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Evaluation of the conservation requirements of Trichoptera from the Tsitsikamma mountain streams in South Africa

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Abstract

A four-season survey of Trichoptera between April 2008 and January 2009, from 20 sites in 11 rivers flowing off the Tsitsikamma mountains in the Eastern and Western Cape, collected 42,683 adults and 6741 larvae, comprising 48 species in 22 genera and 12 families. Trichoptera were the numerically dominant freshwater macroinvertebrate taxon. Of the species collected, 15 are recognised regional Cape Floristic Realm (CFR) endemics. Some specimens of Trichoptera that could not be recognised as described species are now the subject of further studies. Distinct differences between rivers, in terms of species composition of Trichoptera, were noted. The variation in species composition can be partially explained by the physicochemical and ecological attributes of the rivers surveyed. Anthropogenic disturbances were noted in most of the lower reaches of the rivers. The upper reaches of the rivers could be statistically grouped together and thus be considered as a unit for conservation. The highest diversity, 25 species, was recorded from the pristine upper reaches of the Bobbejaans River. An evaluation of conservation requirements identified a number of threats: increased loads of fine sediment and nutrients, higher water temperature regimes, and changes to pH, from the natural acid (pH < 5.5) to neutral or alkaline conditions. Changes in any of these would be detrimental to the survival of many of the endemic Trichoptera in the CFR, and all of these changes would be exacerbated by decreased water-flow volumes. It is thus important to limit the levels of water abstraction from these rivers: to ensure the maintenance of cool temperature and acidic pH regimes while limiting nutrient levels in the rivers. To maintain conservation of the lower reaches of the rivers it is recommended that an ecologically-functional continuity with upstream reaches is maintained to enable the occupation of all zones of the rivers with a diversity of CFR freshwater endemic species. Some CFR Trichoptera were selected as indicators of favourable conditions for the survival and maintenance of viable populations of other CFR-endemic freshwater species.

Keywords: Caddisflies, Western Cape, Eastern Cape, southern Cape, Cape Floral Kingdom

Introduction

The Tsitsikamma mountain range in South Africa forms the eastern extension of the Cape Fold mountains, falling within the Cape Floristic Realm (CFR), which is recognised as one of the worlds mediterranean climatic regions, known for its high concentration of endemic aquatic biota (Wishart & Day 2002, de Moor & Day 2013). The Tsitsikamma mountains are characterised by ancient sedimentary Table Mountain sandstone (TMS) rock formations with deeply incised river gorges (Fig. 1) with evenly distributed year-round rainfall. Because of its low mineral content and age of the sediments these rivers are oligotrophic and strong to mildly

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acidic (pH 3.2- 6.9) (Harrison & Agnew 1962, Byren & Davies 1989) with acidity strongly influenced by decaying endemic fynbos vegetation leaching complex polyphenolic compounds into the water (de Moor & Day 2013). As a result of these conditions the aquatic biota have evolved to become stenotopic and acidobiontic and have adapted to survive in extreme oligotrophic conditions, making them vulnerable to anthropogenic alterations and eutrophication of water quality. The specialisation and restricted distribution of this highly specialised largely-endemic aquatic invertebrate fauna in the western and southern Cape was already recognised by Barnard (1934, 1940), Harrison & Agnew (1962) and is discussed in detail by de Moor & Day (2013).

FIGURE 1. Deeply-incised gorge with bridge crossing the Bloukrans River, at the border of the Eastern Cape and Western Cape Provinces, South Africa. Photo F.C. de Moor.

Following a request to stock alien brown trout *Salmo trutta* (Linnaeus, 1758) into the Salt River in the southern Cape in 2000, surveys were conducted in that river to assess whether there were any indigenous freshwater fish that would be threatened by this introduction and also to assess the aquatic macroinvertebrate diversity in that river (Barber-James 2000, Bok 2000, 2001; de Moor & Barber-James 2001). Data gathered during these surveys indicated that there were no indigenous freshwater fish in the Salt River but that there was a large diversity of macroinvertebrates, including a number of undescribed species. The aquatic invertebrates were dominated by Trichoptera both in species diversity and numerically. A permit to stock non-breeding brown trout into the Salt River was denied because it was considered that these fish would pose a threat to the rich and diverse assemblage of aquatic macroinvertebrates recorded from that river.

In 2004 the Nature's Valley Trust (NVT) requested that a further survey of the macroinvertebrates of the Salt River should be conducted, the main objectives being as follows: to obtain a more complete coverage of species throughout an annual cycle; and to assess whether changes in the macroinvertebrate assemblages had occurred because of a number of developments that had taken place in the catchment and along sections of the riparian zone since the surveys conducted in 2000. Results of the 2004 survey found the following: three additional species of Trichoptera, not recorded previously, of which one was an undescribed species; a number of potential threats to the continued, sustainable survival of the mostly restricted Cape endemic species of macroinvertebrates were identified. Recommendations to conserve and monitor the aquatic invertebrates and devise a conservation plan to ensure that good water quality and environmental conditions would be sustained were also put forward (de Moor *et al*. 2004).

