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**Is aquatic invertebrate endemism in the
Western Cape region of South Africa
related to the fynbos blackwaters?**

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Abstract

The south-western Cape of South Africa has a very endemic, specialized terrestrial flora and aquatic fauna. It has been argued that the high degree of endemism is related to the origin of the fauna, the multiplicity of habitats present and the harsh water chemistry characterized by low pH. The aim of this project was to look at the relationship between pH and endemism. Specifically I asked if there is a trichopteran and ephemeropteran fauna confined to the Cape and if this is true, I attempted to find out whether it is the acidic waters or its biogeographical origin that limits its distribution. I also attempted to identify a group of species that occurs at a wide range of pH values (i.e. pH insensitive) and another group that is intolerant of acidic waters. This was done by looking at historical data on species distribution and the pH ranges at which they were found, and these data then re-analysed in the light of fieldwork performed on the Breede River in the western Cape. A number of species within different genera (e.g. *Lithogloea*, *Leptecho* and *Agapetus*) appears to be confined to the Cape. Their distribution is determined by both their origin and water chemistry conditions, which are characterised by low pH and pure, silt-free water. A warm stenothermal group, comprising *Leptonema*, *Elassoneuria* and *Eatonica* spp. is limited to the subtropical regions of South Africa, where water is alkaline. A eurythermal, pH-insensitive group that includes *Castanophlebia calida*, *Ecnomus* and *Cheumatopsyche* spp has a widespread distribution throughout the country. Lastly, there appears to be another eurythermal group (e.g. *Pseudopannota maculosa*, *Pseudocloeon glaucum*) that is intolerant of low pH values. As research is continuously discovering new species and new distribution records for old ones, it is likely that the above categories will need revision as more data are collected.

Introduction

The south-western Cape region of South Africa is renowned for its high levels of endemism both in its terrestrial flora and aquatic fauna (100% of amphipod, 76% of caddisfly, 41% of blackfly and 38% of mayfly species (Wishart & Day, 2001)). There has been much speculation regarding the reasons behind this trend, but no definitive conclusion has been reached thus far. The hypotheses are however numerous, and it is most likely that the interaction of various factors has resulted in the patterns encountered. An analysis of the literature regarding aquatic invertebrate endemism in the fynbos region reveals interesting information as to the possible causes of this remarkable level of endemism.

Firstly, a high degree of endemism in the area can be attributed to the biogeographic origin of the south-western Cape fauna which, according to Harrison (1965a) can be classified into two main groups: the Old (Palaeogenic) and the Pan-Ethiopian elements. The Old Element descends from the south temperate Gondwanian fauna (Harrison, 1978), which has retained some affinities with taxa found in the other continents that were part of Gondwanaland (Harrison, 1965a). In early Jurassic times, Africa lay south of its present position, where it experienced a colder and wetter climate, and was joined to the continental landmasses of South America, Australia and Antarctica. In the late Jurassic, as Africa moved northwards, it separated from the rest of Gondwanaland and began to enter warmer climatic zones. The northern areas of the country moved into the tropical and sub-tropical zones, while the southern parts entered more favorable temperate climatic areas, with subsequent increases in temperature and reductions in precipitation. The south-western Cape remained the only region in South Africa with a temperate climate. Speciation and divergent evolution occurred as a result of the new climatic conditions. Numerous species (e.g. the Siphoneuridae) that could not withstand the warmer climate disappeared; the relatively more tolerant ones became confined to mountainous areas of the Cape Fold Belt and the Drakensberg chain (the palaeogenic fauna: Stuckenberg, 1962); and new species that were adapted to higher temperatures developed (Harrison, 1965a). Many of the endemic species encountered in the south-

western Cape are thus part of the paleogenic fauna, which Stuckenberg (1962) defined as mostly relict, primitive elements that belong to ancient taxa and are associated with specific humidity and temperature ranges typical of montane areas. Some of these taxa are present in the Eastern Highlands too, extending from the Drakensberg to the Amatola Ranges and Eastern Plateau Slopes (Harrison, 1978). Others, like *Aprionyx* spp, appear to be mostly confined to southern mountain ranges in the Cape (Harrison, 1978), where higher numbers of both species and genera are encountered (Stuckenberg, 1962).

Other taxa in the south-western Cape originate from the Pan-Ethiopian element that comprises the majority of South African riverine species (Harrison, 1965a). Included in this group are the cold stenothermal montane species that are generally characteristic of mountain streams, but in the Western Cape can even be found at sea level (Harrison, 1965a). Some of these species have very wide distributions, extending north-eastwards in the country; others are endemic to the south-western Cape due, according to Stuckenberg (1962), to their inability to disperse over large gaps separating suitable habitats.

The Gondwanan fauna comprises the oldest and least disturbed group of species in the continent of Africa, given that many taxa could survive only in the temperate Western Cape (Endrödy-Younga, 1988), an area which has had minimal climatic or geological change over the past 200 million years and did not experience glaciation during the Pleistocene Ice Ages (Deacon *et al.*, 1992). This climatic and geological stability could therefore account for the high degree of endemism encountered in south-western Cape rivers.

Secondly, the south-western Cape has a very high diversity of habitats. One finds steep physical gradients, with mountains of high relief arising from flat coastal or intermontane valleys, which are deeply cut by ravines and drainage features that might be expected to promote allopatric speciation (Stuckenberg, 1962). The climate is also very variable with two clear gradients, one running in a north-south direction from the escarpment to the south coast, and another running eastwards from the west coast to the south-east coast (Fuggle & Ashton, 1979). These gradients are superimposed on a mountainous topography, in this way giving rise to a combination of climatic zones (Fuggle & Ashton, 1979), with the peaks and sea-facing slopes experiencing higher precipitation than the

land-facing slopes (Stuckenberg, 1962). Furthermore, the extreme southwest experiences winter rainfall, while moving eastwards from Swellendam and Agulhas, aseasonal rainfall patterns predominate. The geology is also varied, with a mosaic of sandstones and shales producing different soil-types which, as a consequence have allowed very high diversity patterns and endemism to develop among the flora and fauna (Wishart & Day, 2001).

The flora itself is believed to be in part responsible for the high degree of endemism encountered among the invertebrates. The Cape Floral Kingdom (CFK) is renowned for its extraordinary levels of diversity and endemism: it comprises 4% of South Africa's area while containing 42% of its plants, with 70% of these endemic to the region (Wishart & Day, 2001). It is believed that the high diversity is a result of the multiplicity of habitats present, created by the inception of the Mediterranean climate approximately 5My, and variations in physical gradients (Goldblatt, 1997). The main families in the CFK belong to the Proteaceae, Restionaceae and Ericaceae, which mainly comprise sclerophyllous evergreen vegetation that is associated with nutrient-poor, sandy, leached soils (Midgley & Schafer, 1992). This type of vegetation produces dissolved organic compounds such as phenols, tannins and humic / fulvic acids, which, once released into the soil and consequently into rivers, cause the waters to become acidic, black and foamy (Midgley & Schafer, 1992). Forest species encountered in the Cape have also been found to release polyphenols in the soil, thus producing acidic river waters (Midgley & Schafer, 1992). Since the appearance of fynbos vegetation during the Pliocene, acidity levels in river waters have increased (Wishart & Day, 2001), thus promoting divergent evolution once again: species that could not cope with low pH values disappeared (e.g. several crustaceans are not tolerant of high acidity), while other species adapted themselves to the new conditions (Wishart & Day, 2001). Endemism in freshwater invertebrates is thus likely to have also developed in this way, with new species being prevented from invading due to the unfavourable environment (Wishart & Day, 2001).

Another reason linked to the low pH values found in the Cape region is related to the erosion of the Karoo sediments that gave way to the hard, resistant quartzitic rocks

belonging to the Table Mountain Sandstones group (Wishart & Day, 2001). This produces soils that are oligotrophic and leached. The water of rivers is consequently soft (low carbonate, magnesium and calcium content), oligo- to mesotrophic and unbuffered, with pH values ranging from 4 to 7 (Wishart & Day, 2001). These distinct chemical characteristics, combined with physical gradients, have thus created very distinctive patterns in the hydrobiology of the systems in the Cape, allowing only a limited suite of organisms to flourish in the waters.

Endemism in rivers around the city of Cape Town is also believed by Harrison & Barnard (1971) to be the result of the erosion of the land bridge that used to link the Cape Peninsula mountains to the Hottentot's Holland range on the opposite side of Table Bay, in the process giving rise to the Cape Flats. The erosion of the Table Mountain Sandstones (TMS) began approximately 248 million years ago and was completed by 3-4 MYr (Wishart & Day, 2001). This caused species with poor dispersal abilities to become confined to the mountain ranges they inhabited, as the conditions of the rivers on the Cape Flats was not suitable, with sluggish, alkaline streams predominating (Harrison & Barnard, 1971), and thus creating a barrier to species wanting to migrate. Thus vicariant events caused the faunas that became separated to undergo divergent evolution: Wishart *et al.* (in press), in their study on the genetic differences between populations of four species inhabiting streams on Table Mountain versus others in the Hottentot's Holland range, encountered distinct patterns. The species with the widest dispersal potential had the least genetic difference between separate catchments; those with limited dispersal abilities were the most genetically distinct, although the patterns of genetic variability were relatively weak given the rather recent demographic history of the organisms in question (Wishart *et al.*, in press). Picker & Samways (1996), on the other hand, found high levels of invertebrate endemism in the Cape Peninsula, which were mostly concentrated on Table Mountain, especially in upper-reach forest streams, riverine forest and caves on south-facing slopes at elevations higher than 200m above m.s.l.. Furthermore, plant and invertebrate endemism (both terrestrial and aquatic) were found to be significantly correlated (Picker & Samways, 1996).

There are therefore numerous hypotheses regarding the high levels of endemism encountered in the Cape region of South Africa. These range from biogeographic factors (the fauna's ancient origin, vicariance and allopatric speciation) to the diverse and constraining environment to which the organisms have had to adapt (physical gradients, relatively harsh water chemistry).

The focus of this paper is an investigation of the relationship between pH and endemism. Given that fynbos vegetation is very diverse and endemic, I questioned the existence of a link between the flora and invertebrates inhabiting rivers. I hypothesized that through the release of polyphenols in the water, a specific water chemistry develops, with very low pH values that allow only a suite of specialised organisms to survive, and this therefore creates the link that translates into high endemism for the fauna too.

Specifically, I was interested in discovering whether there is a suite of organisms that is confined to acidic waters and is thus only encountered in the Cape, and whether there is a gradation in the distribution of these organisms from the south-western Cape (highest levels), to the southern Cape (lower occurrence), to the rest of the country (no presence). I was also interested in discovering which taxa, if any, appear to be insensitive to pH, and are thus ubiquitous, and if there are any acidophobic taxa. I chose to focus on members of the Ephemeroptera and Trichoptera, which are known for their high levels of endemism in the south-western Cape (de Moor, 1992).

According to Harrison & Agnew (1962), there is a group of taxa specialised to the acidic waters (pH<6) of the fynbos region, as well as another group common in alkaline waters, and a third group of species that appears not to be pH-sensitive. In their study, mostly members of the Ephemeroptera and Trichoptera were found to be common in the upper reaches of acidic rivers that experienced high precipitation. Their distribution extended as far as the eastern limit of the TMS formation, due to the fact acidic waters flow off this type of geological formation, and fynbos is common in the area. In the Eastern Cape, however, it was found that rivers that were slightly acidic and which experienced high precipitation, did not contain species that were found to be endemic to the acid waters of the western and southern Cape. This would appear to support the restricted distribution of

certain taxa, either due to limited dispersal abilities over boundaries, or their restricted ranges due to their Gondwanaland origin, while rejecting the idea that chemistry is the ultimate factor determining distribution. Acidic rivers also included pH-insensitive species, while streams which had slightly acidic waters were found to contain both species that could stand the neutral to low pH as well as others that formed a component of the acid streams.

The project therefore sought to verify the patterns encountered by Harrison & Agnew (1962), but to also move beyond this. If I found a suite of organisms that appeared to be confined to acidic waters, as Harrison & Agnew (1962) claimed, I questioned their origins, to verify whether they had been previously identified as part of the paleogenic element, or if they dispersed from the Pan-Ethiopian suite of organisms. I believe this could provide us with clues regarding possible causes of endemism, to investigate whether chemical factors or biogeographic factors appear to be most supported. It is however important to mention, at this point, that given the paucity of literature on the subject, a degree of speculation did indeed occur.

Furthermore, the patterns encountered were analyzed in the light of the river sub-region in which the organisms were encountered. There are in fact very few rivers that have not been modified in their course (e.g. by impoundments) or whose catchments have not been altered (e.g. land-use change, such as clearing of natural vegetation to be replaced with agriculture, urban or industrial features). As a consequence, rivers vary greatly in their chemical characteristics between their upper and lower reaches, as the catchments in the headwaters are generally left relatively untouched. Water chemistry in the south-western Cape also changes naturally as one moves downstream, due to increased evaporation, vegetation changes, increased weathering and calcium levels, and changes in geology (Dallas & Day, 1993). Malmesbury Shales, which contain high quantities of leachable ions, become more common in the valleys, causing total dissolved solids (TDS) in the water to increase (Dallas & Day, 1993). Species are therefore generally more specialised and show a higher degree of endemism in the upper reaches, while in the lower reaches, one finds more hardy, generalist species of widespread distribution. Headwater species,

also called rhithronic species, are thus more adapted to oligotrophic, unbuffered waters of high oxygen tension, low pH and low silt content (Harrison, 1965b). They are often cold stenothermal forms, although some, such as baetids, are eurythermal, but still generally demand clean, silt-free water (Harrison, 1965b). Species typical of the lower reaches are found in waters of higher nutrient concentration, due to seepage of fertilizers and pollutants from the land-use, of higher pH due to the clearance of fynbos and of higher silt quantities. Lower-reach species are often eurythermal, but may sometimes be warm stenothermal, especially in rivers at lower latitudes, where the rhithronic forms are pushed to higher and higher altitudes (Harrison, 1965b). Despite anthropogenic and natural changes, lower reaches of few rivers may maintain a relatively low pH. I therefore attempted to ascertain whether the species found in these areas were part of the widespread component or whether they have maintained endemism. If the species in these reaches are mainly endemic, it will indicate that high pH limits their distribution, versus biogeographical factors that maintain that endemism is encountered in upper montane reaches due to these areas being refuges for Gondwanan elements. I therefore compared the species encountered in the upper and lower reaches of a number of rivers in the western Cape and related them to their origins and distributions, and once more I tried to identify acidophilic, acidophobic and pH-insensitive species.

In order to answer the questions I posed, historical data on invertebrate composition of various rivers was compared to identify endemic species and the pH ranges at which they were found. This was done by using the Biological and Chemical Database (BCD) designed by Dallas & Janssens (1998), asking a number of specific questions and comparing the results obtained with Harrison & Agnew's (1962) findings, and results arising from a study attempting to classify South African rivers (Eekhout *et al.*, 1997). The questions posed related to which Ephemeroptera and Trichoptera taxa were found in the lower versus upper reaches at five pH ranges ($\text{pH} \leq 4,5$; $4,5 < \text{pH} \leq 5,5$; $5,5 < \text{pH} \leq 6,5$; $6,5 < \text{pH} \leq 7,5$; $\text{pH} > 7,5$) in the 18 South African bioregions.

These results were then compared to a number of studies on rivers in the south-western Cape, as well as to benthic macroinvertebrate samples I collected on ten sites along the Breede River and its tributaries. The sites were chosen in the mountain stream, foothill,

transitional and lowland subregions and included mainly reference sites which were relatively unimpacted.

I believe that this research will help to assess the usefulness of the BCD, as this is among the first studies making use of the database. Furthermore, in terms of conservation, the results may be of value in identifying the degree to which anthropogenic land-use and disturbance have modified the species composition of rivers. The research can also contribute to an understanding of the species requirements in terms of water quality (referring to pH) and give a broader grasp of the origin and distribution of aquatic macro-invertebrate species of the south-western Cape, research that has not been looked at for the past three decades. This information will therefore assist in identifying appropriate management strategies for river systems and their catchments, and will have implications for conservation.

Methods

Study Area

The research focused on the south-western Cape region of South Africa (Figure 1), home to one of the world's six floral kingdoms, situated between a latitude of 31 and 34°S.

This area experiences a Mediterranean climate, with relatively wet winters and dry summers, typified by strong south-easterly winds. Precipitation is very variable, ranging between more than 2000mm on high mountains to less than 200mm on leeward slopes of the interior ranges and along the western coastline (Goldblatt, 1997), and shifts from being seasonal (winter rain) to aseasonal as one moves eastwards. Variations in rainfall also exist moving from the coast to the interior, and according to a mountain's aspect.

The geology of this area is very ancient, being derived from pre-Carboniferous rocks (>300 million years old). It consists of alternating layers of quartzitic sandstone (Table Mountain group) and fine-grained siltstones and mudstones (Bokkeveld and Witteberg groups) overlying the shales of the Malmesbury System (Goldblatt, 1997). These strata

were folded and warped at the break of Gondwanaland, causing one rock type to be entrained in the other and initiating the formation of the Cape Fold Mountains. These run parallel to the coast and rise 1-2 000m above sea level (Goldblatt, 1997). Due to differential weathering of the parent rock there are two soil-types in the region: coarse-grained, oligotrophic sandy soils, and richer, fine-grained clay soils. Additionally, in deep valleys one finds granitic schists, while in coastal areas limestone becomes exposed (Goldblatt, 1997).

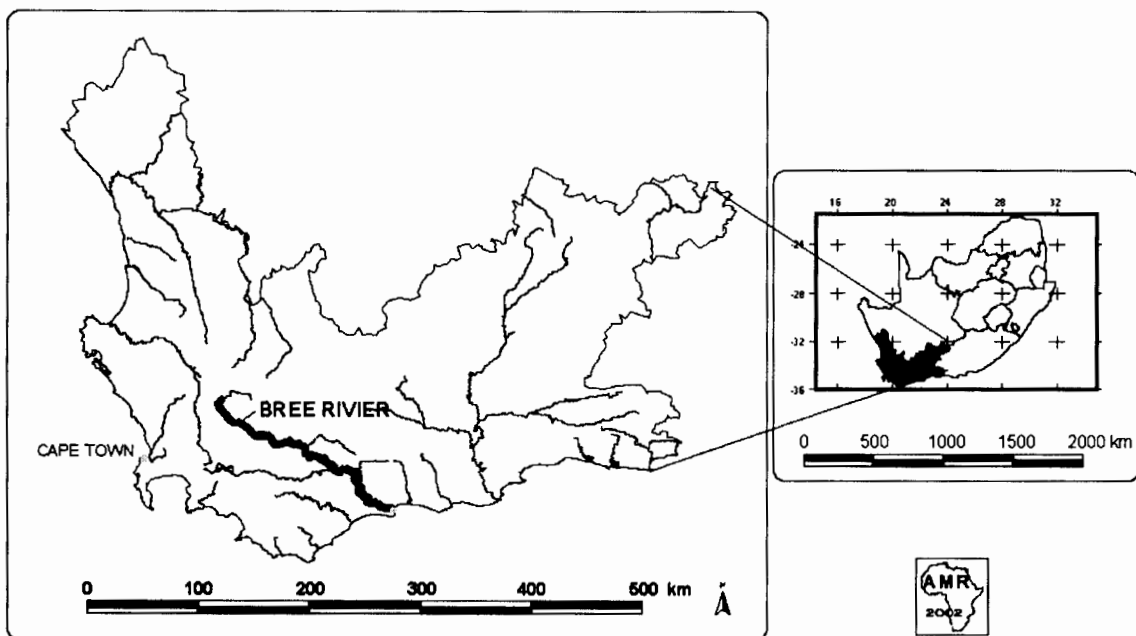


Figure 1: Map of the Western Cape in relation to the rest of South Africa (see inset), showing the main rivers in the province. The Breede River, where the fieldwork was performed, is in bold.

The Cape region has five vegetation types: Fynbos, Renosterveld, Karoo Steppe or succulent shrubland, forest thickets and evergreen forest (Goldblatt, 1997). The Cape Floral Kingdom (CFK) occupies an area of 90 000km² and includes 8 650 species of flowering plants, a remarkably high level of diversity, considering tropical East Africa only has 11 500 (Goldblatt, 1997). Fynbos flora is characterised by macchia-like

vegetation comparable to the Californian chaparral and Australian kwongan. It comprises three main plant families, Ericaceae, Proteaceae and Restionaceae that are generally associated with soils derived from nutrient-poor sandstones. Consequently this vegetation has high levels of polyphenols and secondary plant compounds, and it leaches humic and fulvic acids.

The combination of the above climatic (winter rainfall), geologic (oligotrophic substrata) and biotic (polyphenol-rich vegetation) factors gives rise to rivers of acidic, humic-stained water, with low buffering capacity and nutrient content. To put this into the broader context of the rest of the country, a few words will be spared to describe the other regions from which data were taken in the project (based on de Moor (1992) and Day & King (1995)).

As one moves eastwards from the CFK, rainfall becomes aseasonal and occurs occasionally throughout the year. The Cape Supergroup (TMS) still predominates and the main ions found in the waters are Na^+ and Cl^- , so that acidic and neutral conditions still prevail. Further eastwards and northwards, where a raised plateau occupies the centre of the country, these ions remain common, but Mg^{2+} and HCO_3^- arise from the shales and sandstones of the Karoo System, rendering the water more alkaline. The rainfall also decreases, and except on high mountains (and south of 32°S) now becomes strongly summer seasonal. In the north and north-east of the country, moving into Kwa-Zulu Natal, extrusions of volcanic rock (basalt) become increasingly common, with the dominant ions being Ca^{2+} , Mg^{2+} , HCO_3^- and Na^+ . Rivers tend to be alkaline and sluggish, with often high suspended sediment loads. The geology of north-central South Africa is rather complex, including igneous, metamorphic and sedimentary geologic features; Ca^{2+} , Mg^{2+} , HCO_3^- are the dominant ions in this area. Climatically, the south-western Cape, the eastern coastline and the mountainous areas are the only regions to receive relatively high levels of precipitation, and thus to support perennial rivers. The extreme north-west is very dry, with the Orange River being the only perennial river flowing between 17 and 31° latitude. Other rivers are episodic, while in the centre of the country they tend to be periodic.

The fieldwork was performed on the Breede River, one of the main rivers in the south-western Western Cape province. This arises from streams draining the slopes of the Skurwe Mountains (1-2000m a.s.l.), which then become the Breede River in the town of Ceres (Coetzer, 1986). From here the river flows southwards, turning first westwards and then south-east before emerging in the Indian Ocean. The Breede River is partially regulated, with water diverted to increase the supply reaching Voëlvlei Dam and water from the Brandvlei dam released at Worcester, while the Riviersonderend, its main tributary, is affected by the Theewaterskloof Dam in its upper reaches (Coetzer, 1986). The river flows through agricultural land with orchards and vineyards in the upper areas, descending then through a number of towns where one finds light industry and wheatlands in the catchment (Coetzer, 1986). Fynbos vegetation is common in the upper reaches, while alien infestation becomes visible as one moves downstream (with *Acacia saligna* and *Sesbania punicea* prominent) and also in certain degraded sites in the upper catchment (*Acacia longifolia* and *A. mearnsii* prominent) (Boucher & Rode, 2001). Most of the runoff in the Breede and tributaries is naturally of good quality, but is being increasingly affected by salinisation and rising nutrient and agrochemical levels due to agricultural leaching and discharging effluents into the stream.

Ten sites were chosen out of the 50 that were used in the Breede River Catchment Assessment (figure 2), part of the Water Research Commission project aimed at investigating water quality requirements for aquatic organisms (Dallas *et al.*, 1998). Four sites that had been classified as reference mountain stream sites were chosen, while the other three mountain sites were impacted. The foothill, transitional and lowland sites were all selected from those that had been classified as reference. The results obtained for pH during the Catchment Assessment project were at the basis underlying the choice of sites. Sites in the lower end of the pH scale were chosen for all but one of the mountain sites, to attempt to isolate the pH factor from others that could influence macroinvertebrate community composition. Hence the choice of reference sites in the foothill, transitional and lowland reaches, as these were least impacted and therefore still showed relatively low pH values. For a description of the sites see tables 1 and 2.

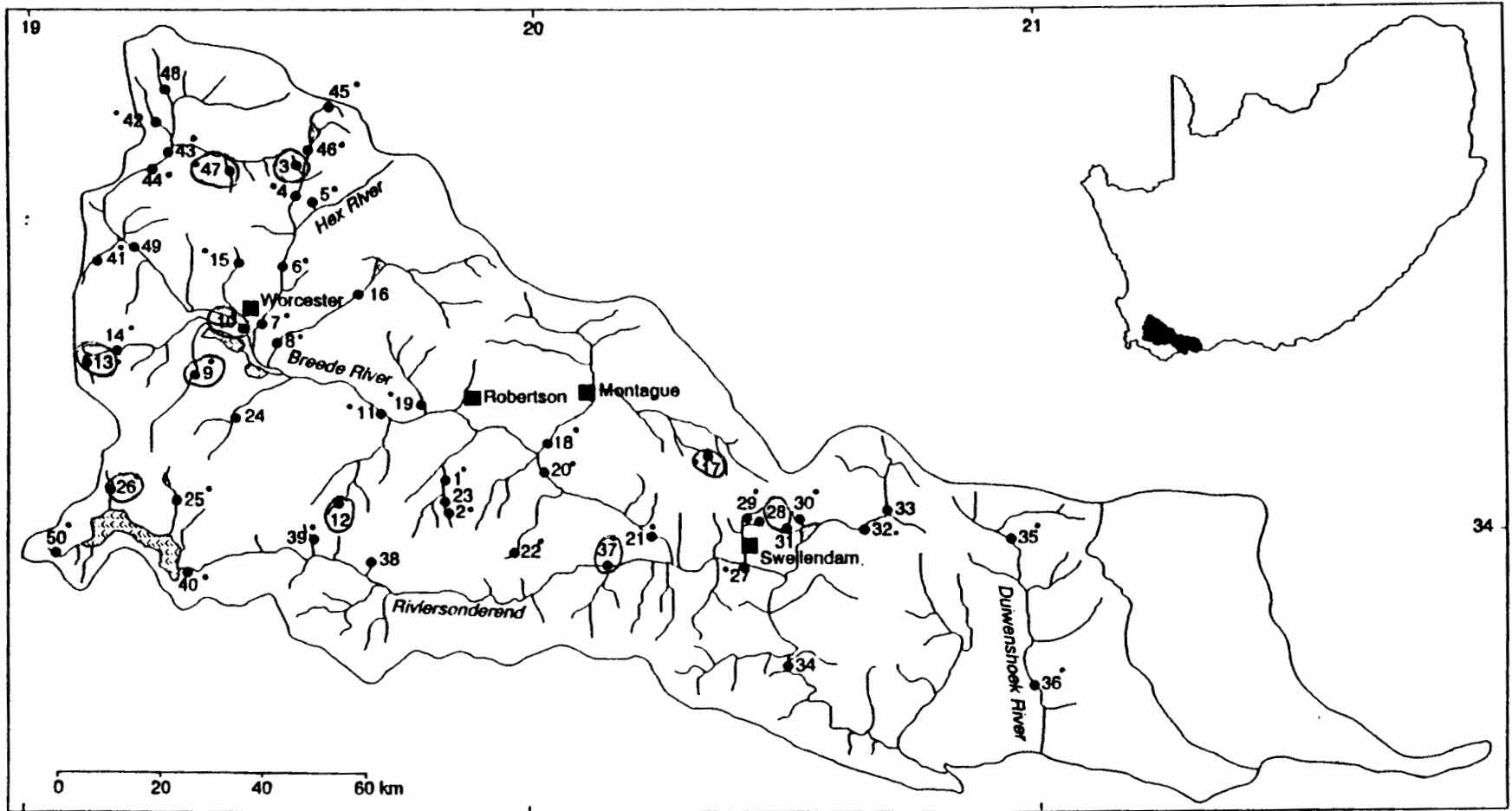


Figure 2: Map of the Breede River and its tributaries. Circled are the ten sites that were sampled during the fieldwork (From Dallas *et al.*, 1998)

Analysis of Historical Data

In order to identify acidophilic, acidophobic and pH-insensitive species, the results obtained by Harrison & Agnew (1962) were compared with historical data contained in the Biological and Chemical Database designed by Dallas & Janssen (1998), and with results obtained in the Classification of South African Rivers by Eekhout *et al.* (1997).

Table 1: Description of the ten sites on the Breede River and tributaries for which fieldwork was undertaken. R and I stand for Reference and Impacted sites respectively, as classified by Dallas *et al.* (1998). Site position and date refers to where and when the chemical and biological samples were taken.

