper determines the bottom distribution of some aquatic macro-invertebrates in relation to vegetation and abiotic variables in a reservoir well known for excellent trout fishing.

Evidence from Lake Superior indicates that Ephemeroptera, Plecoptera and Trichoptera can occur in deep water providing that aquatic vegetation is present (Barton & Smith 1984). Similarly, Crass (1955) suggested that in KwaZulu-Natal, Ephemeroptera were affected by depth of water because of oxygen

requirements. Together, these findings suggest that there may be strict abiotic and biotic limitations which strongly influence the distribution of the aquatic invertebrates. This point is investigated here with respect to invertebrate conservation as well as trout fishing.

Methods

The study site was a 60-year old artificial reservoir in the Dargle area near Inhlalane in the KwaZulu-Natal Midlands (29°53'E, 29°33'S) (elevation: 1527m a.s.l.), about 2 km² in area fed by a perennial stream. The maximum depth of the reservoir was about 6 metres. Bottom sampling was done at four depths, (0.5 m, 1 m, 2 m, and 3 m) measured using an electronic gauge (Citizen Aqualand). The four depths

were, respectively, 0 m, 10 m, 20 m and 40 m from the shore.

Quantitative sampling of benthic macro-invertebrates was completed from the 26 to 28 March 1994. Benthic macro-invertebrates were sampled with a stainless steel triangular coarse net (340 mm base, 385 mm sides, a depth of 100 mm, and a mesh size of 1 mm). The net was carefully drawn along the bottom for 5 m, ten times (i.e. a 50 m transect). At the 2 m and 3 m depths, this was done with the aid of SCUBA equipment. Specimens were hand-picked, placed in 80% ethyl alcohol and later identified.

Aquatic macrophyte cover was estimated in 1 m² quadrats at each of the four depths, on a scale of 1 to 5, of increasing cover. Water temperature, pH and dissolved oxygen were measured with a Jenway (Model 3405) electrochemical analyser. There were ten replicates of measurements of environmental variables, made at each of the four depths. A Lambda quantum radiometer was used for measuring Photosynthetically Active Radiation (PAR) (light intensity) in microEinsteins (μE⁻¹cm⁻²).

Results

Light intensity and dissolved oxygen decreased significantly with depth (light intensity: $F_{3,36} = 54.35$, $n = 10$, $P < 0.01$; dissolved oxygen: $F_{3,36} = 283.9$, $n = 10$,

$P < 0.01$) (Table 1). Water temperature and pH did not differ significantly (at the 5 % level) at the different depths (Table 1).

The rooted, aquatic plants *Elodea* spp. were dominant at 0.5 m, while the algae *Chara* spp. were dominant, but decreasingly dense, at 1 m, 2 m and 3 m (Table 1).

A total of 1988 individuals, in 21 species and 14 families, were sampled. Over 98 % of all individuals occurred at a depth of 1 m or less. There was a rapid decline in numbers of individuals deeper than 1 m (Fig. 1). Species richness also rapidly declined with depth, with 21 species at 0.5 m, 13 at 1 m, 5 at 2 m, and only 1 (the snail, *Gyraulus costulatus*) at 3 metres. All species, except the *Hydracarina* sp. 1, were represented at 0.5 metres.

At 0.5 m, by far the most dominant group were the Ephemeroptera, especially Caenidae (*Caenis* sp.). At 1 m, the baetid Ephemeroptera (especially *Cleon palidulosum*) was dominant. Indeed, only *C. palidulosum*, *Hydracarina* species 1, *Corixidae* species 1 and 2, and *Notonectidae* species 1 were more abundant at 1 m than at 0.5 m.

Table 1

Environmental variables and vegetation cover recorded at different depths. Mean density (SD) of variables (n=10), and relative cover of vegetation on an increasing density scale of 1 to 5

Variable	Depth (m)			
	0.5	1.0	2.0	3.0
Light intensity (μEs ⁻¹ cm ⁻²)	4350 (5.98)	2050 (5.77)	890 (5.77)	531 (4.71)
Temperature (°C)	20.8 (0.01)	20.7 (0.01)	19.9 (0.01)	19.7 (0.01)
Dissolved oxygen (mg.l ⁻¹)	13 (1.76)	9.6 (0.64)	4.5 (0.13)	1.8 (0.07)
pH	13 (1.76)	9.6 (0.64)	4.5 (0.13)	1.8 (0.07)
Vegetation				
<i>Elodea</i> spp.	3	0	0	0
<i>Chara</i> spp.	0	5	3	2