The South African National Parks (SANParks), who administer a large area along the southern Cape coast as a marine reserve and also the inland area for conservation purposes, requested a survey of other rivers in the Tsitsikamma Mountains to assess whether the rich diversity of invertebrates seen in the Salt River was also evident in other rivers flowing off these mountains. Between 2008 and 2009 eleven selected rivers were surveyed seasonally, for a full annual cycle, at 20 sites along the upper and lower reaches of each river system (de Moor & Bellingan 2010, Bellingan 2011).

One of the main findings of the study was that Trichoptera were the most abundant and species-rich order of aquatic insects collected, with 42,683 adults and 6,741 larvae comprising 48 species. The total number of individuals recorded for the other aquatic insect orders were: Ephemeroptera 8,683 individuals in 20 species, Odonata 1,221 individuals in 31 species, Plecoptera 1,968 individuals in 5 species and Megaloptera 219 individuals in 3 species.

The significance of the research on the Tsitsikamma Mountain's rivers is that 51 taxa with 48 identified species of Trichoptera have been recorded in this region, with 15 of the species recognised as regional endemics (de Moor & Scott 2003). If earlier studies are included an estimated 18 species in these mountain streams are undescribed. There is a clear distinction between the species composition of the higher- and lower-altitude sites on these rivers. Most of the lower sites are impacted by anthropogenic activity on the Piedmont plain and this has resulted in some deterioration of the water quality with concomitant changes in species presence and abundance.

The aims of this paper are as follows: to select the Trichoptera collected in the 2008-2009 survey to assess the conservation status of the different rivers and sections of river and to use this information to formulate a protocol that could be used for developing an informed and measurable conservation plan. This plan would protect the sustainability of the quality of the water resources and aquatic environment that would enable all fauna and flora, adapted to these conditions, to survive in sufficient abundance to maintain the natural biodiversity of these rivers.

Study area and methods

For the purpose of this survey of the Tsitsikamma mountains, 20 sites on 11 rivers were selected (Fig. 2, Table 2). Selection of sites had to fulfil several criteria. For each river surveyed, an upper and lower site had to be selected. As we were working with colleagues from the Department of Water Affairs and Environment (DWAE) easy access to sites near roads to serve as future routine monitoring sites for the assessment of water quality, using the SASS5 biomonitoring protocol (Dickens & Graham 2002), was a requirement. Even with this in mind two upper sites could only be accessed by means of a helicopter. Sites that were heterogeneous as regards substrate types, and flow condition were chosen, in order to cover a diversity of aquatic biotopes and to ensure that maximum species diversity was recorded. The four surveys were conducted during the following periods (respectively defined as 'Autumn', 'Winter', 'Spring' and 'Summer'); 31 March - 13 April, 30 June - 13 July, 30 September - 12 October 2008; and 16 - 30 January 2009. We were assisted in the surveys by the DWAE team (water chemistry and biomonitoring), Dr J Simaika from University of Stellenbosch with support from SANParks rangers (Odonata survey).

At each sampling site temperature, pH, electrical conductivity, Dissolved Oxygen, Turbidity and Total Dissolved Solids (TDS) were measured and recorded in the field at the time of sampling, using a YSI6 Sonde Multimeter with a variety of probes. In addition, water samples were collected in plastic bottles, and preserved and frozen for later laboratory analysis by Talbot Laboratories Pietermaritzburg, KwaZulu-Natal. The water-chemistry parameters that were analysed included Nitrate/Nitrite, Ammonia, Total Phosphate, Orthophosphate, Cadmium, Chromium, Copper, Iron, Lead, Magnesium, Mercury, Zinc, Bromide, Chloride, Fluoride, Sodium, Sulphate, Sulphide.

In addition, Climastats Thermocron i-button temperature-data-loggers (-40 to 85 °C ± 1 °C accuracy) were installed at each site to record water temperature, at a 0.5 °C resolution, every two hours from January 2008 to January 2009. The data loggers were placed in Ziploc® plastic bags and stored in plastic containers with a sealing screw-top. Each sealed logger was placed in a galvanised pipe (diameter: 50 mm; length: 300 mm) that was closed at either end with stainless steel bolts and nuts. The pipe was attached by means of a stainless steel cable and rawlbolt, to a river boulder. Loggers were placed in rivers, at protected sites in deep pools, and retrieved and replaced (for the purpose of data capture) during each quarterly survey.

