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CONSERVING DRAGONFLIES (ODONATA) ALONG STREAMS RUNNING THROUGH COMMERCIAL FORESTRY

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Commercial afforestation of natural ecosystems is increasing worldwide. There is little information however, on the extent to which biodiversity is being affected by this practice. This is especially so for stream fauna, including the conspicuous Odon. Some dragonflies and damselflies may decline when their natural environment is anthropogenically changed and, as a group, they are sensitive to the impact of afforestation.The sites were four pine plantations in KwaZulu-Natal, South Africa.14 environmental factors were recorded along stretches of streams running through each of the four sites.The diversity of Odon. spp. and their abundances along these streams were measured.There was a strong positive correlation between certain abiotic factors, for example, boulder cover and shade, with the local distributions of these insects. Water pH was also a strong correlate. Most spp. required both unpolluted water and a sunlit stream. Particular vegetation type and exact distance of pine trees from the water's edge (so long as they did not shade the stream) were not strong correlates.This meant that species diversity dropped dramatically where the water was completely shaded by a closed canopy, whether it was from natural forest or from exotic trees. It is recommended that no plantation trees should shade a stream edge, and should be planted at least 30m from the water. All highly invasive, dense-canopy weeds, especially *Acacia mearnsii*, should be removed, and extensive and intensive cattle trampling of the banks avoided.

INTRODUCTION

The single most important cause of insect extinctions is the disturbance to and loss of natural habitats (PYLE et al,, 1981). The main change to most landscapes is fragmentation of indigenous habitats, with commercial and agricultural impacts becoming increasingly significant (PYLE et al., 1981). Afforestation refers to the planting of trees, usually exotic, in monoculture. Afforestation affects natural habitats and reduces indigenous species richness by excluding those species that are sensitive to particular environmental conditions (SAMWAYS & STEYTLER, 1996).

Headwater streams are highly sensitive to land-use change, and this has far--reaching effects for the catchment area as a whole, not only in terms of water quality, but also for biodiversity (VUORI & JOENSUU, 1995). Afforestation can potentially have an impact, including fragmentation of native populations. The fragmentation of large tracts of land into small parcels commonly causes the disruption of the stream network system (FORMAN, 1995). Additionally, commercial forestry involving natural pine stands in the Northern Hemisphere can cause an increase in run-off (once the plantation has been clear-felled) that, in turn, causes the removal of topsoil and valuable minerals. These impacts can alter river dynamics (flow rate, mineral content, pH and temperature) and eventually reduce biodiversity (FORMAN, 1995).

In South Africa, planted trees (*Pinus* spp. and *Eucalyptus* spp.) use large quantities of water and reduce the flow rate of rivers by up to 22%, as does the Sabie/Sand river running into Mozambique (Anonymous, 1997). Such changes in river dynamics can be monitored by Odonata species, which are sensitive indicators of water quality and landscape disturbance (WATSON et al., 1982; CASTELLA, 1987; BROWN, 1991; SAMWAYS, 1993).

The disturbance to habitats may cause a reduction in breeding sites and natural prey items and lead to extirpations (PYLE et al., 1981). MOORE (1991a) showed that in temperate regions, the greatest threat to many Odonata species is the intensification of modern agriculture and the use of fertilizers. In Richmond Park, London, aesthetic improvements to natural features caused a 50% local decrease in the number of Odonata species (FRY & LONSDALE, 1991).

In KwaZulu-Natal, wetlands have been lost to dam construction, agricultural expansion, urbanization and commercial afforestation, with the highest impact coming from agriculture (BEGG, 1986). Extensive draining of wetlands and logging can drastically alter the structure and function of streams, even if the streams are left untouched (VUORI & JOENSUU, 1995). Also draining of wetlands severely alters the ability of rivers to keep the water free of large amounts of topsoil and minerals. In turn, the pH of the river is also altered.