Table 2.
Abundance of different taxa in the samples collected at each
depth in the reservoir

Taxon	Depth (m)			
	0.5	1.0	2.0	3.0
Hydracarina				
Species 1	0	30	17	0
Ephemeroptera				
Baetidae				
<i>Cloeon palidulosum</i> Crass	102	736	13	0
Caenidae				
<i>Caenis</i> sp.	500	11	5	0
Hemiptera				
Corixidae				
Species 1	4	6	0	0
Species 2	81	90	0	0
Species 3	2	0	2	0
Species 4	14	0	0	0
Species 5	10	0	0	0
Species 6	2	0	0	0
Notonectidae				
Species 1	29	168	0	0
Odonata				
Aeshnidae				
<i>Anax imperator mauricianus</i> Rambur	13	1	0	0
Gomphidae				
<i>Ceratogomphus pictus</i> Hagen	2	0	0	0
Libellulidae				
<i>Trithemis dorsalis</i> Rambur	7	0	0	0
Coenagrionidae				
<i>Ischnura senegalensis</i> Rambur	3	1	0	0
<i>Enallagma glaucum</i> (Burmeister)	1	1	0	0
Coleoptera				
Dytiscidae				
Species 1	15	15	0	0
<i>Hydrovatus</i> sp.	2	1	0	0
Trichoptera				
Leptoceridae				
<i>Athripsodes harrisoni</i> group species	30	0	0	0
Hydropsychidae				
<i>Cheumatopsyche</i> sp.	2	0	0	0
Pulmonata				
Lymnaeidae				
<i>Lymnaea columella</i> (Say)	1	4	0	0
Planorbidae				
<i>Gyraulus costulatus</i> (Krauss)	33	3	1	5
<i>Bulinus tropicus</i> (Krauss)	20	2	0	0
Total number of individuals	876	1069	38	5
Density (No. m ⁻²)	18	21	0.8	0.1

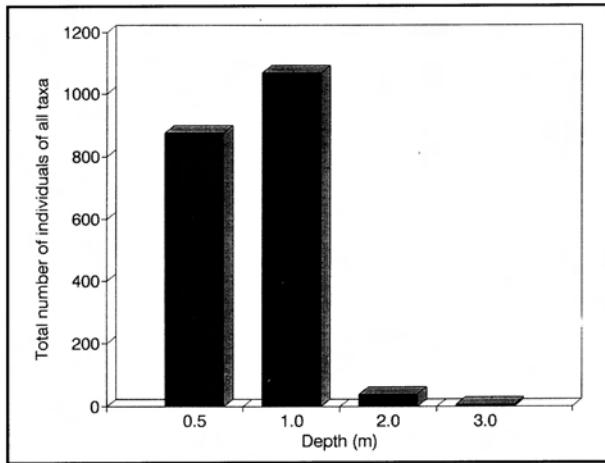


Fig. 1. The total number of individuals of all invertebrate taxa at different depths in the reservoir

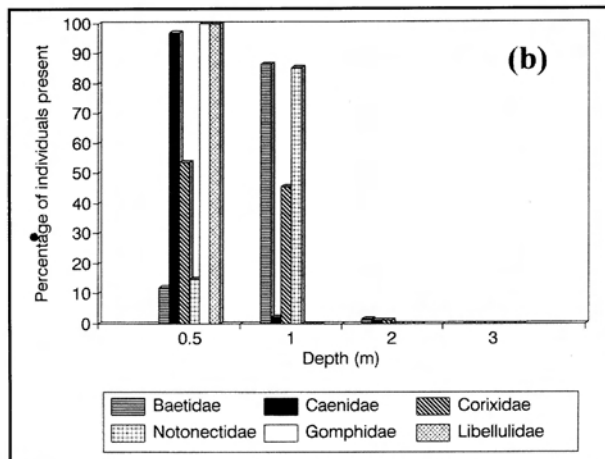
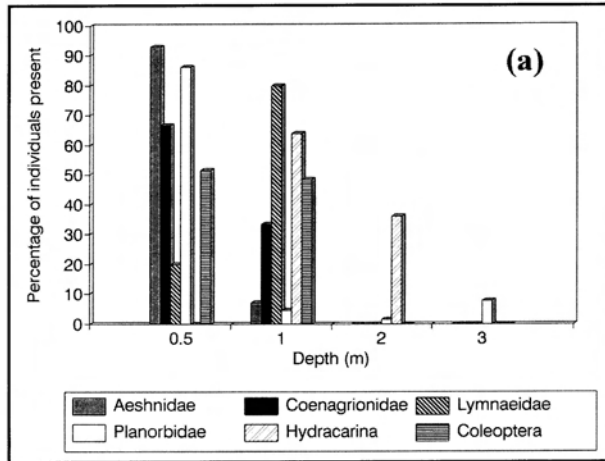


Fig. 2a & 2b. Percentage of individuals of invertebrate families collected at different depths.