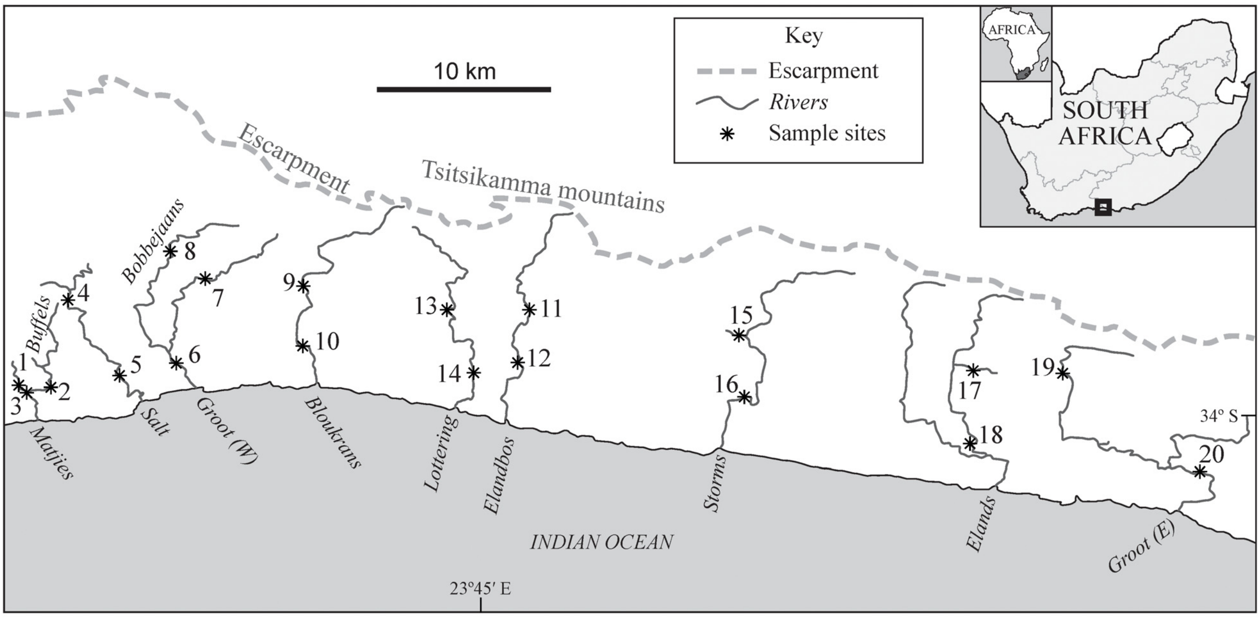

FIGURE 2. Map showing the localities of the twenty sites used for the surveys of rivers in the Tsitsikamma Mountains. Refer to Table 2 for details of sites.

On each sampling occasion, digital photographs were taken at each site, to obtain visual records of aquatic biotopes and prevailing conditions at the time of sampling. Aquatic invertebrates were sampled using a selection of water and aerial hand nets, ranging in net mesh size from 80 µm (0.08 mm) to 1000 µm (1 mm). Sampling of aquatic stages was also carried out by the DWAE team, using a standard SASS net (mesh size 1 mm) (Dickens & Graham 2002). Further collecting was also undertaken, using a hand-net (mesh size 250 µm), and a small D hand-net (mesh size 80 µm), the latter for sampling bedrock in swift flowing cascades and hygropetric splash zones of waterfalls. In addition, general hand-picking of stones, lodged branches and other removable substrates was undertaken on each sampling occasion, in order to cover a wide diversity of aquatic biotopes at each site. Light traps, using a 4W-6V super-actinic light source over a white tray, partially filled with water and a few drops of detergent, for the collection of adult stages of many aquatic insects, were set overnight at all sites during Autumn, Spring and Summer. Where time permitted, general collecting of flying adult insects using hand nets was also carried out. Each sample collected was assigned a unique catalogue number that provided further information relating to site, date and biotope. Samples were preserved in 80% ethanol. All sampled material was recorded and given a sample number under the Tsitsikamma Rivers catalogue TSR or Southern Cape Rivers catalogue SCR (from earlier surveys) in the Albany Museum collection. Where unnamed species are included in the analysis they are given collection sample number with added alphabetical listing for the specific taxon, to designate the specimens identified as representing the unnamed species. All of the specimens collected were identified as far as possible and counted.

For the purpose of statistical analysis, Trichoptera distribution data from all samples (adults and larvae) collected at sites on a particular date were combined to assess variability, in terms of abundance and distribution of species, found between different rivers. In contrast, only light-trap samples were analysed for comparing the overall distribution and abundance of 19 selected species at the 20 sampling sites.

Because Leptoceridae were the most speciose and numerically-abundant family of Trichoptera collected during the surveys, they were selected to assess seasonal presence and abundance of species at the 20 river sites used for the study.

For non-metric multidimensional scaling (NMDS) analysis based on distribution and abundance of all recorded larvae and adult Trichoptera, PRIMER version 6 (Clarke & Gorley 2006) was used. NMDS is in preference to principal components analysis (PCA) because of the highly heterogeneous nature of the community data and because fewer assumptions are made when using NDMS (compared to PCA) concerning the interrelationship of the samples or form of the data. The Bray-Curtis similarity data matrix was Log (x+1) transformed and 50 restarts of the data-run were executed. Results were plotted as a 2-dimensional configuration.

Results

Results of the physico-chemical water analyses are summarised in Table 1. Concentrations of nutrients (nitrate/nitrite, orthophosphate and total phosphate) recorded during the surveys were within a low-to-moderate range and remained well below South African recommended guidelines for the protection of aquatic organisms (Dallas & Day 1993, Palmer *et al.* 1996). The recorded ammonia and sulphate levels were also within the expected natural range.

TABLE 1. Summary of physicochemical parameters measured during the survey of 20 river sites over four seasons in the Tsitsikamma mountain streams.