Although MacDONALD (1989) states that alteration and alien tree invasion are two of the eight major land transformations that negatively affect the conservation of natural biota in South Africa, the impacts of commercial forestry on biodiversity have in fact been little studied in the country. WINTERBOTTOM (1970) showed that plantations in the Fynbos biome were depauperate in bird species compared to indigenous habitats in the same region. The exotic tree plantations acted like a selective filter impeding the flight of certain bird species. DONNELLY & GILIOMEE (1985) also showed that ant species richness declines when the Fynbos is planted to pines.

Of concern are that both weedy exotic trees and plantation trees on riverbanks

Table I
The sites and subsites type of disturbance, rainfall, grid reference and stream name

Sites	Grid reference	Rainfall	Stream name	Type of disturbance	Width and type of riparian vegetation strips
BLINKWATER	30°27'28"E / 29°15'46"S		MVOTI		
B1		1084 mm		Natural grassland	No boundaries as it flows through a grassland
B2		1084 mm		Natural riparian forest	The riparian forest runs in a 40 m belt on both margins of the stream
B3		1084 mm		Pine compartments	Pine trunks 2 m from stream margin
GILBOA	30°17'38"E / 29°15'S		MHLOWENI		
G1		1366 mm		Clear-felled pine compartments	Pines were originally 15 m from stream margin Riparian grassland to plantation margin
G2		1366 mm		Pine compartments	Pines are planted 10 m from stream margin. Brambles and weeds cover the bank as well as some indigenous species
G3		1366 mm		Pine compartments	Pines are planted 10 m from stream margin. Brambles and weeds cover the bank as well as some indigenous species
G4		1366 mm		Pine compartments	Pines are planted 10 m from stream margin. Brambles and weeds cover the bank as well as some indigenous species
LINWOOD	30°04'36"E / 29°34'12"S		GQISHI		
L1		848.5 mm		Thick wattle bush	Wattle is against stream bank as well as some indigenous species. The stream has also been redirected
L2		848.5 mm		Cattle trampling and wattle	Wattle is against stream bank as well as some indigenous species
L3		848.5 mm		Cattle trampling and wattle	Wattle is against stream bank as well as some indigenous species
TETWORTH	30°11'20"E / 29°22'08"S		KUSANE		
T1		1060 mm		Natural grassland	Closest plantations are 200 m from stream margin with natural grassland flanking the stream
T2		1060 mm		Canalized streambed	Closest plantations are 75 m from stream margin. Cut grass and wattle cover stream margin
T3		1060 mm		Pine compartments	Pines are planted 10 m from stream margin. Brambles and weeds cover stream margin
T4		1060 mm		Pine compartments	Pines are planted 10 m from stream margin. Brambles and weeds cover stream margin

can reduce local biodiversity, especially dragonflies (ORMEROD et al., 1990; SAMWAYS & STEYTLER, 1996).

SAMWAYS & STEYTLER (1996) suggested that a large variety of natural habitats enhance local abundance and Odonata species richness. Conversely the introduction of a tree monoculture may reduce the number of habitats and hence impoverish the Odonata fauna.

The aim here is to investigate the extent to which the various types of agroforestry land-use have on Odonata species richness and abundances. There is special emphasis on pine plantations, in their various forms and cycle stage, as they are subject to strict permit regimes. The results are then used to make riparian management recommendations of local and global relevance.

METHODS, SITES AND MATERIAL

SITES. – Four sites, each with a stream running through it, were chosen in the KwaZulu-Natal Midlands (Tab. I), on the basis that they were comparable in elevation and in land-use. The subsites that were sampled within each of the sites were on the same stream.

SAMPLING OF SPECIES. – Odonata assemblages were assessed visually along a 15-m transect. The transect was made up of the stream and the stream margins up to 2m from the stream's edge. At each subsite, six transects were walked, and this was repeated three times between February and May 1998. The measuring was done only on sunny days between 10h00 and 12h00, as this has been shown by SCHMIDT (1985) to be the best time to sample Odonata assemblages.