Site No.	Site Code	River	Subregion	I vs. R	Site position	GPS	DATE
1	MAR	Glen Stream	Mountain Stream	R	Above weir	33°59'51S 20°26'43E	21-3-02
2	KLIP	Riviersonderend	Lowland	R	Below weir	34°04'44S 20°08'41E	21-3-02
3	VALS	Vals River	Mountain Stream	I	Below dam	33°26'01S 19°24'19E	26-3-02
4	TRIBSAND	Tributary of Sanddrifskloof	Mountain Stream	R	Above weir	33°27'56S 19°31'58E	26-3-02
5	NEK	Breede River	Transitional	R	Upstream of bridge	33°41'04S 19°25'17E	26-3-02
6	HOL	Holsloot River	Foothill	R	Below dam	33°45'41S 19°19'53E	26-3-02
7	RIV	Riviersonderend	Mountain Stream	R	Above weir	34°03'44S 19°04'15E	1-4-02
8	ELAND	Elandskloof River	Mountain Stream	I	Below dam	33°57'08S 19°16'55E	1-4-02
9	DUT	Du Toits River	Mountain Stream	R	Upstream of bridge / weir	33°56'18S 19°09'42E	1-4-02
10	TRIBMOL	Tributary of Molenaars	Mountain Stream	I	Above culvert	33°43'30S 19°09'11E	1-4-02

The Biological and Chemical Database (BCD) contains the results of 43 studies performed on South African rivers between 1951 and 1998, including virtually all data from ecological research studies for which both biological and chemical data were concurrently collected (Dallas *et al.*, 1998). It therefore contains approximately 140 000 taxonomic and 34 000 chemical records for 684 sites on a number of rivers (Dallas *et al.*,

Table 2: Description of the ten sites along the Breede River and tributaries for which biological and chemical data were collected. I and R stand for Impacted and Reference sites respectively, as classified by Dallas *et al.* (1998).

Site No.	River	Subregion	I vs. R	Altitude (m)	Site description
1	Glen Stream	Mountain Stream	R	243	Very pristine. Fynbos & indigenous trees. Cobble bed with riffles & runs. Narrow and shallow. In Marloth Nature Reserve
2	Riviersonderend	Lowland	R	244	Relatively pristine. Aliens (<i>Acacia mearnsii</i>), fynbos, reeds and sedges (<i>Restios</i> , <i>Prionium serratum</i> and <i>Phragmites</i>) present. Weir followed by stones and cobbles, riffles and runs. Wide river, relatively deep.
3	Vals River	Mountain Stream	I	675	Pristine. Fynbos, abundant <i>Prionium serratum</i> . Cobbles, boulders and big pools, ripples and runs alternating. Relatively narrow and shallow.
4	Tributary of Sanddrifskloof	Mountain Stream	R	457	Very pristine. Overhanging vegetation, Fynbos, sedges and grasses at water's edge; bryophytes and grasses on rocks in water. Cobbles and large boulders, ripples and runs, few pools, shady. Narrow and mostly shallow.
5	Breede River	Transitional	R	205	Relatively degraded and slightly polluted with decaying organic matter. Fynbos present further up surrounding mountains, aliens (<i>Acacia salignum</i> , <i>A. cyclops</i> , <i>A. mearnsii</i> , eucalypts), grass and <i>Prionium serratum</i> growing around water. Silty substratum with stones, smooth running water. Wide river, alternating deep and shallow patches.
6	Holsloot River	Foothill	R	300	Almost pristine (dam construction upstream but not visible). Fynbos vegetation, with wattles, reeds, rushes, shrubs and grass at edges. Large boulders, cobbles and sand. Ripples, runs and eddies. Very shallow, fairly fast flowing and very wide.
7	Riviersonderend	Mountain Stream	R	340	Pristine. Fynbos, <i>Prionium serratum</i> and grass. Cobbles and boulders covered with moss and algae. Riffles and quiet pools. Pine plantation downstream of site. Relatively wide and shallow.
8	Elandskloof River	Mountain Stream	I	452	Relatively impacted with dry plant material on banks. Many aliens (<i>A. mearnsii</i>), and fynbos higher on mountainsides. Boulders and cobbles, heavily covered in algae and sediment/silt. Slow flow. Very shallow and narrow. Development with housing and cows grazing nearby.
9	Du Toits River	Mountain Stream	R	452	Pristine. Fynbos, overhanging vegetation, grass and indigenous trees. Boulders with moss, some cobbles and stones. Deep pools and small cascades. Shaded, dead plant material in water. Relatively narrow and mostly shallow. Part of conservancy area, stormwater drainage from road.
10	Tributary of Molenaars	Mountain Stream	I	427	Relatively impacted, with plastic pipe through river (water abstraction?), culverts downstream. Fynbos, dead plants and overhanging vegetation. Rocks and sandy substratum, riffles, runs and pools. Narrow and shallow. No aquatic vegetation or aliens.

1998), and these can be accessed and queried at different geographical scales, focusing on specific aspects of interest. The most useful feature of the database for the purpose of this project was its ability to link biological and chemical data in such way that the relation between pH and present taxa could be investigated. The BCD in fact allows one to select criteria such as a particular family and/or chemical variable, focusing for example at the sub-regional scale of a river.

The questions that were asked mainly related to the pH ranges at which members of Ephemeroptera and Trichoptera, two orders that show high levels of endemism in the south-western Cape (Harrison & Agnew, 1962; de Moor, 1992), were encountered at both species and family level. The scale of focus was that of the bioregions that the BCD has subdivided the country into, according to the 18 Biogeographic Regions outlined by Brown *et al.* (1996, in Dallas & Janssens (1998)) (see Figure 3). A bioregion is defined on the basis of fish, riparian vegetation and macro-invertebrate distribution patterns, related to other driving variables like temperature, slope, altitude, water quality and substratum (Brown *et al.*, 1996).

Given that differences between the upper and lower reaches of rivers were being sought, the scale of sub-region was deemed important. Sub-regions occur within each bioregion, and account for the variation in the biotic character of a river, as a result of its longitudinal nature (Brown *et al.*, 1996). In Fynbos, for instance, the sub-regions present include the source, mountain stream, foothill, transitional, lowland and rejuvenated. The data obtained in the BCD were therefore divided into upper and lower reaches. In the upper reaches I decided to include source, mountain stream, mountain headwater, upland plateau and foothill subregions. In the lower reaches, on the other hand I placed the upland transitional, foothill/transitional, transitional and lowland subregions, although each bioregion did not necessarily contain all of the above. Specifically, the questions asked were:

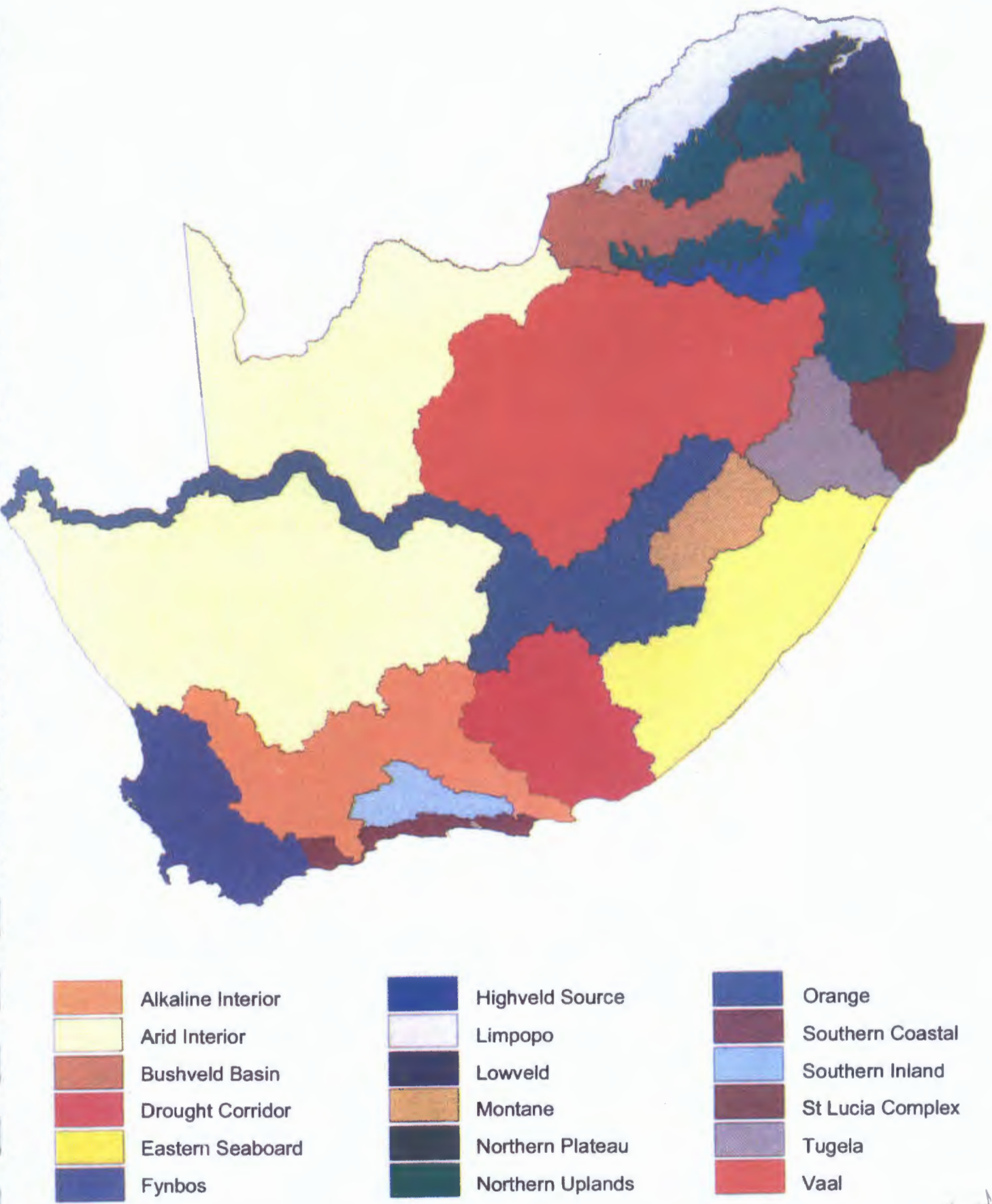


Figure 3: Map of the 18 Bioregions of South Africa (taken from Dallas & Janssens (1998)).

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- What is the pH range found in South African bioregions? What is the average pH in Fynbos subregions?
- At what pH range are ephemeropteran and trichopteran species encountered in different bioregions?
- Which Ephemeroptera and Trichoptera spp are encountered in the different bioregions in both upper and lower reaches at:
 - $\text{pH} \leq 4.5$
 - $4.5 < \text{pH} \leq 5.5$
 - $5.5 < \text{pH} \leq 6.5$
 - $6.5 < \text{pH} \leq 7.5$
 - $\text{pH} > 7.5$?
- Where do Ephemeroptera and Trichoptera spp occur within South Africa?

The distribution patterns specified by the Biological and Chemical Database were then compared to the maps of biotic regions indicating the distribution of Ephemeroptera and Trichoptera species, as compiled by Eekhout *et al.* (1997). These maps were created in an attempt to develop a regional, biotic classification for South African rivers. The focus was on the distribution of individual species of six groups of riverine organisms, among which were riparian vegetation, freshwater fish, Simuliidae, freshwater Mollusca, Ephemeroptera and Trichoptera, amounting to a total of 646 species. The biogeographic data required for the compilation of maps were obtained from collections housed in the Albany Museum and other institutes, from national records, as well as published and unpublished reports and student theses. The spatial unit of focus was the secondary catchment, which is defined on the basis of drainage patterns (D. Hughes, pers. comm.), with 137 being identified within 22 major drainage regions.

The comparison between the BCD results and the maps showing ephemeropteran and trichopteran species distributions was made to attempt to identify and confirm species endemic to the fynbos region, and to correlate these to the pH ranges found in the BCD. According to the pH range at which species were found, their distribution, and the way Harrison & Agnew (1962) classified them, each one was codified with an A* (acidophilic

spp), an I (pH insensitive spp), an A (alkaline spp) or a ?. These categories were chosen subjectively, so that species in the A* category were those to show occurrence at $4 \leq \text{pH} \leq 8$ with an average pH generally below 6.5. The pH insensitive spp (I) were found at acidic pH values ($\text{pH} < 6$) but also at pH higher than 8 and had a wide geographic range, while the alkaline spp (A) generally occurred at $\text{pH} > 7$. I used the ? when I was unsure, e.g. when only few occurrences of a taxon were recorded, when most occurrences were between pH 6 and 8, or when the BCD did not recognise the taxon.

Fieldwork

Benthic invertebrate samples were collected qualitatively at each site using a kicknet (frame dimensions: 0.2m x 0.3m; mesh size: 250 μm) following the SASS4 procedure (see Dallas *et al.*, 1998). The kicknet was held immediately downstream of a number of biotopes (stones-in-current, stones-out-of-current, marginal vegetation, aquatic vegetation, gravel and mud). Stones and substrata were kicked and stirred for approximately five minutes, and boulders and vegetation were washed in such way that dislodged macroinvertebrates were swept into the net by the current. The collected material was preserved in jars in 4% formalin for one week, and subsequently transferred into a 70% alcohol solution in the laboratory. Trichoptera and ephemeroptera were extracted from the samples and identified to species level using a number of different taxonomic keys including Scott (1983), McCafferty (1990), Davies & Day (1998), Gerber & Gabriel (2002), and de Moor (unpublished). Expert advice was also required to confirm the identifications and was obtained from H. Barber-James and F. de Moor of the Albany Museum. The macroinvertebrates were donated to the Albany Museum in Grahamstown.

Each site was described, and its altitude and co-ordinates were measured using a Magellan GPS reader (with 25m accuracy). Temperature was measured with a mercury thermometer (accurate to $\pm 0.5^\circ\text{C}$) and conductivity using a Crison CDTM-523 conductivity meter (accurate to 0.01 mS cm^{-1} and with a built-in temperature compensation of 25°C). pH was measured using a Crison model 506 pH/mv meter

(accurate to 0.01 pH units) and dissolved oxygen was recorded with a Syland Simclair F dissolved oxygen meter. Water samples from sites 5 to 10 were collected, stored in acid-washed vials, and frozen within 24 hours back in the laboratory in order to confirm the pH values recorded in the field. Their pH was measured using a Crison micro pH 2001 meter (accurate to 0.01pH units).

The identified macroinvertebrates were then categorised according to the pH range at which they were encountered, using the same categories as were used for the BCD results, and to the reach (upper or lower) in which they were found.

Results

Examination of the Biological and Chemical Database (BCD)

- Ephemeroptera

Table 3 shows that in the upper reaches of the Fynbos bioregion the greatest number of genera of Ephemeroptera was recorded between pH 5.5 and 7.5. Numbers of genera and species fell above pH 7.5 and also relatively few were encountered in very acid conditions ($\text{pH} \leq 4.5$). The greatest number of species was recorded between pH 5.5 and 6.5. In the lower reaches, on the other hand, most Ephemeroptera genera and species were recorded at a pH range of 5.5 to 6.5. Relatively few species and genera were encountered below pH 5.5, while taxon numbers fell relatively little above pH 7.5. There was a notable loss in the number of genera between the 5.5-6.5 and 6.5-7.5 pH ranges, when compared to the pattern encountered in the upper reaches. Overall, there were more genera and species in the upper versus lower reaches in all categories but the last ($\text{pH} > 7.5$).

Table 3: Number of genera and species of ephemeropterans encountered at 5 ranges of pH in the upper reaches (UR) and lower reaches (LR) of the Fynbos bioregion, according to studies included in the Biological and Chemical Database. The numbers in brackets next to no. of genera and species refer to the total number of ephemeropteran genera and species present in Fynbos, according to the BCD. Number of new or lost genera refers to the genera gained or lost from one pH range to the following. No records were obtained for pH values ≤ 4.5 in the lower reaches. Note that the same taxon can occur at more than one pH range.

EPHEMEROPTERA – FYNBOS								
pH range	No. genera (25)		No. species (94)		No. new genera		No. lost genera	
	UR	LR	UR	LR	UR	LR	UR	LR
≤ 4.5	4	/	4	/	/	/	/	/
4.5 - 5.5	15	5	23	5	11	/	/	/
5.5 - 6.5	21	20	38	28	6	16	/	1
6.5 - 7.5	21	16	35	26	/	3	/	7
>7.5	5	14	11	21	/	/	16	2

Table 4 shows the number of bioregions, and of ephemeropteran genera and species encountered in the upper reaches at different pH ranges. The only bioregions with records below a pH of 6.5 were Fynbos and those surrounding it (semi-acidic bioregions) or those affected by pollution events (the Highveld Source). The greatest number of bioregions (10 out of a total of 18) were represented at $\text{pH} > 7.5$, although the greatest number of genera and species was found between pH 6.5 and 7.5. It is interesting to note that the taxa present in Fynbos comprised a very large proportion of the total found across South Africa. For example, despite the fact there were five bioregions recorded at $\text{pH} < 6.5$, all of the taxa recorded occurred in Fynbos, while a subset of these was found in the other four bioregions. Similarly in the 6.5-7.5 pH range, 68% of genera and 56% of species found in all bioregions occurred, although not all of them exclusively, in Fynbos. It is therefore not surprising that the same drop in the number of taxa seen at $\text{pH} > 7.5$ in Fynbos (Table 3) was repeated when looking at all bioregions in that pH category (Table 4).

Table 4: Genera and species of ephemeropterans found in the upper reaches of all bioregions according to records in the BCD. Number of new or lost bioregions refers to the bioregions gained or lost from one pH range to the following, as seen in the last column. AI= Alkaline Interior; DC= Drought Corridor; ES= Eastern Seaboard; F= Fynbos; HS= Highveld Source; L= Lowveld; NU= Northern Uplands; SC= Southern Coastal; SI= Southern Interior; T= Tugela; V= Vaal. (Total number of bioregions is 18)

EPHEMEROPTERA (UPPER REACHES) – All Bioregions						
pH range	No. bioregions	No. genera	No. species	No. new bioregions	No. lost bioregions	Bioregions present
≤4.5	2	4	4	/	/	F, HS
4.5 - 5.5	3	15	23	1	/	F, SC, SI
5.5 - 6.5	3	21	38	1	1	F, SC, AI
6.5 - 7.5	7	31	62	5	1	F, SI, T, AI, ES, DC, HS
>7.5	10	23	49	3	/	F, SI, T, AI, ES, DC, HS, NU, L, V

In the lower reaches the greatest number of bioregions were again represented at relatively high pH values (pH>6.5) (Table 5). Most genera occurred between pH 6.5 and 7.5, although more species were recorded above pH 7.5. No records were found at pH lower than or equal to 4.5. There was a notable increase in the number of bioregions and consequently more than a doubling in species numbers between pH 5.5-6.5 and 6.5-7.5. The relative contribution of Fynbos to the total number of taxa encountered is less evident in the lower reaches, especially in the high-pH categories.

Table 5: Genera and species of ephemeropterans found in the lower reaches of all bioregions according to records in the Biological and Chemical Database. Number of new or lost bioregions refers to the bioregions gained or lost from one pH range to the following. AI= Alkaline Interior; Ar= Arid Interior; DC= Drought Corridor; ES= Eastern Seaboard; F= Fynbos; Li= Limpopo; L= Lowveld; O= Orange; SC= Southern Coastal; St= St. Lucia; T= Tugela; V= Vaal.

EPHEMEROPTERA (LOWER REACHES) – All Bioregions						
pH	No. bioregions	No. genera	No. species	No. new bioregions	No. lost bioregions	Bioregions present
≤4.5	/	/	/	/	/	/
4.5 - 5.5	2	9	10	/	/	F, SC
5.5 - 6.5	1	20	28	/	1	F
6.5 - 7.5	9	33	57	8	/	F, ES, AI, T, L, Li, V, Ar, O
>7.5	9	32	58	2	2	F, ES, AI, T, L, V, Ar, DC, St

- Trichoptera

In table 6, one can see that the greatest number of trichopteran species and genera in the upper reaches of Fynbos rivers was found between pH 4.5 and 5.5, with a considerable drop occurring at the next pH range (5.5-6.5), followed by an increase between pH 6.5 and 7.5. Relatively few taxa occurred at the two extremes of pH. In the lower reaches, the greatest number of trichopteran genera occurred at pH range 5.5-6.5, while most species were found between pH 5.5 and 7.5. Once again, relatively few taxa occurred in the two extreme categories. The overall number of taxa in the lower reaches was lower than that in the mountain stream and foothill areas.

Table 6: Number of genera and species of trichopterans encountered at 5 ranges of pH in the upper reaches (UR) and lower reaches (LR) of the Fynbos bioregion according to studies included in the BCD. The numbers in brackets next to no. of genera and species refer to the total number of trichopteran genera and species present in Fynbos, according to the BCD. Number of new or lost genera refers to the genera gained or lost from one pH range to the following. No records occurred at pH \leq 4.5 in the lower reaches. Note that the same taxon can occur at more than one pH range.

TRICHOPTERA – FYNBOS								
PH range	No. genera (29)		No. species (99)		No. new genera		No. lost genera	
	UR	LR	UR	LR	UR	LR	UR	LR
\leq 4.5	8	/	8	/	/	/	/	/
4.5 – 5.5	18	4	22	4	11	/	1	/
5.5 – 6.5	10	10	12	12	2	8	10	2
6.5 – 7.5	15	8	20	12	7	1	2	3
$>$ 7.5	3	4	3	5	/	/	12	4

Table 7 shows that although most bioregions occurred above pH 7.5, the greatest number of taxa was encountered between pH 6.5 and 7.5. As in the case of the Ephemeroptera, the taxa found in Fynbos comprised $>$ 50% of the total number of taxa encountered in all bioregions up to pH 7.5. It is therefore possible that the fall in the number of taxa in the highest pH category, despite the increased number of bioregions, reflected the 80% fall in the number of genera recorded in the upper reaches in Fynbos between pH 6.5-7.5 and pH $>$ 7.5 (Table 6). In Table 7 one can also again see a lowering (as in table 6) in the

number of taxa at pH range 5.5-6.5, with Fynbos being the only bioregion found in this pH category.

Table 7: Genera and species of trichopterans found in the upper reaches of all bioregions according to records in the BCD. Number of new or lost bioregions refers to the bioregions gained or lost from one pH range to the following, as seen in the last column. AI= Alkaline Interior; DC= Drought Corridor; ES= Eastern Seaboard; F= Fynbos; HS= Highveld Source; L= Lowveld; NU= Northern Uplands; SC= Southern Coastal; SI= Southern Interior; T= Tugela; V= Vaal. (Total number of bioregions is 18)

TRICHOPTERA (UPPER REACHES) – All Bioregions						
pH range	No. bioregions	No. genera	No. species	No. new bioregions	No. lost bioregions	Bioregions present
<=4.5	2	10	10	/	/	F, HS
4.5 - 5.5	3	22	27	2	1	F, SC, SI
5.5 - 6.5	1	10	12	/	2	F
6.5 - 7.5	6	29	37	5	/	F, SI, AI, T, ES, DC
>7.5	9	22	28	3	/	F, SI, AI, T, ES, DC, L, V, NU

The greatest number of bioregions in the lower reaches, as well as trichopteran taxa was encountered above a pH of 6.5, with relatively few occurrences found at the lowest pH range (table 8).

Table 8: Genera and species of trichopterans found in the lower reaches of all bioregions according to records in the BCD. Number of new or lost bioregions refers to the bioregions gained or lost from one pH range to the following, as seen in the last column. No records occurred at pH ≤ 4.5. AI= Alkaline Interior; Ar= Arid Interior; ES= Eastern Seaboard; F= Fynbos; Li= Limpopo; L= Lowveld; O= Orange; SC= Southern Coastal; St= St. Lucia; T= Tugela; V= Vaal.

TRICHOPTERA (LOWER REACHES) – All Bioregions						
pH range	No. bioregions	No. genera	No. species	No. new bioregions	No. lost bioregions	Bioregions present
4.5 - 5.5	2	7	7	/	/	F, SC
5.5 - 6.5	1	10	12	/	1	F
6.5 - 7.5	8	24	31	7	/	F, ES, AI, L, Li, V, Ar, O
>7.5	8	25	32	2	2	F, ES, AI, L, V, Ar, St, T

- Trichoptera and Ephemeroptera with respect to pH

The taxa encountered in the lowest pH category in the upper reaches are shown in Table 9. Only sites in Fynbos and the Highveld Source were recorded as having waters with a $\text{pH} \leq 4.5$ and relatively few taxa were found in these systems. Few species also occurred in Fynbos in the lower reaches at $\text{pH} 4.5\text{-}5.5$, as indicated in Table 10, and they appeared to all come from one sampling event on the Palmiet River in which a pH of 5 was recorded.

Table 9: Ephemeropteran and trichopteran taxa and bioregions encountered at $\text{pH} \leq 4.5$ in the upper reaches of all bioregions. Avg pH, Min and Max are the average, minimum and maximum pH values at which the taxa were recorded in this pH category, according to BCD records. n is the number of occurrences of the taxon at the pH indicated, in the shown bioregion. The taxa encountered were often only identified to generic level.

EPHEMEROPTERA & TRICHOPTERA (UPPER REACHES) $\text{pH} \leq 4.5$					
BioRegion	Taxon Level	Avg pH	Min	Max	n
Fynbos	<i>Baetis harrisoni</i>	4.2	4	4.4	2
	<i>Baetis</i> sp.	4.2	4	4.4	2
	<i>Castanophlebia calida</i>	4.2	4	4.4	2
	<i>Lestagella penicillata</i>	4	4	4	1
	<i>Lithogloea harrisoni</i>	4.2	4	4.4	2
	<i>Agapetus</i> sp.	4	4	4	1
	<i>Cheumatopsyche</i> sp.	4.1	3.8	4.4	2
	<i>Dolophilodes</i> sp.	4.3	4	4.5	3
	<i>Orthotrichia bamardi</i>	4.5	4.5	4.5	1
	<i>Parecnomina</i> sp.	4.07	3.8	4.4	3
	<i>Petrothrincus circularis</i>	4.47	4.4	4.5	3
	<i>Stenopsyche ulmeriana</i>	4	4	4	1
	<i>Trichosetodes</i> sp.	4.47	4.4	4.5	3
Highveld Source	<i>Baetis harrisoni</i>	2.9	2.9	2.9	1
	<i>Argyrobothrus</i> sp.	2.9	2.9	2.9	2
	<i>Leptocerus harrisoni</i>	2.9	2.9	2.9	1

Table 10: Ephemeropteran species found in the lowest pH category in the lower reaches of all bioregions, according to BCD results. Avg pH, Min and Max are the average, minimum and maximum pH values at which the taxa were recorded between pH 4.5-5.5. n is the number of occurrences of the species at the pH indicated.

EPHEMEROPTERA (LOWER REACHES) pH: 4.5 - 5.5					
BioRegion	Taxon Level	Avg pH	Min	Max	n
Fynbos	<i>Afronurus harrisoni</i>	5	5	5	1
	<i>Baetis bellus</i>	5	5	5	2
	<i>Ephemerellina penicillata</i>	5	5	5	1
	<i>Lestagella penicillata</i>	5	5	5	1
	<i>Tricorythus discolor</i>	5	5	5	1

The trend in the pH of Fynbos subregions, according to records in the BCD, was as one might expect (figure 4). There was a general increase in pH as one moved downstream, ranging from 5.4 in the mountain stream to 7.4 in the lowland subregions, although the source sites had a higher pH than the mountain stream ones.

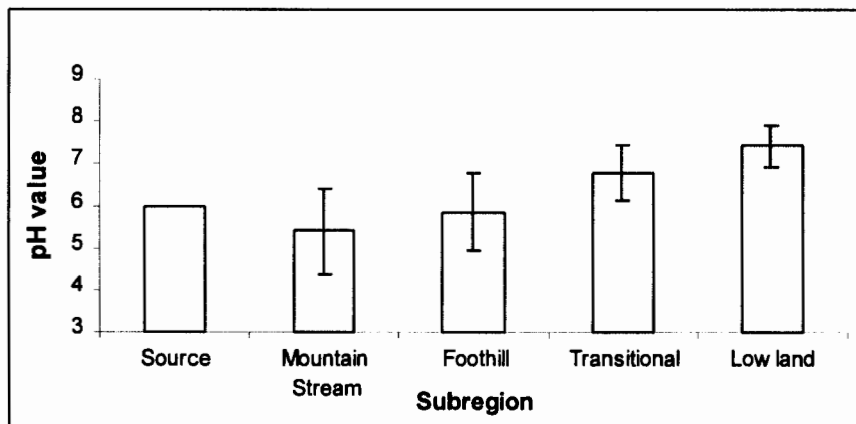


Figure 4: Average pH values (\pm SD) recorded in the subregions of Fynbos rivers according to records in the BCD.

Table 11 shows that the greatest number of times an ephemeropteran species was identified was in the Fynbos bioregion, followed by the Eastern Seaboard and Tugela. The total number of studies undertaken in Fynbos, however, was 17. Five, two of which

comprised more than one river in the study, were undertaken in the Eastern Seaboard, and six concentrated on the Tugela bioregion. The total greatest number of ephemeropteran individuals per bioregion (an estimate based on the sum of the average number of individuals per species found in each study) was encountered in Tugela, closely followed by Fynbos and later by the Eastern Seaboard. Despite the fact Fynbos had the greatest number of species and the second most abundant total count of ephemeropterans, relatively few individuals of the same species were encountered in each sample. Also in the Eastern Seaboard a similar trend occurred whereby the second greatest number of species was recorded, but relatively few individuals were collected in each sample. On the contrary, in the St. Lucia bioregion, only five different species were recorded, but there was an average of approximately 36 individuals per species in each sample.