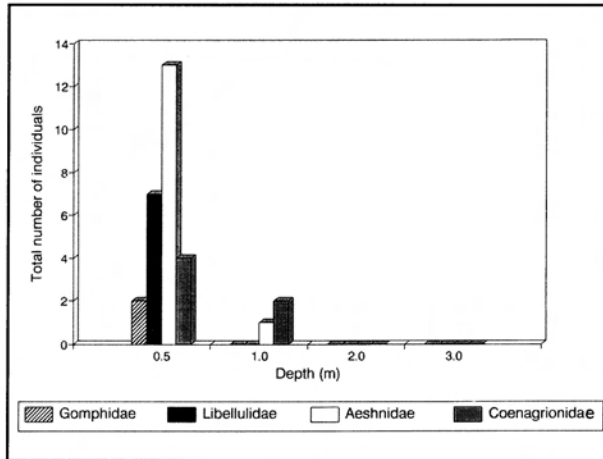


Fig. 3. The total number of individuals of the four families of Odonata collected at different depths in the reservoir (Gomphidae = *Ceratogomphus pictus*; Libellulidae = *Trithemis dorsalis*; Aeshnidae = *Anax imperator mauricianus*; Coenagrionidae = *Ischnura senegalensis*, *Enallagma glaucum*).

The numbers of each family occurring at each depth as a percentage of all four depths are given in Fig. 2a, b. Some taxonomic groups, such as *Caenis* sp. (Fig. 2b) species of Odonata (Fig. 2a; 3), have a distinct preference for shallow water.

The numbers of individuals of *Caenis* sp. were positively correlated with light intensity (Pearson's $r = 0.98$, $n = 4$, $P < 0.05$), while the baetid *C. palidulosum* was strongly correlated with dissolved oxygen ($r = 0.98$, $n = 4$, $P < 0.05$) (Table 3). Odonata and Trichoptera species were also strongly correlated with light intensity (Table 3). *Anax imperator mauricianus* was very strongly correlated with light intensity ($r = 0.99$, $n = 4$, $P < 0.05$). In contrast, Coleoptera and Corixidae species in general were both significantly correlated with water temperature (Table 3).

Discussion

Vegetation and macro-invertebrate distribution

Although water temperature and pH remained fairly constant with depth, light intensity and dissolved oxygen decreased with increasing depth, suggesting that these, and possibly other associated factors, may be important determinants of aquatic invertebrate and plant distribution.

Vegetation density, as well as structure, may also be important for phytophilic invertebrate species. In this study, there were more families present in areas of greater relative cover of vegetation (which was also the shallowest area). The distribution of most of the macro-invertebrates may have been influenced by the distribution of the vegetation (as well as other factors such as prey) and

Table 3.
Pearson's correlation coefficients for the density of invertebrates versus environmental variables at the site. Values significant at the 5% level are indicated with an asterisk and are in bold

Taxon	Light intensity	Water temperature	Dissolved oxygen	Ph
Hydracarina	-0.2896	0.1224	0.0101	0.8792
Baetidae	0.6109	0.9026	0.8280	0.8288
Caenidae	0.9778	0.8365	0.9362	0.2911
Corixidae	0.9506	0.9982*	0.9674	0.5831
Notonectidae	0.9330	0.6429	0.7720	-0.0982
Aeshnidae	0.9902*	0.8073	0.8973	0.0594
Gomphidae	0.9265	0.6295	0.7657	-0.1150
Libellulidae	0.9265	0.6295	0.7657	-0.1150
Coenagrionidae	0.9464	0.9720	0.9753	0.3279
Coleoptera	0.8418	0.9874*	0.9396	0.4579
Trichoptera	0.9948*	0.8373	0.9169	0.0951
Lymnaeidae	0.4597	0.8236	0.6801	0.6351
Planorbidae	0.8481	0.5837	0.6679	-0.3429

not entirely by the oxygen, light or temperature differences associated with different depths. Williams & Feltmate (1992), also found that individuals of the Coenagrionidae, Aeshnidae, Baetidae, and some Coleoptera were associated with submerged rooted aquatic macrophytes such as *Elodea* spp. This was also the case here, with Coenagrionidae and Aeshnidae occurring mainly in shallow water (0.5 m), where *Elodea* spp. were present, but not at 2 m, where the vegetation was *Chara* spp. (Table 1).