Only adult males were noted, as tenerals and adult females are difficult to identify on the wing and are not confined to riverside territories held by the males (CORBET, 1962). The males were identified using close-focus binoculars while walking the transects.

There has been speculation on the accuracy of this technique, but MOORE (1991b) has shown that even though individuals may leave without being counted or return and be counted twice, he expects the counts to be over 80% correct for Zygoptera and 100% for Anisoptera. Despite the errors for Zygoptera, this is the best available method of assessment for Odonata assemblages.

ENVIRONMENTAL VARIABLES. – The proportion of each environmental variable was assessed along the transect in relation to the other environmental variables. River width and depth were measured using a tape measure. The stream pH was measured using a JENWAY 3405 Electrochemical Analyzer. According to CORBET (1962), adult Odonata respond primarily to visual cues, and larval survival ultimately determines the suitability of the habitat. Taking this into account, 14 environmental factors were measured (Tab. III).

STATISTICAL ANALYSIS. – The data from the six transects and the three visits were pooled for each subsite. The species data were not transformed to normality as there were many zero values (TER BRAAK, 1987). The environmental data were also not transformed. Nevertheless, the data were standardized to zero mean and unit variance for interpreting the canonical coefficients.

Canonical Correspondence Analysis (CCA) (TER BRAAK, 1986) from CANOCO version 2.1 was used to relate the environmental variables to the species abundance data.

Diversity, richness and evenness indices were computed for the species data. The indices used were Pielou's evenness, Shannon's diversity and Margalef's & Hill's richness indices (LUDWIG & REYNOLDS, 1988). These indices were computed using the statistical program PRIMER version 4. Rarefaction was performed on the species data to get an equal sample size (n). The reason for doing this was so that species richness could be computed to allow comparisons of richness between the four sites to be made. Rarefaction was computed by using the Program RAREFRAC (LUDWIG & REYNOLDS, 1988).

RESULTS

The 22 species sampled and the presence/absence data for the 14 subsites are given in Table II. In Figure 1(a) and 1(b), B2 (a natural forest patch) had the lowest number of individuals and the lowest species richness. In contrast, L2 had the most individuals and the highest species richness. This subsite was surrounded by invasive wattle stands and cattle regularly entered the stream. The results of the rarefaction are given in Table VI. Even after rarefaction, the order of site richness remained the same.

The cluster analysis in Figure 2 was done to group similar subsites together in terms of their species assemblages. B2 (the natural forest patch) had only two species, and was much more species poor than any of the other subsites. The Tetworth subsites clustered together, which shows that they had very similar species assemblages.

The four sites in Figure 3 showed a similar trend, but with different component

Table II
Species richness for the 14 subsites studied at the four Mondi estates in the KwaZulu-Natal Midlands; [« = presence of species]

Species	Sites													
	Blinkwater			Gilboa				Linwood			Tetworth			
	B1	B2	B3	G1	G2	G3	G4	L1	L2	L3	T1	T2	T3	T4
C. fasciata	«	«		«		«	«	«	«	«				
C. tessellata	«	«	«			«	«	«	«	«	«			
L. plagiata						«	«							
E. glauca				«	«						«			
P. caffrum										«				
P. hageni						«								
P. kersteni				«		«			«	«	«		«	«
P. salisburyense	«		«	«	«	«	«	«	«	«	«	«	«	«
P. spernatum				«		«			«					«
A. leucosticta	«	«						«	«	«				
P. fitzimonsi											«			
A. imperator				«										
A. speratus									«					«
A. minuscula					«	«						«	«	
A. subpupillata	«				«	«	«				«	«	«	«
D. lefebvrii										«			«	
O. caffra	«		«		«	«	«	«	«	«	«	«	«	«
P. flavescens									«					
S. fonscolombei	«								«					
T. arteriosa				«		«			«			«		
T. dorsalis				«	«	«	«		«	«	«	«	«	«
T. stictica				«							«	«		
Species richness	7	3	3	9	6	12	7	5	12	9	9	7	7	7