Table 11: Total number of ephemeropteran species recorded in each bioregion, number of times an ephemeropteran species was identified, estimate of the total number of individual ephemeropterans present in each bioregion and average number of ephemeropteran individuals per species encountered in samples and averaged across all identified taxa and across all studies from each bioregion, according to the BCD.

	No. of species	No. of occurrences	Estimate of total no. of individuals	Average no of individuals/ sample
Fynbos	94	2805	9935	6.84
Highveld Source	12	16	0	N/A
Southern Coastal	17	32	215	8.95
Southern Inland	19	25	109	5.75
Alkaline interior	14	119	438	9.95
Eastern Seaboard	82	1987	4189	4.36
Tugela	51	1216	11656	10.17
Lowveld	69	655	1207	4.02
Limpopo	29	263	343	4.14
Vaal	38	460	1069	3.45
Drought Corridor	18	222	1506	7.24
Arid Interior	9	19	7	0.67
Orange	24	11	9	0.81
St. Lucia Complex	5	9	220	36.61
Northern Uplands	36	41	14	4.62

For trichopterans, the greatest overall number of individuals found in a bioregion, based on the sum of the average number of individuals of each species per sample, was recorded in Fynbos, followed by the Drought Corridor and the Lowveld (Table 12). Occurrences and numbers of trichopteran species were highest in Fynbos, followed by the Eastern Seaboard. The Northern Uplands bioregion was found to have a markedly high average number of trichopteran individuals per sample, followed by the Drought Corridor and the Southern Coastal bioregions. Relatively speaking, Fynbos had low average numbers of individuals of the same species per sample, as was found for Ephemeroptera.

Table 12: Total number of trichopteran species recorded in each bioregion, number of times a trichopteran species was identified, estimate of the total number of individual trichopterans present in each bioregion and average number of trichopteran individuals per species encountered in samples and averaged across all identified taxa and across all studies from each bioregion, according to the BCD.

	No. of species	No. of occurrences	Estimate of total no. of individuals	Average no of individuals/ sample
Fynbos	99	1224	1646	2.10
Highveld Source	6	4	2	1.80
Southern Coastal	12	33	103	5.15
Southern Inland	15	16	53	4.10
Alkaline interior	16	170	213	1.67
Eastern Seaboard	80	871	765	1.73
Tugela	39	289	739	3.64
Lowveld	38	444	865	3.90
Limpopo	16	183	179	2.56
Vaal	19	148	283	2.60
Drought Corridor	14	138	1086	8.23
Arid Interior	6	21	25	2.29
Orange	15	12	12	1.12
St. Lucia Complex	3	3	0	N/A
Northern Uplands	30	14	44	21.75

The lowest average pH at which ephemeropterans were recorded was in the Southern Coastal bioregion (pH 5.5) (Figure 5). This was followed by Fynbos, while the highest average value was recorded in the Drought Corridor (pH of approximately 8.4). For

trichopteran (Figure 6), the lowest average value was recorded in the Highveld Source (pH 2.9 caused by acid mine-drainage), followed by the Southern Coastal and Fynbos bioregions. The highest average pH was again recorded in the Drought Corridor.

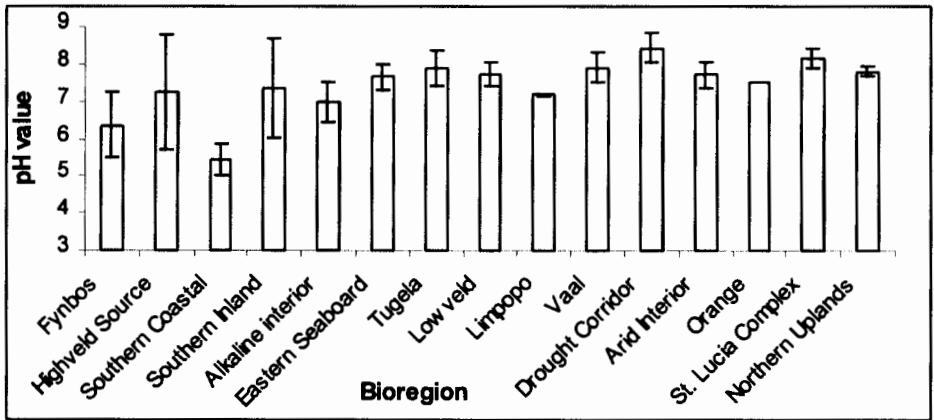


Figure 5: Average pH (\pm SD) at which ephemeropteran spp were encountered according to studies of each bioregion in the BCD.

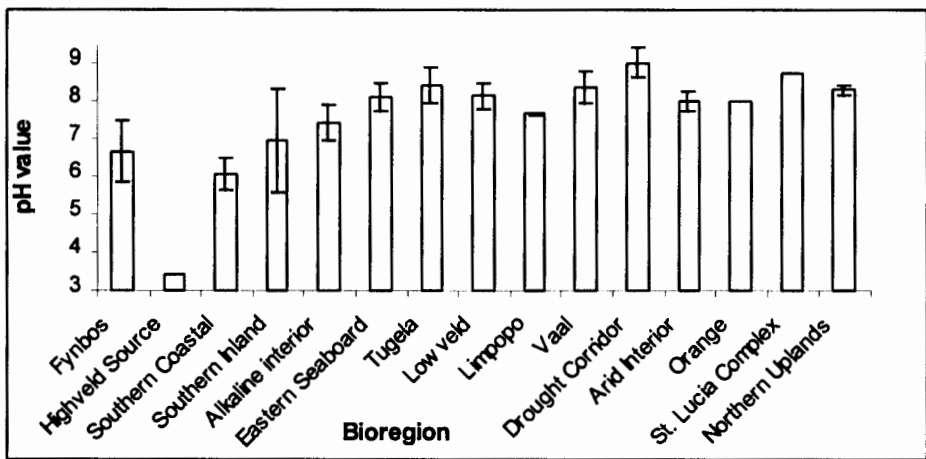


Figure 6: Average pH (\pm SD) at which trichopteran spp were encountered according to studies of each bioregion in the BCD.

There was no notable difference between the pH values at which ephemeropterans and trichopterans occurred and the background pH ranges present in the different bioregions. The only marked difference was in the Highveld Source, where trichopterans were identified in only one study where the recorded pH was 2.9 due to acid mine-drainage, while the average pH in the area was generally 7.3. The lowest average pH values in South Africa were recorded in the Southern Coastal, Fynbos and Southern Inland bioregions respectively, indicating similar water chemistry in the south-western and southern Cape areas. The highest pH values (pH > 8) were recorded in the Drought Corridor and Vaal bioregions (Figure 7).

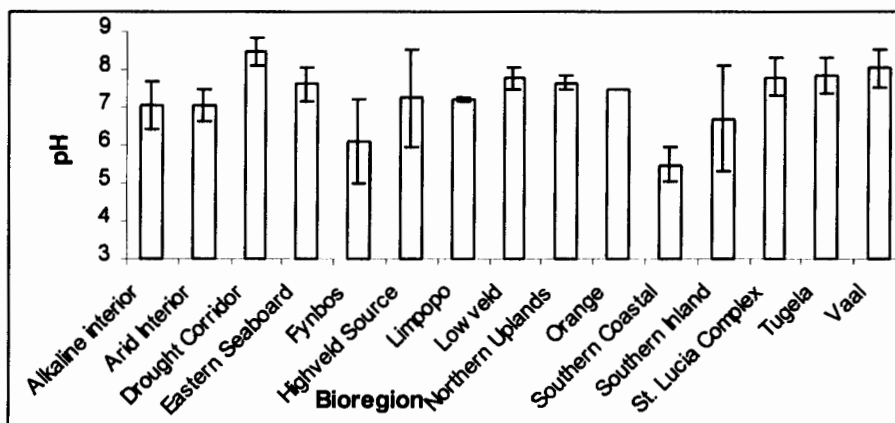


Figure 7: Average pH values (\pm SD) in South African bioregions, according to studies in the BCD.

Breede River material

- Physico-chemical measurements

Table 13 shows the mountain stream sites tended to have colder water than the other subregions, with reference sites showing on average slightly lower temperatures than the impacted ones. No particular trend was found with regard to dissolved oxygen. The lowest value was in fact recorded in a reference mountain stream site, while the highest

was in the transitional reference site. The highest conductivity, on the other hand, occurred at the transitional reference site, while the lowest was at site 3, an impacted mountain stream site. It was surprising to find a conductivity of only $10.2\mu\text{Sm}^{-1}$ at site 8, which was in a degraded state, a value five times lower than that at site 1, which was a pristine river in Marloth Nature Reserve.

It is possible this may be due to problems with the machine, or was perhaps due to the geology, although both sites are underlain by the TMS formation.

Table 13: Results obtained from fieldwork on the Breede River and its tributaries, indicating the date and site at which the variables were recorded. °C – a is the temperature collected with the mercury thermometer; °C – b is the temperature collected with the dissolved oxygen meter. Conductivity units are microSiemens per meter ($\mu\text{S m}^{-1}$) and dissolved oxygen (O_2) is given in parts per million. In the third column, S stands for subregion, with MS = mountain stream, F = foothill, T = transitional, L = lowland. R and I stand for reference and impacted sites respectively.

Site No.	Site Code	S,R vs. I	DATE	°C – a	°C – b	O ₂	Conductivity
1	MAR	MS, R	21-3-02	19	17.4	7.5	50
2	KLIP	T, R	21-3-02	24	22.7	8.8	190
3	VALS	MS, I	26-3-02	20.5	19.6	4.0	0.31
4	TRIBSAND	MS, R	26-3-02	20.2	19.4	7.9	7.0
5	NEK	L, R	26-3-02	24	24.3	4.0	125
6	HOL	F, R	26-3-02	23	22.5	5.8	45
7	RIV	MS, R	1-4-02	19	17.8	8.5	33
8	ELAND	MS, I	1-4-02	22	20.2	4.7	10.2
9	DUT	MS, R	1-4-02	20	18.1	0.69	0.60
10	TRIBMOL	MS, I	1-4-02	19	18.1	6.9	63

Tables 14 - 22 reflect the pH values and macroinvertebrate composition of the ten sites along the Breede River and its tributaries. The same pH ranges as were used to categorize the data from the Biological and Chemical Database were adopted, for comparative purposes. No upper sites had a pH value below 4.5 or above 7.5.

- Ephemeroptera

Most Ephemeroptera taxa in the upper reaches were found in the 5.5-6.5-pH category, where site 6 had by far the highest number of species, 50% of which were baetids (Table 15). In the first pH category (4.5-5.5) Leptophlebiidae and Ephemerellidae comprised a relatively high proportion of the total taxa, which gradually decreased in importance as pH increased. The heptageniid *Afronurus* was also present in the first two groups but disappeared above pH 6.5 (Tables 14 and 15). Baetids comprised a small proportion of the total number of taxa in the lowest pH category, and caenids were also absent below pH 5.5. Above pH 6.5 (Table 16), on the other hand, these two families predominated, and the total number of species encountered was relatively low (9, compared to 14 and 22, in the lowest and medium pH categories respectively). Despite the sites in the same category having relatively similar water chemistry, in terms of pH, one can see that the sites were often relatively unique in terms of their species composition.

Table 14: Presence (Y) and absence () of ephemeropterans at three upper-reach sites that fell within the 4.5-5.5 pH range, as collected from the Breede River and its tributaries.

UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 4.5 - 5.5					
Order	Family	Genus/Species	Site 1	Site 4	Site 7
Ephemeroptera	Baetidae	<i>Baetis harrisoni</i>		Y	Y
		<i>Nigrobaetis</i> sp. nov.			Y
	Heptageniidae	<i>Afronurus</i> sp. 1		Y	
	Leptophlebiidae	<i>Aprionyx</i> sp. 1	Y	Y	Y
		<i>Castanophlebia calida</i>	Y	Y	
		<i>Castanophlebia</i> sp. 1			Y
		<i>Choroterpes nigrescens</i>			Y
	Teloganodidae	<i>Ephemerellina barnardi</i>		Y	
		<i>Lestagella</i> sp. 1		Y	
		<i>Lithogloea</i> sp. 1			Y
Total: 14			2	6	6

Table 15: Presence (Y) and absence () of ephemeropterans at three upper-reach sites that fell within the 5.5-6.5 pH range, as collected from the Breede River and its tributaries.

UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 5.5 - 6.5						
Order	Family	Genus/Species	Site 3	Site 6	Site 9	
Ephemeroptera	Baetidae	<i>Afroptilum sudafricanum</i>		Y		
		<i>Baetis harrisoni</i>		Y		
		<i>Cheleocloeon excisum</i>		Y	Y	
		<i>Cloeodes</i> sp. nov.	Y			
		<i>Cloeon virgiliae</i>	Y			
		<i>Demoreptus capensis</i>			Y	
		<i>Pseudocloeon piscis</i>			Y	
		<i>Pseudocloeon vinosum</i>	Y			Y
		<i>Pseudocloeon</i> sp. 1			Y	
		Caenidae	<i>Caenis</i> spp.		Y	Y
	Heptageniidae	<i>Afronurus ? barnardi</i>		Y		
	Leptophlebiidae	<i>Adenophlebia peringueyella</i>			Y	
		<i>Aprionyx peterseni</i>	Y			
			<i>Aprionyx</i> sp. 1			Y
			<i>Castanophlebia</i> sp 1		Y	Y
			<i>Euthraulius</i> sp. nov.		Y	
	Teloganodidae	<i>Ephemerellina barnardi</i>				Y
<i>Lestagella</i> sp. 1				Y		
Total: 22			4	12	6	

Table 16: Presence (Y) and absence () of ephemeropterans at two upper-reach sites that fell within the 6.5-7.5 pH range, as collected from the Breede River and its tributaries.

UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 6.5 - 7.5					
Order	Family	Genus/Species	Site 8	Site 10	
Ephemeroptera	Baetidae	<i>Afroptilum sudafricanum</i>		Y	
		<i>Baetis harrisoni</i>		Y	
		<i>Cheleocloeon excisum</i>	Y		
		<i>Demoreptus capensis</i>		Y	
		<i>Demoulinia crassi</i>	Y		
	Caenidae	<i>Caenis</i> spp.	Y		
	Leptophlebiidae	<i>Adenophlebia peringueyella</i>			Y
		<i>Castanophlebia calida</i>			Y
	Teloganodidae	<i>Ephemerellina barnardi</i>			Y
	Total: 9			3	6

The two sites in the lower reaches both had pH between 6.5 and 7.5. The Ephemeroptera (Table 17) recorded in these sites were relatively abundant, when compared to the upper sites, and were dominated by baetids and caenids. There were more commonalities between the species encountered at these two sites in comparison with the upper reaches, which appeared more distinctive in terms of their species assemblage.

Table 17: Presence (Y) and absence () of ephemeropterans at two lower-reach sites that fell within the 6.5-7.5 pH range, as collected from the Breede River and its tributaries.

LOWER REACHES (MOUNTAIN AND FOOTHILL) pH: 6.5 - 7.5				
Order	Family	Genus/Species	Site 2	Site 5
Ephemeroptera	Baetidae	<i>Baetis harrisoni</i>	Y	
		<i>Dabulamanzia</i> sp. 1		Y
		<i>Demoulinia crassi</i>		Y
		<i>Pseudocloeon glaucum</i>		Y
		<i>Pseudocloeon latum</i>	Y	
		<i>Pseudocloeon piscis</i>		Y
		<i>Pseudocloeon ? piscis</i>	Y	Y
		<i>Pseudocloeon</i> sp. 1	Y	Y
		<i>Pseudopannota maculosa</i>		Y
	Caenidae	<i>Caenis capensis</i>	Y	
		<i>Caenis</i> sp. 1	Y	Y
		<i>Caenis</i> sp. 2	Y	
	Heptageniidae	<i>Afronurus</i> sp. 1		Y
	Leptophlebiidae	<i>Euthraulius elegans</i>	Y	Y
	Tricorythidae	<i>Tricorythus discolor</i>	Y	Y
Total: 20			9	11

- Trichoptera

In Trichoptera (Tables 18, 19 and 20) the highest number of taxa was found in the lowest pH category, with most species occurring at site 4. If we look at the families encountered, there was a much higher diversity below pH 5.5, with often only one or two member species per family. In the middle-pH category there were fewer families but more species per family, especially among the hydropsychids. Very low species diversity was encountered in the two sites with pH>6.5, but surprisingly, a glossosomatid was encountered, a new taxon that was not found at lower pH. As with Ephemeroptera, a

relatively high distinctiveness in terms of species present at sites falling within the same pH category was noticed.

Table 18: Presence (Y) and absence () of trichopterans at three upper-reach sites that fell within the 4.5-5.5 pH range, as collected from the Breede River and its tributaries.

UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 4.5 - 5.5						
Order	Family	Genus/Species	Site 1	Site 4	Site 7	
Trichoptera	Barbarochthonidae	<i>Barbarochthon brunneum</i>	Y	Y		
	Ecnomidae	<i>Parecnomina</i> sp. 1		Y		
		<i>Ecnomus</i> sp. 1				Y
	Goeridae	<i>Goera hageni</i>	Y			
	Hydropsychidae	<i>Cheumatopsyche ? maculata</i>				Y
		<i>Cheumatopsyche</i> sp 1			Y	
	Hydroptilidae	<i>Hydroptila</i> sp. 1			Y	
	Hydrosalpingidae	<i>Hydrosalpinx</i> sp 1		Y		
	Leptoceridae	<i>Athripsodes harrisoni</i> grp. sp.			Y	
		<i>Leptecho</i> sp.1		Y		
		Unidentified sp. 1			Y	
	Philopotamidae	<i>Chimarra</i> sp. 1			Y	
	Pisuliidae	<i>Dyschimus</i> sp. 1	Y			
	Sericostomatidae	<i>Petroplax curvicosta</i>				Y
	Total: 15			4	7	4

Table 19: Presence (Y) and absence () of trichopterans at three upper-reach sites that fell within the 5.5-6.5 pH range, as collected from the Breede River and its tributaries.

UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 5.5 - 6.5						
Order	Family	Genus/Species	Site 3	Site 6	Site 9	
Trichoptera	Barbarochthonidae	New unidentified sp.			Y	
	Ecnomidae	<i>Parecnomina</i> sp. 1	Y	Y	Y	
		<i>Ecnomus</i> sp. 1	Y			
	Hydropsychidae	<i>Cheumatopsyche</i> sp. 1				Y
		<i>Cheumatopsyche</i> sp. 2			Y	
		<i>Cheumatopsyche</i> sp. 3			Y	
		<i>Sciadorus</i> sp. 1				Y
	Leptoceridae	<i>Athripsodes harrisoni</i> grp. sp.		Y		
		<i>Leptecho</i> sp. 2			Y	Y
	Total: 12			2	5	5

Table 20: Presence (Y) and absence () of trichopterans at two upper-reach sites that fell within the 6.5-7.5 pH range, as collected from the Breede River and its tributaries.

UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 6.5 - 7.5				
Order	Family	Genus/Species	Site 8	Site 10
Trichoptera	Glossosomatidae	<i>Agapetus</i> sp. 1		Y
	Hydroptilidae	<i>Hydroptila</i> sp. 1	Y	
Total: 2			1	1

Trichopterans in the lower reaches were also relatively abundant, but less commonality was encountered between species in site 2 and 5 when compared to Ephemeroptera. A high hydropsychid diversity was found at both sites (Table 21).

Table 21: Presence (Y) and absence () of trichopterans at two lower-reach sites that fell within the 6.5-7.5 pH range, as collected from the Breede River and its tributaries.

LOWER REACHES (MOUNTAIN AND FOOTHILL) pH: 6.5 - 7.5					
Order	Family	Genus/Species	Site 2	Site 5	
Trichoptera	Ecnomidae	<i>Ecnomus</i> sp. 1		Y	
	Hydropsychidae	<i>Amphipsyche scottae</i>		Y	
		<i>Cheumatopsyche afra</i>	Y		
		<i>Cheumatopsyche thomasseti</i>	Y	Y	
		<i>Macrostemum capense</i>	Y	Y	
		<i>Hydroptila</i> sp. 1	Y		
	Leptoceridae	<i>Oxyethira velocipes</i>			Y
		<i>Athripsodes harrisoni</i> grp. sp.			Y
		<i>Oecetis</i> sp. 1			Y
		Unidentified sp. 2			Y
	Total: 12			4	8

Discussion

Biological and Chemical Database (BCD) Data

A relatively great diversity of trichopteran and ephemeropteran species has been recognised in the south-western Cape by both de Moor (1992) and Harrison & Agnew (1962). Tables 11 and 12 showed that although the average number of individuals of the same species collected in Fynbos was relatively low compared to the number of individuals recorded in other bioregions, Fynbos surpassed or was on par with the other bioregions in terms of the total number of individuals recorded and identified, and the number of occurrences of a trichopteran or ephemeropteran taxon. One could argue that this was due to sampling bias, as more studies have been undertaken in Fynbos than in the Eastern Seaboard and Tugela bioregions. De Moor (1992), however, argues that the larger diversity of trichopteran taxa associated with the Fynbos bioregion, compared to the rest of the country, is responsible for increasing the total number of individuals counted. De Moor states that of the 150 described trichopteran species in southern Africa, 86 occur in the south-western and southern Cape, followed by 52 in the Eastern Seaboard region. Therefore, he argues, one needs to search for an explanation of the high diversity and endemism (56 out of 86 species in the Cape) encountered in Fynbos. In order to do this, it is necessary to look at both the biogeographic distribution of different species, and the conditions under which they occur.

At this point, I am interested in understanding the relative roles of one variable, pH, in contrast to biogeographic origin of organisms, in determining distribution of different taxa. Given that differences in pH were recorded among the different bioregions (figures 5, 6 and 7) and between the upper and lower reaches of Fynbos rivers (tables 3 and 6), I will attempt to draw some patterns out of the data presented in the results. As a reminder, resulting from water quality changes, one expects to find more specialised / endemic / sensitive taxa in Fynbos, particularly in the upper reaches, gradually replaced by hardier, more cosmopolitan taxa in the lower areas and moving north-eastwards. When comparing taxa in the upper and lower reaches we can attempt to understand if pH or another water quality variable is limiting their distribution, or if it is their biogeographical origin

(Gondwanaland relicts confined to montane areas) that causes some to be found in certain river reaches rather than others.

The general trend in Ephemeroptera in the upper reaches of streams in different pH categories (see Appendices A & B) saw the acid-sensitive taxa, which often tended to be those endemic to the south-western Cape (e.g. *Aprionyx*, *Ephemerellina*, *Lestagella*: Harrison, 1962) mostly disappear above a pH of 7.5. As pH increased trichopterans and ephemeropterans were also mostly recorded in the north-eastern bioregions, while there were fewer records for the south-western positioned ones. Consequently, at higher pH, species that were judged to be more typical of alkaline systems, or those that appeared insensitive to pH on the basis of BCD findings and Eekhout *et al.* (1997) (Appendix B), became more dominant. Considering that most of these species were part of the Pan-Ethiopian element (Harrison, 1965a), and some of them are today found also in the Cape, it would appear that those that did not expand their ranges south-westwards were prevented by particular factors. One of these could be pH, although there are likely to be several more factors at play. I will now show some specific examples to illustrate the situation.

Members of the Pan-Ethiopian element that were found in numerous bioregions included *Castanophlebia calida*, *Centroptilum excisum* (now known as *Cheleocloeon excisum*), *Pseudocloeon vinosum* and *Choroterpes elegans* (now known as *Euthraulius elegans*) (Harrison, 1965a). As these species occurred at a wide range of pH, from 4 to 9.2, they are likely to be part of the widespread, hardy, pH-insensitive element. Harrison (1962; 1978) refers to such species as having adapted to the low pH found in Fynbos, the Southern Coastal and Southern Inland subregions, while withstanding alkaline conditions too. On the other hand, another group of species was found exclusively in the north-eastern and north-central bioregions. This included, among others, the species *Neurocaenis reticulata* (now *Tricorythus reticulatus*) and *Pseudocloeon inzingae* (now *Cloeodes inzingae*), which were found at minimum pH of 7.3, and the genera *Elassoneuria*, *Eatonica*, *Prosopistoma* and *Notonorus*. While it could be argued that these species were confined to regions of high pH, they are in fact likely to belong to the

warm stenothermal (tropical) group (Barnard, 1932; Harrison, 1978) which descended from central Africa to the northern tropical regions of South Africa. This group is limited by temperature, and confined to areas warmer than the 16°C Effective Temperature isotherm proposed by Stuckenberg (1969), which divides the tropical from temperate faunal components. With winter temperatures in the south-western Cape falling below this level, especially in the high altitude areas, conditions become unsuitable for specialised tropical taxa. If low pH were their limiting factor, on the other hand, these taxa would also be encountered in the Cape in the highest pH category (pH>7.5). Between the above two groups, on the other hand, there were some species, including *Baetis glaucus* (now *Pseudocloeon glaucum*), *B. latus* (now *Pseudocloeon latum*), *Pseudopannota maculosa*, *Austrocloeon virgiliae* (now *Cloeon virgiliae*) and *Cloeon africanum* (now *Procloeon africanum*) that were also widespread in both the southern and north-eastern areas of the country. These, however, seemed to show a degree of intolerance to very acidic conditions: even when they occurred in Fynbos they were found in circumneutral habitats (minimum pH of 6), irrespective of whether it was an upper or lower river reach, and they occurred up to pH 9.6. These taxa also were the main component of the highest pH category (>7.5) in Fynbos, which mainly comprised either pH insensitive or alkaline taxa. These species therefore did not appear to be limited by temperature (i.e. they are eurythermal taxa) or biogeographic constraints, as they were widely distributed. On the contrary, as they were only encountered at pH > 6, one could argue that pH does indeed play a role in their distribution patterns, and one could tentatively classify them as acidophobic.

Two of the four species of Ephemeroptera encountered at pH ≤ 4.5 in the upper reaches (table 9) are widespread, pH-insensitive species (*Castanophlebia calida* and *Baetis harrisoni*) according to the BCD, Eekhout *et al.* (1997) (see Appendix B) and Harrison (1962). The other two, *Lestagella penicillata* and *Lithogloea harrisoni*, seemed to be restricted to the Fynbos and southern Cape bioregions, although *L. harrisoni* was once recorded in the Drought Corridor too (see Appendix B). As these two species have often been misidentified and confused with each other in the past, and *L. harrisoni* has recently been recognised as a Western Cape endemic (Gondwana relict) (McCafferty & Wang,

1997), it is likely that the record in the Drought Corridor was the result of a misidentification. Although both species were found at relatively low average pH values, they did not appear to be intolerant of higher pH values (*L. penicillata* also occurred in the pH>7.5 category). Their presence in circumneutral waters and lower reaches thus contradicts Harrison & Agnew's (1962) contention that they are acid water-restricted species, and McCafferty & Wang's (1997) statement that they mainly occur in mountainous streams and rivers with swift currents. The present results indicate that the distribution of these species was related to their biogeographical origin rather than the effect of pH, and their confinement to the Cape appears to reflect a need for cold water and clear streams associated with mountainous temperate areas, extending from the Cape to the eastern ranges. This idea is supported by the fact *L. penicillata* has been classified by McCafferty & Wang (1997) as extending to the Eastern Cape, and is recognised as a transitional taxon between the archaic African and the Oriental teloganodids. Therefore this species, despite being a Gondwanaland element, shows affinities with species belonging to lineages that have radiated in tropical Asia (McCafferty & Wang, 1997).

Data from the BCD in the lowest pH category for the lower reaches (4.5-5.5, in this case) (table 10) show that species comprised two relatively sensitive taxa (*Ephemerellina penicillata* and *Lestagella penicillata*), and three other species that were more widespread and insensitive (Chutter, 1995). Overall there were very few taxa compared to those encountered in the upper reaches (tables 3 and 10) in the same pH category. This could indicate either that relatively few studies examined sites in lower reaches with pH < 5.5, or that some factor other than pH prevented some species from the upper reaches from surviving in the lower ones. If, however, we compare the taxa that occurred in the 5.5-6.5 pH range in the upper and lower reaches we do not find much difference between distinct river segments (see Appendix A). Similarly, in the 6.5-7.5 pH range species composition was again alike. Therefore there did not appear to be a fauna exclusively found in the upper reaches. At pH > 7.5, the genera found in the upper reaches were in fact a subset of those found in the lower reaches. The additional species in the lower reaches were on the other hand widely distributed, except for the endemic *Aprionyx rubicundus* and *Ephemerellina harrisoni*, and the semi-endemic (also found in the southern Cape)

Lestagella penicillata (see Appendix B). According to Harrison (1965b), a relatively strong similarity in species between upper and lower reaches might be expected in south-western Cape rivers, because they are generally short, steep and flow straight into the sea. This would suggest that many of the south-western Cape rivers virtually do not have a typical lower reach zone, such as that seen in rivers in the rest of South Africa.