The occurrence of the Caenidae in the shallows (0.5 m) (Table 2) may have been in response to substratum and not to vegetation, as most are burrowers in mud (Agnew 1985). The Baetidae, in contrast, cling to rocks, weeds or coarse sand (Agnew 1985). However, species-rich Ephemeroptera assemblages are associated with vegetation (Brittain 1982). This, and the fact that most Baetidae larvae are phytophilic, explained the high abundance of these species at 1 m

depth, which had the greatest coverage of *Chara* spp. The distribution of Gomphidae (*Ceratogomphus pictus* in this study) which are burrowers in sediment, was less likely to be determined by the presence and cover of vegetation, than were those of the other families. The increasingly anoxic conditions at greater depths may have been the important limiting factor for *C. pictus*.

The higher numbers of Odonata species and individuals at 0.5 m (Fig. 4), may have been because the *Elodea* spp. provided a stronger physical support for the larvae than did *Chara*. The Coenagrionidae, Aeshnidae, and many Libellulidae are well known to cling to and climb on vegetation (Corbet 1962), or rest on the substratum beneath vegetation (Osborn 1995).

The presence of the *Chara* spp. may have been more important to *Cleon palidulosum* (Baetidae) than light intensity or dissolved oxygen, as its abundance was weakly corre-

lated with these two variables. The Baetidae are also phytophilic.

Feeding and light intensity

Apart from the Hydracarina, many taxa showed a strong positive correlation with light intensity (Table 3). This is not surprising with families such as the Aeshnidae which are visual predators (Corbet 1962) which actively hunt for their prey (Osborn 1995). The Odonata, Corixidae, and Dytiscidae are all predacious, and their distribution could have been negatively affected by the lower levels of light intensity at greater depths. Certainly, highly turbid waters with low visibility are avoided by Odonata species (Osborn & Samways 1996). Turbid waters can also interfere with respiration in Odonata.

Aquatic macrophytes are less abundant where the light intensity is reduced, as was evidenced here with *Elodea* spp. and *Chara* spp., decreasing with depth and light intensity. Species dependent on these plants for food or as refuge from predators would, therefore, also be reduced.

Water temperature and dissolved oxygen

Many taxa positively correlated with water temperature and dissolved oxygen (Table 3). With the Caenidae (*Cloeon* sp.) this could have been because these nymphs inhabit mud in shallower waters, thus avoiding the anoxic and cold conditions of deeper waters. Baetidae, in contrast, can occur on plants in deeper water because they remain at a higher level in the water column by their habit of clinging to vegetation. Oxygen concentration may have been important for many of the species because lentic waters show great spatial variation in oxygen levels, and dissolved oxygen strongly influences the distribution of aquatic insects (Leggot & Pritchard, 1986; Ward 1992; Williams &

Feltmate 1992). This was the case here, with dissolved oxygen concentrations being markedly higher in the shallower water (Table 1). Indeed, most species here appeared to be hypopneustic i.e. dependent on dissolved oxygen, and were therefore limited to the shallow, well-vegetated parts of the reservoir.

In a study like this, it is impossible to separate the effects of decreasing light and oxygen from decreasing temperature with depth. Nevertheless, it is well known that temperature plays an important role in determining the microdistribution of aquatic organisms (Leggot & Pritchard 1986; Ward 1992). This may well have been the case here, with nearly all the taxa, especially the Corixidae and Coleoptera, positively correlating with temperature (Table 3). The overall temperature in this reservoir decreased by 1.1 °C from 0.5 m to 3 m depth.

Significance of results for trout fishing and macro-invertebrate conservation

Aquatic insects are well known for being important as waterfowl food (Ward 1984) and for salmonid game fish (McCafferty 1984). The management implications from this study are that reservoirs ideally should have a shallow rim which encourages a profuse growth of submerged vegetation such as *Elodea* spp. Besides providing for an increase in area of occupancy for invertebrates such as dragonflies (Samways 1989), it also provides an increase in aquatic invertebrate biomass which inevitably increases waterbirds and trout. A corollary is that it is also important to maintain a constant water level, as fluctuating levels are impoverishing to submerged and emergent plants and to the macro-invertebrates (Osborn & Samways 1996).

Acknowledgements

We thank C.C. Appleton, W.P. McCafferty and G. Whiteley for identifications. M. Kimber kindly allowed access to the site and P. Sweet helped process the manuscript. Financial assistance came from the Foundation for Research Development and the University of Natal Research Fund.

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