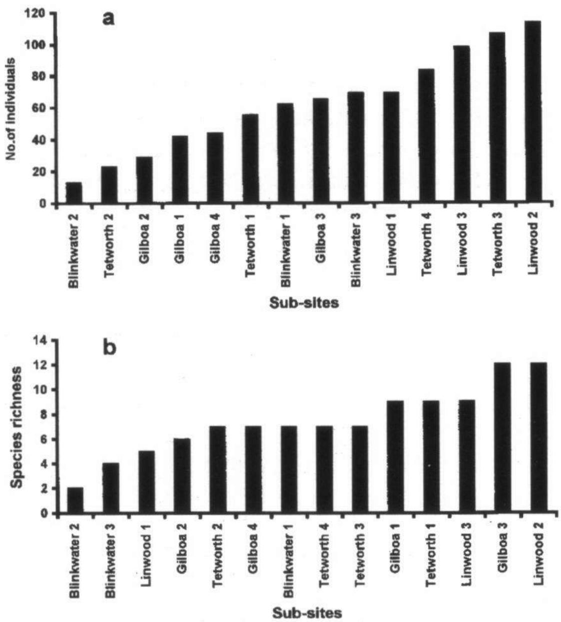

Fig. 1. Number of Odonata individuals (a) and species (b) recorded at each of the 14 subsites at the four sites.

species. The trend is that for the seventh species onwards, the sites showed similar species percentages, except Blinkwater, that only had seven species. The dominant species and species richness for the four sites are given in Table V, which shows that three out of the four sites were zygopteran-dominated. Table IV gives species richness, diversity and evenness indices (LUDWIG & REYNOLDS, 1988). The diversity of the 14 subsites were similar, with the exception of B2 (a natural forest patch) and L1 [an enclosed canopy of alien invasive *Acacia mearnsii* (De Wild)], which had very low species diversity, with values of 0.617 and 0.649 respectively. Site G3 had high diversity with a value of 2.17, and had pines > 10m from the stream bank. The rest of the subsites had values ranging from 1.21 to 1.90.

An ordination plot (Canonical Correspondence Analysis) was undertaken to relate the species data to the environmental variables. The subsites grouped into sites by the environmental variables. TableVII represents the canonical coefficient data for the first two axes of the ordination plot. The most important variables were shade, boulder cover, pH and sedge.

DISCUSSION

SPECIES COMPOSITION BETWEEN AND WITHIN SITES

Gilboa was the richest of the four sites, with 15 species. Only three species out of 22 (14%) were shared by all sites. The shared species were the zygopterans *Chlorolestes tessellata* and *Pseudagrion salisburyense* and the anisopteran *Orthetrum caffra* (Tab. I). These results support those of STEWART & SAMWAYS (1998) who also found large differences between numbers of species at other neighbouring South African sites. However, STEWART & SAMWAYS (1998) worked

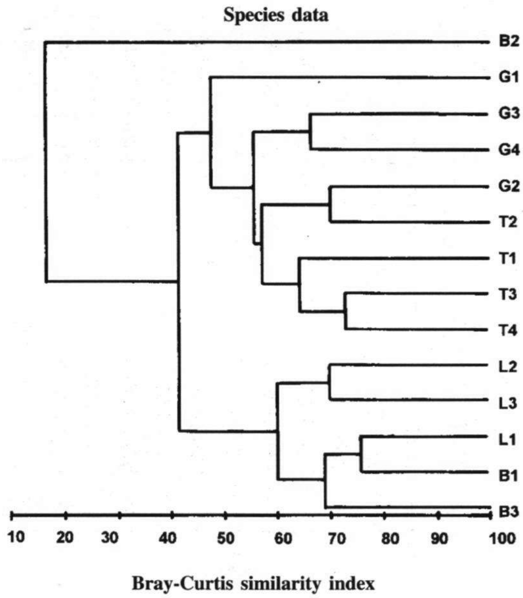

Fig. 2. A Bray Curtis similarity cluster analysis of the 14 subsites at the four sites: B1-3 = Blinkwater subsites 1-3; – G1-4 = Gilboa subsites 1-4; – L1-3 = Linwood subsites 1-3; – T1-4 = Tetworth subsites 1-4.