In the Trichoptera, as seen in the Ephemeroptera, there was a general replacement of species to the north-east, as typically acidophilic south-western Cape forms gave way to other species. Some of the latter (e.g. *Leptonema*, *Pseudoneureclipsis*, *Amphipsyche* and *Aethaloptera*) belonged to tropical Gondwanaland groups (Scott, 1986), which are confined to the warm alkaline waters of the Lowveld, Limpopo, Vaal and Eastern Seaboard bioregions. Others, like *Orthotrichia*, *Hydroptila* and *Chimarra* are more widespread, pH-insensitive elements that often have Palaearctic or Oriental origins (Scott, 1988) and dominate the eastern parts of the country. These genera were relatively rare in the south-western Cape, but could nonetheless withstand the low pH values of Fynbos rivers. On the other hand the eastern Cape, as recognised by Scott (1988), represents a transitional fauna between the south-western and north-eastern faunas. This is not surprising given the similarities in pH, and water chemistry in general, between these contiguous areas (figure 7) and the fact that several mountain ranges are connected from the south-western to the southern Cape, thus allowing endemics to migrate between them (Harrison & Agnew, 1962). Therefore in this area one still finds Gondwanan elements such as *Sciadorus obtusus* and *Barbarochthon brunneum* extending to the East Cape mountain ranges (Southern Coastal and Southern Inland bioregions), while Pan-Afrotropical taxa with more cosmopolitan distributions (e.g. *Cheumatopsyche* and *Ecnomus* spp: Scott, 1988) are found in the Drought Corridor.

The Trichoptera showed a curious drop in the number of taxa in the pH range 5.5-6.5 in the upper reaches (table 6). This could not be attributed to a shortage of studies covering that pH range, as this trend was not evident for ephemeropterans. The studies from which the data were taken were indeed numerous ($n > 10$), and spanned a time-period from 1951 until 1994, in a range of rivers around the Fynbos bioregion. It is thus unusual that all the

studies, in all rivers, together recorded relatively few taxa. Even when comparing all bioregions, only Fynbos was present at this range. We could hypothesise that trichopterans did not cope well with this relatively acid pH, either needing a very acid environment (pH<5.5) or a circumneutral one (pH>6.5). This does not seem plausible however, since some of the species present at pH 4.5-5.5 reappeared in the range 6.5-7.5, so there was not a complete species shift. This result might simply be coincidental since fieldwork results showed the 5.5-6.5 pH category to have had higher species diversity than the 6.5-7.5 one.

The majority of the species that were lost between pH 4.5-5.5 and 5.5-6.5 (see Appendix A) were endemic taxa, generally typical of acidic conditions, with some (e.g. *Barbarochthon brunneum*, *Myspoleo agilis*, *Petroplax* spp, *Petrothrincus* spp, *Parecnomina* spp, and *Agapetus* spp) recognised as being part of the paleogenic Gondwana element (Harrison, 1962; Harrison, 1965a; Scott, 1986). In the pH range 6.5-7.5, numerous endemics were again found, except for the genus *Dolophilodes*. This was the highest pH at which they were recorded, however, and above pH 7.5, the few taxa comprised cosmopolitan species such as *Cheumatopsyche afra*, belonging to the Pan-Ethiopian element (Harrison, 1965a). The fact that only widespread elements were left at high pH ranges would suggest that the endemics indeed show a degree of intolerance to alkaline conditions. Biogeographic reasons should however be attributed to the fact that these endemics remained confined to the south-western and southern Cape, as they did not occur at low pH ranges in any of the other bioregions.

The patterns in the Trichoptera in the upper reaches in the lowest pH category (table 9) show there once again appeared to be a link between being pH insensitive and having widespread distribution. Three (*Trichosetodes*, *Orthotrichia* and *Cheumatopsyche* spp.) of the eight genera belonged to the hardy group found over a relatively wide pH range and occurred in numerous bioregions around the country (BCD: Appendix C). The other five genera, on the contrary, comprised mostly endemic, acidophilic species. Of these, *Petrothrincus circularis* has been recognised as a Cape Peninsula endemic by Picker & Samways (1996) and a Gondwana relict by Harrison (1965a), while *Agapetus* sp.,

Stenopsyche ulmeriana, *Parecnomina* and *Dolophilodes* spp. appear to be restricted to the Fynbos and Southern Coastal bioregions. Given that *Agapetus* and *Parecnomina* spp were found at maximum pH values of 7.1 and 7.2 respectively, and *Dolophilodes* spp. (to pH 6) and *Stenopsyche ulmeriana* were restricted to even lower pH ranges, it would appear that both biogeographic and water chemistry factors (in terms of pH) limited the distribution of these species. If pH did not play a role we would have expected to encounter these taxa above pH 7.5 in the Fynbos bioregion and its surroundings. If biogeography was not important, these taxa would have also occurred in acidic waters further eastwards, including the Eastern Highlands, which can still provide clean, oligotrophic mountain water for these taxa. All of the above four taxa also appear to be restricted to the upper reaches, but it is not possible to say why this is so given the paucity of recent literature on the distribution of aquatic invertebrates in southern Africa. Perhaps an unidentified water quality variable, hydrological or biological reasons, which make the conditions unsuitable for these taxa in the lower reaches of rivers.

A number of endemic species of trichopterans such as *Argyrobothrus velocipes*, *B. brunneum* and numerous *Athripsodes* spp were found in the lower reaches. Nonetheless, as mentioned above, the majority of endemics that occurred in the upper reaches, with the exception of *Petrothrincus circularis*, were absent from the lower reaches. As several of these were cold stenothermal, refugial species, which are often restricted to silt-free streams (Harrison, 1978), it is possible that water quality changes in the lower river reaches made conditions unsuitable for their survival. Refugial species were in fact widespread when South Africa lay further south, but became confined to high-altitude mountain river reaches when Gondwanaland broke up and South Africa moved northwards (Harrison, 1978). The increase in silt, suspended solids, nutrients and pH, enabling snails and crustaceans to survive and possibly to prey on or compete with trichopterans for food (de Moor, 1992), might be responsible for the disappearance of many of the sensitive endemics in the lower reaches. The widespread, hardy elements used to the less pure waters in the rest of South Africa, on the other hand, would be favoured in these conditions and indeed comprise the majority of species in the lower reaches.

Another bioregion, the Highveld Source, was also registered in the “upper reaches and lowest pH” category. The study from which these data were collected was Harrison (1958), who investigated the effects of sulphuric acid pollution on rivers in the former Transvaal and the measured pH value was 2.9. The only species present were the trichopterans *Argyrobothrus* and *Leptocerus harrisoni*, and the baetid *Baetis harrisoni*. These are all relatively insensitive to both pH and poor water quality (Chutter, 1995) and therefore seemed able to survive the detrimental effects of anthropogenically-induced acidification, although a pH of 2.9 is extremely low, especially considering the fact pH is a logarithmic scale.

Studies in the Highveld Source region also included sites with higher pH values. For example above pH 7.5 the genera were *Austrocaenis* (lower pH limit 5.3) and *Austroclaeon* (lower pH limit 5.2), and the species *Neurocaenis discolor* (now *Trycorythus discolor*, lower pH limit 6.6). These taxa are therefore present in this bioregion in relatively alkaline conditions, but were absent at the pH value of 2.9. If we assume that they were originally at the site where the pollution event occurred, given they are relatively widespread, it would appear that they cannot survive under extremely low-pH conditions but are limited to more alkaline situations. *Neurocaenis discolor* is also found in Fynbos, but only above pH 6.6, once again suggesting that this species cannot withstand acidic environments.

It is important to remember the distinction between pollution / acid-rain-related acidification of aquatic ecosystems and naturally occurring low pH water bodies, such as blackwater streams. Naturally acidic water-bodies are common in certain tropical and boreal areas, where rivers flow over peat swamps, or podzolised white quartzitic sand soils that have been leached of most nutrients and have low ion retention properties (Janzen, 1974). These systems are very different from those suffering from anthropogenically-induced acidification, as caused by acid-rain and pollution releases by mines and industries. Both the effects of acidity and the fact low pH causes the concentration of the most toxic form of aluminium and other heavy metals to increase, cause very detrimental effects on the biota, at both the individual and community level

(see Rosemond *et al.*, 1992; Winterbourn *et al.*, 1992). It is therefore likely that the biota of the above river affected by acid mine-drainage suffered of these consequences too. On the contrary, despite the acidic conditions encountered in rivers associated to the Fynbos biome, both the BCD results and those from the fieldwork indicated a far from depauperate fauna. Several studies have recognised that blackwaters have a very specialised and unique fauna and flora, consisting of organisms that over generations have adapted to the low pH and apparently unfavourable environment (Eifac, 1969).

Breede River material

Looking at the invertebrates collected in the Breede River and its tributaries, one sees that as pH increased and as sites became more impacted the sensitive taxa (e.g. Teloganodidae, Heptageniidae and Leptophlebiidae), indicative of good water quality gradually were replaced by hardier, cosmopolitan, insensitive taxa (Baetidae, Caenidae) (Chutter, 1995). In the Trichoptera there was a reduction in the number of families, especially the sensitive members like Sericostomatidae, Barbarochthonidae and Hydrosalpingidae, as pH increased (Chutter, 1995). In the lower reaches the more tolerant, widespread taxa predominated, although other taxa indicative of good water quality, such as Tricorythidae and Heptageniidae (Gerber & Gabriel, 2002), still persisted.

The sites with highest species diversity were lower-reach sites 2 and 5 and the foothill site 6. Although all three sites were dominated by baetids, caenids, leptocerids and hydropsychids there were also a number of endemics like *Parecnomina*, *Leptecho* and *Lestagella* in the foothill reach, which indicated good water quality in this site. These findings reflect those of Dallas *et al.* (1998) in their SASS study of the Breede River and its tributaries. Their research showed that although the Holsloot site 6 had fewer taxa than Die Nekkie (site 5) or Klipfontein (site 2), its SASS score was higher because some sensitive taxa (i.e. the above-mentioned endemics) increased its score. The Average Score per Taxon (ASPT) for the three sites also showed this, with site 6 scoring 8.57, versus 6.69 and 6.47 for sites 5 and 2 respectively (Dallas *et al.*, 1998). One of the taxa

present at these sites (*Amphipsyche scottae*) was a member of the Tropical Gondwanaland group that was previously thought to be confined to the north-eastern bioregions (Scott, 1986), but that was found in the Breede River in the course of the fieldwork for the present project (F.C. de Moor pers. comm.). This shows that there is still much research to be done on species distribution records (and taxonomy) as new findings are continuously being made.

Sites 1, 3, 8 and 10 had the lowest species richness and supported mainly baetids and caenids. These two families generally predominate in impacted sites given their ability to withstand turbid and silty waters caused for example by erosion and vegetation removal (Chutter, 1995). Yet at site 10, one of the two most degraded sites sampled, a member of the Glossosomatidae, a very sensitive south-western Cape family (Gerber & Gabriel, 2002) was encountered. Either this taxon is more resilient than previously thought, or this site has only recently become degraded and intolerant species have not yet disappeared. Among the Ephemeroptera, sensitive members like *Ephemerellina barnardi* and two leptophlebiids occurred in this site. On the other hand, site 1 appeared to be pristine and it is unclear why few species occurred here.

The water at the collecting sites was mainly acidic to circumneutral. Since no extremely acidic or alkaline pH values were recorded, it was not possible to detect species tolerant of either very high or very low pH. Nevertheless, we can confirm that *Baetis harrisoni*, *Castanophlebia calida*, *Cheumatopsyche* and *Ecnomus* showed insensitivity to pH. Species (*Pseudocloeon glaucum*, *P. latum* and *Pseudopannota maculosa*) previously identified as intolerant of low pH were again found only in circumneutral waters, while *Cloeon virgiliae* was found at lower pH (5.5-6.5).

Lastly, in terms of conservation, there was relatively little overlap in the species present at the different sites, especially in the upper reaches, and very few taxa were found in all samples. Even the cosmopolitan *B. harrisoni* was only found at 50% of the sampled locations. This suggests that many of the sites show a relative degree of uniqueness in terms of their species assemblages. Therefore, although most sites have been classified as

reference mountain stream sites by Dallas *et al.* (1998) and have similar pH, one must be cautious when deciding to conserve one representative river of a category, because often this means losing many species that could be found in the other sites.

Comments on the Data

A number of problems or considerations need to be taken into account with regard to analysing the data and attempting to draw patterns from it.

Firstly, generalisations regarding species distribution are often dangerous and thus subject to controversy, as the majority of systems show a relative degree of uniqueness (Tharme & King, 1998; King & Schael, 2001). Further, community composition and structure in rivers are affected by a variety of species-specific factors, among which are the number and type of available biotopes, the geomorphology and geology of the catchment, the degree of and temporal variability in water movement, the historical distribution of species, biotic interactions, and the ranges of water quality variables (Dallas & Day, 1993). All of these factors (biotic and abiotic) can influence an organism's ability to successfully colonise an area and some (e.g. mountain ranges or the absence of water) may be important as barriers to dispersal (Balinsky, 1962).

Furthermore, it must also be remembered that species distribution is dynamic, subject to fluctuations in environmental conditions and variations in population pressure (Balinsky, 1962).

This project considered the effects of one water quality variable, pH, while ignoring the myriad other factors that determine species distribution, richness and endemism in a particular area. For example factors like isolation and latitude, which are also strong determinants of species richness should caution us from making comparisons between different systems located in different geographical areas purely on the basis of pH (Fryer, 1980). When we saw that some species were limited to, for example, the north-eastern portion of the country, we could therefore not determine whether the species occurred there because they were unable to survive in acidic conditions, or whether their biogeographic distribution was such that it corresponded to areas of relatively more alkaline water. Temperature, too, is often recognised as being an important element in

allowing the expansion of certain species' range, and is used in explaining the division of the tropical and temperate faunas (Stuckenberg, 1969). We could talk similarly about each of the other factors (geomorphology, degree of water permanence etc.) and its relation to species distribution. What is more important, however, is to understand that the interplay of all of these ingredients may obfuscate trends that may indeed be caused by a variable like pH, and this should be considered when speculating on the data.

Another consideration in studies relating pH to distribution patterns of organisms concerns the fact that presence and absence of a taxon may not necessarily be related to pH, but may be due to a variable not accounted for (e.g. heavy metal presence, shortage of nutrients or light etc.), or a taxon's rarity and thus we should not be tempted to draw cause and effect relationships (Eifac, 1969; Guerold *et al.*, 1991). Another factor to be also considered is the diurnal fluctuations in pH caused by photosynthesis (Dallas *et al.*, 1998), as this may affect what the recorded measurement is and therefore the conclusions reached. This is, however, only likely to play a more significant role in systems that have very abundant aquatic macrophytes and riverine vegetation that would significantly alter the rate of CO₂ uptake or in very eutrophic conditions. Nonetheless, water acidity may vary yearly, monthly (or seasonally, e.g. when the first winter rains flush organic material rich in humic acids from the catchment into the river) or even hourly (Cresser & Edwards, 1988). The ideal is thus to measure pH repeatedly over a period of time in order to obtain the most reliable records (Cresser & Edwards, 1988).

Other considerations in the use of the data and its interpretation in this project include the fact that different sources were used, therefore leading to inconsistencies in the methods of collection, the identification of organisms and their taxonomic subdivisions.

Specifically, in the Biological and Chemical Database, as recognised by Dallas & Janssens (1998), the material collected covered uneven spatial and temporal scales and used different measurements and degrees of accuracy for the chemical data. Given the relatively large number of studies included in the BCD and the fact numerous were more than 20 years old, it is also likely that the classification of rivers into the different subregions was not standardised, making comparisons of the distribution of different taxa

not always compatible. One should also remember that the number of studies present in the BCD was relatively small, and therefore the patterns encountered were the result of a limited number of sampling events. Thus the pH range at which organisms were met and reported in Biobase did not necessarily reflect a tolerance range, but simply that at which organisms were found. If a certain area was not sampled, or if organisms were absent from the sample at the time when the material was collected, it would appear that they were not tolerant of the pH present, whereas the cause of their absence may have been the result of a one-off event at that site (e.g. oil-spill) or any of numerous other factors. Furthermore the natural geographical variation in species distribution is not shown, as the geographic area indicated by Biobase is a reflection of the studies performed in that area, and not of the species' distribution (Dallas & Janssens, 1998). The data reported were also generally the result of spot sampling events, particularly for the chemical measurements, so that long-term fluctuations in the system are ignored. Thus, if an organism was recorded within a specific pH range in the BCD, this did not necessarily mean that the conditions were its ideal; in fact it may have been on the point of disappearing or recovering from a pollution event that had occurred. Similarly, as the work was qualitative, changes in relative abundances of organisms due to variations in water quality remained unknown, and we could not assume that the mere presence of an organism reflected a healthy population. It is also important to note that when sampling on a one-off basis, casual migrants that are not biologically meaningful for the system in question may be collected. If repeated sampling was undertaken, these members would be weeded out.

Lastly, when comparing the data from Harrison & Agnew (1962), with that from Biobase and Eekhout *et al.* (1997), problems were experienced due to inconsistencies in classification and division of organisms among different families or sub-families, their identification at species level and distribution records. It has in fact been recognised that several invertebrate groups are still poorly known, new species are discovered very frequently, as seen in this project, and many taxa are cryptic and undersampled (Stuckenberg, 1962; Picker & Samways, 1996). Although the Trichoptera and Ephemeroptera are among the best known orders (de Moor, 1999), we still found a

number of inconsistencies that will gradually be eliminated through research. These discrepancies were in part caused by the fact numerous studies in the BCD were more than twenty years old, and during the past two decades much research has been expended in order to gain a greater taxonomic understanding and agreement. Ideally, the data in the BCD would need to be updated with the more recent studies that have been undertaken, changing old species names and wrong distribution records. This would create an extremely useful tool that could give us a truer perspective on distribution patterns and species tolerance ranges, not only related to pH but to all variables. Nonetheless, the BCD was found to be very useful in identifying patterns of species distributions and relating them to water quality variables.

A last comment is included to put this project into a wider perspective. As mentioned above, blackwater systems are common in a number of tropical and boreal regions around the world, the biggest of which is claimed to be the Rio Negro flowing in the Amazon (Janzen, 1974). Dark-stained water-bodies are also found in southern USA, the Lake District in the UK and New Zealand and species in these systems also tend to be relatively diverse and endemic. For example, in New Zealand, a study on brown rivers indicated that the fauna was dominated by trichopterans, ephemeropterans, plecopterans and dipterans (Winterbourn & Collier, 1987). Although acidity did not reduce species richness, also in this system a level was reached (below a pH of 4.6) when the number of taxa fell sharply, possibly indicating this was the lowest acceptable limit for numerous species. Taxon distribution did not appear to be related to the physicochemical properties of water, as a comparison of stream faunal assemblages indicated that species were generally generalist in their habitat requirements (irrespective of pH), and rather tended to distribute themselves in adjacent water-bodies (Winterbourn & Collier, 1987).

Conclusion

In the light of the above discussion, it is difficult at this point to draw substantial conclusions on the determinants of distribution of the different species under discussion. We can tentatively distinguish four groups of taxa that differ in their requirements and origins:

1. Species confined to the south-western and southern Cape bioregions. I believe a combination of factors was responsible for their distribution, among which was their relictual nature that forced them to inhabit temperate or high-altitude regions, with low water temperatures, pure, silt-free and relatively acidic conditions.
2. Species part of the tropical Gondwana group that are limited to the subtropical bioregions, where river waters are warmer, sluggish and alkaline.
3. Taxa part of the Pan-Ethiopian element that were cosmopolitan in their distribution, eurythermal and insensitive to pH, therefore found from very acidic to very alkaline waters.
4. Species that appeared to be eurythermal, but seemed intolerant of very acidic conditions.

Given the paucity of recent literature on macroinvertebrate biogeographic distribution, the problems mentioned above with the BCD, new species being continuously discovered and old ones changing names and being found in new areas, it was difficult to draw clear categories for the species, especially regarding group 4. A systematic study undertaken on a number of rivers per bioregion throughout South Africa, such as that done on the Breede system in the fieldwork, would likely be the best way to investigate species distributions and the water chemistry variables under which they are encountered. This could help in identifying ideal conditions under which the different taxa live. What is clear is that, in terms of the effect of pH on organisms, naturally acidic systems are diverse and unique in their species assemblages. On the contrary, anthropogenically-acidified systems suffer pronounced species loss and become, in the long run, practically lifeless systems (Rosemond *et al*, 1992).

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Appendix A: Ephemeropteran and trichopteran taxa recorded in studies in the Biological and Chemical Database in pH categories 4.5-5.5, 5.5-6.5, 6.5-7.5, >7.5. Avg, Min and Max stand for average, minimum and maximum pH at which the species occurred, and n were the number of occurrences of that taxon at the specified pH range.

EPHEMEROPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 4.5 - 5.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	5.08	4.51	5.50	38
	<i>Acentrella capensis</i>	5.24	4.70	5.50	20
	<i>Acentrella sp.</i>	5.35	5.35	5.35	1
	<i>Aprionyx sp.</i>	4.99	4.62	5.35	2
	<i>Baetis harnsoni</i>	5.22	4.62	5.50	23
	<i>Baetis sp.</i>	5.18	4.62	5.50	10
	<i>Castanophlebia calida</i>	5.18	4.62	5.50	27
	<i>Lestagella penicillata</i>	5.16	4.62	5.50	13
	<i>Lithogloea harnsoni</i>	5.18	4.62	5.50	15
	<i>Adenophlebia peringueyella</i>	5.40	5.40	5.40	1
	<i>Afronurus harnsoni</i>	5.24	4.70	5.50	12
	<i>Aprionyx intermedius</i>	5.28	4.70	5.50	8
	<i>Aprionyx peterseni</i>	5.18	4.70	5.50	11
	<i>Aprionyx tabularis</i>	5.40	5.30	5.50	4
	<i>Austrocaenis sp.</i>	5.42	5.30	5.50	5
	<i>Baetis bellus</i>	5.11	5.00	5.50	8
	<i>Caenis sp.</i>	5.30	5.30	5.30	1
	<i>Centroptilum excisum</i>	5.30	4.70	5.50	6
	<i>Centroptilum sp.</i>	5.26	4.80	5.50	9
	<i>Centroptilum sudafricanum</i>	5.17	4.80	5.50	6
	<i>Choroterpes elegans</i>	5.42	5.30	5.50	5
	<i>Choroterpes nigrescens</i>	5.40	5.30	5.50	7
	<i>Lithogloea pennicillata</i>	5.21	4.70	5.50	13
	<i>Lithogloea sp.</i>	5.43	5.30	5.50	4
	<i>Pseudocloeon sp.</i>	5.15	4.70	5.50	10
	<i>Pseudocloeon vinosum</i>	5.21	4.70	5.50	13
	<i>Tricorythus discolor</i>	5.00	5.00	5.00	1
	<i>Aprionyx rubicundus</i>	5.38	5.00	5.50	5
	<i>Castanophlebia sp.</i>	4.96	4.96	4.96	1
	<i>Choroterpes sp.</i>	4.96	4.96	4.96	1
	<i>Ephemerellina sp.</i>	4.96	4.96	4.96	1
	<i>Lestagella sp.</i>	4.96	4.96	4.96	1
	<i>Ephemerellina harnsoni</i>	5.00	5.00	5.00	1
	<i>Ephemerellina penicillata</i>	5.00	5.00	5.00	2
	<i>Ephemerellina barnardi</i>	5.50	5.50	5.50	1
Fynbos Total		5.20	4.51	5.50	286
Southern Coastal	Unspecified	5.00	5.00	5.00	1
	<i>Castanophlebia calida</i>	5.00	5.00	5.00	1
	<i>Lithogloea harnsoni</i>	5.00	5.00	5.00	1
	<i>Choroterpes nigrescens</i>	5.00	5.00	5.00	1
	<i>Lithogloea pennicillata</i>	5.00	5.00	5.00	1
	<i>Pseudocloeon vinosum</i>	5.00	5.00	5.00	1
Southern Coastal Total		5.00	5.00	5.00	6
Southern Inland	<i>Castanophlebia calida</i>	5.10	5.10	5.10	1
	<i>Aprionyx peterseni</i>	5.10	5.10	5.10	1
Southern Inland Total		5.10	5.10	5.10	2

EPHEMEROPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 5.5 - 6.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	6.05	5.52	6.50	91
	<i>Adenophlebia sp.</i>	5.98	5.65	6.50	6
	<i>Castanophlebia sp.</i>	5.74	5.52	5.92	3
	<i>Choroterpes sp.</i>	6.20	6.00	6.50	3
	<i>Ephemerellina sp.</i>	5.96	5.52	6.40	2
	<i>Lestagella sp.</i>	5.71	5.52	5.90	2

	<i>Acentrella capensis</i>	6.12	5.60	6.50	47
	<i>Adenophlebia peringueyella</i>	6.17	5.80	6.40	3
	<i>Afronurus harrisoni</i>	6.14	5.60	6.50	21
	<i>Aprionyx intermedius</i>	5.92	5.60	6.10	10
	<i>Aprionyx peterseni</i>	6.13	5.60	6.50	18
	<i>Aprionyx tabularis</i>	6.05	5.80	6.50	10
	<i>Austrocaenis sp.</i>	6.16	5.80	6.50	16
	<i>Austrocloeon virgiliae</i>	6.35	6.30	6.40	2
	<i>Baetis bellus</i>	6.26	5.80	6.50	17
	<i>Baetis glaucus</i>	6.43	6.30	6.50	4
	<i>Baetis harrisoni</i>	6.16	5.60	6.50	56
	<i>Baetis latus</i>	6.10	6.10	6.10	1
	<i>Baetis sp.</i>	6.09	5.60	6.50	26
	<i>Caenis sp.</i>	6.40	6.10	6.50	4
	<i>Castanophlebia calida</i>	6.05	5.60	6.50	35
	<i>Centroptilum excisum</i>	6.16	5.60	6.50	25
	<i>Centroptilum sp.</i>	6.00	5.80	6.50	9
	<i>Centroptilum sudafricanum</i>	6.20	5.80	6.50	9
	<i>Choroterpes elegans</i>	6.14	5.80	6.50	12
	<i>Choroterpes nigrescens</i>	6.02	5.80	6.50	11
	<i>Lithogloea harrisoni</i>	6.09	5.60	6.50	14
	<i>Lithogloea pennicillata</i>	6.19	5.60	6.50	23
	<i>Lithogloea sp.</i>	6.04	5.80	6.30	8
	<i>Pseudocloeon maculosum</i>	6.28	6.10	6.50	5
	<i>Pseudocloeon sp.</i>	5.83	5.60	6.10	3
	<i>Pseudocloeon vinosum</i>	6.16	5.60	6.50	27
	<i>Tricorythus discolor</i>	6.18	6.00	6.40	4
	<i>Aprionyx rubicundus</i>	5.98	5.60	6.50	11
	<i>Lestagella penicillata</i>	6.01	5.60	6.50	18
	<i>Ephemerellina barnardi</i>	6.10	6.00	6.30	4
	<i>Acentrella sp.</i>	6.24	6.00	6.50	9
	<i>Cloeon africanum</i>	6.05	6.00	6.10	2
	<i>Pseudocloeon saxophilum</i>	6.14	6.00	6.30	5
	<i>Adenophlebia auriculata</i>	6.00	6.00	6.00	1
	<i>Afroptilum ?tarsale</i>	6.10	6.10	6.10	1
	<i>Afroptilum sp.</i>	6.20	6.00	6.50	3
	<i>Aprionyx complex A</i>	6.00	6.00	6.00	1
	<i>Caenis capensis</i>	6.20	6.00	6.50	3
	<i>Caenodes sp.</i>	6.05	6.00	6.10	2
	<i>Centroptilum indusii</i>	6.10	6.10	6.10	1
	<i>Demoulinia complex A</i>	6.20	6.00	6.50	3
	<i>Demoulinia crassi</i>	6.10	6.10	6.10	1
	<i>Ephemerellina complex A</i>	6.10	6.10	6.10	1
	<i>Pseudopannota maculosa</i>	6.10	6.10	6.10	1
	<i>Austrocaenis capensis</i>	6.35	6.30	6.40	2
	<i>Ephemerellina harrisoni</i>	6.30	6.30	6.30	1
Fynbos Total		6.11	5.52	6.50	597
Alkaline interior	Unspecified	6.28	5.73	6.50	8
Southern Coastal	<i>Aprionyx peterseni</i>	5.90	5.90	5.90	1
	<i>Baetis harrisoni</i>	5.90	5.90	5.90	1
	<i>Castanophlebia calida</i>	5.90	5.90	5.90	2
	<i>Lithogloea harrisoni</i>	5.90	5.90	5.90	2
	<i>Lithogloea pennicillata</i>	5.90	5.90	5.90	2
	<i>Lithogloea sp.</i>	5.90	5.90	5.90	1
	<i>Pseudocloeon sp.</i>	5.90	5.90	5.90	1
	<i>Pseudocloeon vinosum</i>	5.90	5.90	5.90	2
Southern Coastal Total		5.90	5.90	5.90	12

EPHEMEROPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) pH: 6.5 - 7.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	6.89	6.55	7.40	41
	<i>Adenophlebia sp.</i>	6.59	6.59	6.59	1
	<i>Aprionyx sp.</i>	6.99	6.99	6.99	1