Parameter measured	Minimum to maximum recorded
Nitrate/ Nitrite	0.16 – 1.46 mg $N\ell^{-1}$
Ammonia	0.07 – 0.40 mg $N\ell^{-1}$
Orthophosphate	0.001 – 0.075 mg $P\ell^{-1}$
Total Phosphate	<0.15 – 45 µg $P\ell^{-1}$
Sulphate	2.22 – 24.6 mg $SO_4\ell^{-1}$
pH range	4.5 – 8.1
Annual temperature range	4.5 - 29°C

The pH levels recorded at each of the sites indicated that the Matjies River and both sites on the Buffels Rivers were neutral to slightly alkaline, whereas the pH levels at all the other rivers surveyed were slightly to strongly acidic (Table 2).

Water temperatures recorded in the rivers of the Tsitsikamma region show an annual range of 24.5°C (Table 1) and reveal an interesting pattern of diel and seasonal fluctuation (Table 2, Fig. 3).

Distribution patterns of a selection of 19 species, collected over three seasons with light traps, are summarised in Table 3. The seasonal distribution and abundance of 17 species of Leptoceridae are summarised in Tables 4-6.

Discussion

The water quality data (Table 1), although indicating trends, in terms of variations of concentrations in the different rivers, were reported on in detail (de Moor & Bellingan 2010, Bellingan 2011) but are not considered further for the study reported on in this article. Differences in pH also coincided with differences in other water chemistry parameters and can be attributed to the surrounding geology of soft Gydo Formation shales of the Bokkeveld Group that give rise to the formation of loamy soils in the catchment of the Buffels and Matjies Rivers, whereas the substrates found in the remainder of the rivers in this study are predominately composed of Table Mountain Sandstone (Geological Survey 1979). Although the neutral pH regimes in the Matjies and Buffels rivers are buffered by Carbonate ions in the soils (Hynes 1970), this is not the case in TMS soils that are leached, poorly buffered, and acidic.

TABLE 2. Sampling site, altitude, pH and summary of range of temperatures recorded at 2-hourly intervals from Thermocron i-buttons at each of 20 river sampling sites for the duration of the full four-season sampling period.

River site	Altitude masl	pH	Min °C	Max °C	Range °C	Mean with SD °C
1. U. Matjies	51	7.4 – 8.1	5.5	20.5	15.0	13.5 ± 3.5
2. L. Buffels	32	6.9 – 7.6	5.5	22.5	17.0	12.9 ± 4.0
3. U. Buffels	61	7.2 – 7.9	4.5	22.5	18.0	13.8 ± 4.2
4. U. Salt	265	4.9 – 5.1	8.0	23.0	15.0	15.2 ± 3.3
5. L. Salt	47	6.2 – 6.8	8.0	26.5	18.5	16.3 ± 4.2
6. L. Groot (W)	14	4.5 – 6.4	10.5	24.0	13.5	16.4 ± 3.5
7. U. Groot (W)	313	4.7 – 5.2	6.0	24.0	18.0	14.0 ± 4.0
8. U. Bobbejaans	414	5.4 – 6.9	7.0	26.5	19.5	14.3 ± 3.9
9. U. Bloukrans	276	5.3 – 5.5	5.5	28.5	23.0	15.4 ± 4.9
10. L. Bloukrans	40	4.6 – 5.2	8.5	25.0	16.5	15.9 ± 4.4
11. U. Elandsbos	254	4.6 – 5.0	8.5	25.5	17.0	16.1 ±3.8
12. L. Elandsbos	215	4.6 – 5.3	7.5	25.0	17.5	15.7 ± 3.9
13. U. Lottering	267	4.9 – 5.2	7.5	25.0	16.5	15.0 ± 3.6
14. L. Lottering	218	4.7 – 5.4	8.0	23.5	15.5	15.4 ±3.8
15. U. Storms	285	4.9 – 5.1	8.0	19.0	11.0	13.5 ± 2.7
16. L. Storms	65	5.1 – 5.7	9.0	29.0	20.0	16.4 ± 4.4
17. U. Elands	313	4.5 – 4.6	8.5	24.0	15.5	14.8 ± 3.3
18. L. Elands	56	6.6 – 6.9	7.5	25.0	17.5	15.4 ± 4.2
19. U. Groot (E)	275	4.7 – 5.0	8.0	24.0	16.0	15.2 ± 3.2
20. L. Groot (E)	14	6.1 – 6.5	7.0	26.5	19.5	16.9 ±5.3