in the savanna ecosystem where highly varying weather conditions (resulting in slowing and/or drying out of rivers), plus strong anthropogenic disturbance upstream, caused changes in species composition. In the study here, although the banks of the stream were, at least to the human eye, often highly disturbed, the headwaters were maintained intact and the stream water was regular in flow and unpolluted. In the savanna, the Odonata assemblages are Anisoptera--dominated, but in this montane study here, three out of the four sites were Zygoptera--dominated (Tab. V). PINHEY (1984) first pointed out that the Anisoptera are more common than Zygoptera along the larger, more open, rivers of the savanna biome. It appears indeed that there is also a converse trend, as in the results presented here, that meandering, upland streams are more suitable to Zygoptera.

Certain sites clustered together, to form subgroups, but it can be seen that B2 (a natural forest patch), in terms of species, was very different to the other subsites. This may be related to the variation in the riparian vegetation type and/or stream dynamics. At the Blinkwater site, for example, the three subsites comprised pristine grassland, a natural forest patch and commercial forestry.

ENVIRONMENTAL VARIABLES

The environmental variables caused the subsites of each site to group together, for example, at Linwood (Tab. VII). Each site had its characteristic set of environmental variables, which determined its species composition. For example, *Chlorolestes tessallata* was strongly associated with the stretch of stream that had exposed boulders. To a lesser extent, the water pH and indigenous trees also affected the local distribution of this species (Tab. VII).

Chlorolestes fasciata was strongly associated with the environmental variables

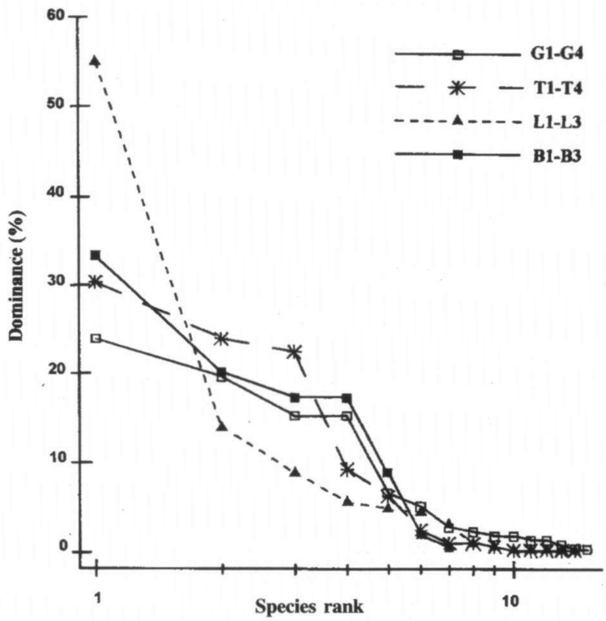

Fig.3. Species rank-abundance curves for the four sites.

of shade, flow rate and exotic plants. *C. fasciata* was the dominant species at Linwood, where the stream was fast flowing, extremely shady in places and the dominant vegetation type was invasive *Acacia mearnsii*. These stands provided shade and possibly oviposition sites.

Two environmental variables, depth of the stream and the presence of *Erica* species on the banks were not significant. This is surprising, as river depth can determine substrate type, which, in turn, sets conditions for certain larvae (CORBET, 1962). A further point is that *Erica* spp. are a natural oviposition site for *Chlorolestes* species and would have seemed to be important.