	<i>Castanophlebia</i> sp.	6.91	6.59	7.28	4
	<i>Choroterpes</i> sp.	6.83	6.76	6.90	2
	<i>Ephemerellina</i> sp.	6.90	6.76	6.99	4
	<i>Lestagella</i> sp.	6.92	6.85	6.99	2
	<i>Acentrella capensis</i>	6.77	6.56	7.20	19
	<i>Baetis</i> sp.	6.87	6.56	7.40	24
	<i>Baetis bellus</i>	6.92	6.60	7.40	24
	<i>Baetis latus</i>	6.95	6.70	7.10	6
	<i>Centroptilum excisum</i>	6.90	6.60	7.40	27
	<i>Pseudocloeon vinosum</i>	6.91	6.60	7.40	26
	<i>Adenophlebia peringueyella</i>	7.03	6.80	7.20	3
	<i>Baetis harrisoni</i>	6.90	6.60	7.40	31
	<i>Castanophlebia calida</i>	6.87	6.60	7.20	7
	<i>Centroptilum sudafricanum</i>	7.02	6.70	7.40	15
	<i>Lithogloea pennicillata</i>	6.72	6.60	6.80	5
	<i>Pseudocloeon maculosum</i>	7.02	6.70	7.40	13
	<i>Afronurus harrisoni</i>	6.85	6.60	7.20	11
	<i>Aprionyx petersenii</i>	6.93	6.80	7.20	3
	<i>Austrocaenis</i> sp.	6.83	6.60	7.20	6
	<i>Austrocloeon virgiliae</i>	6.80	6.70	6.90	3
	<i>Baetis glaucus</i>	6.73	6.60	6.80	3
	<i>Caenis</i> sp.	6.74	6.60	6.90	7
	<i>Centroptilum</i> sp.	6.80	6.80	6.80	1
	<i>Choroterpes elegans</i>	6.94	6.80	7.20	5
	<i>Choroterpes nigrescens</i>	6.80	6.80	6.80	1
	<i>Lithogloea harrisoni</i>	6.73	6.60	6.90	6
	<i>Tricorythus discolor</i>	6.80	6.70	6.90	5
	<i>Aprionyx tabularis</i>	6.80	6.80	6.80	2
	<i>Aprionyx rubicundus</i>	7.03	6.80	7.20	3
	<i>Lestagella penicillata</i>	6.93	6.60	7.20	4
	<i>Acentrella</i> sp.	6.99	6.70	7.40	15
	<i>Centroptilum crassi</i>	6.90	6.70	7.10	3
	<i>Cloeon africanum</i>	6.88	6.70	7.10	5
	<i>Pseudocloeon saxophilum</i>	6.98	6.70	7.40	13
	<i>Austrocaenis capensis</i>	6.80	6.80	6.80	1
	<i>Cloeon lacunosum</i>	7.40	7.40	7.40	1
	<i>Cloeon</i> sp.	7.20	7.20	7.20	1
	<i>Ephemerellina barnardi</i>	6.95	6.80	7.10	2
	<i>Ephemerellina harrisoni</i>	7.03	6.80	7.20	3
	<i>Afroptilum</i> sp.	6.90	6.90	6.90	1
	<i>Caenis capensis</i>	6.90	6.90	6.90	1
	<i>Caenodes</i> sp.	6.90	6.90	6.90	1
	<i>Demoulinia complex A</i>	6.90	6.90	6.90	1
	<i>Demoulinia crassi</i>	6.90	6.90	6.90	1
	<i>Pseudopannota maculosa</i>	6.90	6.90	6.90	1
Fynbos Total		6.90	6.55	7.40	365
Southern Inland	Unspecified	6.54	6.54	6.54	1
	<i>Baetis bellus</i>	6.70	6.70	6.70	1
	<i>Pseudocloeon vinosum</i>	6.70	6.70	6.70	1
	<i>Baetis harrisoni</i>	6.70	6.70	6.70	1
	<i>Centroptiloides bifasciatum</i>	6.70	6.70	6.70	1
	<i>Centroptilum sudafricanum</i>	6.70	6.70	6.70	1
	<i>Pseudocloeon maculosum</i>	6.70	6.70	6.70	1
Southern Inland Total		6.68	6.54	6.70	7
Tugela	Unspecified	7.26	6.73	7.50	41
	<i>Choroterpes</i> sp.	7.31	6.97	7.50	9
	<i>Baetis</i> sp.	7.32	7.00	7.43	4
	<i>Baetis bellus</i>	7.20	6.58	7.50	34
	<i>Baetis latus</i>	7.28	6.96	7.50	24
	<i>Centroptilum excisum</i>	7.26	6.58	7.50	25
	<i>Pseudocloeon vinosum</i>	7.27	6.96	7.50	16
	<i>Baetis harrisoni</i>	7.28	6.97	7.50	24
	<i>Centroptilum sudafricanum</i>	7.32	7.00	7.50	9

	<i>Pseudocloeon maculosum</i>	7.21	6.97	7.45	4
	<i>Afronurus harrisoni</i>	7.30	7.30	7.30	1
	<i>Austrocaenis sp.</i>	7.23	6.70	7.47	7
	<i>Austrocloeon virgiliae</i>	7.13	7.00	7.20	3
	<i>Baetis glaucus</i>	7.38	7.22	7.47	8
	<i>Caenis sp.</i>	7.30	7.30	7.30	1
	<i>Centroptilum pulchrum</i>	7.50	7.50	7.50	1
	<i>Choroterpes elegans</i>	7.36	7.30	7.47	3
	<i>Afronurus sp.</i>	7.21	6.70	7.50	7
	<i>Austrocaenis capensis</i>	7.28	7.18	7.47	4
	<i>Cloeon sp.</i>	7.17	7.11	7.23	2
	<i>Adenophlebia auriculata</i>	7.20	7.20	7.20	1
	<i>Tricorythus sp.</i>	7.28	6.97	7.50	7
	<i>Austrocloeon africanum</i>	7.34	7.34	7.34	1
	<i>Centroptilum parvum</i>	7.30	7.30	7.30	1
	<i>Baetis cataractae</i>	7.20	7.20	7.20	1
	<i>Centroptilum medium</i>	7.23	7.11	7.36	3
	<i>Cloeon virgiliae</i>	7.45	7.41	7.49	2
	<i>Eatonica schoutedeni</i>	7.23	7.23	7.23	1
	<i>Neurocaenis reticulata</i>	7.30	7.30	7.30	2
	<i>Centroptiloides sp.</i>	7.44	7.44	7.44	1
Tugela Total		7.27	6.58	7.50	247
Alkaline interior	Unspecified	7.05	6.60	7.50	20
	<i>Acentrella cf. capensis</i>	6.60	6.60	6.60	1
	<i>Adenophlebia peringueyella</i>	6.60	6.60	6.60	2
	<i>Baetis harrisoni</i>	6.60	6.60	6.60	2
	<i>Castanophlebia calida</i>	6.60	6.60	6.60	1
	<i>Centroptilum sudafricanum</i>	6.60	6.60	6.60	2
	<i>Lithogloea pennicillata</i>	6.60	6.60	6.60	1
	<i>Neurocaenis discolor</i>	6.60	6.60	6.60	1
Alkaline interior Total		6.90	6.60	7.50	30
Eastern Seaboard	Unspecified	7.39	7.30	7.48	5
	<i>Baetis sp.</i>	7.45	7.42	7.48	2
	<i>Baetis bellus</i>	7.33	7.10	7.48	13
	<i>Baetis latus</i>	7.33	7.10	7.50	13
	<i>Centroptilum excisum</i>	7.34	7.10	7.50	8
	<i>Pseudocloeon vinosum</i>	7.29	7.10	7.42	9
	<i>Baetis harrisoni</i>	7.30	7.00	7.50	18
	<i>Castanophlebia calida</i>	7.20	7.00	7.30	3
	<i>Centroptiloides bifasciatum</i>	7.28	7.10	7.30	8
	<i>Centroptilum sudafricanum</i>	7.27	7.00	7.43	15
	<i>Neurocaenis discolor</i>	7.26	7.10	7.30	10
	<i>Pseudocloeon maculosum</i>	7.30	7.10	7.50	3
	<i>Austrocaenis sp.</i>	7.34	7.10	7.50	8
	<i>Austrocloeon virgiliae</i>	7.10	7.00	7.30	4
	<i>Baetis glaucus</i>	7.30	7.30	7.30	5
	<i>Caenis sp.</i>	7.29	7.00	7.50	13
	<i>Centroptilum pulchrum</i>	7.31	7.19	7.46	4
	<i>Centroptilum sp.</i>	7.29	7.10	7.46	5
	<i>Choroterpes elegans</i>	7.40	7.30	7.50	5
	<i>Acentrella sp.</i>	7.43	7.42	7.43	2
	<i>Cloeon africanum</i>	7.46	7.43	7.48	2
	<i>Adenophlebia sylvatica</i>	7.20	7.00	7.30	3
	<i>Afronurus sp.</i>	7.27	7.10	7.42	9
	<i>Adenophlebia auriculata</i>	7.29	7.00	7.50	8
	<i>Centroptilum indusii</i>	7.24	7.10	7.30	7
	<i>Tricorythus sp.</i>	7.45	7.42	7.48	2
	<i>Austrocloeon africanum</i>	7.46	7.46	7.46	1
	<i>Austrocloeon sp.</i>	7.30	7.30	7.30	2
	<i>Centroptilum parvum</i>	7.34	7.30	7.50	5
	<i>Centroptilum vanum</i>	7.27	7.10	7.30	7
	<i>Notonurus sp.</i>	7.29	7.10	7.48	2
	<i>Aprionyx tricuspoidatus</i>	7.15	7.00	7.30	2

	<i>Centroptilum 'near excisum'</i>	7.15	7.00	7.30	2
	<i>Baetis cataractae</i>	7.30	7.30	7.30	3
	<i>Centroptilum medium</i>	7.30	7.30	7.30	5
	<i>Acentrella natalensis</i>	7.30	7.10	7.48	10
	<i>Elassoneuria trimeniana</i>	7.20	7.10	7.30	2
	<i>Euthraulius bugandensis</i>	7.27	7.10	7.30	7
	<i>Oligoneuriopsis lawrenci</i>	7.25	7.10	7.30	4
	<i>Prosopistoma sp.</i>	7.29	7.10	7.42	6
	<i>Acentrella monticola</i>	7.36	7.30	7.42	2
	<i>Pseudocloeon inzingae</i>	7.36	7.30	7.42	2
	<i>Ephoron savigni</i>	7.30	7.30	7.30	1
	<i>Prosopistoma crassi</i>	7.30	7.30	7.30	1
	<i>Neurocaenis reticulata</i>	7.50	7.50	7.50	1
	<i>Machadorythus sp.</i>	7.48	7.48	7.48	1
	<i>Centroptilum flavum</i>	7.46	7.46	7.46	1
Eastern Seaboard Total		7.30	7.00	7.50	251
Drought Corridor	<i>Baetis harrisoni</i>	7.20	7.20	7.20	1
	<i>Centroptilum sudafricanum</i>	7.20	7.20	7.20	1
	<i>Choroterpes elegans</i>	7.20	7.20	7.20	1
	<i>Cloeon africanum</i>	7.30	7.30	7.30	1
	<i>Austrocaenis capensis</i>	7.30	7.30	7.30	1
	<i>Cloeon sp.</i>	7.30	7.30	7.30	1
	<i>Neurocaenis sp.</i>	7.20	7.20	7.20	1
Drought Corridor Total		7.24	7.20	7.30	7
Highveld Source	<i>Baetis harrisoni</i>	7.50	7.50	7.50	1

EPHEMEROPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) pH > 7.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	8.06	7.70	8.53	4
	<i>Baetis bellus</i>	7.70	7.70	7.70	1
	<i>Baetis harrisoni</i>	7.80	7.70	7.90	2
	<i>Baetis latus</i>	7.70	7.70	7.70	1
	<i>Baetis sp.</i>	7.80	7.70	7.90	2
	<i>Centroptilum sudafricanum</i>	7.90	7.90	7.90	1
	<i>Acentrella sp.</i>	7.80	7.70	7.90	2
	<i>Centroptilum excisum</i>	7.80	7.70	7.90	2
	<i>Cloeon africanum</i>	7.70	7.70	7.70	1
	<i>Pseudocloeon maculosum</i>	7.80	7.70	7.90	2
	<i>Pseudocloeon vinosum</i>	7.80	7.70	7.90	2
	<i>Centroptilum crassi</i>	7.70	7.70	7.70	1
	<i>Pseudocloeon saxophilum</i>	7.80	7.70	7.90	2
Fynbos Total		7.83	7.70	8.53	23
Eastern Seaboard	Unspecified	7.87	7.55	8.10	11
	<i>Austrocaenis sp.</i>	7.57	7.51	7.62	2
	<i>Baetis bellus</i>	7.83	7.60	8.00	7
	<i>Baetis harrisoni</i>	7.94	7.51	8.60	19
	<i>Baetis latus</i>	7.75	7.51	8.00	10
	<i>Baetis sp.</i>	7.79	7.62	8.00	5
	<i>Centroptilum medium</i>	7.60	7.60	7.60	1
	<i>Centroptilum sudafricanum</i>	7.99	7.55	8.60	14
	<i>Acentrella monticola</i>	7.81	7.55	8.00	4
	<i>Acentrella natalensis</i>	7.78	7.60	7.96	2
	<i>Acentrella sp.</i>	7.66	7.55	7.80	3
	<i>Adenophlebia aunculata</i>	8.00	8.00	8.00	2
	<i>Adenophlebia sp.</i>	8.04	7.55	8.60	10
	<i>Afronurus sp.</i>	7.81	7.55	8.00	9
	<i>Baetis glaucus</i>	7.89	7.60	8.10	4
	<i>Castanophlebia sp.</i>	7.82	7.55	8.00	4
	<i>Centroptiloides bifasciatum</i>	7.90	7.60	8.10	5
	<i>Centroptilum excisum</i>	7.93	7.55	8.50	17
	<i>Centroptilum indusii</i>	7.76	7.60	7.92	2
	<i>Centroptilum varium</i>	7.75	7.60	7.90	2
	<i>Choroterpes elegans</i>	7.96	7.55	8.60	16

	<i>Cloeon africanum</i>	8.02	7.55	8.50	3
	<i>Ephoron sp.</i>	7.63	7.63	7.63	1
	<i>Prosopistoma sp.</i>	7.77	7.60	7.92	4
	<i>Pseudocloeon inzingae</i>	7.84	7.55	8.00	3
	<i>Pseudocloeon maculosum</i>	7.91	7.60	8.10	6
	<i>Pseudocloeon vinosum</i>	7.83	7.60	8.00	7
	<i>Tricorythus sp.</i>	7.85	7.55	8.00	9
	<i>Austrocloeon virgiliae</i>	7.60	7.60	7.60	1
	<i>Pseudocloeon sp.</i>	7.90	7.90	7.90	1
	<i>Centroptilum parvum</i>	7.85	7.60	8.10	2
	<i>Notonurus sp.</i>	7.80	7.60	8.00	5
	<i>Austrocloeon near virgiliae</i>	7.60	7.60	7.60	1
	<i>Caenis sp.</i>	8.17	7.60	8.90	9
	<i>Centroptilum sp.</i>	7.60	7.60	7.60	1
	<i>Elassoneuna trimeniana</i>	7.60	7.60	7.60	1
	<i>Euthraulus bugandensus</i>	7.60	7.60	7.60	1
	<i>Lithogloea near harrisoni</i>	7.60	7.60	7.60	1
	<i>Neurocaenis discolor</i>	7.60	7.60	7.60	1
	<i>Neurocaenis reticulata</i>	7.93	7.60	8.10	4
	<i>Oligoneuriopsis lawrenci</i>	7.60	7.60	7.60	1
	<i>Prosopistoma crassi</i>	7.60	7.60	7.60	1
	<i>Afronurus harrisoni</i>	8.05	8.00	8.10	2
	<i>Choroterpes nigrescens</i>	8.50	8.50	8.50	1
Eastern Seaboard Total		7.89	7.51	8.90	215
Tugela	Unspecified	8.08	7.55	9.39	154
	<i>Austrocaenis sp.</i>	7.89	7.51	8.40	10
	<i>Baetis bellus</i>	8.01	7.56	8.65	123
	<i>Baetis harrisoni</i>	8.15	7.60	9.07	88
	<i>Baetis latus</i>	8.00	7.56	8.73	111
	<i>Baetis sp.</i>	8.17	7.73	9.20	7
	<i>Centroptilum medium</i>	7.78	7.63	7.90	9
	<i>Centroptilum sudafricanum</i>	7.97	7.60	8.49	20
	<i>Acentrella monticola</i>	8.00	7.90	8.10	2
	<i>Acentrella natalensis</i>	8.25	7.90	8.60	2
	<i>Afronurus sp.</i>	8.26	7.70	9.20	26
	<i>Baetis glaucus</i>	8.22	7.60	9.20	42
	<i>Centroptilum excisum</i>	8.05	7.56	9.20	109
	<i>Choroterpes elegans</i>	8.20	7.90	8.60	3
	<i>Cloeon africanum</i>	7.70	7.70	7.70	1
	<i>Prosopistoma sp.</i>	8.92	8.79	9.00	3
	<i>Pseudocloeon maculosum</i>	7.80	7.60	8.10	3
	<i>Pseudocloeon vinosum</i>	7.99	7.56	9.20	52
	<i>Tricorythus sp.</i>	8.13	7.70	8.73	18
	<i>Cloeon sp.</i>	8.00	7.55	8.41	7
	<i>Cloeon virgiliae</i>	7.92	7.65	8.49	6
	<i>Choroterpes sp.</i>	8.22	7.60	9.20	55
	<i>Austrocloeon virgiliae</i>	7.80	7.60	7.90	3
	<i>Centroptilum parvum</i>	8.20	7.90	8.60	3
	<i>Caenis sp.</i>	7.92	7.60	8.40	6
	<i>Centroptilum sp.</i>	7.81	7.81	7.81	1
	<i>Neurocaenis reticulata</i>	8.30	7.90	8.60	3
	<i>Cloeon crassi</i>	8.22	7.70	8.49	3
	<i>Afronurus harrisoni</i>	8.20	7.90	8.60	3
	<i>Centroptiloides sp.</i>	8.00	7.70	8.24	3
	<i>Cloeon elevatum</i>	7.81	7.81	7.81	1
Tugela Total		8.07	7.51	9.39	877
Highveld Source	<i>Austrocaenis sp.</i>	7.80	7.70	7.90	2
	<i>Austrocloeon africanum</i>	7.70	7.60	7.80	3
	<i>Baetis harrisoni</i>	7.74	7.60	7.90	5
	<i>Austrocloeon virgiliae</i>	7.65	7.60	7.70	2
	<i>Neurocaenis discolor</i>	7.70	7.70	7.70	1
Highveld Source Total		7.72	7.60	7.90	13
Northern Uplands	<i>Austrocaenis sp.</i>	7.83	7.70	8.00	3

	<i>Austroclleon africanum</i>	7.73	7.60	8.00	3
	<i>Baetis bellus</i>	7.85	7.70	8.00	2
	<i>Baetis harrisoni</i>	7.74	7.60	8.00	5
	<i>Baetis latus</i>	7.70	7.70	7.70	1
	<i>Centroptilum medium</i>	7.75	7.70	7.80	2
	<i>Centroptilum excisum</i>	7.74	7.60	8.00	5
	<i>Choroterpes elegans</i>	7.85	7.70	8.00	2
	<i>Pseudocloeon maculosum</i>	7.75	7.70	7.80	2
	<i>Austroclleon virgiliae</i>	7.65	7.60	7.70	2
	<i>Austroclleon sp.</i>	7.70	7.70	7.70	1
	<i>Neurocaenis discolor</i>	8.00	8.00	8.00	1
	<i>Afronurus harrisoni</i>	7.75	7.70	7.80	2
Northern Uplands Total		7.76	7.60	8.00	31
Alkaline interior	Unspecified	7.98	7.70	8.10	4
Drought Corridor	Unspecified	8.39	8.20	8.80	15
	<i>Baetis harrisoni</i>	8.50	7.70	9.60	34
	<i>Baetis latus</i>	9.10	8.60	9.60	2
	<i>Baetis glaucus</i>	8.49	7.70	9.60	33
	<i>Centroptilum excisum</i>	8.37	7.70	9.00	24
	<i>Choroterpes elegans</i>	8.32	7.80	8.60	22
	<i>Cloeon africanum</i>	8.53	7.80	9.10	10
	<i>Cloeon sp.</i>	8.45	8.30	8.60	2
	<i>Austrocaenis capensis</i>	8.62	8.20	9.10	13
	<i>Centroptilum sp.</i>	8.60	8.60	8.60	1
	<i>Neurocaenis reticulata</i>	8.50	7.70	9.60	32
	<i>Cloeon crassi</i>	8.65	7.80	9.10	10
Drought Corridor Total		8.48	7.70	9.60	198
Lowveld	Unspecified	7.70	7.70	7.70	1
	<i>Centroptilum medium</i>	7.70	7.70	7.70	1
	<i>Afronurus sp.</i>	7.70	7.70	7.70	1
	<i>Baetis glaucus</i>	7.70	7.70	7.70	1
	<i>Tricorythus sp.</i>	7.70	7.70	7.70	1
	<i>Choroterpes sp.</i>	7.70	7.70	7.70	1
	<i>Notonurus sp.</i>	7.70	7.70	7.70	1
	<i>Centroptiloides spinulosa</i>	7.70	7.70	7.70	1
	<i>Centroptilum flavum</i>	7.70	7.70	7.70	1
	<i>Elassoneuria sp.</i>	7.70	7.70	7.70	1
	<i>Euthraulus sp.</i>	7.70	7.70	7.70	1
	<i>Ophelmatostoma sp.</i>	7.70	7.70	7.70	1
Lowveld Total		7.70	7.70	7.70	12
Vaal	Unspecified	8.35	8.30	8.40	4
	<i>Austroclleon africanum</i>	8.40	8.40	8.40	1
	<i>Baetis harrisoni</i>	8.35	8.30	8.40	4
	<i>Centroptilum pulchrum</i>	8.40	8.40	8.40	1
	<i>Centroptilum sudafricanum</i>	8.35	8.30	8.40	4
	<i>Adenophlebia sp.</i>	8.33	8.30	8.40	3
	<i>Afronurus sp.</i>	8.33	8.30	8.40	3
	<i>Baetis glaucus</i>	8.30	8.30	8.30	1
	<i>Centroptilum excisum</i>	8.35	8.30	8.40	4
	<i>Pseudocloeon vinosum</i>	8.40	8.40	8.40	1
	<i>Choroterpes sp.</i>	8.33	8.30	8.40	3
	<i>Austroclleon sp.</i>	8.40	8.40	8.40	1
	<i>Centroptilum parvum</i>	8.30	8.30	8.30	1
	<i>Centroptilum sp.</i>	8.30	8.30	8.30	1
	<i>Euthraulus sp.</i>	8.33	8.30	8.40	3
	<i>Neurocaenis sp.</i>	8.33	8.30	8.40	3
Vaal Total		8.34	8.30	8.40	38
Southern Inland	Unspecified	8.50	8.50	8.50	1
	<i>Baetis bellus</i>	8.50	8.50	8.50	1
	<i>Baetis harrisoni</i>	8.50	8.50	8.50	1
	<i>Centroptilum pulchrum</i>	8.50	8.50	8.50	1
	<i>Centroptilum excisum</i>	8.50	8.50	8.50	1
	<i>Centroptilum indusii</i>	8.50	8.50	8.50	1

	<i>Choroterpes elegans</i>	8.50	8.50	8.50	1
	<i>Pseudocloeon maculosum</i>	8.50	8.50	8.50	1
	<i>Austrocloeon sp.</i>	8.50	8.50	8.50	1
	<i>Afronurus harrisoni</i>	8.50	8.50	8.50	1
	<i>Adenophlebia peringueyella</i>	8.50	8.50	8.50	1
Southern Inland Total		8.50	8.50	8.50	11

EPHEMEROPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH: 4.5 - 5.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	<i>Afronurus harrisoni</i>	5.00	5.00	5.00	1
	<i>Baetis bellus</i>	5.00	5.00	5.00	2
	<i>Ephemerellina penicillata</i>	5.00	5.00	5.00	1
	<i>Lestagella penicillata</i>	5.00	5.00	5.00	1
	<i>Tricorythus discolor</i>	5.00	5.00	5.00	1
Fynbos Total		5.00	5.00	5.00	6
Southern Coastal	Unspecified	5.20	5.20	5.20	1
	<i>Baetis harrisoni</i>	5.20	5.20	5.20	1
	<i>Castanophlebia calida</i>	5.20	5.20	5.20	1
	<i>Austrocloeon africanum</i>	5.20	5.20	5.20	1
	<i>Lithogloea pennicillata</i>	5.20	5.20	5.20	1
	<i>Pseudocloeon vinosum</i>	5.20	5.20	5.20	1
Southern Coastal Total		5.20	5.20	5.20	6

EPHEMEROPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH: 5.5 - 6.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	6.33	5.82	6.50	13
	<i>Austrocaenis sp.</i>	6.43	6.30	6.50	4
	<i>Baetis latus</i>	6.40	6.40	6.40	1
	<i>Baetis sp.</i>	6.42	6.30	6.50	5
	<i>Acentrella capensis</i>	6.43	6.30	6.50	4
	<i>Afronurus harrisoni</i>	6.43	6.30	6.50	4
	<i>Apronyx intermedius</i>	6.50	6.50	6.50	1
	<i>Austrocloeon virgiliae</i>	6.35	6.30	6.40	2
	<i>Baetis bellus</i>	6.43	6.30	6.50	4
	<i>Baetis glaucus</i>	6.43	6.30	6.50	4
	<i>Baetis harrisoni</i>	6.43	6.30	6.50	7
	<i>Caenis sp.</i>	6.43	6.30	6.50	4
	<i>Castanophlebia calida</i>	6.42	6.30	6.50	5
	<i>Centroptilum excisum</i>	6.43	6.30	6.50	4
	<i>Centroptilum pulchrum</i>	6.35	6.30	6.40	2
	<i>Centroptilum sp.</i>	6.50	6.50	6.50	1
	<i>Lithogloea harrisoni</i>	6.44	6.30	6.50	7
	<i>Lithogloea pennicillata</i>	6.50	6.50	6.50	2
	<i>Pseudocloeon maculosum</i>	6.35	6.30	6.40	2
	<i>Pseudocloeon vinosum</i>	6.42	6.30	6.50	5
	<i>Tricorythus discolor</i>	6.35	6.30	6.40	2
	<i>Acentrella sp.</i>	6.40	6.30	6.50	2
	<i>Adenophlebiodes sp.</i>	6.30	6.30	6.30	1
	<i>Afroptilum sp.</i>	6.40	6.30	6.50	2
	<i>Apronyx sp.</i>	6.30	6.30	6.30	1
	<i>Centroptiloides sp.</i>	6.50	6.50	6.50	1
	<i>Lestagella sp.</i>	6.30	6.30	6.30	2
	<i>Rhithrocloeon sp.</i>	6.37	6.30	6.50	3
	<i>Caenis capensis</i>	6.40	6.40	6.40	1
	<i>Caenodes sp.</i>	6.40	6.40	6.40	1
	<i>Centroptilum indusii</i>	6.40	6.40	6.40	1
	<i>Demoulinia complex A</i>	6.40	6.40	6.40	2
	<i>Demoulinia crassi</i>	6.40	6.40	6.40	1
	<i>Pseudopannota maculosa</i>	6.40	6.40	6.40	2
	<i>Tricorythus sp.</i>	6.40	6.40	6.40	1
Fynbos Total		6.40	5.82	6.50	104

EPHEMEROPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH: 5.5 - 6.5					
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BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	6.97	6.60	7.50	29
	<i>Austrocaenis sp.</i>	7.10	6.60	7.50	28
	<i>Centroptilum excisum</i>	7.06	6.60	7.50	58
	<i>Baetis sp.</i>	7.09	6.60	7.40	33
	<i>Adenophlebia peringueyella</i>	7.50	7.50	7.50	1
	<i>Baetis bellus</i>	7.06	6.60	7.50	63
	<i>Baetis harrisoni</i>	7.12	6.60	7.50	54
	<i>Castanophlebia calida</i>	7.50	7.50	7.50	1
	<i>Centroptilum sudafricanum</i>	7.23	6.70	7.50	4
	<i>Lithogloea pennicillata</i>	6.70	6.60	6.80	2
	<i>Pseudocloeon maculosum</i>	7.06	6.70	7.40	20
	<i>Pseudocloeon vinosum</i>	7.03	6.60	7.40	50
	<i>Aprionyx intermedius</i>	7.05	6.60	7.50	2
	<i>Austrocloeon virgiliae</i>	6.80	6.80	6.80	1
	<i>Centroptilum pulchrum</i>	6.91	6.70	7.40	7
	<i>Centroptilum sp.</i>	6.80	6.80	6.80	1
	<i>Lithogloea harrisoni</i>	6.70	6.60	6.80	2
	<i>Acentrella capensis</i>	6.95	6.60	7.50	7
	<i>Afronurus harrisoni</i>	6.88	6.60	7.50	6
	<i>Baetis glaucus</i>	7.08	6.60	7.50	12
	<i>Baetis latus</i>	7.04	6.70	7.40	14
	<i>Caenis sp.</i>	7.04	6.60	7.50	14
	<i>Tricorythus discolor</i>	7.06	6.70	7.40	9
	<i>Lestagella penicillata</i>	7.50	7.50	7.50	1
	<i>Acentrella sp.</i>	7.06	6.70	7.40	9
	<i>Pseudocloeon saxophilum</i>	7.10	6.70	7.40	10
	<i>Centroptilum crassi</i>	7.00	6.90	7.10	4
	<i>Aprionyx rubicundus</i>	7.50	7.50	7.50	1
	<i>Cloeon lacunosum</i>	7.43	7.35	7.50	2
	<i>Ephemerellina harrisoni</i>	7.50	7.50	7.50	1
Fynbos Total		7.06	6.60	7.50	446
Eastern Seaboard	Unspecified	7.30	7.10	7.50	6
	<i>Austrocaenis sp.</i>	7.31	7.03	7.50	10
	<i>Centroptilum excisum</i>	7.28	7.10	7.43	9
	<i>Baetis sp.</i>	7.22	6.72	7.50	7
	<i>Baetis bellus</i>	7.32	7.10	7.50	11
	<i>Baetis harrisoni</i>	7.32	7.10	7.50	8
	<i>Castanophlebia calida</i>	7.40	7.40	7.40	1
	<i>Centroptiloides bifasciatum</i>	7.41	7.41	7.41	1
	<i>Centroptilum sudafricanum</i>	7.29	7.10	7.50	4
	<i>Neurocaenis discolor</i>	7.30	7.30	7.30	1
	<i>Pseudocloeon maculosum</i>	7.32	7.10	7.50	5
	<i>Pseudocloeon vinosum</i>	7.27	7.15	7.40	5
	<i>Austrocloeon virgiliae</i>	7.29	7.20	7.38	3
	<i>Centroptilum sp.</i>	7.26	7.21	7.30	2
	<i>Baetis glaucus</i>	7.30	7.10	7.50	6
	<i>Baetis latus</i>	7.24	6.72	7.50	12
	<i>Caenis sp.</i>	7.34	7.20	7.48	5
	<i>Choroterpes elegans</i>	7.32	7.10	7.50	5
	<i>Centroptilum indusii</i>	7.15	7.15	7.15	1
	<i>Tricorythus sp.</i>	7.28	7.15	7.41	2
	<i>Centroptilum crassi</i>	7.15	7.15	7.15	1
	<i>Afronurus sp.</i>	7.34	7.15	7.48	3
	<i>Castanophlebia sp.</i>	7.10	7.10	7.10	1
	<i>Centroptilum varium</i>	7.30	7.30	7.30	2
	<i>Cloeon africanum</i>	7.27	7.10	7.50	5
	<i>Austrocloeon africanum</i>	7.20	7.20	7.20	1
	<i>Pseudocloeon sp.</i>	6.98	6.98	6.98	1
	<i>Ephoron sp.</i>	7.15	7.15	7.15	1
	<i>Machadorythus sp.</i>	7.15	7.15	7.15	1
	<i>Adenophlebia sp.</i>	7.44	7.41	7.50	3
	<i>Cloeon virgiliae</i>	7.50	7.50	7.50	1

	<i>Notonurus sp.</i>	7.28	7.15	7.40	3
	<i>Austrocloeon sp.</i>	7.29	7.20	7.38	2
	<i>Lithogloea near harrisoni</i>	7.30	7.30	7.30	1
	<i>Elassoneuria tnmeniana</i>	7.30	7.30	7.30	1
	<i>Austrocloeon cf. africanum</i>	7.50	7.50	7.50	1
Eastern Seaboard Total		7.29	6.72	7.50	132
Alkaline Interior	<i>Adenophlebia peringueyella</i>	6.60	6.60	6.60	1
	<i>Centroptilum sudafricanum</i>	6.60	6.60	6.60	1
	<i>Pseudocloeon vinosum</i>	6.60	6.60	6.60	1
Tugela	<i>Baetis latus</i>	7.48	7.48	7.48	1
	<i>Baetis cataractae</i>	7.48	7.48	7.48	1
Lowveld	Unspecified	7.24	6.90	7.50	7
	<i>Austrocaenis sp.</i>	7.20	6.90	7.47	6
	<i>Centroptilum excisum</i>	7.30	7.20	7.40	2
	<i>Baetis sp.</i>	7.14	6.90	7.40	5
	<i>Baetis bellus</i>	7.15	6.90	7.40	2
	<i>Centroptiloides bifasciatum</i>	7.15	7.10	7.20	2
	<i>Baetis glaucus</i>	7.20	6.90	7.50	6
	<i>Choroterpes sp.</i>	7.14	6.90	7.40	5
	<i>Tricorythus sp.</i>	7.50	7.50	7.50	1
	<i>Centroptilum medium</i>	7.14	6.90	7.40	5
	<i>Adenophlebiodes sp.</i>	7.07	6.90	7.20	3
	<i>Afrobaetodes beneri</i>	7.07	6.90	7.20	3
	<i>Afronurus sp.</i>	7.20	6.90	7.50	6
	<i>Castanophlebia sp.</i>	7.23	7.10	7.40	3
	<i>Centroptiloides ?spinulosa</i>	7.15	7.10	7.20	2
	<i>Centroptilum 'near excisum'</i>	7.15	6.90	7.40	4
	<i>Centroptilum flavum</i>	7.14	6.90	7.40	5
	<i>Centroptilum vanum</i>	7.13	7.10	7.20	3
	<i>Cloeon africanum</i>	7.15	7.10	7.20	2
	<i>Diceromyzon sp.</i>	7.15	7.10	7.20	2
	<i>Elassoneuria sp.</i>	7.17	6.90	7.40	3
	<i>Tricorythus 'lowveld'</i>	7.14	6.90	7.40	5
	<i>Pseudocloeon sp.</i>	7.20	7.20	7.20	1
	<i>Baetis quintus</i>	7.20	7.20	7.20	1
	<i>Prosopistoma sp.</i>	7.15	7.10	7.20	2
	<i>Cloeon sp.</i>	7.20	7.20	7.20	1
	<i>Machadorythus sp.</i>	7.20	7.20	7.20	1
	<i>Oligoneuriopsis elizabethae</i>	7.10	7.10	7.10	1
	<i>Euthraulus sp.</i>	7.50	7.50	7.50	1
	<i>Ophelmatostoma sp.</i>	7.50	7.50	7.50	1
	<i>Pseudopannota sp.</i>	7.50	7.50	7.50	1
Lowveld Total		7.18	6.90	7.50	92
Limpopo	Unspecified	7.20	7.20	7.20	5
	<i>Austrocaenis sp.</i>	7.19	7.10	7.20	7
	<i>Centroptilum excisum</i>	7.20	7.20	7.20	1
	<i>Baetis sp.</i>	7.18	7.10	7.20	6
	<i>Baetis bellus</i>	7.20	7.20	7.20	3
	<i>Centroptiloides bifasciatum</i>	7.20	7.20	7.20	3
	<i>Baetis glaucus</i>	7.19	7.10	7.20	7
	<i>Choroterpes sp.</i>	7.19	7.10	7.20	7
	<i>Centroptilum medium</i>	7.20	7.20	7.20	6
	<i>Afronurus sp.</i>	7.19	7.10	7.20	7
	<i>Centroptiloides ?spinulosa</i>	7.20	7.20	7.20	3
	<i>Centroptilum 'near excisum'</i>	7.20	7.20	7.20	4
	<i>Centroptilum flavum</i>	7.17	7.10	7.20	3
	<i>Centroptilum varium</i>	7.20	7.20	7.20	1
	<i>Cloeon africanum</i>	7.20	7.20	7.20	3
	<i>Diceromyzon sp.</i>	7.20	7.20	7.20	2
	<i>Elassoneuria sp.</i>	7.20	7.20	7.20	2
	<i>Tricorythus 'lowveld'</i>	7.18	7.10	7.20	6
	<i>Pseudocloeon sp.</i>	7.19	7.10	7.20	7
Limpopo Total		7.19	7.10	7.20	83

Vaal	Unspecified	7.32	7.10	7.50	10
	<i>Centroptilum excisum</i>	7.39	7.15	7.50	8
	<i>Baetis sp.</i>	7.45	7.30	7.50	4
	<i>Baetis bellus</i>	7.41	7.25	7.50	6
	<i>Neurocaenis discolor</i>	7.40	7.21	7.50	3
	<i>Baetis glaucus</i>	7.33	7.15	7.50	5
	<i>Baetis latus</i>	7.50	7.50	7.50	1
	<i>Centroptilum flavum</i>	7.38	7.38	7.38	1
	<i>Austrocloeon africanum</i>	7.37	7.25	7.50	5
	<i>Cloeon virgiliae</i>	7.15	7.15	7.15	1
	<i>Austrocloeon sp.</i>	7.37	7.25	7.50	5
	<i>Notonurus cooperi</i>	7.36	7.25	7.50	4
Vaal Total		7.37	7.10	7.50	53
Arid Interior	Unspecified	7.40	7.40	7.40	1
	<i>Pseudocloeon vinosum</i>	7.40	7.40	7.40	1
	<i>Baetis latus</i>	7.40	7.40	7.40	1
	<i>Caenis capensis</i>	7.40	7.40	7.40	1
	<i>Caenodes sp.</i>	7.40	7.40	7.40	1
	<i>Centroptilum indusii</i>	7.40	7.40	7.40	1
	<i>Demoulinia complex A</i>	7.40	7.40	7.40	1
Arid Interior Total		7.40	7.40	7.40	7
Orange	Unspecified	7.50	7.50	7.50	2
	<i>Centroptiloides bifasciatum</i>	7.50	7.50	7.50	2
	<i>Baetis glaucus</i>	7.50	7.50	7.50	3
	<i>Choroterpes sp.</i>	7.50	7.50	7.50	1
	<i>Tricorythus sp.</i>	7.50	7.50	7.50	3
Orange Total		7.50	7.50	7.50	11

EPHEMEROPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH > 7.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	8.01	7.52	8.94	16
	<i>Austrocaenis sp.</i>	7.72	7.60	7.80	5
	<i>Baetis sp.</i>	7.80	7.80	7.80	1
	<i>Centroptilum sudafricanum</i>	7.60	7.60	7.60	1
	<i>Acentrella sp.</i>	7.80	7.60	8.00	2
	<i>Baetis bellus</i>	7.72	7.60	7.80	5
	<i>Baetis glaucus</i>	7.70	7.60	7.80	2
	<i>Baetis harrisoni</i>	7.74	7.60	8.00	7
	<i>Baetis latus</i>	7.87	7.60	8.00	3
	<i>Centroptilum excisum</i>	7.84	7.60	8.10	9
	<i>Pseudocloeon maculosum</i>	7.80	7.60	8.00	3
	<i>Pseudocloeon vinosum</i>	7.75	7.60	7.80	4
	<i>Pseudocloeon saxophilum</i>	7.90	7.60	8.10	4
	<i>Acentrella capensis</i>	7.60	7.60	7.60	1
	<i>Adenophlebia peringueyella</i>	7.60	7.60	7.60	1
	<i>Afronurus harrisoni</i>	7.60	7.60	7.60	1
	<i>Apronyx rubicundus</i>	7.60	7.60	7.60	1
	<i>Castanophlebia calida</i>	7.60	7.60	7.60	1
	<i>Cloeon lacunosum</i>	8.16	7.60	8.40	5
	<i>Ephemerellina harrisoni</i>	7.60	7.60	7.60	2
	<i>Lestagella penicillata</i>	7.60	7.60	7.60	1
	<i>Caenis sp.</i>	7.80	7.60	8.00	3
	<i>Centroptilum pulchrum</i>	7.80	7.80	7.80	1
	<i>Tricorythus discolor</i>	7.80	7.80	7.80	1
Fynbos Total		7.83	7.52	8.94	80
Tugela	<i>Austrocaenis sp.</i>	7.89	7.80	8.03	4
	<i>Baetis sp.</i>	7.97	7.90	8.10	3
	<i>Baetis bellus</i>	8.03	8.03	8.03	1
	<i>Baetis harrisoni</i>	8.07	7.92	8.20	3
	<i>Baetis latus</i>	7.97	7.80	8.20	3
	<i>Centroptilum excisum</i>	8.20	8.20	8.20	1
	<i>Pseudocloeon vinosum</i>	8.20	8.20	8.20	1
	<i>Caenis sp.</i>	8.20	8.20	8.20	1

	<i>Austrocloeon virgiliae</i>	7.80	7.80	7.80	1
	<i>Centroptilum sp.</i>	8.20	8.20	8.20	1
	<i>Baetis cataractae</i>	8.10	8.10	8.10	1
Tugela Total		8.02	7.80	8.20	20
St. Lucia Complex	Unspecified	8.21	8.14	8.35	3
	<i>Austrocaenis sp.</i>	8.25	8.25	8.25	1
	<i>Baetis sp.</i>	7.91	7.56	8.25	2
	<i>Afronurus sp.</i>	8.25	8.25	8.25	1
	<i>Baetis latus</i>	8.22	8.15	8.28	2
St. Lucia Complex Total		8.15	7.56	8.35	9
Eastern Seaboard	Unspecified	7.91	7.58	8.23	28
	<i>Austrocaenis sp.</i>	7.87	7.65	8.28	10
	<i>Baetis sp.</i>	8.01	7.80	8.28	7
	<i>Centroptilum medium</i>	7.78	7.70	8.03	4
	<i>Centroptilum sudafricanum</i>	7.74	7.58	8.12	9
	<i>Afronurus sp.</i>	7.84	7.70	8.11	12
	<i>Acentrella natalensis</i>	7.70	7.70	7.70	3
	<i>Adenophlebia aunculata</i>	7.73	7.60	7.93	3
	<i>Baetis bellus</i>	7.89	7.60	8.23	27
	<i>Baetis glaucus</i>	7.91	7.60	8.23	18
	<i>Baetis harrisoni</i>	7.86	7.58	8.28	29
	<i>Baetis latus</i>	7.85	7.60	8.28	24
	<i>Castanophlebia sp.</i>	7.93	7.75	8.11	2
	<i>Centroptiloides bifasciatum</i>	7.85	7.70	8.11	11
	<i>Centroptilum excisum</i>	7.87	7.58	8.23	21
	<i>Centroptilum indusii</i>	7.80	7.58	8.12	8
	<i>Centroptilum varium</i>	7.85	7.70	8.12	7
	<i>Choroterpes elegans</i>	7.89	7.58	8.15	12
	<i>Cloeon africanum</i>	7.98	7.60	8.23	12
	<i>Prosopistoma sp.</i>	7.90	7.70	8.15	9
	<i>Pseudocloeon maculosum</i>	7.89	7.58	8.23	18
	<i>Pseudocloeon vinosum</i>	7.86	7.60	8.15	16
	<i>Tricorythus sp.</i>	7.87	7.58	8.11	11
	<i>Cloeon virgiliae</i>	8.13	8.12	8.15	3
	<i>Neurocaenis discolor</i>	7.70	7.70	7.70	5
	<i>Austrocloeon africanum</i>	7.89	7.70	8.28	3
	<i>Austrocloeon sp.</i>	7.74	7.70	7.82	3
	<i>Adenophlebia sp.</i>	7.72	7.60	7.95	4
	<i>Centroptilum crassi</i>	8.12	8.12	8.12	1
	<i>Notonurus sp.</i>	7.84	7.70	8.12	7
	<i>Pseudocloeon sp.</i>	7.88	7.70	8.06	2
	<i>Castanophlebia calida</i>	7.70	7.70	7.70	1
	<i>Caenis sp.</i>	7.70	7.70	7.70	5
	<i>Baetis quintus</i>	7.70	7.70	7.70	1
	<i>Austrocloeon virgiliae</i>	7.70	7.70	7.70	1
	<i>Centroptilum parvum</i>	7.70	7.70	7.70	1
	<i>Austrocloeon near virgiliae</i>	7.70	7.70	7.70	2
	<i>Centroptilum sp.</i>	7.70	7.70	7.70	5
	<i>Elassoneuria trimeniana</i>	7.70	7.70	7.70	4
	<i>Ephoron savigni</i>	7.70	7.70	7.70	2
	<i>Euthraulius bugandensus</i>	7.70	7.70	7.70	3
	<i>Lithogloea near harrisoni</i>	7.70	7.70	7.70	2
	<i>Oligoneuriopsis lawrenci</i>	7.70	7.70	7.70	2
	<i>Prosopistoma crassi</i>	7.70	7.70	7.70	4
	<i>Neurocaenis reticulata</i>	7.70	7.70	7.70	1
	<i>Pseudocloeon inzingae</i>	7.95	7.95	7.95	1
Eastern Seaboard Total		7.85	7.58	8.28	364
Vaal	Unspecified	8.05	7.58	9.70	34
	<i>Baetis sp.</i>	7.94	7.60	9.05	18
	<i>Centroptilum medium</i>	7.98	7.82	8.10	4
	<i>Afronurus sp.</i>	8.13	7.82	8.60	6
	<i>Baetis bellus</i>	7.99	7.58	9.70	18
	<i>Baetis glaucus</i>	8.26	7.58	8.60	5

	<i>Baetis hamsoni</i>	8.21	7.82	8.60	8
	<i>Baetis latus</i>	8.30	8.20	8.40	2
	<i>Centroptiloides bifasciatum</i>	8.10	8.10	8.10	1
	<i>Centroptilum excisum</i>	7.98	7.58	9.05	28
	<i>Choroterpes elegans</i>	7.99	7.82	8.10	8
	<i>Ephoron sp.</i>	7.94	7.82	8.10	3
	<i>Pseudocloeon maculosum</i>	8.00	7.82	8.10	6
	<i>Pseudocloeon vinosum</i>	8.09	7.82	8.50	7
	<i>Neurocaenis discolor</i>	7.58	7.58	7.58	1
	<i>Austrocloeon africanum</i>	7.86	7.58	8.30	19
	<i>Austrocloeon sp.</i>	7.99	7.60	9.05	19
	<i>Notonurus cooperi</i>	7.84	7.58	8.10	18
	<i>Adenophlebia sp.</i>	8.20	8.20	8.20	1
	<i>Cloeon sp.</i>	7.82	7.82	7.82	1
	<i>Choroterpes sp.</i>	8.40	8.20	8.60	2
	<i>Euthraulus sp.</i>	8.40	8.20	8.60	3
	<i>Centroptilum sp.</i>	8.20	8.20	8.20	1
	<i>Prosopistoma crassi</i>	8.09	8.08	8.10	2
	<i>Neurocaenis sp.</i>	8.20	8.20	8.20	1
	<i>Tricorythus ? discolor</i>	7.91	7.82	8.10	3
Vaal Total		8.00	7.58	9.70	219
Alkaline interior	Unspecified	7.80	7.60	8.00	2
Lowveld	Unspecified	7.88	7.60	8.40	23
	<i>Austrocaenis sp.</i>	7.90	7.60	8.30	8
	<i>Baetis sp.</i>	7.93	7.70	8.10	3
	<i>Centroptilum medium</i>	7.83	7.60	8.10	18
	<i>Afronurus sp.</i>	7.79	7.70	8.00	10
	<i>Baetis bellus</i>	7.90	7.70	8.00	4
	<i>Baetis glaucus</i>	7.82	7.60	8.20	23
	<i>Baetis hamsoni</i>	7.60	7.60	7.60	1
	<i>Castanophlebia sp.</i>	7.70	7.70	7.70	1
	<i>Centroptilum excisum</i>	7.80	7.60	8.00	6
	<i>Cloeon africanum</i>	7.82	7.60	8.10	5
	<i>Pseudocloeon maculosum</i>	7.70	7.70	7.70	1
	<i>Pseudocloeon vinosum</i>	7.95	7.90	8.00	2
	<i>Tricorythus sp.</i>	7.88	7.60	8.40	17
	<i>Notonurus sp.</i>	7.80	7.80	7.80	1
	<i>Cloeon sp.</i>	7.70	7.70	7.70	1
	<i>Centroptilum flavum</i>	7.83	7.60	8.10	15
	<i>Choroterpes sp.</i>	7.88	7.60	8.10	8
	<i>Elassoneuria sp.</i>	7.84	7.70	8.20	13
	<i>Euthraulus sp.</i>	7.86	7.60	8.40	21
	<i>Ophelmatostoma sp.</i>	7.90	7.70	8.10	4
	<i>Povilla adusta</i>	8.00	7.60	8.20	4
	<i>Pseudopannota maculosa</i>	7.60	7.60	7.60	1
	<i>Pseudopannota sp.</i>	7.90	7.70	8.10	3
	<i>Centroptilum 'near excisum'</i>	7.77	7.60	8.00	3
	<i>Tricorythus 'lowveld'</i>	7.84	7.60	8.10	7
	<i>Baetis quintus</i>	8.00	8.00	8.00	1
	<i>Centroptilum sp.</i>	8.30	8.30	8.30	1
	<i>Centroptiloides ? spinulosa</i>	7.90	7.80	8.00	2
	<i>Afrobaetodes beneri</i>	8.00	8.00	8.00	1
Lowveld Total		7.85	7.60	8.40	208
Arid Interior	Unspecified	8.00	8.00	8.00	1
	<i>Afroptilum ?tarsale</i>	8.00	8.00	8.00	1
	<i>Caenodes sp.</i>	8.00	8.00	8.00	1
	<i>Demoulinia complex A</i>	8.00	8.00	8.00	1
Arid Interior Total		8.00	8.00	8.00	4
Drought Corridor	<i>Centroptilum excisum</i>	8.40	8.40	8.40	1
	<i>Cloeon africanum</i>	8.40	8.40	8.40	1
	<i>Cloeon sp.</i>	8.30	8.30	8.30	1
Drought Corridor Total		8.37	8.30	8.40	3

TRICHOPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) ph: 4.5 - 5.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	5.07	4.51	5.50	40
	<i>Agapetus sp.</i>	5.30	4.80	5.50	4
	<i>Athripsodes sp.</i>	5.30	4.70	5.50	6
	<i>Cheumatopsyche sp.</i>	4.93	4.60	5.10	9
	<i>Dolophilodes sp.</i>	5.35	4.90	5.50	4
	<i>Ecnomus sp.</i>	5.05	5.05	5.05	1
	<i>Hydroptila capensis</i>	4.70	4.70	4.70	1
	<i>Orthotrichia barnardi</i>	5.13	4.80	5.50	6
	<i>Parecnomina sp.</i>	5.36	5.05	5.50	8
	<i>Petrothrincus circularis</i>	5.21	4.90	5.50	8
	<i>Trichosetodes sp.</i>	4.75	4.60	5.05	3
	<i>Argyrobothrus velocipes</i>	5.20	4.70	5.40	4
	<i>Athripsodes bergensis</i>	5.35	5.30	5.40	2
	<i>Athripsodes harrisoni</i>	5.35	5.00	5.50	8
	<i>Athripsodes schoenobates</i>	5.40	5.30	5.50	4
	<i>Athripsodes sp. near scramasax</i>	5.21	4.70	5.50	13
	<i>Barbarochthon brunneum</i>	5.17	4.70	5.50	13
	<i>Cheumatopsyche maculata</i>	5.29	4.70	5.50	10
	<i>Chimarra ambulans</i>	5.34	5.00	5.50	7
	<i>Hydroptila sp.</i>	5.40	5.40	5.40	1
	<i>Myspoleo agilis</i>	5.42	5.30	5.50	5
	<i>Oecetis modesta</i>	5.45	5.40	5.50	2
	<i>Petroplax sp.</i>	5.50	5.50	5.50	2
	<i>Protodipseudopsis sp.</i>	5.43	5.30	5.50	4
	<i>Chimarra sp.</i>	5.45	5.40	5.50	2
	<i>Petrothrincus triangularis</i>	5.50	5.50	5.50	1
	<i>Macronema sp.</i>	5.00	5.00	5.00	1
	<i>Orthotrichia sp.</i>	5.00	5.00	5.00	1
Fynbos Total		5.20	4.51	5.50	170
Southern Coastal	<i>Athripsodes sp.</i>	5.00	5.00	5.00	1
	<i>Barbarochthon brunneum</i>	5.00	5.00	5.00	1
	<i>Chimarra sp.</i>	5.00	5.00	5.00	1
	<i>Agapetus agilis</i>	5.00	5.00	5.00	1
	<i>Athripsodes sp. near bergensis</i>	5.00	5.00	5.00	1
Southern Inland	Unspecified	5.10	5.10	5.10	1
	<i>Dyschimus sp.</i>	5.10	5.10	5.10	1
	<i>Polyplectropus sp.</i>	5.10	5.10	5.10	1
	<i>Sciadorus obtusus</i>	5.10	5.10	5.10	1
	<i>Sinion cf. hageni</i>	5.10	5.10	5.10	1

TRICHOPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) ph: 5.5 - 6.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	6.29	5.82	6.50	10
	<i>Argyrobothrus velocipes</i>	6.40	6.30	6.50	3
	<i>Athripsodes harrisoni</i>	6.50	6.50	6.50	2
	<i>Athripsodes sp.</i>	6.37	6.30	6.50	3
	<i>Hydroptila capensis</i>	6.43	6.40	6.50	3
	<i>Cheumatopsyche sp.</i>	6.43	6.30	6.50	6
	<i>Chimmarus sp.</i>	6.30	6.30	6.30	1
	<i>Orthotrichia sp.</i>	6.35	6.30	6.40	2
	<i>Athripsodes (Bergensis Group) sp. B</i>	6.40	6.40	6.40	1
	<i>Cheumatopsyche afra</i>	6.40	6.40	6.40	1
	<i>Cheumatopsyche thomasseti</i>	6.43	6.40	6.50	3
	<i>Chimarra sp.</i>	6.40	6.40	6.40	1
	<i>Ecnomus thomasseti</i>	6.45	6.40	6.50	2
	<i>Oecetis sp.</i>	6.50	6.50	6.50	1
	<i>Oxyethira velocipes</i>	6.40	6.40	6.40	1
Fynbos Total		6.38	5.82	6.50	40
TRICHOPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) ph: 6.5 - 7.5					
BioRegion	Taxon Level	Avg	Min	Max	n

Fynbos	Unspecified	6.88	6.56	7.40	37
	<i>Athripsodes sp.</i>	6.73	6.60	6.80	3
	<i>Cheumatopsyche maculata</i>	6.76	6.60	6.90	9
	<i>Chimarra sp.</i>	6.75	6.60	6.90	2
	<i>Hydroptila sp.</i>	6.96	6.70	7.40	8
	<i>Cheumatopsyche afra</i>	6.99	6.70	7.40	15
	<i>Cheumatopsyche thomasseti</i>	7.03	6.70	7.40	6
	<i>Orthotrichia sp.</i>	7.02	6.70	7.40	13
	<i>Oxyethira sp.</i>	7.02	6.80	7.40	6
	<i>Argyrobothrus velocipes</i>	6.80	6.70	6.90	6
	<i>Athripsodes bergensis</i>	6.60	6.60	6.60	1
	<i>Athripsodes hamsoni</i>	6.73	6.60	6.80	6
	<i>Barbarochthon brunneum</i>	6.70	6.60	6.80	2
	<i>Hydroptila capensis</i>	6.91	6.65	7.20	5
	<i>Myspoleo agilis</i>	6.77	6.60	6.90	7
	<i>Orthotrichia barnardi</i>	6.78	6.60	7.10	3
	<i>Petrothnncus circularis</i>	6.80	6.80	6.80	1
	<i>Protodipseudopsis sp.</i>	6.70	6.60	6.80	2
	<i>Agapetus sp.</i>	6.85	6.60	7.10	2
	<i>Cheumatopsyche sp.</i>	6.88	6.60	7.20	9
	<i>Ecnomus thomasseti</i>	7.00	6.90	7.10	2
	<i>Macrostemum capense</i>	7.00	6.90	7.10	2
	<i>Oxyethira velocipes</i>	6.60	6.60	6.60	1
	<i>Athripsodes (Bergensis group) sp.</i>	6.95	6.80	7.10	2
	<i>Parecnomina resima</i>	7.03	6.80	7.20	3
	<i>Athripsodes (Bergensis Group) sp.</i>	6.90	6.90	6.90	1
	<i>Athripsodes (Bergensis Group) sp.</i>	6.90	6.90	6.90	1
Fynbos Total		6.89	6.56	7.40	155
Southern Inland	Unspecified	6.54	6.54	6.54	1
	<i>Cheumatopsyche maculata</i>	6.70	6.70	6.70	1
	<i>Hydroptila sp.</i>	6.70	6.70	6.70	1
	<i>Macronema sp.</i>	6.70	6.70	6.70	1
	<i>Oxyethira velocipes</i>	6.70	6.70	6.70	1
Southern Inland Total		6.67	6.54	6.70	5
Alkaline interior	Unspecified	7.05	6.60	7.50	20
	<i>Athripsodes sp.</i>	6.60	6.60	6.60	2
	<i>Cheumatopsyche maculata</i>	6.60	6.60	6.60	2
	<i>Chimarra sp.</i>	6.60	6.60	6.60	1
	<i>Hydroptila sp.</i>	7.03	6.60	7.40	9
	<i>Macronema sp.</i>	6.80	6.60	7.00	6
	<i>Cheumatopsyche afra</i>	6.98	6.60	7.50	13
	<i>Cheumatopsyche thomasseti</i>	7.13	6.70	7.50	14
	<i>Orthotrichia sp.</i>	7.10	6.80	7.50	11
	<i>Oxyethira sp.</i>	7.06	6.70	7.50	12
Alkaline interior Total		7.02	6.60	7.50	90
Tugela	Unspecified	7.38	7.38	7.38	1
	<i>Athripsodes sp.</i>	7.35	7.20	7.50	2
	<i>Cheumatopsyche maculata</i>	7.30	7.30	7.30	1
	<i>Hydroptila sp.</i>	7.43	7.43	7.43	1
	<i>Cheumatopsyche afra</i>	7.33	7.14	7.50	7
	<i>Cheumatopsyche thomasseti</i>	7.32	7.14	7.41	8
	<i>Orthotrichia sp.</i>	7.40	7.40	7.40	1
	<i>Oxyethira sp.</i>	7.00	7.00	7.00	1
	<i>Orthotrichia barnardi</i>	7.28	7.28	7.28	1
	<i>Cheumatopsyche sp.</i>	7.29	6.97	7.50	10
	<i>Oecetis sp.</i>	7.20	7.20	7.20	1
	<i>Goerodes sp.</i>	7.20	7.20	7.20	1
	<i>Amphipsyche sp.</i>	7.34	7.14	7.44	6
	<i>Leptocerus hamsoni</i>	7.23	7.19	7.30	3
	<i>Leptocerus sp.</i>	7.23	7.19	7.26	2
	<i>Hydropsyche sp.</i>	7.41	7.38	7.44	2
Tugela Total		7.30	6.97	7.50	48
Eastern Seaboard	Unspecified	7.39	7.30	7.48	2