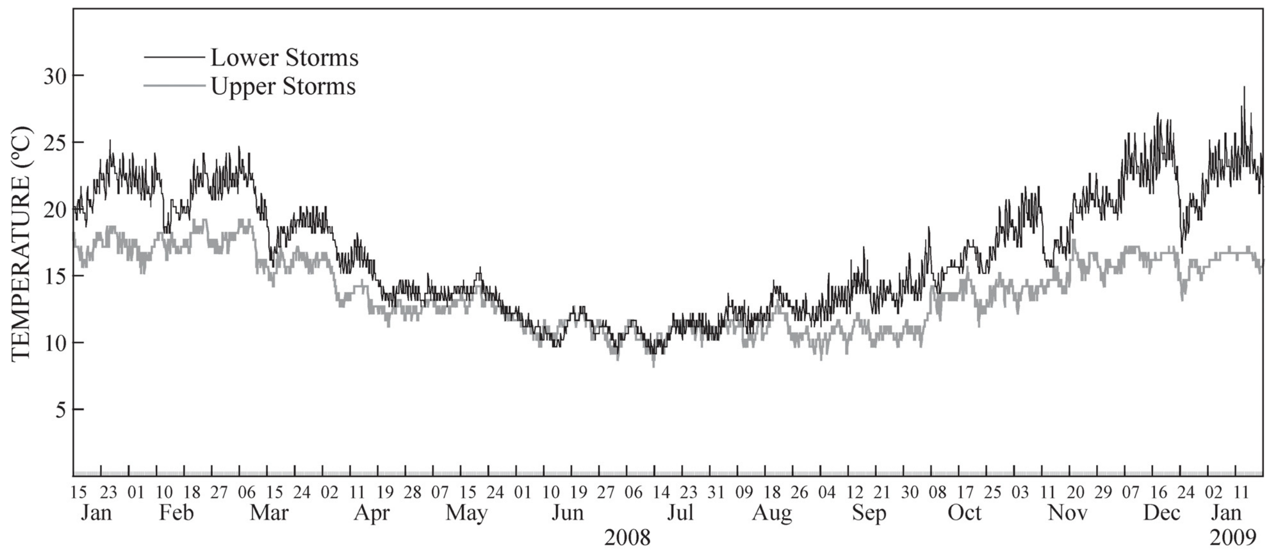

FIGURE 3. Plot of temperature records taken at two-hourly intervals over an annual cycle at sampling sites on the Upper and Lower Storms River.

TABLE 3. Selection of Trichoptera species and their abundance collected from light traps at 20 sites during the four-season survey. Unshaded sites = upper altitudes above 200masl; Shaded light blue sites = lower altitude below 100 masl; Species abundance shaded; green = higher altitude restricted, yellow = widely distributed, pink = lower altitude restricted, dark blue = narrowly restricted.

	U. Matjies	L. Buffels	U. Buffels	U. Salt	L. Salt	L. Groot (W)	U. Groot (W)	U. Bobbejaans	U. Bloukrantz	L. Bloukrantz	U. Elandsbos	L. Elandsbos	U. Lottering	L. Lottering	U. Storms	L. Storms	U. Elands	L. Elands	U. Groot (E)	L. Groot (E)
Site numbers	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**6**	**17**	**18**	**19**	**20**
Agapetus murinus	0	0	0	2	0	0	8	1	0	0	1	15	0	4	1		0	0	0	0
Hydroptila cruciata	1	6	12	0	11	5	3	1	0	0	1	3	0	4	0	2	0	335	2	1
Oxyethira velocipes	0	15	22	5	49	9	0	4	2	1	10	2	0	5	0	10	0	1	2	0
Chimarra ambulans	0	1	3	27	153	6	242	620	0	239	70	411	165	9	0	1099	0	0	4	0
Thylakion urceolus	0	0	0	19	1	2	38	23	15	26	17	0	3	9	27	2	24	0	1	0
Cheumatopsyche afra	3	9	0	0	21	1	0	0	2	2	0	0	0	0	0	219	0	78	0	6
Sciadorus obtusus	0	0	0	2	0	0	0	1	2	0	3	0	0	0	3	0	0	0	0	0
Ecnomus similis	15	67	22	12	1	21	9	13	0	10	0	0	0	3	0	5	1	0	1	13
Parecnomina resima	0	0	0	13	0	0	34	29	2	38	29	24	104	99	0	13	0	0	20	0
Paranyctiophylax SCR213T	0	0	0	0	0	0	0	0	0	78	0	0	0	0	0	9	0	0	0	0
Dipseudopsis capensis	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Silvatares collyrifer	0	0	0	5	0	0	19	9	1	0	1	0	1	1	13	2	13	0	1	0
Silvatares SCR248F	0	0	0	7	0	0	0	0	6	0	3	5	9	2	0	1	2	0	0	0
Athripsodes bergensis	5	12	11	420	10236	1160	621	524	311	4244	354	436	896	11200	35	3744	1	140	56	190
Athripsodes harrisoni	1	12	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptecho SCR265K	0	2	0	75	0	0	727	442	7	204	30	2	59	225	0	9	3	1	32	0
Oecetis modesta	2	4	12	5	18	4	0	4	0	29	2	0	1	1	1	14	0	1	0	5
Barbarochthon brunneum	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Petrothrincus demoori	0	0	0	0	0	0	6	3	0	0	4	2	26	54	7	0	0	0	0	0

TABLE 4. Adult Leptoceridae recorded from light trap samples in autumn April 2008. Yellow shading indicates dominant species green shading second most abundant species at site. Site numbers as for table 3.

	U. Matjies	L. Buffels	U. Buffels	U. Salt	L. Salt	L. Groot (W)	U. Groot (W)	U. Bobbejaans	U. Bloukrantz	L. Bloukrantz	U. Elandsbos	L. Elandsbos	U. Lottering	L. Lottering	U. Storms	L. Storms	U. Elands	L. Elands	U. Groot (E)	L. Groot (E)
Athripsodes bergensis	5	3		95	200	531	121	200	248	79	222	400	500	10000		2000		3	3	
Athripsodes harrisoni		3																		
Athripsodes oryx							1		4		2		1		27					
Athripsodes potes																				
Athripsodes prionii				1		1					8	10	1			1				
Athripsodes scramasax													1		66		19			
Athripsodes spatula																				
Athripsodes SCR258N																1				
Athripsodes TSR472C								2			18	12	10	15		1			1	
Leptecho TSR491i																				
Leptecho TSR363H																				
Leptecho SCR258K											1	3	2							
Leptecho SCR265K				4			27						5	1						
Oecetis modesta			1	2	2	1		2		2						1				
Oecetis SCR164N															7					
Oecetis TSR513B	5																			

TABLE 5. Adult Leptoceridae recorded from light trap samples in spring October 2008. Yellow shading indicates dominant species, green shading second most abundant species at site. Site numbers as for table 3.