ENVIRONMENTAL IMPACTS ON THE DRAGONFLY ASSEMBLAGE

Adult Odonata often show preferences for specific sunlight-versus-shade regimes (CLARK & SAMWAYS, 1996; McGEOCH & SAMWAYS, 1991; SAMWAYS & STEYTLER, 1996; STEWART & SAMWAYS, 1998). When a stream is totally covered by expansive canopies of exotic *Eucalyptus* spp., Odonata diversity drops greatly, sometimes to zero (STEYTLER & SAMWAYS, 1995). Interestingly, the natural forest canopy, as at Blinkwater here, where there was a closed canopy with only sunspots along the stream, only two species were recorded, *Chlorolestes tessellata* and *Allocnemis leucosticta*, both of which are heliophobic zygopterans. This supports earlier observations that Anisoptera, as well as many Zygoptera, in general do not enter this type of closed-canopy riparian vegetation (PINHEY, 1984). Clearly, it does not matter whether the trees are exotic or indigenous. If there is no sunshine on the stream, Odonata diversity will be very low or absent.

STEWART & SAMWAYS (1998) suggested that *Chlorolestes* species need indigenous bushes for oviposition, but this study shows that it is not so much whether the trees are exotic or indigenous, but whether the architecture permits the right

Table III
Environmental variables measured in this study

Environmental variables	Blinkwater			Gilboa				Linwood			Tetworth			
	B1	B2	B3	G1	G2	G3	G4	L1	L2	L3	T1	T2	T3	T4
Boulder cover (%)	22.50	30.80	58.30	0.00	8.30	19.20	9.20	3.70	29.20	16.70	37.00	12.30	37.00	20.00
Shade cover (%)	28.30	84.20	48.80	42.50	0.00	11.70	28.30	31.70	66.20	60.80	30.30	0.00	25.50	0.00
Width (m)	1.25	2.5	1.5	0.43	4	2.5	4	1.73	2.58	2.1	5.5	4.16	3.58	6
Depth (m)	0.4	1.02	0.55	0.6	-.63	0.68	0.4	0.87	0.37	0.33	1.02	0.5	0.83	0.28
Speed ($m.s^{-1}$)	0.2	0.2	0.14	0.08	0.1	0.08	0.2	0.3	0.3	0.3	0.25	0.63	0.06	0.03
Grass (%)	59.20	0.00	0.80	40.00	30.00	35.80	11.70	36.70	28.30	38.30	54.20	83.30	32.50	27.50
Reed (%)	0.00	0.00	0.80	6.70	20.80	1.70	4.20	0.00	0.00	0.00	16.70	0.00	0.00	0.00
Exotic bushes (%)	0.00	0.00	79.20	3.30	4.20	32.50	0.00	24.20	18.30	35.00	9.20	10.00	65.80	35.00
Forb (%)	3.30	0.00	0.00	0.00	30.80	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sedge (%)	0.00	0.00	0.00	50.00	14.20	0.80	7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Erica spp. (%)	37.50	0.00	0.00	0.00	0.00	28.30	76.70	0.00	0.00	6.70	15.00	0.00	0.00	25.80
Exotic trees (%)	0.00	0.00	19.20	0.00	0.00	0.00	0.00	39.21	48.30	20.00	3.30	6.70	1.70	11.70
Indigenous trees (%)	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	1.70	0.00	0.00	0.00
pH	7.1	7.1	7.1	5.7	5.7	5.7	5.7	6.5	6.5	6.5	6.2	6.2	6.2	6.2