	<i>Chimarra</i> sp.	7.34	7.30	7.48	5
	<i>Hydroptila</i> sp.	7.23	7.00	7.42	8
	<i>Macronema</i> sp.	7.42	7.42	7.42	1
	<i>Cheumatopsyche afra</i>	7.26	7.00	7.50	14
	<i>Cheumatopsyche thomasseti</i>	7.28	7.10	7.30	8
	<i>Orthotrichia</i> sp.	7.24	7.00	7.30	8
	<i>Oxyethira</i> sp.	7.19	7.00	7.42	6
	<i>Athripsodes bergensis</i>	7.00	7.00	7.00	1
	<i>Athripsodes harrisoni</i>	7.30	7.30	7.30	1
	<i>Ecnomus</i> sp.	7.23	7.00	7.30	8
	<i>Cheumatopsyche</i> sp.	7.44	7.42	7.48	3
	<i>Ecnomus thomasseti</i>	7.43	7.43	7.43	1
	<i>Macrostemum capense</i>	7.50	7.50	7.50	1
	<i>Trichosetodes</i> sp.	7.30	7.30	7.30	1
	<i>Athripsodes prionii</i>	7.26	7.00	7.48	10
	<i>Oecetis</i> sp.	7.34	7.30	7.48	7
	<i>Triaenodes</i> sp.	7.32	7.30	7.42	5
	<i>Hydroptila cruciata</i>	7.23	7.00	7.30	7
	<i>Goerodes</i> sp.	7.42	7.42	7.42	1
	<i>Hydropsyche longifurca</i>	7.27	7.10	7.30	7
	<i>Leptocerus</i> sp.	7.47	7.46	7.48	2
	<i>Goerodes cafrariae</i>	7.30	7.30	7.30	1
	<i>Ithytrichia</i> sp.	7.30	7.30	7.30	2
	<i>Sinion</i> sp.	7.30	7.30	7.30	1
	<i>Macronema natalensis</i>	7.30	7.30	7.30	2
	<i>Pseudoneureclipsis</i> sp.	7.30	7.30	7.30	3
	<i>Dipseudopsis</i> sp.	7.43	7.39	7.46	2
	<i>Ecnomus near kimminsi</i>	7.32	7.32	7.32	1
	<i>Hydropsyche</i> sp.	7.48	7.48	7.48	1
	<i>Anisocentropus</i> sp.	7.43	7.43	7.43	1
	<i>Leptocerina</i> sp.	7.47	7.46	7.48	2
Eastern Seaboard Total		7.29	7.00	7.50	123
Drought Corridor	<i>Cheumatopsyche afra</i>	7.20	7.20	7.20	1
	<i>Cheumatopsyche thomasseti</i>	7.20	7.20	7.20	1
	<i>Hydroptila capensis</i>	7.20	7.20	7.20	1

TRICHOPTERA UPPER REACHES (MOUNTAIN AND FOOTHILL) pH > 7.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	7.80	7.70	7.90	2
	<i>Hydroptila</i> sp.	7.70	7.70	7.70	1
	<i>Cheumatopsyche</i> sp.	8.53	8.53	8.53	1
	<i>Orthotrichia</i> sp.	7.90	7.90	7.90	1
	<i>Cheumatopsyche afra</i>	7.80	7.70	7.90	2
Fynbos Total		7.90	7.70	8.53	7
Eastern Seaboard	Unspecified	7.91	7.80	8.00	3
	<i>Hydroptila</i> sp.	7.72	7.51	8.00	7
	<i>Athripsodes prionii</i>	7.77	7.55	8.00	9
	<i>Catoxyethira</i> sp.	7.91	7.90	7.92	2
	<i>Cheumatopsyche</i> sp.	8.02	7.55	8.90	16
	<i>Chimarra</i> sp.	7.70	7.55	7.80	4
	<i>Ecnomus</i> sp.	7.60	7.60	7.60	1
	<i>Goerodes</i> sp.	7.69	7.55	7.96	4
	<i>Hydropsyche</i> sp.	7.88	7.63	8.00	7
	<i>Oecetis</i> sp.	7.83	7.60	8.00	7
	<i>Orthotrichia</i> sp.	7.82	7.55	8.00	9
	<i>Oxyethira</i> sp.	7.78	7.63	7.90	3
	<i>Polycentropus</i> sp.	7.80	7.80	7.80	1
	<i>Pseudoneureclipsis</i> sp.	7.76	7.60	8.00	4
	<i>Sinion</i> sp.	7.55	7.55	7.55	1
	<i>Triaenodes</i> sp.	7.89	7.80	7.96	3
	<i>Trichosetodes</i> sp.	8.00	8.00	8.00	1
	<i>Cheumatopsyche thomasseti</i>	8.22	7.60	8.90	6
	<i>Leptocerus</i> sp.	7.92	7.92	7.92	1

	<i>Athripsodes sp.</i>	7.80	7.80	7.80	1
	<i>Cheumatopsyche afra</i>	8.18	7.60	8.90	9
	<i>Hydroptila cruciata</i>	7.60	7.60	7.60	1
	<i>Hydropsyche longifurca</i>	7.60	7.60	7.60	1
	<i>Ecnomus thomasseti</i>	8.20	8.00	8.50	3
	<i>Polyplectropus sp.</i>	7.90	7.90	7.90	1
	<i>Orthotrichia barnardi</i>	8.10	8.10	8.10	1
	<i>Macrostemum capense</i>	8.25	8.00	8.90	4
Eastern Seaboard Total		7.91	7.51	8.90	110
Tugela	Unspecified	7.78	7.70	7.93	5
	<i>Hydroptila sp.</i>	8.24	7.62	8.73	14
	<i>Athripsodes prionii</i>	7.80	7.60	8.10	4
	<i>Cheumatopsyche sp.</i>	8.28	7.60	9.20	44
	<i>Ecnomus sp.</i>	7.85	7.60	8.10	2
	<i>Goerodes sp.</i>	7.62	7.62	7.62	1
	<i>Hydropsyche sp.</i>	8.30	7.70	9.20	30
	<i>Oecetis sp.</i>	7.90	7.90	7.90	1
	<i>Orthotrichia sp.</i>	8.00	7.80	8.20	2
	<i>Trienodes sp.</i>	8.20	8.08	8.47	4
	<i>Cheumatopsyche thomasseti</i>	8.09	7.70	8.60	19
	<i>Athripsodes sp.</i>	8.40	8.40	8.40	1
	<i>Cheumatopsyche afra</i>	8.11	7.70	8.60	7
	<i>Hydroptila capensis</i>	7.80	7.70	7.90	2
	<i>Cheumatopsyche indent?</i>	7.80	7.80	7.80	1
	<i>Orthotrichia barnardi</i>	7.70	7.70	7.70	2
	<i>Amphipsyche sp.</i>	7.93	7.70	8.24	8
	<i>Ecnomus oppidanus</i>	7.81	7.81	7.81	1
Tugela Total		8.16	7.60	9.20	148
Alkaline interior	Unspecified	7.93	7.70	8.10	3
	<i>Cheumatopsyche thomasseti</i>	7.85	7.70	8.00	2
Alkaline interior Total		7.90	7.70	8.10	5
Drought Corridor	Unspecified	8.69	8.10	9.60	20
	<i>Hydroptila sp.</i>	8.40	8.40	8.40	1
	<i>Cheumatopsyche sp.</i>	8.20	8.20	8.20	1
	<i>Ecnomus sp.</i>	8.71	8.40	9.10	8
	<i>Cheumatopsyche thomasseti</i>	8.51	7.70	9.60	54
	<i>Cheumatopsyche afra</i>	8.56	7.80	9.60	44
	<i>Ecnomus thomasseti</i>	8.30	8.30	8.30	1
Drought Corridor Total		8.56	7.70	9.60	129
Lowveld	Unspecified	7.70	7.70	7.70	1
	<i>Oecetis sp.</i>	7.70	7.70	7.70	1
	<i>Orthotrichia sp.</i>	7.70	7.70	7.70	1
	<i>Trichosetodes sp.</i>	7.70	7.70	7.70	1
	<i>Cheumatopsyche thomasseti</i>	7.70	7.70	7.70	1
	<i>Hydroptila capensis</i>	7.70	7.70	7.70	1
	<i>Amphipsyche scottae</i>	7.70	7.70	7.70	1
	<i>Catoxyethira pinheyi</i>	7.70	7.70	7.70	1
	<i>Ceraclea sp.</i>	7.70	7.70	7.70	1
Northern Uplands	Unspecified	7.75	7.70	7.80	2
	<i>Macronema sp.</i>	7.90	7.80	8.00	2
	<i>Cheumatopsyche thomasseti</i>	7.83	7.70	8.00	3
	<i>Cheumatopsyche afra</i>	7.90	7.80	8.00	2
	<i>Hydroptila capensis</i>	7.90	7.80	8.00	2
	<i>Cheumatopsyche zuluensis</i>	7.80	7.80	7.80	1
Northern Uplands Total		7.85	7.70	8.00	12
Vaal	<i>Cheumatopsyche thomasseti</i>	8.35	8.30	8.40	4
	<i>Cheumatopsyche afra</i>	8.35	8.30	8.40	4
	<i>Amphipsyche scottae</i>	8.40	8.40	8.40	1
	<i>Macronema capense</i>	8.40	8.40	8.40	1
Vaal Total		8.36	8.30	8.40	10
Southern Inland	<i>Ecnomus sp.</i>	8.50	8.50	8.50	1
	<i>Orthotrichia sp.</i>	8.50	8.50	8.50	1
	<i>Cheumatopsyche zuluensis</i>	8.50	8.50	8.50	1

	<i>Cheumatopsyche maculata</i>	8.50	8.50	8.50	1
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TRICHOPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH: 4.5 - 5.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	5.00	5.00	5.00	1
	<i>Cheumatopsyche</i> sp.	5.00	5.00	5.00	2
	<i>Macronema</i> sp.	5.00	5.00	5.00	1
	<i>Orthotrichia</i> sp.	5.00	5.00	5.00	1
	<i>Petrothrincus circularis</i>	5.00	5.00	5.00	2
Fynbos Total		5.00	5.00	5.00	7
Southern Coastal	<i>Agapetus agilis</i>	5.20	5.20	5.20	1
	<i>Athripsodes</i> sp. near <i>bergensis</i>	5.20	5.20	5.20	1
	<i>Chimarra</i> sp.	5.20	5.20	5.20	1

TRICHOPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH: 5.5 - 6.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	6.29	5.82	6.50	10
	<i>Argyrobothrus velocipes</i>	6.40	6.30	6.50	3
	<i>Athripsodes harrisoni</i>	6.50	6.50	6.50	2
	<i>Athripsodes</i> sp.	6.37	6.30	6.50	3
	<i>Hydroptila capensis</i>	6.43	6.40	6.50	3
	<i>Cheumatopsyche</i> sp.	6.43	6.30	6.50	6
	<i>Chimmarus</i> sp.	6.30	6.30	6.30	1
	<i>Orthotrichia</i> sp.	6.35	6.30	6.40	2
	<i>Athripsodes (Bergensis Group)</i> sp. B	6.40	6.40	6.40	1
	<i>Cheumatopsyche afra</i>	6.40	6.40	6.40	1
	<i>Cheumatopsyche thomasseti</i>	6.43	6.40	6.50	3
	<i>Chimarra</i> sp.	6.40	6.40	6.40	1
	<i>Ecnomus thomasseti</i>	6.45	6.40	6.50	2
	<i>Oecetis</i> sp.	6.50	6.50	6.50	1
	<i>Oxyethira velocipes</i>	6.40	6.40	6.40	1
Fynbos Total		6.38	5.82	6.50	40

TRICHOPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH: 6.5 - 7.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	7.00	6.63	7.50	20
	<i>Athripsodes</i> sp.	6.60	6.60	6.60	1
	<i>Cheumatopsyche maculata</i>	7.10	6.70	7.40	6
	<i>Cheumatopsyche zuluensis</i>	7.15	6.70	7.40	8
	<i>Hydroptila</i> sp.	7.07	6.70	7.40	11
	<i>Argyrobothrus velocipes</i>	7.04	6.70	7.40	18
	<i>Athripsodes harrisoni</i>	7.00	6.60	7.30	10
	<i>Barbarochthon brunneum</i>	7.50	7.50	7.50	1
	<i>Ecnomus</i> sp.	7.40	7.40	7.40	2
	<i>Hydroptila capensis</i>	7.28	6.90	7.40	8
	<i>Cheumatopsyche afra</i>	7.06	6.70	7.40	8
	<i>Cheumatopsyche thomasseti</i>	7.06	6.70	7.40	13
	<i>Orthotrichia</i> sp.	7.03	6.70	7.40	9
	<i>Oxyethira</i> sp.	7.00	6.70	7.40	7
	<i>Athripsodes (Bergensis group)</i> sp.	7.50	7.50	7.50	1
Fynbos Total		7.07	6.60	7.50	123
Eastern Seaboard	Unspecified	7.42	7.42	7.42	1
	<i>Oecetis</i> sp.	7.34	7.15	7.50	7
	<i>Athripsodes</i> sp.	7.29	7.19	7.38	2
	<i>Chimarra</i> sp.	7.29	7.10	7.50	4
	<i>Hydroptila</i> sp.	7.17	7.15	7.19	2
	<i>Ecnomus</i> sp.	7.27	7.15	7.38	2
	<i>Hydroptila capensis</i>	7.12	7.03	7.20	2
	<i>Cheumatopsyche</i> sp.	7.30	7.10	7.50	6
	<i>Cheumatopsyche thomasseti</i>	7.30	7.30	7.30	2
	<i>Orthotrichia</i> sp.	7.39	7.15	7.50	5
	<i>Oxyethira</i> sp.	7.20	7.20	7.20	1
	<i>Goerodes</i> sp.	6.72	6.72	6.72	1

	<i>Leptocerina sp.</i>	7.26	6.72	7.50	5
	<i>Leptonema sp.</i>	6.72	6.72	6.72	1
	<i>Catoxyethira sp</i>	7.15	7.15	7.15	1
	<i>Leptocerus sp.</i>	7.28	7.15	7.41	2
	<i>Hydropsyche sp.</i>	7.41	7.41	7.41	1
	<i>Hydroptila cruciata</i>	7.33	7.30	7.40	3
	<i>Athripsodes prionii</i>	7.35	7.15	7.50	3
	<i>Triaenodes sp.</i>	7.36	7.30	7.41	2
Eastern Seaboard Total		7.28	6.72	7.50	53
Alkaline Interior	<i>Cheumatopsyche maculata</i>	6.60	6.60	6.60	1
	<i>Macronema sp.</i>	6.60	6.60	6.60	1
	<i>Oxyethira velocipes</i>	6.60	6.60	6.60	1
Lowveld	Unspecified	7.14	6.90	7.40	5
	<i>Oecetis sp.</i>	7.23	7.10	7.40	3
	<i>Athripsodes sp.</i>	7.15	7.10	7.20	2
	<i>Chimarra sp</i>	7.15	6.90	7.40	4
	<i>Hydroptila sp.</i>	7.20	7.20	7.20	1
	<i>Ecnomus sp.</i>	7.22	6.90	7.50	5
	<i>Hydroptila capensis</i>	7.20	7.10	7.40	4
	<i>Orthotrichia barnardi</i>	7.20	7.10	7.40	4
	<i>Amphipsyche scottae</i>	7.33	7.10	7.50	3
	<i>Cheumatopsyche afra</i>	7.15	7.10	7.20	2
	<i>Cheumatopsyche thomasseti</i>	7.20	6.90	7.50	6
	<i>Orthotrichia sp.</i>	7.50	7.50	7.50	1
	<i>Psychomyiellodes sp.</i>	7.20	7.20	7.20	1
	<i>Catoxyethira sp.</i>	7.15	6.90	7.40	4
	<i>Leptocerus inflatus</i>	7.10	7.10	7.10	1
	<i>Trichosetodes sp.</i>	7.14	6.90	7.40	5
	<i>Barbarochthon sp.</i>	7.20	7.20	7.20	1
	<i>Aethaloptera sp.</i>	7.30	7.20	7.40	2
	<i>Dyschimus sp.</i>	7.20	7.20	7.20	1
	<i>Leptocerus ?schoenobates</i>	7.30	7.20	7.40	2
Lowveld Total		7.20	6.90	7.50	57
Limpopo	Unspecified	7.19	7.10	7.20	7
	<i>Oecetis sp.</i>	7.20	7.20	7.20	4
	<i>Chimarra sp.</i>	7.19	7.10	7.20	7
	<i>Ecnomus sp.</i>	7.18	7.10	7.20	6
	<i>Hydroptila capensis</i>	7.20	7.20	7.20	6
	<i>Orthotrichia barnardi</i>	7.19	7.10	7.20	7
	<i>Amphipsyche scottae</i>	7.18	7.10	7.20	6
	<i>Cheumatopsyche afra</i>	7.15	7.10	7.20	2
	<i>Cheumatopsyche thomasseti</i>	7.19	7.10	7.20	7
	<i>Catoxyethira sp.</i>	7.20	7.20	7.20	3
	<i>Leptocerus inflatus</i>	7.20	7.20	7.20	5
	<i>Trichosetodes sp.</i>	7.20	7.20	7.20	6
	<i>Barbarochthon sp.</i>	7.17	7.10	7.20	3
	<i>Aethaloptera sp.</i>	7.20	7.20	7.20	1
Limpopo Total		7.19	7.10	7.20	70
Vaal	<i>Ecnomus sp.</i>	7.38	7.38	7.38	1
	<i>Cheumatopsyche afra</i>	7.25	7.21	7.29	2
	<i>Cheumatopsyche thomasseti</i>	7.27	7.10	7.50	5
	<i>Orthotrichia sp.</i>	7.25	7.10	7.40	3
	<i>Leptocerus inflatus</i>	7.28	7.25	7.30	2
Vaal Total		7.27	7.10	7.50	13
Arid Interior	Unspecified	7.40	7.40	7.40	1
	<i>Hydroptila capensis</i>	7.40	7.40	7.40	1
	<i>Orthotrichia barnardi</i>	7.40	7.40	7.40	1
	<i>Amphipsyche scottae</i>	7.40	7.40	7.40	1
	<i>Cheumatopsyche afra</i>	7.40	7.40	7.40	1
	<i>Cheumatopsyche sp</i>	7.40	7.40	7.40	1
	<i>Cheumatopsyche thomasseti</i>	7.40	7.40	7.40	1
	<i>Ecnomus thomasseti</i>	7.40	7.40	7.40	1
Orange	Unspecified	7.50	7.50	7.50	2

	<i>Amphipsyche scottae</i>	7.50	7.50	7.50	3
	<i>Ceraclea sp.</i>	7.50	7.50	7.50	1
	<i>Cheumatopsyche thomasseti</i>	7.50	7.50	7.50	2
	<i>Ecnomus thomasseti</i>	7.50	7.50	7.50	1
	<i>Orthotrichia sp.</i>	7.50	7.50	7.50	2

TRICHOPTERA LOWER REACHES (TRANSITIONAL AND LOWLAND) pH > 7.5					
BioRegion	Taxon Level	Avg	Min	Max	n
Fynbos	Unspecified	7.90	7.52	8.45	8
	<i>Hydroptila sp.</i>	7.80	7.60	8.00	2
	<i>Orthotrichia sp.</i>	7.80	7.60	8.00	2
	<i>Cheumatopsyche thomasseti</i>	7.90	7.60	8.10	3
	<i>Argyrobothrus velocipes</i>	7.80	7.80	7.80	2
	<i>Cheumatopsyche zuluensis</i>	7.80	7.80	7.80	1
Fynbos Total		7.86	7.52	8.45	18
St. Lucia Complex	Unspecified	8.25	8.25	8.25	1
Eastern Seaboard	Unspecified	7.87	7.58	8.12	8
	<i>Athripsoides "pseudoleptocerus"</i>	8.09	8.06	8.12	2
	<i>Catoxyethira sp.</i>	7.91	7.75	8.06	4
	<i>Cheumatopsyche sp.</i>	7.91	7.58	8.23	21
	<i>Chimarra sp.</i>	7.82	7.58	8.12	8
	<i>Dipseudopsis sp.</i>	7.58	7.58	7.58	1
	<i>Ecnomus sp.</i>	7.91	7.70	8.12	2
	<i>Ecnomus thomasseti</i>	8.02	7.82	8.12	3
	<i>Goerodes sp.</i>	7.98	7.98	7.98	1
	<i>Hydropsyche sp.</i>	7.90	7.75	8.06	7
	<i>Hydroptila sp.</i>	7.89	7.69	8.12	12
	<i>Leptonema sp.</i>	7.65	7.65	7.65	1
	<i>Macronema sp.</i>	8.02	7.93	8.11	2
	<i>Oecetis sp.</i>	7.86	7.60	8.12	15
	<i>Orthotrichia sp.</i>	7.82	7.70	8.12	8
	<i>Oxyethira sp.</i>	7.75	7.70	7.80	2
	<i>Pseudoneureclipsis sp.</i>	7.98	7.90	8.06	2
	<i>Trichosetodes sp.</i>	7.97	7.78	8.12	4
	<i>Cheumatopsyche thomasseti</i>	7.70	7.70	7.70	5
	<i>Cheumatopsyche afra</i>	7.77	7.70	8.03	5
	<i>Athripsodes prionii</i>	7.88	7.60	8.12	13
	<i>Athripsodes sp.</i>	7.93	7.70	8.12	5
	<i>Leptocerus sp.</i>	7.75	7.69	7.80	3
	<i>Parasetodes sp.</i>	8.12	8.12	8.12	1
	<i>Triaenodes sp.</i>	7.92	7.69	8.23	9
	<i>Hydroptila capensis</i>	7.82	7.82	7.82	1
	<i>Hydroptila cruciata</i>	7.70	7.70	7.70	5
	<i>Hydropsyche longifurca</i>	7.70	7.70	7.70	4
	<i>Macronema natalensis</i>	7.70	7.70	7.70	2
	<i>Cheumatopsyche triangularis</i>	7.70	7.70	7.70	1
	<i>Leptocerina sp.</i>	7.82	7.82	7.82	1
Eastern Seaboard Total		7.86	7.58	8.23	158
Vaal	Unspecified	8.10	8.10	8.10	1
	<i>Cheumatopsyche sp.</i>	8.10	8.10	8.10	2
	<i>Ecnomus sp.</i>	8.06	8.00	8.10	3
	<i>Hydropsyche sp.</i>	7.95	7.82	8.08	2
	<i>Orthotrichia sp.</i>	7.92	7.58	8.60	14
	<i>Cheumatopsyche thomasseti</i>	8.19	7.80	9.05	16
	<i>Leptocerus inflatus</i>	7.74	7.58	7.90	9
	<i>Cheumatopsyche afra</i>	8.13	7.80	8.50	8
	<i>Aethaloptera maxima</i>	7.86	7.82	7.90	2
	<i>Amphipsyche scottae</i>	8.10	7.82	8.60	11
	<i>Hydroptila cruciata</i>	8.08	7.82	8.40	5
	<i>Macronema capense</i>	8.15	7.82	8.60	8
	<i>Triaenodes falcata</i>	7.86	7.82	7.90	2
	<i>Trichosetodes semibrunea</i>	8.00	7.82	8.10	3
Vaal Total		8.04	7.58	9.05	86

Alkaline interior	Unspecified	7.60	7.60	7.60	1
	<i>Hydroptila sp.</i>	7.60	7.60	7.60	1
	<i>Orthotrichia sp.</i>	7.60	7.60	7.60	1
	<i>Cheumatopsyche thomasseti</i>	7.60	7.60	7.60	1
Alkaline interior Total		7.60	7.60	7.60	4
Lowveld	Unspecified	7.81	7.60	8.10	9
	<i>Catoxyethira sp.</i>	7.73	7.60	8.00	4
	<i>Chimarra sp.</i>	8.03	8.00	8.10	3
	<i>Ecnomus sp.</i>	7.82	7.60	8.10	10
	<i>Hydroptila sp.</i>	7.85	7.70	8.00	2
	<i>Oecetis sp.</i>	7.77	7.70	8.00	9
	<i>Orthotrichia sp.</i>	7.84	7.60	8.20	15
	<i>Trichosetodes sp.</i>	7.83	7.60	8.40	11
	<i>Cheumatopsyche thomasseti</i>	7.85	7.60	8.40	28
	<i>Cheumatopsyche afra</i>	8.00	8.00	8.00	1
	<i>Athripsodes sp.</i>	7.70	7.70	7.70	1
	<i>Leptocerus sp.</i>	7.75	7.70	7.80	2
	<i>Triaenodes sp.</i>	7.77	7.70	7.80	3
	<i>Hydroptila capensis</i>	7.84	7.70	8.00	8
	<i>Aethaloptera maxima</i>	7.93	7.70	8.40	10
	<i>Amphipsyche scottae</i>	7.83	7.60	8.40	23
	<i>Catoxyethira pinheyi</i>	7.85	7.60	8.20	12
	<i>Macrostemum sp.</i>	7.70	7.70	7.70	1
	<i>Aethaloptera sp.</i>	7.90	7.70	8.10	3
	<i>Leptocerus ?schoenobates</i>	7.70	7.70	7.70	1
	<i>Orthotrichia barnardi</i>	7.80	7.60	8.10	5
	<i>Ceraclea sp.</i>	7.88	7.80	8.10	4
Lowveld Total		7.84	7.60	8.40	165
Tugela	<i>Cheumatopsyche sp.</i>	8.01	7.92	8.10	2
	<i>Oecetis sp.</i>	7.93	7.80	8.10	4
	<i>Hydroptila capensis</i>	8.20	8.20	8.20	1
Tugela Total		7.99	7.80	8.20	7
Arid Interior	Unspecified	8.00	8.00	8.00	1
	<i>Hydroptila capensis</i>	8.00	8.00	8.00	1
	<i>Orthotrichia barnardi</i>	8.00	8.00	8.00	1

Appendix B: Classification of ephemeropteran taxa into acidic (A*), alkaline (A), pH-insensitive (I) species. The ? was given to taxa which were not included in the BCD or for which there was uncertainty. HAR, BCD and EEK indicate whether the taxon was included by Harrison & Agnew (1962), studies in the BCD and Eekhout *et al.* (1997) respectively. A Y/N means that some of the listed taxa were included while others were not. The n stands for the number of individuals of that taxon that were collected throughout BCD studies. Ave pH, MIN and MAX indicate the average, minimum and maximum pH at which the taxon was found in BCD studies. Alkaline pH indicates that the taxa were found at pH>7.5. Distribution shows the distribution of the organisms by the BCD and Eekhout *et al.* (1997). Unspecified spp indicates that the organism was only identified to generic level. East of country means that the species was found from the Eastern Seaboard bioregion north-eastwards. Widespread distribution indicates that the species occurred in the south-western Cape as well as in the north-eastern bioregions. AI= Alkaline Interior; Ar= Arid Interior; DC= Drought Corridor; ES= Eastern Seaboard; F= Fynbos; HS= Highveld Source; Li= Limpopo; L= Lowveld; M= Montane; NP= Northern Plateau; NU= Northern Uplands; O= Orange; SC= Southern Coastal; SI= Southern Inland; St= St. Lucia; T= Tugela; V= Vaal.