	U. Matjies	L. Buffels	U. Buffels	U. Salt	L. Salt	L. Groot (W)	U. Groot (W)	U. Bobbejaans	U. Bloukrantz	L. Bloukrantz	U. Elandsbos	L. Elandsbos	U. Lottering	L. Lottering	U. Storms	L. Storms	U. Elands	L. Elands	U. Groot (E)	L. Groot (E)
Athripsodes bergensis			1	66	36	629		12	4	2	29	4				18	1			10
Athripsodes harrisoni	1		4																	
Athripsodes oryx																				
Athripsodes potes											1					8				
Athripsodes prionii		3		7		8					3		1							2
Athripsodes scramasax									1											
Athripsodes spatula								22					8							
Athripsodes SCR258N																				
Athripsodes TSR472C						6		1			2		1							
Leptecho TSR491i																				
Leptecho TSR363H																				
Leptecho SCR258K						4					1									
Leptecho SCR265K																				
Oecetis modesta				3	1															4
Oecetis SCR164N						1														

TABLE 6. Adult Leptoceridae recorded from light trap samples in summer January 2009. Yellow shading indicates dominant species green shading second most abundant species at site. Site numbers as for table 3.

	U. Matjies	L. Buffels	U. Buffels	U. Salt	L. Salt	L. Groot (W)	U. Groot (W)	U. Bobbejaans	U. Bloukrantz	L. Bloukrantz	U. Elandsbos	L. Elandsbos	U. Lottering	L. Lottering	U. Storms	L. Storms	U. Elands	L. Elands	U. Groot (E)	L. Groot (E)
Athripsodes bergensis		9	10	259	10000		500	312	59	4163	103	32	396	1200	35	1726		137	53	175
Athripsodes harrisoni		9	3																	
Athripsodes oryx							28	1		4					7	2				
Athripsodes potes																				
Athripsodes prionii							6					5		3						
Athripsodes scramasax				1									2	2	17		150		1	
Athripsodes spatula																				
Athripsodes SCR258N																				
Athripsodes TSR472C				1									1							2
Leptecho TSR491i								1					2	1						
Leptecho TSR363H																				
Leptecho SCR258K											151		11	14					123	
Leptecho SCR265K		2		71			700	442	7	204	30	2	54	224		9	3	1	32	
Oecetis modesta	2	4	11		15	3		2		27	2		1	1	1	13		1		1
Oecetis SCR164N		3		1			2	1	6						4					
Oecetis TSR513B						2														
Oecetis TSR547L		1	2													1				

These rivers can be considered as 'cool', with mean annual temperatures, for the sites surveyed, ranging from 12.9 – 16.9°C (Table 2). Similar temperatures were recorded in upper and lower reaches of rivers during the cooler winter period, but in most rivers (for example, the Storms River: Fig. 3), the upper reaches are cooler during summer. It was also notable that temperatures fluctuated over a range of more than 10°C within a few days when a cold front passed over the region such as in December 2009 (Fig. 3). Daily temperature fluctuations were also larger in summer than in winter. Thermal extremes were large but, as long as temperatures in excess of 25°C were not exceeded for prolonged periods, such extremes appeared to have a limited role in influencing the biological fitness and survival of the cold-stenothermal, endemic and indigenous species in these rivers (Rivers-Moore *et al*. 2013, Ross-Gillespie 2014).

The NMDS ordination of similarities of sites (based on presence and abundance of 51 taxa) calculated for all combinations of data from the 11 rivers, revealed a reliable 2-dimensional separation (stress value 0.09) for sites 1, 2, 3, 5 as well as sites 18 and 20 from the remainder of the sites (Fig. 4, refer to Tables 2 and 3 and Fig. 2 for site names, altitudes and localities). These sites are lower-altitude sites (below 100 masl) that have all been impacted by development in the Piedmont plain in the middle reaches of the rivers, below the mountains. The effects of these impacts are also borne out by the water chemistry analysis that revealed some nutrient enrichment and increased pH levels at sites 1, 2, 3, 5, 18 and 20 (de Moor & Bellingan 2010, Bellingan 2011). Sites 10 and 16 are lower-altitude sites on the margins of the Tsitsikamma National Park and have therefore not been influenced by development. Of the other sites that group together in the ordination, Sites 15 and 17 are within upper natural-forested reaches in tributaries and Site 6 is in a lower naturally-forested reach. Site 9 is in an upper, natural-forested site that had been influenced by a previous flooding event that caused bedrock exposure and altered riparian vegetation, which resulted in a reduced Trichoptera species community (Fig. 2). Sites 4, 7, 8, 11, 12, 13, 14 and 19 are all sites at altitudes above 200masl (Table 2).