Table IV
Richness, diversity and eveness indices for the species data

Site	S	N	Margalef R1	Shannon	Pielou J	Hill N1	Hill N2
B1	7	62	1.45	1.63	0.837	5.09	4.43
B2	2	13	0.39	0.62	0.89	1.85	1.86
B3	4	69	0.71	1.21	0.871	3.35	3.05
G1	9	42	2.14	1.69	0.767	5.39	4.58
G2	6	29	1.48	1.49	0.834	4.46	3.94
G3	12	65	2.64	2.17	0.845	8.74	7.64
G4	7	44	1.59	1.59	0.815	4.89	4.22
L1	5	69	0.94	0.65	0.403	1.91	1.45
L2	12	113	2.33	1.63	0.656	5.11	3.14
L3	9	98	1.74	1.71	0.776	5.5	4.42
T1	9	55	2	1.71	0.777	5.51	4.63
T2	7	23	1.91	1.9	0.974	6.66	8.43
T3	7	106	1.29	1.53	0.784	4.6	4.18
T4	7	83	1.36	1.38	0.707	3.96	3.27

combination of sunlight and shade.This right combination is necessary for thermal balance and for encouraging low bushes under the tree canopy, which are necessary for perching and ovipositing. This was emphasized here by *Chlorolestes tessellata*, being abundant at Blinkwater where the stream banks were dominated by commercial forestry. As the stream was unpolluted and the physical environmental conditions suitable for *C. tessellata*, it was able to thrive despite the apparent huge anthropogenic impact.

In a review of threatened, endemic dragonflies heavy cattle trampling was noted as a threat to the survival of *Chlorolestes apricans* (Wilmot) in the Eastern Cape (SAMWAYS, 1995). At the Eastern Cape site, it was not the presence of cattle per se but the degree of damage that they did to the bank that was significant. This situation was aggravated by thick stands of invasive *Acacia mearnsii* which also excluded the strongly heliophilic *C. apricans*. In the study here, however, the

Table V
Species richness and dominant species of the four sites studied

Site	Total species	Dominant species	Suborder
Blinkwater	7	*Chlorolestes tessallata*	Zygoptera
Gilboa	15	*Trithemis dorsalis*	Anisoptera
Linwood	14	*Chlorolestes fasciata*	Zygoptera
Tetworth	13	*Pseudagrion salisburyense*	Zygoptera

Linwood site had cattle continually trampling the banks of the stream and *A. mearnsii* was present, yet *C. fasciata* was still abundant. This mirrors the situation in the Eastern Cape where *C. fasciata* is also abundant even in the presence of cattle and *A. mearnsii*. It is clearly a much more tolerant species of anthropogenic disturbance than *C. apricans*.

The largest localized threat facing the Odonata in this study were roads that caused naturally fast flowing streams to become stagnant pools where the roads crossed the streams. The diversity at these subsites was severely reduced as a result of the changed stream dynamics. The species present at these sites were those that preferred ponds and meandering rivers. The species assemblage changed from one characteristic of fast-flowing, small streams to one of ponds.

The exotic weeds *Solanum mauritianum* (Scop.) and *Rubus cuneifolius* (Pursh.) which, in places, replaced the natural riparian vegetation on the stream banks in this study also did not change the assemblages. These bushy weeds were used as perches, both during the day for sunning and at night for resting.

SINGLE SPECIES INDICATORS

STEYTLER & SAMWAYS (1995) suggested that certain single Odonata species could be used as indicators of habitat disturbance caused by commercial forestry. This was based on the finding that *C. tessellata* population levels decreased greatly when the stream entered an area of closed-canopy commercial forestry. In the study here, however the reverse was found, with *C. tessellata* increasing when the stream entered a commercial forest patch, albeit an open-canopy above the stream. This finding agrees with that of AMIET & LIBERT (1995) who showed that replacement of montane forest with *Eucalyptus* in Cameroon stimulated a local increase in butterfly species richness. This suggests extreme caution on defining which type of disturbance is being monitored. Simply lumping all types of commercial forestry together is insufficiently focussed. Clearly, it is particular aspects of disturbance, forestry or otherwise, that is significant. The whole Odonata assemblage, rather than simply single species is probably a more robust indicator as shown here by noticeable change in assemblage composition when roads dammed the streams.