TAXON	HAR	BCD	EEK	n	Ave pH	MIN	MAX	Distribution	Type
<i>Acentrella capensis</i>	Y	Y	Y	98	6.153	4.70	7.60	Eekhout: widespread; BCD: F	A*
<i>Acentrella cf. capensis</i>	N	Y	N	1	6.600	6.60	6.60	BCD: AI, SC	?
<i>Acentrella sp.</i>		Y		45	6.928	5.35	8.00	Unspecified spp; BCD: F, ES, L	I
<i>Adenophlebia auriculata</i>	N	Y	Y	15	7.379	6.00	8.00	Eekhout: widespread; BCD: F, ES, T, NU	?
<i>Adenophlebia peringueyella</i>	Y	Y	Y	13	6.800	5.40	8.50	Eekhout: widespread; BCD: F, SC, SI, AI	I
<i>Adenophlebia sp.</i>		Y		28	7.476	5.65	8.60	Unspecified spp; BCD: F, ES, L, V	I
<i>Adenophlebia sylvatica</i>	N	Y	Y	3	7.200	7.000	7.300	Eekhout: east of country; BCD: ES, T	A
<i>Adenophlebiodes bicolor</i>		N	Y					Eekhout: ES, L	?
<i>Adenophlebiodes sp.</i>	N	Y	Y	4	6.875	6.30	7.20	Unspecified spp; BCD: F, L	?
<i>Afrobaetodes beneri</i>	N	Y	Y	4	7.300	6.90	8.00	Eekhout: L, NU, Li; BCD: L	?
<i>Afrobaetodes delicatissimus</i>	N	N	Y					Eekhout: F	?
<i>Afronurus barnardi</i>	N	N	Y					Eekhout: widespread	?
<i>Afronurus harrisoni</i>	Y	Y	Y	65	6.443	4.70	8.60	Eekhout, BCD: widespread	I
<i>Afronurus sp.</i>		Y		100	7.781	6.70	9.20	Unspecified spp; BCD: widespread	I
<i>Afroptilum excisum</i>	N	N	Y					Eekhout: widespread	?
<i>Afroptilum falcatum, flavum, indusii, medium, parvum,</i>	N	N	Y					Eekhout: east of country	?
<i>Afroptilum sp.</i>		Y		6	6.383	6.00	6.90	Unspecified spp; BCD: F, O	A*
<i>Afroptilum sudafricanum</i>	N	N	Y					Eekhout: widespread	?
<i>Aprionyx complex A</i>	N	Y	N	1	6.000	6.00	6.00	BCD: F	A*
<i>Aprionyx intermedius</i>	Y	Y	Y	21	5.810	4.70	7.50	Eekhout: SI & SC too; BCD: F	A*
<i>Aprionyx pellucidulus</i>	Y	N	Y					Eekhout: F	A*
<i>Aprionyx peterseni</i>	Y	Y	Y	34	5.856	4.70	7.20	Eekhout: AI, SI & SC too; BCD: F, SI, SC	A*
<i>Aprionyx rubicundus</i>	Y	Y	Y	21	6.135	5.00	7.60	Eekhout: F; BCD: F	A*
<i>Aprionyx sp.</i>		Y		4	5.815	4.62	6.99	Unspecified spp; BCD: F, ES	A*
<i>Aprionyx tabularis</i>	Y	Y	Y	16	5.981	5.30	6.80	Eekhout: F; BCD: F	A*
<i>Aprionyx tricuspoidatus</i>	N	Y	Y	2	7.150	7.00	7.30	Eekhout: ES, T; BCD: ES	A
<i>Austrocaenis capensis</i>	N	Y	N	21	8.000	6.300	9.100	BCD: F, T, DC	A
<i>Austrocaenis sp.</i>		Y		142	7.186	5.30	8.40	Unspecified spp; BCD: widespread	I
<i>Austrocloeon africanum</i>	Y	Y	N	38	7.679	5.20	8.40	BCD: widespread, not in F	I
<i>Austrocloeon virgiliae</i>	Y	Y	N	28	7.192	6.30	7.90	BCD: widespread	I
<i>Baetis bellus</i>	Y	Y	Y	377	7.449	5.00	9.70	Eekhout, BCD: widespread	I
<i>Baetis glaucus</i>	Y	Y	Y	192	7.815	6.30	9.60	Eekhout, BCD: widespread	I
<i>Baetis harrisoni</i>	Y	Y	Y	437	7.326	2.90	9.60	Eekhout, BCD: widespread	I
<i>Baetis latus</i>	Y	Y	Y	233	7.727	6.10	9.60	Eekhout, BCD: widespread	I
<i>Baetis sp.</i>		Y		176	7.018	4.00	9.20	Unspecified spp; BCD: widespread	I
<i>Caenis capensis</i>	N	Y	Y	6	6.550	6.00	7.40	Eekhout: widespread; BCD: F, NU, O	A*
<i>Caenis sp.</i>		Y		73	7.290	5.30	8.90	Unspecified spp; BCD: F, ES, T	I
<i>Caenodes sp.</i>		Y		6	6.800	6.00	8.00	Only in BCD: F, O, AR	?

<i>Castanophebia albicauda</i>	Y	N	Y					Eekhout: F	?
<i>Castanophebia calida</i>	Y	Y	Y	89	5.905	4.00	7.70	Eekhout, BCD: widespread	A*
<i>Castanophebia sp.</i>		Y		19	7.023	4.96	8.11	Unspecified spp; BCD: F, ES, L	I
<i>Centroptiloides bifasciatum</i>	Y	Y	Y	34	7.565	6.70	8.11	Eekhout, BCD: widespread; not in F	A
<i>Centroptiloides sp.</i>		Y		5	7.586	6.50	8.24	Unspecified spp; BCD: F, L, T	I
<i>Centroptilum crassi</i>	N	Y	N	10	7.167	6.70	8.12	BCD: F, ES	I
<i>Centroptilum excisum</i>	Y	Y	N	401	7.546	4.70	9.20	BCD: widespread	I
<i>Centroptilum flavum</i>	N	Y	N	26	7.586	6.900	8.100	BCD: east of country	A
<i>Centroptilum indusii</i>	Y	Y	N	22	7.461	6.10	8.50	BCD: F, ES, SI, AR	?
<i>Centroptilum medium</i>	N	Y	N	58	7.619	6.90	8.10	BCD: east of country	A
<i>Centroptilum parvum</i>	N	Y	N	13	7.715	7.300	8.600	BCD: ES, T, V	A
<i>Centroptilum pulchrum</i>	Y	Y	N	17	7.209	6.30	8.50	BCD: widespread	?
<i>Centroptilum sp.</i>		Y		40	6.697	4.80	8.60	Unspecified spp; BCD: widespread	I
<i>Centroptilum sudafricanum</i>	Y	Y	N	116	7.316	4.80	8.60	BCD: widespread	I
<i>Centroptilum varium</i>	Y	Y	N	22	7.478	7.10	8.12	BCD: F, ES, L, Li	A
<i>Choroerpes elegans</i>	N	Y	N	100	7.561	5.30	8.60	BCD: widespread	I
<i>Choroerpes nigrescens</i>	Y	Y	Y	21	5.919	5.00	8.50	Eekhout: F, ES, SC; BCD: F, ES, SC	I
<i>Choroerpes sp.</i>		Y		97	7.845	4.96	9.20	Unspecified spp; BCD: widespread	I
<i>Cleodes saxophilus</i>	N	N	Y					Eekhout: F, SC	?
<i>Cloeon africanum</i>	N	Y	Y	53	7.716	6.00	9.10	Eekhout, BCD: widespread	I
<i>Cloeon agnewi, crassi, elevatum, rhodesiae</i>	N	Y/N	Y				Alkaline pH	Eekhout, BCD: east of country	?
<i>Cloeon lacunosum</i>	Y	Y	Y	8	7.881	7.35	8.40	Eekhout: F, SC; BCD: F	A
<i>Demoulinia complex A</i>	N	Y	N	8	6.713	6.00	8.00	BCD: AR, F	?
<i>Demoulinia crassi</i>	N	Y	Y	3	6.467	6.10	6.90	Eekhout: widespread; BCD: F	A*
<i>Ephemerellina barnardi</i>	Y	Y	Y	7	6.257	5.50	7.10	Eekhout: AI too; BCD: F	A*
<i>Ephemerellina brincki</i>	N	N	Y					Eekhout: F	?
<i>Ephemerellina complex A</i>	N	Y	N	1	6.100	6.10	6.10	BCD: F	A*
<i>Ephemerellina crassi</i>	N	N	Y					Eekhout: F	?
<i>Ephemerellina harrisoni</i>	N	Y	N	8	6.888	5.00	7.60	BCD: F	A*
<i>Ephemerellina penicillata</i>	N	Y	N	3	5.000	5.00	5.00	BCD: F	A*
<i>Ephemerellina sp.</i>		Y		7	6.351	4.96	6.99	Unspecified spp; BCD: F	A*
<i>Euthraulus elegans</i>	Y	N	N						?
<i>Euthraulus sp.</i>		Y	Y	29	7.945	7.50	8.60	Unspecified spp; BCD: F, L	A
<i>Lestagella penicillata</i>	N	Y	Y	39	5.819	4.00	7.60	Eekhout: F, SC, SI & AI; BCD: F	A*
<i>Lestagella sp.</i>		Y		7	6.117	4.96	6.99	Unspecified spp; BCD: F	A*
<i>Lithogloea harrisoni</i>	Y	Y	Y	49	5.857	4.00	6.90	Eekhout: SC, DC, F; BCD: F, SC	A*
<i>Lithogloea near harrisoni</i>	N	Y	N	4	7.575	7.30	7.70	BCD: ES	A
<i>Lithogloea pennicillata</i>	Y	Y	N	50	5.974	4.70	6.80	BCD: F, SC, AI	A*
<i>Lithogloea sp.</i>		Y		13	5.838	5.30	6.30	Unspecified spp; BCD: F & SC	A*
<i>Neurocaenis discolor</i>	Y	Y	N	24	7.420	6.60	8.00	BCD: widespread	A
<i>Neurocaenis reticulata</i>	N	Y	N	43	8.335	7.30	9.60	BCD: ES, T, DC	A
<i>Notonorus, Diceromyzon, Ellassoneuria, Oligoneuriopsis, Prosopistoma, Ephoron, Machadorythus, Oligoneuriopsis, Eatonica, Opheimatosoma, Povilla spp</i>			Y	Y			Alkaline pH	Eekhout, BCD: east of country	A
<i>Pseudocleon magae</i>	N	N	Y					Eekhout: F	?
<i>Pseudocleon inzingae</i>	N	Y	N	6	7.697	7.30	8.00	BCD: ES, T	A
<i>Pseudocleon maculosum</i>	N	Y	N	95	7.389	6.10	8.50	BCD: widespread	?
<i>Pseudocleon saxophilum</i>	N	Y	N	34	7.047	6.00	8.10	BCD: F	?
<i>Pseudocleon sp.</i>		Y		26	6.271	4.70	8.06	Unspecified spp; BCD: widespread	I
<i>Pseudocleon vinosum</i>	Y	Y	Y	250	7.160	4.70	9.20	Eekhout, BCD: widespread	I
<i>Pseudopannota maculosa</i>	N	Y	Y	5	6.680	6.10	7.60	Eekhout: widespread; BCD: L, F	A*
<i>Rhithrocleon sp.</i>	N	Y	N	3	6.367	6.30	6.50	BCD: F	A*
<i>Tricorythus discolor</i>	N	Y	Y	23	6.639	5.00	7.80	Eekhout: widespread; BCD: F, NU, O	A*
<i>Tricorythus 'lowveld'</i>	N	Y	N	18	7.428	6.90	8.10	BCD: L, Li	?
<i>Tricorythus reticulatus</i>	N	N	Y					Eekhout: east of country	?

Please note: the following taxa names have been changed: *Centroptilum varium* = *Acanthiops varius*; *Centroptilum parvum* = *Afroptilum parvum*; *Centroptilum sudafricanum* = *Afroptilum sudafricanum*; *Centroptiloides bifasciatum* and *Centroptilum bifasciata* = *Centroptiloides bifasciata*; *Centroptilum excisum* = *Cheleocloeon excisum*; *Pseudocloeon inzingae* and *Pseudocloeon saxophilum* = *Cloeodes inzingae*; *Austrocloeon virgiliae* = *Cloeon virgiliae*; *Centroptilum flavum* = *Crassbwa flava*; *Centroptilum indusii* = *Dabulamanzia indusii*; *Centroptilum medium* = *Dabulamanzia media*; *Afroptilum tarsale* = *Dabulamanzia tarsale*; *Acentrella capensis* = *Demoreptus capensis*; *Acentrella monticola* = *Demoreptus monticola*; *Acentrella natalensis* = *Demoreptus natalensis*; *Centroptilum pulchrum* = *Demoulinia crassi*; *Centroptiloides spinulosa* = *Dicentroptilum spinulosum*; *Cloeon africanum* and *Austrocloeon africanum* = *Procloeon africanum*; *Baetis bellus* = *Pseudocloeon bellum*; *Baetis cataractae* = *Pseudocloeon cataractae*; *Baetis glaucus* and *Baetis quintus* = *Pseudocloeon glaucum*; *Baetis latus* = *Pseudocloeon latum*; *Pseudocloeon maculosum* = *Pseudopannota maculosa*; *Notonurus cooperi* = *Componeuriella bequaerti*; *Neurocaenis discolor* = *Tricorythus discolor*; *Neurocaenis reticulata* = *Tricorythus reticulatus*; *Lithogloea penicillata* = *Lestagella penicillata*; *Ephemerellina harrisoni* = *Lithogloea harrisoni*; *Austrocaenis capensis* = *Caenis capensis*; *Eatonica schoutedeni* = *Ephemera mooiana*; *Choroterpes elegans* = *Euthraulus elegans* From <http://www.ru.ac.za/academic/departments/zooento/Martin/ephemeropteraAfrica.html>

Appendix C: Classification of trichopteran taxa into acidic (A*), alkaline (A), pH-insensitive (I) species. The ? was given to taxa which were not included in the BCD or for which there was uncertainty. HAR, BCD and EEK indicate whether the taxon was included by Harrison & Agnew (1962), studies in the BCD and Eekhout *et al.* (1997) respectively. A Y/N means that some of the listed taxa were included while others were not. The n stands for the number of individuals of that taxon that were collected throughout BCD studies. Ave pH, MIN and MAX indicate the average, minimum and maximum pH at which the taxon was found in BCD studies. Alkaline pH indicates that the taxa were found at pH>7.5. Distribution shows the distribution of the organisms by the BCD and Eekhout *et al.* (1997). Unspecified spp indicates that the organism was only identified to generic level. East of country means that the species was found from the Eastern Seaboard bioregion north-eastwards. Widespread distribution indicates that the species occurred in the south-western Cape as well as in the north-eastern bioregions. AI= Alkaline Interior; Ar= Arid Interior; DC= Drought Corridor; ES= Eastern Seaboard; F= Fynbos; HS= Highveld Source; Li= Limpopo; L= Lowveld; M= Montane; NP= Northern Plateau; NU= Northern Uplands; O= Orange; SC= Southern Coastal; SI= Southern Inland; St= St. Lucia; T= Tugela; V= Vaal.

TAXON	HAR	BCD	EEK	n	AVE pH	MIN	MAX	Comments	Type
<i>Abaria sp.</i>		Y		1	6.1	6.1	6.1	Unspecified spp; BCD: F	A*
<i>Adicella sp.</i>	N	Y	Y	6	6.333	6.2	6.5	Eekhout: F; BCD: F, NU	A*
<i>Aethaloptera maxima</i>		Y	Y	12	7.9183	7.7	8.4	Eekhout: V, O, L, HS, T; BCD: L, V, O	A
<i>Aethaloptera sp.</i>		Y		6	7.5833	7.2	8.1	Unspecified spp; BCD: L, Li	A
<i>Agapetus agilis</i>	Y	Y	Y	3	5.367	5	5.9	Eekhout: F; BCD: SC	A*
<i>Agapetus murinus</i>	Y	N	Y					Eekhout: F	?
<i>Agapetus sp.</i>		Y		22	5.835	4	7.1	Unspecified spp; BCD: F	A*
<i>Amphipsyche scottae</i>		Y	Y	49	7.7637	7.1	8.6	Eekhout: widespread; BCD: L, Li, V, Ar, O	A
<i>Amphipsyche sp.</i>		Y		14	7.6764	7.14	8.24	Unspecified spp; BCD: NU, T	A
<i>Anisocentropus sp.</i>		Y		1	7.43	7.43	7.43	Unspecified spp; BCD: ES	A
<i>Argyrothrus sp.</i>		Y		2	2.9	2.9	2.9	Unspecified spp; BCD: HS, V	?
<i>Argyrothrus velocipes</i>	N	Y	N	39	6.667	4.7	7.8	Only in BCD: F	A*
<i>Arthripsodes bergensis</i>	Y	N	Y					Eekhout: F	?
<i>Arthripsodes bibulus</i>	Y	N	Y					Eekhout: F	?
<i>Arthripsodes caricaria</i>	Y	N	Y					Eekhout: F	?
<i>dieselii, elaphus, longistylis,</i>	Y	N	Y					Eekhout: F	?
<i>Arthripsodes corniculans</i>	N	N	Y					Eekhout: F	?
<i>Arthripsodes elaphas,</i>	N	N	Y					Eekhout: F	?
<i>Arthripsodes fissus</i>	N	N	Y					Eekhout: V, F, T	?
<i>Arthripsodes harrisoni</i>	N	N	Y					Eekhout: V, F, T	?
<i>Arthripsodes stephanus</i>	Y	N	Y					Eekhout: F, SC	?
<i>Aselas camella</i>	Y	N	Y					Eekhout: F	?
<i>Athripsodes (Berg Grp) sp. A</i>		Y		4	6.375	6	6.9	Unspecified spp; BCD: F	A*
<i>Athripsodes (Berg Grp) sp. B</i>		Y		3	6.467	6.1	6.9	Unspecified spp; BCD: F	A*
<i>Athripsodes (Berg Grp) sp. C</i>		Y		1	6.100	6.1	6.1	Unspecified spp; BCD: F	A*
<i>Athripsodes (Berg Grp) sp. D</i>		Y		1	6.100	6.1	6.1	Unspecified spp; BCD: F	A*
<i>Athripsodes (Harr Grp) sp. A</i>		Y		2	6.050	6	6.1	Unspecified spp; BCD: F	A*
<i>Athripsodes prionii</i>	Y	Y	Y	39	7.648	7	8.12	Eekhout: St, T, F; BCD: ES, T	A
<i>Athripsoides "pseudoleptocerus"</i>	N	Y	N	2	8.090	8.06	8.12	BCD: ES	A
<i>Barbarochthon sp.</i>		Y		4	7.175	7.1	7.2	BCD: L, Li	A
<i>Barbarochthon brunneum</i>	Y	Y	Y	33	5.750	4.7	7.5	Eekhout: F, ES, AI, SC; BCD: F, SC	A*
<i>Catoxyethira pinheyi</i>		Y	N	13	7.8385	7.6	8.2	BCD: L	A
<i>Catoxyethira sp.</i>		Y		18	7.5394	6.9	8.06	Unspecified spp; BCD: ES, L, Li	A
<i>Ceraclea cuprea</i>	N	N	Y					Eekhout: F	?
<i>Ceraclea schoutedeni</i>	N	N	Y					Eekhout: V	?
<i>Ceraclea sp.</i>	N	Y	Y	7	7.543	6.1	8.1	Unspecified spp; BCD: F, L, O	?
<i>Cheimacheramus caudalis</i>	Y	N	Y					Eekhout: F	?
<i>Cheumatopsyche afra</i>		Y	Y	164	7.6382	5.9	9.6	Eekhout, BCD: widespread	I
<i>Cheumatopsyche indent?</i>		Y	N	1	7.8	7.8	7.8	BCD: T	A
<i>Cheumatopsyche maculata</i>	N	Y	Y	58	6.295	4.7	8.5	Eekhout: SI, SC, F; BCD: widespread	I
<i>Cheumatopsyche sp.</i>		Y	Y	144	7.453	3.8	9.2	Unspecified spp; Eekhout, BCD: widespread	I

<i>Cheumatopsyche thomasseti</i>	Y	Y	Y	225	7.784	5.9	9.6	Eekhout, BCD: widespread	I
<i>Cheumatopsyche triangularis</i>		Y	Y	1	7.7	7.7	7.7	Eekhout: T, NP, Li; BCD: ES	A
<i>Cheumatopsyche zuluensis</i>		Y	N	12	7.2667	5.9	8.5	BCD: F, NU, SI, SC	I
<i>Chimarra ambulans</i>	Y	Y	Y	21	5.886	5	6.5	Eekhout: F, AI, SC, SI; BCD: F	A*
<i>Chimarra georgensis</i>	Y	N	Y					Eekhout: SC only	?
<i>Chimarra sp.</i>		Y	Y	49	7.056	5	8.12	Unspecified spp; Eekhout, BCD: widespread	I
<i>Chimmarus sp.</i>		Y	N	1	6.3	6.3	6.3	Unspecified spp; BCD: F	A*
<i>Dipseudopsis sp.</i>	Y	Y	Y	3	7.477	7.39	7.58	Unspecified spp; Eekhout, BCD: east of country	A
<i>Dolophilodes sp.</i>	N	Y	Y	13	5.335	4	6	Eekhout: F, SC; BCD: F	A*
<i>Dyschimus collyrifer</i>	Y	N	Y					Eekhout: SC, Si, AI, F	?
<i>Dyschimus sp.</i>		Y		2	6.150	5.1	7.2	Unspecified spp; BCD: L, SI	A*
<i>Dyschimus thrymmifer</i>	Y	N	Y					Eekhout: F	?
<i>Ecnomus sp.</i>	Y	Y	Y	52	7.663	5.05	9.1	Unspecified spp; Eekhout, BCD: widespread	I
<i>Ecnomus thomasseti</i>		Y		16	7.4244	6.1	8.5	Eekhout, BCD: widespread	I
<i>Goerodes caffraiae</i>	N	Y	Y	1	7.3	7.3	7.3	Eekhout: T, DC; BCD: ES	A
<i>Goerodes sp.</i>		Y		9	7.520	6.72	7.98	Unspecified spp; BCD: ES, NU, T	A
<i>Homilia knysnaensis</i>	Y	N	Y					Eekhout: V	?
<i>Hydropsyche longifurca</i>		Y	Y	12	7.4417	7.1	7.7	Eekhout: O, Ar, T, NU; BCD: ES, O	A
<i>Hydropsyche sp.</i>		Y		50	8.0996	7.38	9.2	Unspecified spp; BCD: ES, NU, T, V	A
<i>Hydroptila capensis</i>	Y	Y	Y	57	7.110	4.7	8.2	Eekhout, BCD: widespread	I
<i>Hydroptila cruciata</i>		Y	Y	21	7.5762	7	8.4	Eekhout: east of country; BCD: ES, NU, V	A
<i>Hydroptila sp.</i>		Y		90	7.3868	5.4	8.73	Unspecified spp; BCD: widespread	I
<i>Hydrosalpinx sericea</i>	Y	N	Y					Eekhout: F	?
<i>Ithytrichia sp</i>		Y		2	7.3	7.3	7.3	Unspecified spp; BCD: ES	A
<i>Leptecho helichotecha</i>	Y	Y	Y	1	6.100	6.1	6.1	Eekhout: F; BCD: F	A*
<i>Leptecho scirpi, lupi</i>	Y	N	Y					Eekhout: F	?
<i>Leptecho sp.</i>		Y		1	6.1	6.1	6.1	Unspecified spp; BCD: F	A*
<i>Leptocerina sp.</i>		Y		8	7.3813	6.72	7.82	Unspecified spp; BCD: ES, NU, T	A
<i>Leptocerus harrisoni</i>	N	Y	N	4	6.1475	2.9	7.3	BCD: NU, HS, T, V	A*
<i>Leptocerus inflatus</i>		Y	Y	17	7.4865	7.1	7.9	Eekhout, BCD: L, Li, V	A
<i>Leptocerus sp.</i>		Y		12	7.5508	7.15	7.92	Unspecified spp; BCD: ES, L, NU, T, O	A
<i>Leptonema sp</i>		Y		2	7.185	6.72	7.65	Unspecified spp; BCD: ES	A
<i>Macronema capense</i>		Y	N	9	8.1778	7.82	8.6	BCD: F, V	A
<i>Macronema natalensis</i>		Y	N	4	7.5	7.3	7.7	BCD: ES	A
<i>Macronema sp.</i>		Y		17	6.8153	5	8.11	Unspecified spp; BCD: F, ES, L, NU, SI, AI	I
<i>Macrostemum capense</i>	N	Y	Y	8	7.575	6.1	8.9	Eekhout: V, NU, L, ES, F; BCD: F, ES	I
<i>Macrostemum sp.</i>		Y		1	7.7	7.7	7.7	Unspecified spp; BCD: L	A
<i>Myspoleo agilis</i>	N	Y	N	30	6.177	5.3	6.9	Only in BCD: F	A*
<i>Nyctiophylax sp.</i>	N	Y	Y	2	6.300	6.1	6.5	Eekhout: V only; BCD: F	A*
<i>Oecetis lucipetens</i>	Y	N	Y					Eekhout: F	?
<i>Oecetis modesta</i>	Y	Y	Y	6	5.750	5.4	6	Eekhout: F, T, V; BCD: F	A*
<i>Oecetis sp.</i>		Y	Y	63	7.548	6	8.12	Unspecified spp; Eekhout, BCD: widespread	I
<i>Orthotrichia barnardi</i>	N	Y	Y	39	6.735	4.5	8.1	Eekhout: F, T; BCD: widespread	I
<i>Orthotrichia sp.</i>		N		121	7.344	5	8.6	Unspecified spp; BCD: widespread	I
<i>Oxyethira sp.</i>		Y		39	7.135	6.3	7.9	Unspecified spp; BCD: widespread	I
<i>Oxyethira velocipes</i>	Y	Y	Y	5	6.420	5.8	6.7	Eekhout: V, F; BCD: F, SI, SC, AI, DC	A*
<i>Parasetodes sp.</i>		Y		1	8.12	8.12	8.12	Unspecified spp; BCD: ES	A
<i>Parecnomina resima</i>	N	Y	Y	3	7.033	6.8	7.2	Eekhout: F; BCD: F	?
<i>Parecnomina spp</i>		Y		22	5.493	3.8	6.5	Unspecified spp; BCD: F	A*
<i>phleophila</i>	Y	N	Y					Eekhout: SC, AI	?
<i>Petroplax curvicosta</i>	Y	Y	Y	1	6.100	6.1	6.1	BCD: F	A*
<i>Petroplax spp</i>		Y		3	5.600	5.5	5.8	Unspecified spp; BCD: F	A*
<i>Petrothrincus circularis</i>	Y	Y	Y	22	5.436	4.4	6.8	Eekhout: O, M; BCD: F	A*
<i>Petrothrincus spp</i>		Y		2	6.000	6	6	Unspecified spp; BCD: F	A*
<i>Petrothrincus triangularis</i>	Y	Y	Y	1	5.500	5.500	5.500	BCD: F	A*
<i>Polycentropus sp.</i>		Y		1	7.8	7.8	7.8	Unspecified spp; BCD: ES	A
<i>Polyplectropus sp.</i>	Y	Y	Y	3	6.300	5.1	7.9	Eekhout: V; BCD: ES, SC, SI	A*
<i>Protodipseudopsis sp.</i>	N	Y	N	16	6.000	5.3	6.8	BCD: F	A*
<i>Pseudoneureclipsis sp.</i>		Y		9	7.6544	7.3	8.06	Unspecified spp; BCD: ES	A

<i>Psychomyiellodes sp.</i>	N	Y	Y	2	6.650	6.1	7.2	Unspecified spp; BCD: F, L	?
<i>Rhoizema furciferum</i>	N	N	Y					Eekhout: F	?
<i>Rhoizema saxiferum</i>	Y	N	Y					Eekhout: F	?
<i>Rhoizema spinosum</i>	Y	N	Y					Eekhout: F	?
<i>Sciadorus acutus</i>	Y	N	Y					Eekhout: F	?
<i>Sciadorus obtusus</i>	Y	Y	Y	1	5.100	5.1	5.1	Eekhout: SI, F; BCD: SI	A*
<i>Setodes barnardi</i>	N	N	Y					Eekhout: F	?
<i>Sinion hageni</i>	Y	Y	N	1	5.100	5.1	5.1	BCD: SI	A*
<i>Sinion sp</i>	N	Y	N	2	7.425	7.3	7.55	Unspecified spp; BCD: ES	A
<i>Stenopsyche ulmeriana</i>	N	Y	N	1	4	4	4	BCD: F	A*
<i>Triaenodes faiculata</i>	N	Y	Y	2	7.86	7.82	7.9	Eekhout: V; BCD: V	A
<i>Triaenodes sp.</i>		Y		26	7.785	7.3	8.47	Unspecified sp; Eekhout, BCD: east of country	A
<i>Trichosetodes semibrunnea</i>		Y	N	3	8	7.82	8.1	BCD: V	A
<i>Trichosetodes sp.</i>	N	Y		36	7.041	4.4	8.4	Unspecified spp; BCD: F, ES, L, Li	I
<i>Trichosetodes triangularis</i>	N	N	Y					Eekhout: V	?