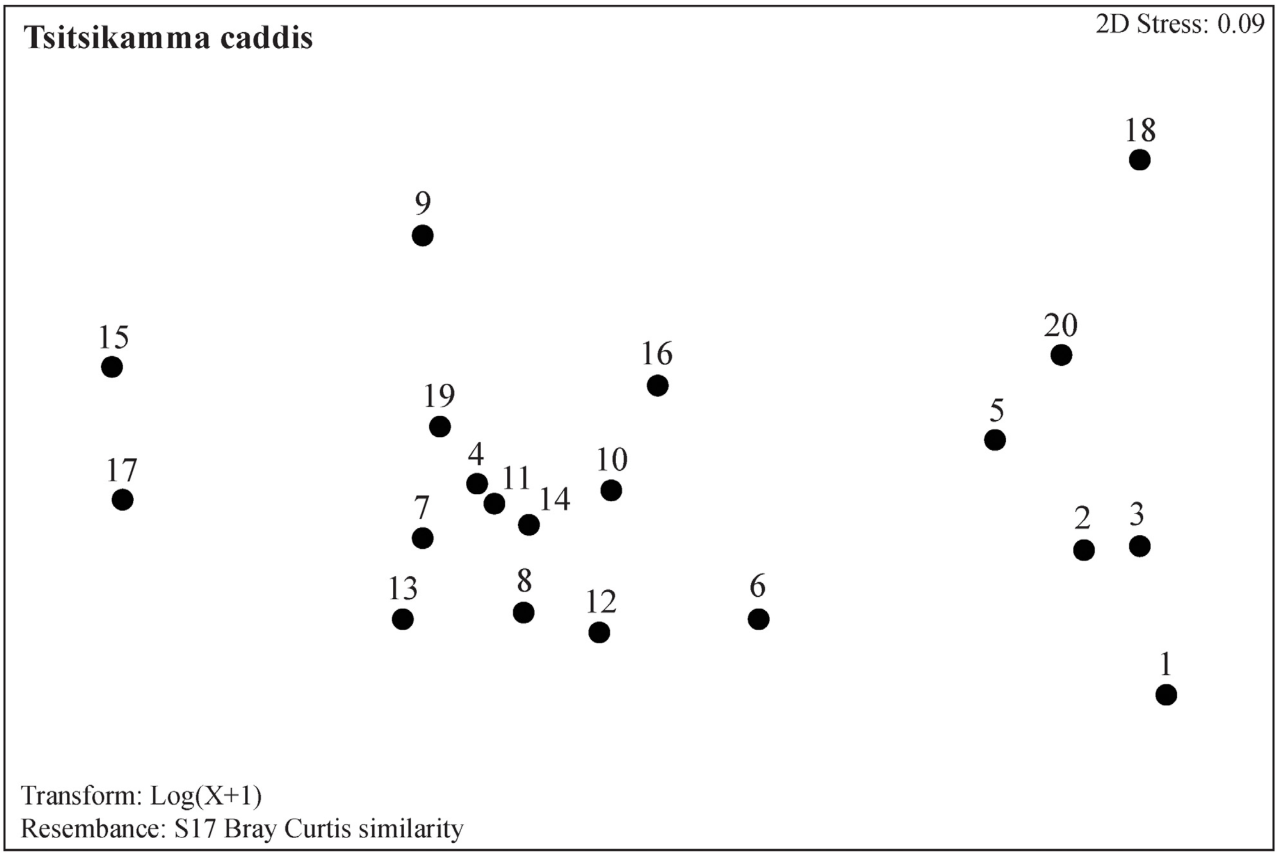

FIGURE 4. Non-metric Multidimensional ordination plot of 20 river sites, based on Bray-Curtis similarity coefficients, of the presence and abundance of all Trichoptera species (larvae and adults) collected during the surveys. Stress = 0.09 indicates a reliable 2-dimensional separation of the data.

The NMDS ordination of the sites surveyed indicated that species composition and abundances separated the higher- and lower-altitude sites. A further separation indicated that lower-altitude sites in catchments, where anthropogenic activity occurred, were isolated from higher-altitude sites that were in more natural undisturbed catchments. Most of the sites in the upper catchments grouped together because of similarities in species composition and abundance. Some of the higher-altitude forested streams contained distinctly unique species. The seasonally-varying, numerical abundance of different species was strongly influenced by altitude.

The analysis of distribution and abundance of 19 selected species indicate distinct preferences, in certain taxa, for lower (below 100masl) or higher (above 200masl) altitudes (Table 3). Species such as *Agapetus murinus* (Barnard, 1934), *Sciadorus obtusus* Barnard, 1934, two species of *Silvatares* (*Silvatares collyrifer* (Barnard, 1934) and an undescribed species) and *Petrothrincus demoori* Scott, 1993 indicate a clear preference for higher altitudes, whereas *Cheumatopsyche afra* (Moseley, 1935), *Paranyctiophylax* SCR213T and *Dipseudopsis capensis* Walker, 1852 are apparently restricted to lower altitudes. There are also a number of species — such as *Hydroptila cruciata* Ulmer, 1912, *Oxyethira velocipes* (Barnard, 1934), *Chimarra ambulans* (Barnard, 1934), *Thylakion urceolus* (Barnard, 1934), *Ecnomus similis* Mosely, 1932, *Athripsodes bergensis* Scott, 1958, *Leptecho* SCR265K and *Oecetis modesta* (Barnard, 1934)— that are widespread over a range of altitudes. Furthermore, there are some species, such as *Parecnomina resima* Morse, 1974 and *Athripsodes harrisoni* (Barnard, 1934), that are not restricted by altitude but by other influencing factors. *Barbarochthon brunneum* Barnard, 1934, a species abundant in benthic samples collected, was conspicuously absent from the light trap samples in the surveys conducted (except for one specimen collected from the upper Bobbejaans River).