Table VI

Species richness for the four study sites using the program RAREFRAC (LUDWIG & REYNOLDS, 1988); – [The data in parentheses are before rarefaction was done]

	Blinkwater	Gilboa	Linwood	Tetworth
Species richness	7(7)	13(15)	10(14)	9(14)
Sample size (n)	96	96	96	96

RECONCILIATION OF APPARENTLY CONFLICTING RESULTS

The results here and those of STEWART & SAMWAYS (1998) and SAMWAYS & STEYTLER (1996) appear in places to be contradictory. This is because the Odonata species are responding in subtle ways, and these three studies have brought to light these subtleties. As a first premise, it is clear that the stream water must be unpolluted, without a high sediment load and must remain at a reasonably constant level throughout the year (OSBORN & SAMWAYS, 1996). Different yet closely--related species can respond to changed habitat in quite different ways. This was highlighted by the fact that *C. apricans* and *C. fasciata* are differently sensitive to the intensity of cattle trampling and the extent of the modification of their habitat by invasive vegetation, particularly *A. mearnsii*. The impacts of cattle can be varying. Unquestionably, it is distinctly adversely synergistic with overgrowth from wattle. Cattle trampling appears to have three important facets: (1) direct destruction of bank side form and vegetation, (2) trampling of the larval habitat, and (3) the siltation of the stream.

The impact of *A. mearnsii* is interesting in that it does not appear to be the fact that it is an exotic invasive per se, but that it has such a thick canopy that it blocks out the sunlight. The same affect is seen when any vegetation, whether it be *Eucalyptus*, *Pinus* or indigenous forest trees, form a canopy that completely excludes sunlight from the stream. It is important that thick, extensive stands of *A. mearnsii* be cleared, and, in addition, planted trees should be established so that their canopies are not intrusive on the sunlight reaching the stream (i.e. 30m from the stream edge). The exception of course, would be if the intention was to simulate natural forest, but in this case an appropriate choice, when biodiversity in general is being considered, would be to restore indigenous forest.

In general terms, if the aim were to maximize biodiversity, then at least for Odonata, this would arise naturally when habitat heterogeneity is increased (STEYTLER & SAMWAYS, 1995). This means that a stream running through commercial forestry should be managed in a way that various stages of secondary succession are present, which would provide opportunities for the largest number of Odonata species. This would also be coupled with rotational management of natural riparian vegetation.

Table VII
The canonical coefficients data for the 12 environmental variables used in this study

Environmental variables	Canonical coeffecients Axes 1	Axes 2
Boulder	-0.57	0.29
Shade	0.40	-0.13
Width	-0.16	0.24
Speed	-0.04	0.10
PH	0.44	0.50
Grass	-0.25	-0.22
Reed	0.09	-0.10
Weed	-0.06	0.13
Forb	-0.13	-0.07
Sedge	-0.50	0.14
Exotic trees	-0.01	-0.35
Indigenous trees	-0.05	-0.07

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

As sensitive endemic Odonata species require unpolluted and apparently unsilted water, care should be taken that the stream catchments are minimally disturbed and that detrimental run-off is avoided.

(1) No commercial forest trees should be planted within 30m of the stream edge. The reasons for this are threefold (1) to provide the necessary sunny conditions for Odonata and other sun-loving invertebrates (2) to allow the native vegetation to grow along the banks, and (3) to reduce the effects of run-off.

(2) Highly invasive weeds, particularly those that shade out native vegetation, should be removed. Surprisingly, this study showed that a tangle of invasive bushes (*Solanum mauritianum* and *Rubus cuneifolius*) and native plants can maintain the endemic damselflies, assuming of course that the water is clean. Nevertheless, for native biodiversity in general, it is preferable to remove all alien invasive plants (SAMWAYS et al., 1996). Where the intention is to restore native Afro-montane forest, one can expect a dramatic decrease in Odonata species. This of course, is a natural situation and emphasizes that biodiversity maintenance and restoration is not necessarily simply about species numbers.

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