Athripsodes bergensis was the most abundant species at most sites during all three seasons when light traps were set (Tables 4-6). During Autumn *Athripsodes scramasax* (Barnard, 1934) and *Athripsodes oryx* (Barnard, 1934) were the most abundant species in the forested Upper Storms River (Site 15) and the former species was also recorded at other higher altitude sites during Summer (Tables 4 & 6). *Athripsodes prionii* Scott, 1958 was collected during all three seasons but was most abundant during Spring. *Athripsodes* TSR472C was most abundant at the higher-altitude sites during Autumn and was recorded at one lower-altitude site (Site 6) in Spring. *Athripsodes spatula* (Barnard, 1940) was recorded only in Spring as the most abundant species at Sites 8 and13, whereas *Athripsodes potes* (Barnard, 1934) was also found only during Spring at Sites 11 and 16 (Table 5). *Leptecho* SCR258K and *Leptecho* SCR265K were recorded in abundance at several higher-altitude sites during the Summer and in lower numbers at higher-altitude sites during Autumn and Spring. *Oecetis modesta* was found at a number of higher and lower-altitude sites throughout all seasons. Certain species that are clearly widespread are present as adults during all three seasons, whereas the emergence periods of other species are mainly during Spring or Autumn.

The overall numerical abundance of *A. bergensis* throughout the study period indicated that conditions for successful breeding of this species were highly suitable at most sites throughout the year. It was noted that a large flood event, during November 2007, resulted in a major transformation of sections of river channels at most sites, resulting in the removal of small islands and riparian vegetation, and the homogenisation of stream bed structure, by disrupting riffle-pool sequences and creating shallow runs. It can be expected that such a major disturbance event would favour species with early-colonising life-history attributes.

The ancient well-leached geological formations also contributed to a greater number of species adapted to the acidic, oligotrophic waters, in the first to third order streams at the higher-altitude sites. Species that are indicative of such conditions include *Agapetus murinus*, *Sciadorus obtusus*, *Barbarochthon brunneum* and *Petrothrincus demoori*. The presence of natural forested conditions in some the higher-altitude sites provided leaf litter and created biotopes suitable for the leaf shredding feeding behaviour of the three species of *Silvatares*, which were recorded during these and previous (de Moor *et al.* 2004) surveys. Species such as the filter feeding *Cheumatopsyche* spp. and burrowing *Dipseudopsis capensis* are confined to the lower altitude sites (<100 masl) where the rivers are wider and characterised by a high degree of sedimentation and eutrophication, leading to the development of more fine particulate organic matter.

A conservation recommendation would be that the upper catchments of the rivers should be conserved as a unit. This can be achieved through careful catchment management, with the aim being to supply high-quality water.

Temperatures in the upper and lower reaches of rivers were similar during the cooler Winter period but the upper reaches are cooler in Summer. Thermal extremes are important abiotic factors that influence the biological fitness and survival of the endemic and indigenous species in these rivers. To ensure the continued existence of the cool stenothermal species, as well as maintaining migration routes for the more ubiquitous eurythermal species, such as *A. bergensis*, it is important to maintain connectivity between the upper and lower reaches of these rivers. This would ensure the opportunity of different species to move freely upstream or downstream, to enable their survival under optimal thermal and trophic conditions.

The absence of freshwater fish in three rivers (Salt River, Lottering River and Bobbejaans River upstream of confluence with Groot River W) is also an important conservation factor to consider (de Moor & Belligan 2010), as behaviour of some of the endemic species of caddisflies that move around freely on the upper surfaces of stony substrata, would make them vulnerable to fish predation. Maintaining these rivers free of fish, whether 'indigenous species' found in other local waters, or alien introduced species, would be an important conservation action.

Major threats to the survival of the endemic CFR Trichoptera species are mainly caused by anthropogenic modifications of the landscape and water usage. These can be summarised as follows: increased fine sediment loads in the lower reaches of rivers; increased loads of nutrients leading to eutrophication; raising the pH to create alkaline water conditions; increased water temperatures and decreased flow volumes. All of the above impacts are exacerbated by lower flow volumes. If the predicted increase in global temperatures occurs within the next 50 years, there will be serious consequences for the endemic Trichoptera species that are cold-stenothermal specialised, and adapted to thrive under oligotrophic conditions. The natural hydrological regime and low nutrient levels of the rivers should be maintained to ensure that the impact on the biodiversity is minimised. The presence and abundance of some of the species mentioned above could be used as indicator, umbrella or keystone species (New 1993).

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